jOiNEd For sUsTainability - bUilding climate REsilient communities in WB and EU

DELIVERABLE NR. D6.2

< 1FUTURE SYMPOSIUM >

DUE DATE: 30/11/2025

MAIN AUTHOR: <UOM, UTA, UNS>

https://1future.feut.edu.al/

Co-funded by the European Union

Deliverable No.	D6.3
Work Package	WP4
Author(s)	UOM, UTA, UNS
Date	30/11/2025
File Name	1FUTURE SYMPOSIUM
Status	Completed
Revision	All partners
Reviewed by (if applicable)	UKIM

Classification:

Draft	☐
Final	☒
Confidential	☐
Restricted	☐
Public	☒

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them.

Version History

Version	Implemented by	Revision Date	Changes Description
V1	UOM, UTA	27/11/2025	Draft

This document has been prepared in the framework of the European project 1FUTURE.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them.

Co-funded by
the European Union

CONTACT:

Website: 1future.feut.edu.al

E-mail : 1future@feut.edu.al

Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

CONTENTS

1 INTRODUCTION 4
2 SYMPOSIUM CALL 5
3 SYMPOSIUM AGENDA 8
4 SYMPOSIUM PICTURES 10
5 LIST OF PARTICIPANTS 12
16 OCTOBER 12
17 OCTOBER: 15
6 PROCEEDINGS 18

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

1 INTRODUCTION

Climate change and sustainability have become urgent global priorities, demanding collective action across sectors. Human activities—from emissions to deforestation—have triggered environmental disruptions that threaten ecosystems, deepen social inequalities, and hinder progress toward the Sustainable Development Goals (SDGs). In response, the University of Montenegro, the Faculty of Economics at the University of Tirana, and the University of Novi Sad, within the 1Future project, organized on the 16 and 17 October 2025 the International Symposium "Bridging Research Between Business and Academia for a Greener Tomorrow." This event aimed to enhance interdisciplinary dialogue and promote innovative research addressing the critical challenges of climate change and sustainable development. Scholars, policymakers, and practitioners contributed and explored the intersections of business, research, and sustainability, in the fields of:

- Sustainable economic and business models
- Environmental justice and equity in public policies
- The role of technology and innovation in sustainability
- Engineering, Energy and Resource Management
- Sustainable urban and rural development
- Education and Communication

The symposium call was disseminated through all Project Partners webpages and/or social networks. It is currently published under one separate space in the 1FUTURE website, where all materials are published:

https://1future.feut.edu.al/?page_id=1376

LinkedIn page of the project was mainly used for disseminating the event beyond the project partnership.

The next part of the report will include the materials produced within the Symposium, as per project proposal, including: Invitation (Call), agenda, signed presence list (which includes number of participants), book of proceedings, and presentations.

Mos materials are also available for download in the webpage of the project.

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

2 SYMPOSIUM CALL

Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

3 SYMPOSIUM AGENDA

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica

PROGRAM

Thursday, October 16th

16.10.2025	09:00-09:30		Registration and welcoming	
16.10.2025	09:30-10:00		Welcome Speech and Keynote Speaker	
			Symposium Presentations – First Session	
16.10.2025	10:00-11:30		**Authors & Papers**	**Presenter**
	10:00-10:10	39	Brikena Leka and Anisa Nipolli. The Impact of Plastic Pollution on Recreational River Use and Sustainable Tourism; Special Case -Shkumbin River	Anisa Nipolli
	10:10-10:20	47	Elona Pojani, Zyra Mahmuti and Perseta Grabova. PLASTIC WASTE REDUCITION IN RESTAURANTS AND HOTELS ALONG THE SHKUMBINI RIVER	Zyra Mahmuti
	10:20-10:30	50	Perseta Grabova and Julia Dado. WASTE MANAGEMENT SECTOR: EVALUATING THE MUNICIPAL WASTE SYSTEM IN ELBASAN AND OPPORTUNITIES FOR IMPROVEMENT	Julia Dado
	10:30-10:40	24	Xhuana Xhika, Entela Çobani and Denisa Selimi. MANAGEMENT PROBLEM OF OLIVE POMACE GENERATED AS A WASTE BY-PRODUCT DURING THE OLIVE OIL PRODUCTION. CASE OF THREE-PHASE OLIVE OIL MILL IN ELBASAN COUNTY, ALBANIA.	Xhuana Xhika
	10:40-10:50	49	Joana Gjipalaj, Oltion Marko, Denisa Selimi and Xhuana Xhika. MANAGEMENT OF GEOTHERMAL WATERS AFTER THEIR USE FOR BALNEOLOGICAL PURPOSES: ENVIRONMENTAL IMPACTS AND THE IMPORTANCE OF SUSTAINABLE PRACTICES. CASE STUDY: LLIXHA OF ELBASAN-ALBANIA	Denisa Selimi
	10:50-11:00	29	Kristjana Omeri and Teida Shehi. ENERGY EFFICIENCY IN BUILDINGS AS A SOURCE OF CARBON CREDITS. THE CASE OF THE CITY OF PRRENJAS.	Kristjana Omeri
	11:00-11:10	25	Vlorlinda Daja, Entela Çobani and Ledia Aleksi. CLIMATE CHANGE IMPACT ASSESSMENT AND ADAPTATION MEASURES IDENTIFICATION FOR THE MUNICIPALITY OF TIRANA	Vlorlinda Deja
	11:10-11:20	53	Florenca Gjorduni, Leudita Ademi and Resina Pllaha. THE IMPACT OF IMMIGRATION ON THE LABOR MARKET OF THE BALKAN COUNTRIES	
16.10.2025	11:30-12:00		Coffee Break	
			Symposium Presentations – Second Session	
16.10.2025	12:00-14:00		**Authors & Papers**	**Presenter**
	12:00-12:10	31	Frida Kuçi and Sera Mara. CIRCULAR ECONOMY IN ACTION: A CASE STUDY OF AZ GROUP'S SUSTAINABLE PRACTICES IN ALBANIA	Frida Kuçi
	12:10-12:20	22	Ljiljana Popović, Nenad Medić and Suzana Draganić. INTEGRATING ADVANCED TECHNOLOGIES AND CIRCULAR ECONOMY PRACTICES FOR SUSTAINABLE BUSINESS TRANSFORMATION	
	12:20-12:30	33	Mirjana Laban, Olivera Bedov, Suzana Draganić and Ljiljana Popović. CIRCULAR ECONOMY AND MILLENNIUM GOALS	Olivera Bedov
	12:30-12:40	12	Vittoria Ridolfi. ADAPTIVE GOVERNANCE FOR COASTAL THRESHOLDS: NEGOTIATING SUSTAINABILITY IN TIMES OF CLIMATE CRISIS	Vittoria Ridolfi
	12:40-12:50	13	Vittoria Ridolfi, Elena Ferraioli, Filippo Magni and Giulia Lucertini. STRATEGIES FOR CLIMATE TRANSITION IN ITALIAN CITIES: COLLECTIVE GOVERNANCE FOR ADAPTIVE AND RESILIENT TERRITORIES	Vittoria Ridolfi
	12:50-13:00	7	Abdurahman Aljić, Edisa Nukić and Jelena Marković. INFORMATION TECHNOLOGY AND HUMANITARIAN RESPONSE EFFICIENCY: A CASE STUDY OF THE RED CROSS SOCIETY OF BOSNIA AND HERZEGOVINA	Abdurahman Aljić
	13:00-13:10	52	Jonida Bekteshi and Zhaklina Dhamo. ADOPTION OF ARTIFICIAL INTELLIGENCE IN THE ECONOMY AND BUSINESS	Zhaklina Dhamo
	13:10-13:20	15	Maja Kin, Zvjezdan Karadžin, Edisa Nukić and Jelena Marković. ASSESSMENT OF POLLUTION LOAD FROM COAL MINES ON THE MODRAC MULTIPURPOSE WATER RESERVOIR: ECOLOGICAL AND SOCIO-ECONOMIC IMPLICATIONS	Zvjezdan Karadžin
	13:20-13:30	36	Mirzo Selimić, Hadžib Salkić, Samir Šćebić and Nermin Pelić. EDUCATION AND COMMUNICATION IN CONTEMPORARY SOCIETY: A STUDY IN BOSNIA AND HERZEGOVINA	Mirzo Selimić
	13:30-13:40	17	Heike Molitor. Nature experience areas and informal educational processes	Heike Molitor
	13:40-13:50	9	Jovana Topalić, Anka Starčev-Ćurčin and Suzana Draganić. INSTAGRAM AS A COMMUNICATION AND EDUCATIONAL TOOL IN CIVIL ENGINEERING: CONNECTING STUDENTS, ACADEMIA, AND INDUSTRY	
	13:50-14:00			
16.10.2025	14:00-15:00		Lunch Break	
16.10.2025	15:00-17:00		Project Management Meeting	
16.10.2025	19:00-22:00		Social Dinner	

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

UCG Univerzitet Crne Gore

FAKULTETI EKONOMIKE

UNIVERSITAS STUDIORUM MONTENEGRINA

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica

1FUTURE

PROGRAM

Friday, October 17th

		Symposium Presentations – Third Session		
17.10.2025	09:30-11:30	**Authors & Papers**		**Presenter**
	09:30-09:40	14	Elena Ferraioli. REGENERATIVE PLANNING AND TERRITORIAL TRANSITIONS: REIMAGINING WASTELANDS FOR CIRCULAR URBAN FUTURES	Elena Ferraioli
	09:40-09:50	30	Amer Smailbegović and Mirzo Selimić. ADDRESSING EVOLVING ACTIVE ATTACKS THREATS USING INTEGRATED TRAINING CURRICULUM	Amer Smailbegović
	09:50-10:00	34	Nermin Palić, Grgo Luburić and Dejan Štekić. ANALYSIS OF THE SUSTAINABLE URBAN MOBILITY IN THE MUNICIPALITY OF KISELJAK	Nermin Palić
	10:00-10:10	23	Alexander Cedergren and Henrik Hassel. INTEGRATING THE ANALYSIS OF ADAPTIVE CAPACITY INTO AN ANTICIPATORY METHOD FOR RISK AND VULNERABILITY ASSESSMENT	Henrik Hassel
	10:10-10:20	20	Henrik Hassel, Alexander Cedergren and Lovisa Vallin. A MULTILEVEL ACCOUNT OF ADAPTATIONS AND ADAPTIVE CAPACITY – A CASE STUDY OF AN INCIDENT IN THE HEALTH CARE SECTOR	Henrik Hassel
	10:20-10:30	1	Henrik Hassel, Alexander Cedergren and Magnus Hagelsteen. Towards more mature method development processes in societal safety and resilience	Henrik Hassel
	10:30-10:40	11	Amer Smailbegović and Nermin Palić. MANAGEMENT OF CLIMATE CHANGE AND ENVIRONMENTAL RISKS IN SECURING RAW MATERIAL BASE AND TRANSPORTATION LOGISTICS NETWORK IN THE WESTERN BALKANS	Amer Smailbegović
	10:40-10:50	5	Peter Spathelf, Marcus Lindner and Frits Mohren. FORESTS AND CLIMATE CHANGE	Peter Spathelf
	10:50-11:00	27	Peter Spathelf and Franziska Rottig. CLIMATE CHANGE IMPACTS ON FORESTS	Peter Spathelf
	11:00-11:10	4	Johan Ingvarson. On the Use of Standards in Risk Management Regulations	Johan Ingvarson
	11:10-11:20	19	Sergey Dmitriev and Eva Vitorovic. THE GREEN PROGRAM, KAOSPILOTS, GAME|CHANGERS, AND ZELENO DOBA CASES FOR BRIDGING INDUSTRIES, ACADEMIA, AND COMMUNITIES TO GROW REGENERATIVE LEADERS FOR THE WESTERN BALKAN	Sergey Dmitriev
	11:20-11:30	55	Agima Alia, Anni Dasho Sharko and Geron Kamberi. POST DISASTER NEEDS ASSESSMENT, LEGAL PERSPECTIVE, ALBANIA EARTHQUAKE 2019 CASE	
17.10.2025	11:30-12:00	Coffee Break		
		Symposium Presentations – Fourth Session		
17.10.2025	12:00-13:30	**Authors & Papers**		**Presenter**
	12:00-12:10	3	Zvjezdan Karadžin, Jasmin Isabegović, Miralem Sejdinović and Edisa Nukić. Remediation method for mercury polluted site selected using analytical hyerarachy process	Zvjezdan Karadžin
	12:10-12:20	37	Željka Beljkaš, Snežana Rutešić, Miloš Knežević and Ivona Krulanović. SUSTAINABLE WATER MANAGEMENT UNDER LIMITED RESOURCES THROUGH ARTIFICIAL NEURAL NETWORKS	Ivona Krulanović
	12:20-12:30	42	Meri Cvetkovska, Milica Jovanoska Mitrevska, Todorka Samardžioska, Ognen Marina and Liljana Dimevska Sofronievska. PATHWAYS FOR CIRCULAR ECONOMY IMPLEMENTATION IN CONSTRUCTION	Meri Cvetkovska
	12:30-12:40	44	Marina Rakočević, Vasilija Bojović and Svetislav Popović. SUSTAINABILITY AND RECYCLING OF COMPOSITE MATERIALS	Vasilije Bojović
	12:40-12:50	28	Ivana Ćipranić, Marija Jevrić, Milena Ostojić, Olga Ćalasan and Goran Sekulić. STRENGTHENING RESILIENCE TO FLOODS IN MONTENEGRO: A REVIEW OF LEGISLATION, STRATEGIES, AND EU INTEGRATION	Milena Ostojić
	12:50-13:00	21	Ljiljana Popović, Mirjana Laban and Sandra Nedeljković. INSTITUTIONALISATION OF THE METHODOLOGY FOR DAMAGE AND LOSS ASSESSMENT IN AGRICULTURE	Ljiljana Popović
	13:00-13:10	54	Xhorxhina Prendi, Sherif Bundo and Brixhilda Çekrezi. CHARACTERISTICS OF THE REGIONAL ECONOMY IN THE FACE OF GLOBALIZATION, TOURISM AND TRADITION	Xhorxhina Prendi
	13:10-13:20	56	Anđela Knežević and Dušan Ignjatović. TOWARD THE AI CITY: ARTIFICIAL INTELLIGENCE TECHNOLOGIES DEVELOPMENT AND APPLICATION	Anđela Knežević
	13:10-13:20			
17.10.2025	13:30-14:30	Lunch Break		
17.10.2025	15:00-17:00	Social Activity		

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

4 SYMPOSIUM PICTURES

Co-funded by the European Union

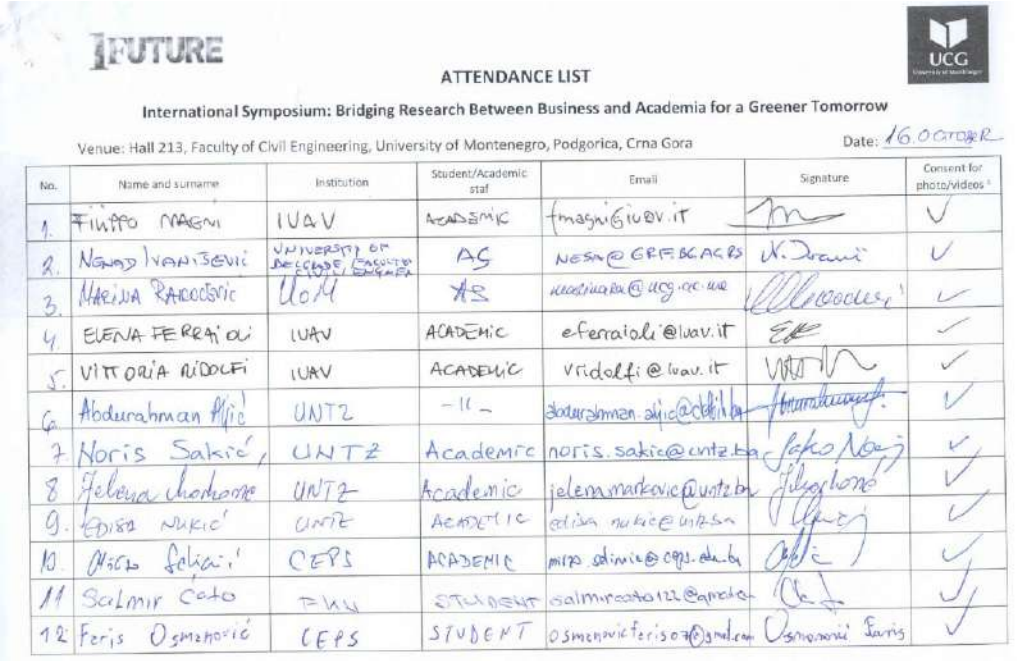
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

5 LIST OF PARTICIPANTS

16 October



1FUTURE

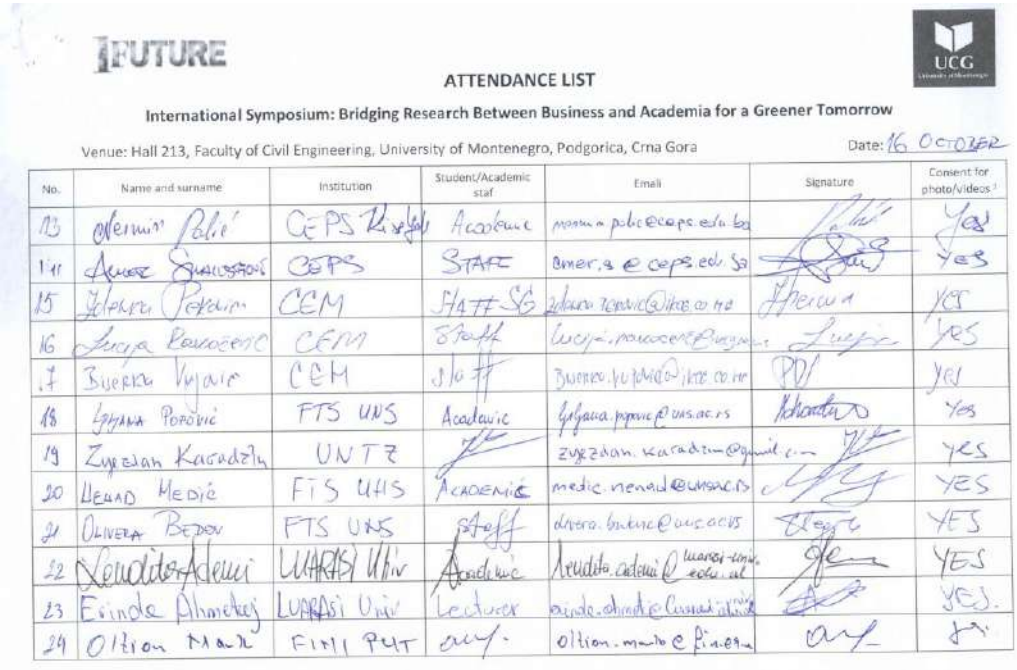
ATTENDANCE LIST

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora

Date: 16 OCTOBER

No.	Name and surname	Institution	Student/Academic staf	Email	Signature	Consent for photo/videos
1.	FILIPPO MAGNI	IUAV	ACADEMIC	fmagni@iuav.it		✓
2.	NEMAD IVANIŠEVIĆ	UNIVERSITY OF MONTENEGRO, FACULTY OF CIVIL ENGINEERING	AS	NESA@GRF.BG.AC.RS	N. Ivanišević	✓
3.	MARINA RADOČIĆ	UoM	AS			✓
4.	ELENA FERRAIOLI	IUAV	ACADEMIC	eferraioli@iuav.it		✓
5.	VITTORIA RIDOLFI	IUAV	ACADEMIC	vridolfi@iuav.it		✓
6.	Abdurahman Ajić	UNTZ	-11-			✓
7.	Noris Sakić	UNTZ	Academic	noris.sakic@untz.ba		✓
8.	Jelena Markovic	UNTZ	Academic	jelena.markovic@untz.ba		✓
9.	EDISA NUKIĆ	UNTZ	ACADEMIC	edisa.nukic@untz.ba		✓
10.	Miro Šelić	CEPS	ACADEMIC	miro.selic@ceps.edu.ba		✓
11.	Salmir Ćato	PMU	STUDENT	salmircato122@gmail.com		✓
12.	Feris Osmanović	CEPS	STUDENT	osmanovicferis07@gmail.com	Osmanović Feris	✓



1FUTURE

ATTENDANCE LIST

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora

Date: 16 OCTOBER

No.	Name and surname	Institution	Student/Academic staf	Email	Signature	Consent for photo/videos
13	Selmir Pelić	CEPS Kinder	Academic			Yes
14	Amer Smajlović	CEPS	STAFF			Yes
15	Zeljko Pecanac	CEM	STAFF			YES
16	Lucija Rakocevic	CEM	Staff			YES
17	Bojana Vujović	CEM	Staff			Yes
18	Ljiljana Popović	FTS UNS	Academic			Yes
19	Zvjezdan Karadžić	UNTZ				YES
20	Nenad Medić	FTS UNS	Academic			YES
21	Olivera Bebov	FTS UNS	Staff			YES
22	Xhemile Ademi	UAMBASI Univ	Academic			YES
23	Erinda Ahmetaj	UAMBASI Univ	Lecturer			YES
24	Oltion Mark	FINI PUT	any			Yes

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

1FUTURE

UCG

ATTENDANCE LIST

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 16 OCTOBER

No.	Name and surname	Institution	Student/Academic staf	Email	Signature	Consent for photo/videos [1]
25	Svetlana Ruresić	MoM	AS	SVETLANA.RURESIC@HOTMAIL.COM		Yes
26	Brikena Ielica	UTA	AS	brikena.ielica@feut.edu.al		Yes
27	Perseta Grabova	UTA	AS	perseta.grabova@feut.edu.al		yes
28	Olona Lapeni	UTA	AS	olona.lapeni@feut.edu.al		YES
29	Hafsa Laçi	UTA	AS	hafsalaci@uamith.edu.al		YES
30	Anisa Nipolli	UTA	S	anisa.nipolli@gmail.com		Yes
31	Zyra Hatmati	UTA	S	zyramatmati@gmail.com		yes
32	Julia Dado	UTA	S	julia.dado9@gmail.com		Yes
33	Sara Mera	UTA	S	saramera141@gmail.com		yes
34	Frida Kuçi	UTA	S	fridakuci18@gmail.com		yes
35	ANA TRAJKOVA-GAVRILOSKA	UKIM	AS	ygavrilovska@gf.ukim.edu.mk		YES
36	Todorka Samardzioska	UKIM	AS	samardzioska@gf.ukim.edu.mk		Yes

1FUTURE

UCG

ATTENDANCE LIST

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 16.10.25

No.	Name and surname	Institution	Student/Academic staf	Email	Signature	Consent for photo/videos [1]
37	Eutela Cobani	PUT	Assistant	eutela.cobani@fet.edu.al		✓
38	Kornelia Gjoka	PUT	Academic staff	kornelia@hotmail.com		✓
39	Leola Hoxha	PUT	Academic staff	leola.dibra@epoli		✓
40	Zeljko Bjelkt	UoM	AS	zeljkob@ucg.ac.me		✓
41	SOKOL DVORNI	PUT	Academic	ing.sokol@gmail.com		✓
42	Miloš Kuveljić	MoM	AS	miloseravicmne@hotmail.com		✓
43	SPATHELF PETER	HNEE	ACS	Peter.Spathelf@hnee.de		✓
44	JOHAN INGVARSSON	LUND	ACS	johan.ingvarsson@gmail.com		✓
45	Henrik Hasse	Lund	AS	henrik.hasse@risk.lth.se		✓
46	Meri Cvetkovska	UKIM	AS	cvetkovska@gf.ukim.edu.mk		✓

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

FUTURE

UCG

ATTENDANCE LIST

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 15/10/2025

No.	Name and surname	Institution	Student/Academic staf	Email	Signature	Consent for photo/videos [1]
46	Mezi Cvetkovska	UKIM	AS	cvetkovska@gf.ukim.edu.mk		
47	Florences Cyerduni	Luarasi	Lotures	florences.gjerduni@luarasi-univ.edu.al		
48	Zhaklina Dhamo	Luarasi	AS	zhaklina.dhamo@luarasi-univ.edu.al		
49	MARKO MARKOVIC	UNS	AS	MARKO_M@UNS.AC.RS		

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

17 October:

FUTURE

ATTENDANCE LIST

UCG

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 17.10.25.

No.	Name and surname	Institution	Student/Academic staf	Email	Signature	Consent for photo/videos [1]
1	Enkelda Cobani	PUT	Academic staf	enkelda.cobani@fin.edu.al		✓
2	Kanaki Gjoka	PUT	Academic staf	kanaki@hotmail.com		✓
3	Ollion Manlo	PUT	Academic	ollion.manlo@fin.edu.al		✓
4	SOKOL DURMO	PUT	Academic	ing.Sokol.@gmail.com		✓
5	Leonie Kleesi	PUT	Academic staf	leonie.kleesi@fin.edu.al		✓
6	SNEZANA RUPCIC	UCG	AS	SNEZANA.RUPCIC@HOTMAIL.COM		✓
7	ZEJNA BEJTEXI	UCG	AS	zejnabejtexi@ucg.ac.me		✓
8	Mezi Cvetkovska	UKIM	AS	cvetkovska@pf.ukim.edu.mk		✓
9	Zhaklina Dhamo	U. Tirana	AS	zhaklina.dhamo		
10	Todorka Samardzioska	UKIM	AS	samardzioska@pf.ukim.edu.mk		✓
11	Florence Gjonduli	Luarasi	AS	florenca.gjonduli		/
12	SLOBODAN BLAGOJEVIĆ	EPCG	S	SLOBODAN.BLAGOJEVIC93@GMAIL.COM		✓

FUTURE

ATTENDANCE LIST

UCG

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 17.10.25.

No.	Name and surname	Institution	Student/Academic staf	Email	Signature	Consent for photo/videos [1]
13	VLORLINDA DAJA	POLYTECHNIC UNIVERSITY OF TIRANA	STUDENT	vlorlinda.daja@fin.edu.al		✓
14	Kristjana Omeri	POLYTECHNIC UNIVERSITY OF TIRANA	Student	kristjanaomeri@gmail.com		✓
15	Denisa Selimi	POLYTECHNIC UNIVERSITY OF TIRANA	student	denisa.selimi@fin.edu.al		✓
16	Leudita Ademi	LUARASI University	Lecturer	leudita.ademi@luarasi-univ.edu.al		✓
17	Xhuana Xhika	Polytechnic University of Tirana	Student	xhuana.xhika@fin.edu.al		✓
18	EDISA NUKIĆ	UNIT	ACADEMIC	edisa.nukic@unt.se		✓
19	JELENA MARKOVIĆ	UNT2	ACADEMIC	jelena.markovic@unt.edu		✓
20	OLIVERA BEDOV	FTS UNS	academic staff	Olivera.bedov@uns.ac.rs		✓
21	MIRJANA LABAN	UNS	AC	mlaban@uns.ac.rs		
22	MARKO MARKOVIĆ	UNS	AC	MARKO_M@UNS.AC.RS		✓
23	Valentina Pobić	CEPS	AC	valentina.pobic@ceps.edu.ba		✓
24	Amra Delić	CEPS	AC	amra.delic@ceps.edu.ba		✓

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

1FUTURE (3) UCG

ATTENDANCE LIST

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 17/10/25

No.	Name and surname	Institution	Student/Academic staf	Emali	Signature	Consent for photo/videos [1]
25	Miloš Kusterić	UCM	AS			✓
26	Zvjezdan Kasadža	UNTZ	AS			✓
27	ELENA FERRAIOLI	IUAV	AS			✓
28	Franziska Bothig	HNEE	AS			—
29	Noris Sakić	UNTZ	AS			✓
30.		UNTZ	AC			✓
31	Henrik Hassel	Lund	AS			—
32.	ANA TROMBEVA-GAVRILOSKA	UKIM	AS			✓
33	JOHAN INGARSON	LNU	AS			✓
34	Todorka Samardžioska	UKIM	AS			✓
35	Hafsa Laci	UTA	AS			✓
36	Brikena Leka	UTA	AS			—

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 17.10.2025

No.	Name and surname	Institution	Student/Academic staf	Emali	Signature	Consent for photo/videos [1]
37	Mari Cvetanovska	UKIM	AS			✓
38	Zdenka Perić	CEM	SS			✓
39	Lucija Ranogajec	CEM	S-S			
40	Vittoria Ridolfi	IUAV	AS			✓
41	SPATHELF PETER	HNEE	AS			✓
42	Perseta Gradova	UT	AS			✓
43	FRIDA AHMETAJ	VLA	Akademik			—
44	Elena Rogani	UTA	AS			✓
45	Selim Cado	FIKH	Student			✓
46	FARIS OSMANOVIĆ	CEPS	STUDENT			✓
47	Frida Kusi	UTA	student			✓
48	Sara Neva	UTA	Student			✓

1-U skladu sa GDPR Uredbom (EU) br. 2016/679, ovim dajem svoju izričitu saglasnost za korišćenje mojih ličnih podataka i slike u svrhu ocjene ili revizije/institucionalne promocije rezultata događaja. Lični podaci NEĆE biti objavljivani, distribuirani niti korišćeni u komercijalne svrhe.
/ In accordance with the GDPR Regulation (EU) No. 2016/679, I hereby give my explicit consent for the use of my personal data and image for the purpose of evaluation or review/institutional promotion of the event's outcomes. Personal data will NOT be published, distributed, or used for commercial purposes.

Co-funded by the European Union

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

1FUTURE

UCG

ATTENDANCE LIST

International Symposium: Bridging Research Between Business and Academia for a Greener Tomorrow

Venue: Hall 213, Faculty of Civil Engineering, University of Montenegro, Podgorica, Crna Gora Date: 17/10/2025.

No.	Name and surname	Institution	Student/Academic staf	Emali	Signature	Consent for photo/videos [1]
49	Ljiljana Popović	FTS UNS	Academic	ljiljana.popovic@uns.ac.rs		yes
50	Medić Nenad	FTS UNS	Academic	medic.nenad@uns.ac.rs		yes
51	Vasilije Bojović	FCE UOM	Academic	vasilije.b@ucg.ac.me		yes
52	Biserka Vujović	CEM	STAFF	biserka.vujovic@ucg.ac.me		yes
53	Amer Smajlbegović	CEPS	STAFF	amer.s@ceps.edu.ba		yes
54	Krstanović Vukatana	UT	Academic	krstanovic.vukatana@uninis.edu.al		yes
55	Marina Lalošević	UoM	AS	marinaka@ucg.ac.me		✓
56	Anatole Klezević	GRF, UG	AS	aklezevic@grf.bg.ac.rs		✓
57	Miloš Ninković	FLU, CT	AS			✗

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

6 PROCEEDINGS

The proceedings are available in the link:
https://www.dropbox.com/scl/fo/ipw8h1qp0kcp53hslg5zo/ANpRP5wQ8aWZMD3S4dN0KWc?e=5&preview=GF_01_Zbornik-2025_A4-210x297mm.pdf&rlkey=y5o5lxr1ebocax760jlu0tedq&st=k4px52ea&dl=0
They are registered with the ISBN Number: ISBN 978-9911-9616-0-0 COBISS.CG-ID 35906052.
A compressed version of the proceedings is available in the project webpage and is attached to this report (within the size allowed for uploading materials). .

7 PRESENTATIONS

All presentations in the symposium are available though the links:
https://drive.google.com/drive/folders/1T6E5Ef0qbVg5SCeh5RvIqGonFWQR_Tr8?usp=sharing
https://drive.google.com/drive/folders/1NIPT_XxUSeAT5KsFfiiBFlXuqksn2rpF?usp=sharing
https://drive.google.com/drive/folders/1GzhbStoIFnkMsDywkoC_ahxz9hEKRbNu?usp=sharing
https://drive.google.com/drive/folders/1riJX_VS5mOgUwnC8G4Nsq2tD_lLkLZ82?usp=sharing

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them."

1FUTURE

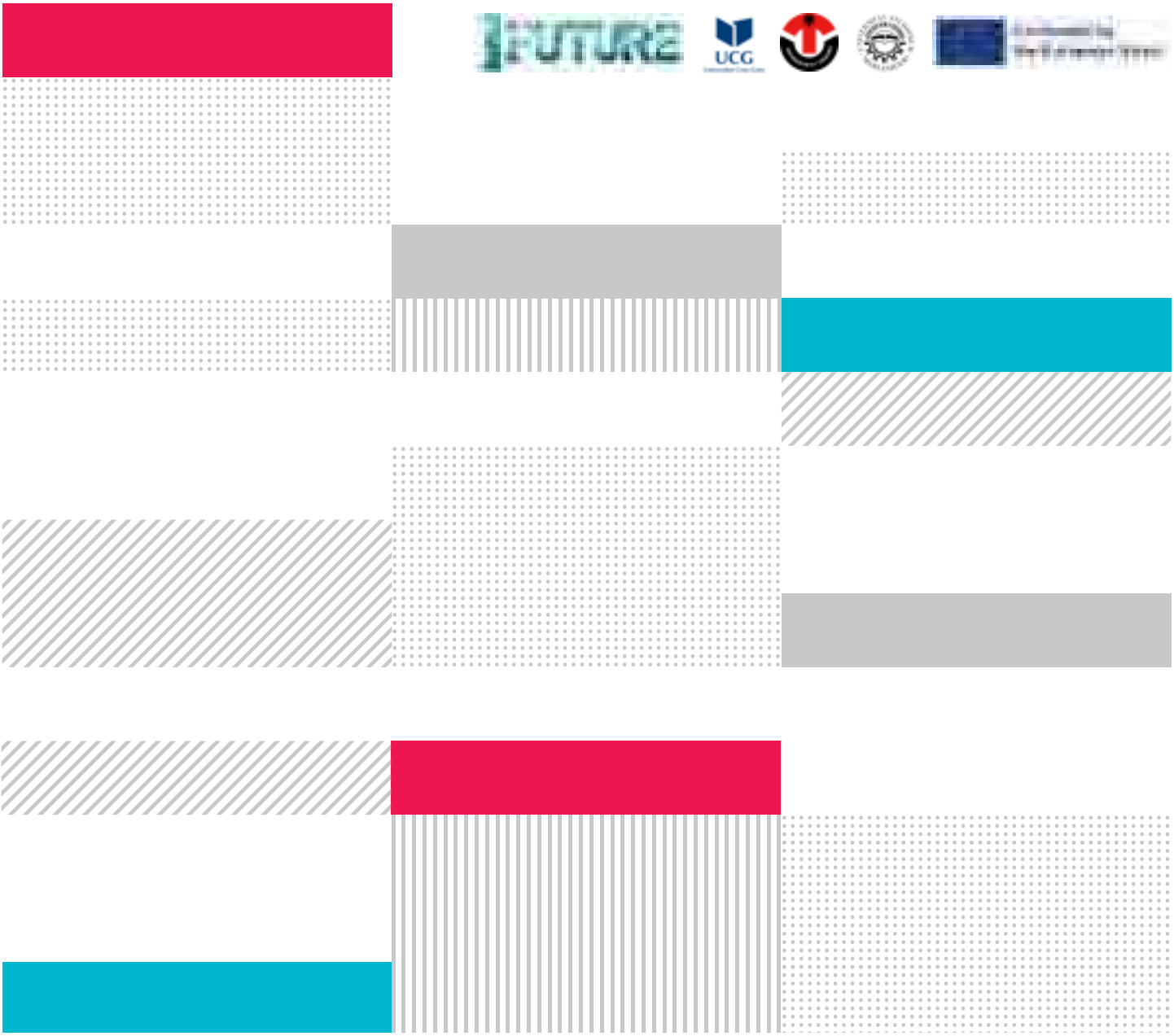
Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them.

Bridging research between Business
and Academia for a Greener Tomorrow

16 – 17 October 2025
Podgorica, Montenegro

1FUTURE
International Symposium



https://www.ucg.ac.me/gf

1future@ucg.ac.me

Funded by the European Union. "Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EACEA. Neither the European Union nor the granting authority can be held responsible for them"

Table of Contents

1FUTURE	Building Resilient Futures: Climate sustainability and community empowerment in WB and EU	
	Podgorica, Montenegro, **16–17 October 2025**	
7		Preface

T1 – Sustainable economic and business models

9	Brikena Leka Anisa Nipolli	The impact of plastic pollution on Recreational River Use and Sustainable Tourism Special Case - Shkumbin River
22	Florenca Gjorduni Leudita Ademi Resina Pllaha	The impact of immigration on the labor market of the Balkan countries
34	Frida Kuçi Sara Mara	Circular Economy in action: A case study of AZ Group's sustainable practices in Albania
48	Irseldo Meraj	Integrating ESG factors into a business valuation model
60	Kendi Cara Julia Dado	Calculation and management of the environmental footprint in Albanian businesses: practices, challenges and impact on risk decision-making
72	Ljiljana Popović Nenad Medić Suzana Draganić	Integrating advanced technologies and circular economy practices for sustainable business transformation
80	Mirjana Laban Olivera Bedov Suzana Draganić Ljiljana Popović	Circular economy and Millennium goals
91	Entela Çobani Xhuana Xhika Denisa Selimi	Management problem of olive pomace generated as a waste by-product during the olive oil production. case of three-phase olive oil mill in Elbasan County, Albania

T2 – Environmental justice and equity in public policies

103	Miloš Knežević Ana Andabaka	CPR 305/2011 and CPR 2024/3110 – Comparative analysis and implications for sustainability and the circular economy

119	Vittoria Ridolfi	Adaptive governance for coastal thresholds: Negotiating sustainability in times of climate crisis
130	Vittoria Ridolfi Elena Ferraioli Filippo Magni Giulia Lucertini	Strategies for climate transition in Italian cities: Collective governance for adaptive and resilient territories

T3 – The role of technology and inovation in sustainability

140	Abdurahman Aljic Edisa Nukic Jelena Marković	Information technology and humanitarian response efficiency: A case study of the red cross society of Bosnia and Herzegovina
152	Faton Spahiu Vladimir Vitanov Ana Trombeva-Gavriloska Teodora Mihajlovska	Design terazzo tiles implementing life cicle assesment
163	Ibrahim Mustafić	Diesel engine without EGR
175	Jonida Bekteshi Zhaklina Dhamo	Adoption of Artificial Intelligence in the Economy and Business
186	Maja Kin Zvjezdan Karadžin Edisa Nukić Jelena Marković	Assessment of pollution load from coal mines on the Modrac multipurpose water reservoir: ecological and socio-economic implications
202	Mirzo Selimić Hadžib Salkić Samir Ščetić Nermin Palić	Education and communication in contemporary society: A study in Bosnia and Herzegovina

T4 – Engineering, Energy and Resource Management

212	Agim Alia Anni Dasho Sharko Geron Kamberi	Post Disaster Needs Assessment, legal perspective, Albania earthquake 2019 case
225	Amer Smailbegović Nermin Palić	Management of climate change and environmental risks in securing raw material base and transportation logistics network in the Western Balkans
234	Cveta Lazić Goran Jeftenić Ljiljana Popović Slobodan Kolaković	Rainfall indices as indicators of climatic trends and extremes: A case study of Novi Sad (2014–2023)
245	Elona Pojani Zyra Mahmuti Perseta Grabova	Plastic waste reducition in restaurants and hotels along the Shkumbini River

257	Joana Gjipalaj Oltion Marko Denisa Selimi Xhuana Xhika	Management of geothermal waters after their use for balneological purposes: Environmental impacts and the importance of sustainable practices. Case study: Llixha of Elbasan-Albania
265	Johan Ingvarson	On the use of standards in risk management regulations
276	Kristjana Omeri Teida Shehi	Energy efficiency in buildings as a source of carbon credits: a case study of Prrenjas, Albania
285	Leonardo Pavičić Nermin Palić	Societal impact of cars with reference to Sarajevo Canton
296	Marina Rakočević Vasilije Bojović Svetislav Popović	Sustainability and recycling of composite materials
308	Meri Cvetkovska Milica Jovanoska-Mitrevska Ana Trombeva Gavriloska	Fire safety of energy-efficient buildings: The role of combustible and circular materials
319	Meri Cvetkovska Milica Jovanoska Mitrevska Todorka Samardzioska Ognen Marina Liljana Dimevska Sofronievska	Pathways for circular economy implementation in construction
330	Perseta Grabova Julia Dado Elona Pojani	Waste management sector: Evaluating the municipal waste system in Elbasan and opportunities for improvement
343	Peter Spathelf Marcus Lindner Frits Mohren	Forests and climate change
354	Silvana Mekić Sanjin Adam Mujagić	Ergonomic risks management in the textile industry
365	Todorka Samardzioska Meri Cvetkovska Milica Jovanoska Mitrevska Maja Putic Marija Menchevska	Application of wood biomass ash as a partial replacement of cement in sustainable concrete
376	Zvjezdan Karadžin Jasmin Isabegović Miralem Sejdinović Edisa Nukić	Remediation method for mercury polluted site selected using analytical hyerarchy process
389	Željka Beljkaš Snežana Rutešić Miloš Knežević Ivona Krulanović	Sustainable water management under limited resources through artificial neural networks

T5 – Sustainable urban and rural development

400	Anđela Knežević Dušan Ignjatović	Towards the AI city: Artificial intelligence technologies development and application
415	Elena Ferraioli	Regenerative planning and territorial transitions: Reimagining wastelands for circular urban futures

426	Ivana Ćipranić Marija Jevrić Milena Ostojić Olga Ćalasan Goran Sekulić	Strengthening resilience to floods in Montenegro: A review of legislation, strategies, and EU integration
436	Ljiljana Popović Mirjana Laban Sandra Nedeljković	Institutionalisation of the methodology for damage and loss assessment in agriculture
445	Nermin Palić Grgo Luburić Dejan Štekić Lejla Viteškić Edin Džumhur Dario Šušnja Benjamin Hasanović Ernis Hadžajlić Minela Balija Valentin Đotlo Adrian Bonjak	Analysis of the sustainable urban mobility in the municipality of Kiseljak
458	Snežana Rutešić Željka Beljkaš Miloš Knežević Stefan Rutešić	Construction waste management as a regulatory and environmental challenge in Montenegro
469	Xhorxhina Prendi Sherif Bundo Brixhilda Çekrezi	Characteristics of the regional economy in the face of globalization, tourism and tradition

T6 – Education and Communication

478	Amer Smailbegović Mirzo Selimić	Addressing evolving active attacks threats using integrated training curriculum
485	Edisa Nukić Aida Krlić Jelena Marković Zvjezdan Karadžin	Importance of communication in disaster risk management
499	Heike Molitor	Nature experience areas and informal educational processes
511	Jovana Topalić Anka Starčev-Ćurčin Suzana Draganić	Instagram as a communication and educational tool in civil engineering: Connecting students, academia, and industry
521	Sergey Dmitriev Eva Vitorović	The GREEN Program, KAOSPILOTS, Game|Changers, and Zeleno Doba cases for bridging industries, academia, and communities to grow regenerative leaders for the Western Balkan

T7 – Other

532	Alexander Cedergren Henrik Hassel	Integrating the analysis of adaptive capacity into an anticipatory method for risk and vulnerability assessment

543	Henrik Hassel Alexander Cedergren Lovisa Vallin	A multilevel account of adaptations and adaptive capacity – A case study of an incident in the health care sector
554	Henrik Hassel Alexander Cedergren Magnus Hagelsteen	Towards more mature method development processes in societal safety and resilience
565	Peter Spathelf Franziska Rottig	Climate change impacts on forests
574	Vlorlinda Daja Entela Çobani Ledia Aleksi	Climate change impact assessment and adaptation measures identification for the Municipality of Tirana

Preface

In recent years, the global scientific and professional community has increasingly recognized that sustainability, climate resilience, and circularity are no longer optional objectives but essential pathways for the survival and progress of our societies. The transition towards a greener and fairer future requires a new paradigm of cooperation – one that effectively bridges science, business, and policy to achieve tangible impact.

The **International Symposium "Bridging Research between Business and Academia for a Greener Tomorrow"**, held on **October 16–17, 2025** at the F**aculty of Civil Engineering, University of Montenegro**, represents one of the flagship events within the Erasmus+ project **1FUTURE**. The symposium brought together researchers, practitioners, and decision-makers from across Europe and beyond, aiming to foster dialogue, exchange innovative ideas, and strengthen interdisciplinary collaboration in advancing sustainable development.

A particular strength of this event lies in the diversity of its participants — including representatives from universities and research centers, as well as **members of the business community, professional chambers, and the non-governmental sector** actively promoting sustainable development and green transition in practice.

This volume comprises 51 peer-reviewed papers authored by 104 scholars, researchers, engineers, business experts, and civil society representatives from more than eight countries. The contributions cover a wide range of topics – from sustainable economic and business models, green infrastructure, and urban resilience, to climate adaptation, environmental justice, and digital transformation of the built environment. Collectively, these papers provide a rich and diverse perspective that advances the understanding of how sustainability principles can be effectively integrated into practice and policy.

This publication is not merely a collection of academic papers, but also a testament to the strength of regional cooperation and shared vision within the academic, engineering, and professional communities of the Western Balkans and Europe. It reaffirms the commitment of the 1FUTURE consortium to building bridges between academia and business, science and policy, knowledge and implementation – all in pursuit of a smarter, greener, and more resilient future.

We express our sincere gratitude to all authors, reviewers, members of the Scientific and Organizing Committees, as well as to the partner institutions whose dedication made this event and publication possible.

Editors: Prof. dr. Miloš Knežević, University of Montenegro
Prof.dr. Elona Pojani, University of Tirana
Prof. dr. Mirjana Laban, University of Novi Sad

Podgorica, October 2025

T1

Sustainable economic and business models

The impact of plastic pollution on recreational river use and sustainable tourism

Special Case - Shkumbin River

Brikena Leka[1]

Anisa Nipolli[2]

1 Professor;University of Tirana, Faculty of Economy
brikena.leka@unitir.edu

2 Student-Master of Science Student in Risk Management, Faculty of Economy, University of Tirana
anisa.nipolli@unitir.edu.al

Abstract

In recent years, tourism has emerged as one of the key sectors for the Albanian economy, contributing approximately 22% to the Albania's GDP in 2024. Nature-based and adventure activities, in particular, are attracting a growing number of domestic and international visitors. Within this context, the Shkumbin River represents a significant site for rafting and other recreational activities in Albania; however, its potential is compromised by unmanaged plastic pollution. Flowing through five municipalities and encompassing both urban and rural communities, the river faces persistent challenges related to inadequate waste management and uncontrolled solid waste disposal. The accumulation of plastic debris along its 181-kilometre course not only degrades the natural environment but also raises ongoing safety concerns for recreational users.

This study focuses specifically on tourists who have experienced rafting on the Shkumbin River, examining how plastic pollution affects their perceptions of river quality, overall satisfaction, and their willingness to pay (WTP) for a cleaner river environment. A structured survey is conducted to collect data on tourists' direct observations, satisfaction levels, and WTP for measures aimed at improving water quality.

The results aim to provide evidence-based insights for local stakeholders about how environmental quality influences tourism demand and tourists' readiness to contribute financially to river conservation. The findings provide preliminary estimates of the potential economic value of small-scale clean-up actions, using the WTP data as input.

By addressing this under-researched topic for the first time in the context of the Shkumbin River, the study seeks to fill an important knowledge gap and to encourage actions that help maintain the river's value as a sustainable destination for adventure tourism, and similar studies for other rivers in Albania, as well as future research for this sport in Shkumbin river.

Keywords

Sustainable tourism, plastic pollution, rafting, willingness to pay

1. Introduction

Plastic pollution is now recognized as one of the major environmental problems of our time, and it reflects how unsustainable many development patterns have been worldwide. The rapid increase in plastic production and consumption, combined with weak or fragmented waste management systems, has led to the accumulation of waste not only in the oceans but also in rivers, lakes, and on land [1]. This build-up affects ecosystems in several ways: it reduces biodiversity, disrupts ecological functions, and ultimately threatens human health and livelihoods. The problem is aggravated by the breakdown of larger plastic items into microplastics, which enter food chains and create risks of bioaccumulation with possible consequences for human health [2].

Plastic pollution is not only an ecological problem but also an economic one. It generates higher costs for public services and businesses involved in clean-up, reduces the quality of natural resources, and undermines revenues in key sectors such as fisheries, tourism, and river transport [3].

In Albania, these challenges are evident in several major rivers, with the Shkumbin standing out as a clear case. Weak local waste management, together with municipal and industrial discharges, has progressively lowered water quality and damaged the river's ecological integrity [4,5]. The Shkumbin has long been central to agriculture and cultural heritage, and more recently has become important for tourism, especially rafting. However, these opportunities are being eroded by illegal dumping, poor wastewater treatment, and infrastructure projects that are often uncoordinated and fragment river habitats, reducing biodiversity and diminishing the landscape's appeal [6,7].

For rafting in particular, the presence of plastic waste reduces visitor satisfaction, discourages repeat visits and recommendations, and creates risks for the long-term growth of the sector [8]. International evidence confirms this pattern: even small amounts of visible litter have been shown to reduce tourists' enjoyment and their willingness to return, both in coastal destinations and in river-based adventure tourism [9–11]. Beyond aesthetics, pollution also increases the operating costs of tourism providers and introduces potential safety issues for both visitors and guides [12,13].

To assess and understand these impacts, economic valuation methods are essential—especially the Contingent Valuation Method (CVM) and the concept of Willingness to Pay (WTP). Studies consistently show that tourists are willing to spend more when environmental conditions improve, particularly with regard to water quality and the cleanliness of natural areas [14,15]. This underlines the close connection between environmental quality and the economic value of recreational experiences. In Albania, however, data of this kind remain very limited, making it difficult for policymakers and stakeholders to design interventions that are both effective and economically justified [16].

One approach that has been discussed is "green rafting," which goes beyond river clean-up to include waste reduction, eco-certification, stronger engagement with local communities, and better cooperation with institutions. The aim is to reduce the ecological footprint of tourism while enhancing its economic and social benefits [17]. Lessons from other countries, such as river management initiatives in Slovenia and Montenegro, suggest that when such measures are combined with consistent governance, they can deliver sustainable improvements in both environmental outcomes and tourism competitiveness [18]. Despite global research progress, some important gaps remain.

Most studies focus on marine systems or on large tourist destinations, while smaller rivers in rural or semi-rural areas receive far less attention [19,20]. Moreover, much of the existing research relies on cross-sectional data, which cannot capture changes over time or properly evaluate policy effectiveness [21]. For rivers like the Shkumbin, where rafting and other water-based activities are growing, the absence of long-term monitoring creates uncertainty for local communities and businesses that depend on tourism revenues. Addressing these gaps requires localized and sustained research that directly links environmental quality with economic outcomes, providing the type of evidence needed for sustainable river tourism management in Albania.

2. Local context: The case of the Shkumbin River

The Shkumbin River is 181 km long, with a catchment area of 2,444 km^2, and plays an important ecological and economic role by supporting biodiversity, agriculture, and local livelihoods [22]. Its water quality, however, has been heavily affected by economic activity and weak waste management, particularly around Elbasan and Librazhd.

The basin is home to about 257,000 residents, with Elbasan Municipality being the most densely populated area [22]. Tourism in this region has traditionally been associated with cultural heritage, but in recent years it has shifted toward nature-based activities. In 2025, rafting attracted around 210 participants, both local and foreign, as part of municipal initiatives to promote Elbasan as a sports and nature destination [22]. The economic value of rafting is reflected in the average price of €20–30 per person, which corresponds closely to the estimated daily expenditure of tourists. The activity also generates social benefits by employing local guides and fostering cooperation between institutions [22].

Plastic pollution, however, poses a significant challenge. The ETMI baseline study documented 18 major waste hotspots along the Shkumbin, including two located directly in the rafting stretch near Kamara Bridge. Of the 1,859 items recorded, 88% were plastics, amounting to about seven tons of plastic entering the Adriatic Sea each year [23]. Additional surveys conducted through the Surfrider Foundation's Plastic Origins initiative confirmed that rafting zones are among the most affected sections of the river [24]. These findings show that visible plastic waste not only diminishes the visitor experience and reduces willingness to contribute to environmental improvements, but also raises concerns about the long-term prospects of rafting as a sustainable tourism product.

Figure 1 – Riverbank monitoring locations and plastic pollution hotspots along the Shkumbin River (Source: Copied from ETMI, 2025)

3. Methodology

This study applies a quantitative approach grounded in environmental economics and non-market valuation to examine the economic impact of plastic pollution on rafting and other water-based tourism in the Shkumbin River. The main method is the Contingent Valuation Method (CVM), a tool often used when market prices are missing, especially for environmental and recreational services such as clean rivers or eco-certified tourism [25]. Although there are no valuation studies for plastic pollution in Albanian rivers, international evidence shows that pollution can reduce tourist arrivals, shorten visits, and harm the image of destinations that rely on ecotourism [26]. By using these frameworks and adapting them to the Shkumbin context, this research aims to provide locally relevant estimates that can inform tourism and environmental policy.

The CVM was applied through a survey scenario that compared current polluted conditions of the river with a hypothetical cleaner state. Respondents were asked how much they would be willing to contribute for an improved experience. The questionnaire, designed in line with NOAA Panel Guidelines [27], used a combination of dichotomous choice (yes/no bidding) and open-ended questions, and also included sections on socio-demographic characteristics, perceptions of pollution, and rafting experience. Similar studies in other river-based tourism settings, such as Abate et al. [26], have shown that tourists are often willing to pay noticeably more for cleaner environments, which reinforces the relevance of this approach.

The target population included all tourists who participated in rafting on the Shkumbin in the 2025 season, estimated at around 210 individuals. According to Krejcie and Morgan's sampling guidelines [28], this population would ideally require about 136

responses for a 95% confidence level and a 5% margin of error. In practice, collecting such a sample is difficult in niche tourism settings, and literature suggests that smaller samples can still provide useful insights [29,30]. In this case, 63 valid responses were obtained. While this number is below the ideal statistical threshold, it represents almost one-third of the entire rafting population and is therefore considered a meaningful dataset for this study [31].

Ethical standards were respected throughout the process. All participants gave informed consent, responses were anonymized, and the Google Forms survey avoided collecting any personal identifiers. The study also acknowledges the issue of hypothetical bias in CVM, where people may state a willingness to pay that differs from what they would actually spend. To reduce this risk, respondents were also asked about their actual tourism expenses (transport, accommodation, food), and these data were compared with official Elbasan tourism statistics to ensure that the WTP values reported were reasonable [32].

Overall, the methodology follows established practices in valuation research but is carefully adjusted to local conditions. While the sample size is smaller than ideal, the combination of internationally recognized techniques, local data, and ethical safeguards makes the findings credible and relevant for discussions on sustainable rafting tourism and river management in Albania.

4. Empiric Analysis

This chapter presents the main results of the survey on tourists' willingness to pay (WTP) for a cleaner rafting experience on the Shkumbin River.

4.1. Sample Characteristics

The majority of participants were domestic tourists (65%), while foreign respondents came from Spain (24%) and Austria (11%) (see Figure 2).

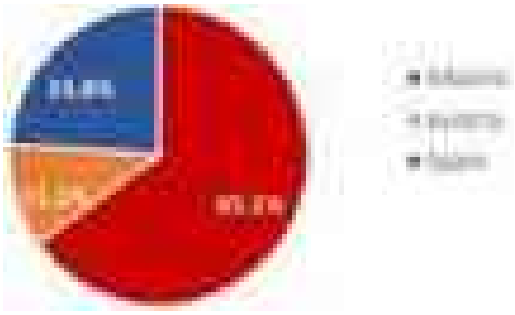


Figure 2 – Distribution of tourists by country of origin (Source: Authors' survey data, 2025).

The average age was 35 years, with most respondents aged 25–44. Gender distribution was nearly balanced (54% male, 46% female). Most visitors (56.5%) stayed 2–3 days, 34% stayed only one day, and fewer than 10% stayed 4–7 days. Expenditures

increased with stay length: one-day visitors spent under €100, those staying 2–3 days spent €101–300, and longer stays were associated with €301–500. These results confirm that longer stays significantly increase tourist spending, highlighting the importance of developing complementary tourism products.

Most respondents were first-time rafters in Albania (71%), and 76% stated that rafting was one of the main reasons for visiting Elbasan. This confirms that the Shkumbin functions as a soft adventure destination, attractive for beginners, unlike the more challenging Osum or the wild Vjosa [33,34].

4.2. Environmental Perceptions and Willingness to Pay

Perceptions of river quality were strongly negative: 89% observed plastic waste, and 97% rated the river as polluted or highly polluted (Figures 3–4).

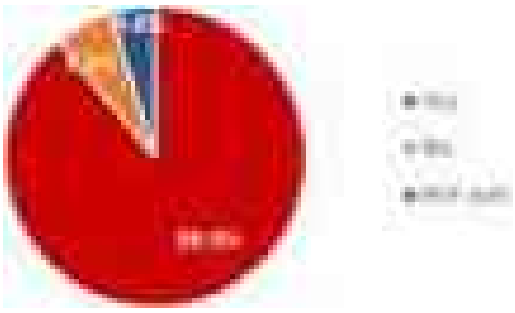


Figure 3 – Observation of Plastic Waste Along the River. (Source:Authors' survey data, 2025).

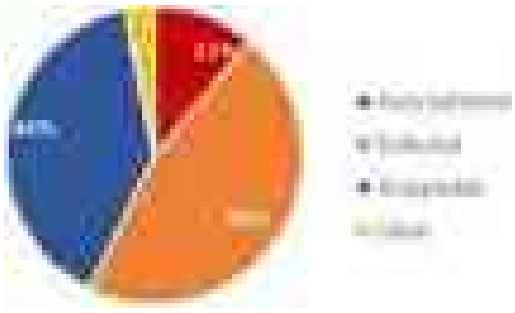


Figure 4 – Perception of River River Cleanliness (Source:Authors' survey data, 2025).

Environmental quality was considered critical for the rafting experience: 40% rated cleanliness as "very important" and 25% as "essential." This perception strongly influenced behaviour:

- 92% said cleanliness would influence their decision to return.
- 82% said it would affect their willingness to recommend rafting (Figures 5-6).

Regarding WTP, 87% expressed willingness to pay an eco-contribution for a cleaner river (Figure 5). The average WTP was €5.49 (median €5.00), with most contributions clustered around €5–10. The majority (75%) preferred integrating the eco-contribution directly into the ticket price, while only 24% supported voluntary donation schemes.

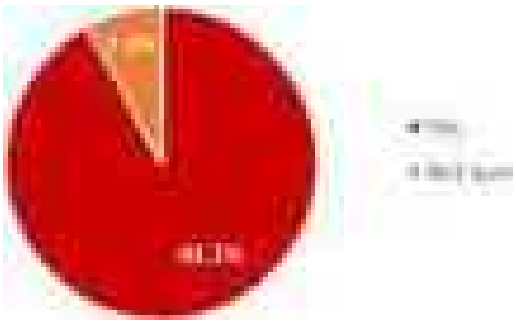


Figure 5 – Impact of river cleanliness on tourists' intention to return (Source: Authors' survey data, 2025)

Figure 6 – Impact of river cleanliness on tourists' intention to recommend (Source: Authors' survey data, 2025)

4.2.1. Differences Across Groups

The analysis of willingness to pay (WTP) reveals statistically significant differences among tourists by country of origin. Both ANOVA ($F(2,60) = 10.72$, $p < 0.001$) and the Kruskal–Wallis test ($\chi^2 = 16.09$, $p < 0.001$) confirm strong group variation, with post-hoc Tukey results showing that Austrian and Spanish tourists are significantly more willing to contribute than Albanian tourists, while no significant difference exists between Austrians and Spaniards.

Following best practice in the Contingent Valuation Method (CVM) [35,36], all 63 respondents were included to ensure representativeness and avoid overestimation. Results show clear differences by origin: Austrians reported the highest WTP (M = €10.71), Spaniards followed (€8.13), while Albanians showed the lowest average (€3.63, median = €2). Although domestic tourists reported modest means, variation exists, with some willing to contribute higher amounts. These findings are consistent with CVM literature, which shows that tourists from high-income countries generally exhibit greater WTP due to stronger financial capacity and environmental awareness, whereas lower contributions from locals often reflect income constraints, weaker environmental education, and reliance on public authorities for environmental management [37,38].

Table 1 – WTP by Country of Origin. (Source: Authors' calculations from survey data)

Country	Mean (€)	Median (€)	SD (€)	Min (€)	Max (€	N
Austria	10.71	10	5.35	0	15	7
Spain	8.13	10	4.72	0	15	15
Albania	3.63	2	4.3	0	20	41

4.3. Regression Analysis

The regression analysis identified two main factors influencing tourists' willingness to pay (WTP) for a cleaner rafting experience on the Shkumbin River: tourist origin and perception of river cleanliness. Results show that foreign tourists are, on average, willing to pay about €7 more than local visitors ($\beta = 7.24$, $p < 0.001$), a finding consistent with earlier group comparisons and supported by international literature linking higher incomes and stronger environmental attitudes with greater WTP [37]. In addition, perception of pollution significantly shaped contributions ($\beta = -1.19$, $p < 0.05$): the more polluted the river was perceived to be, the higher the WTP, indicating that visible waste acts as a trigger for financial support [39,40].

The estimated regression model can be expressed as:

WTP = 5.86 + 7.24 × (Tourist origin) − 1.19 × (Cleanliness rating)

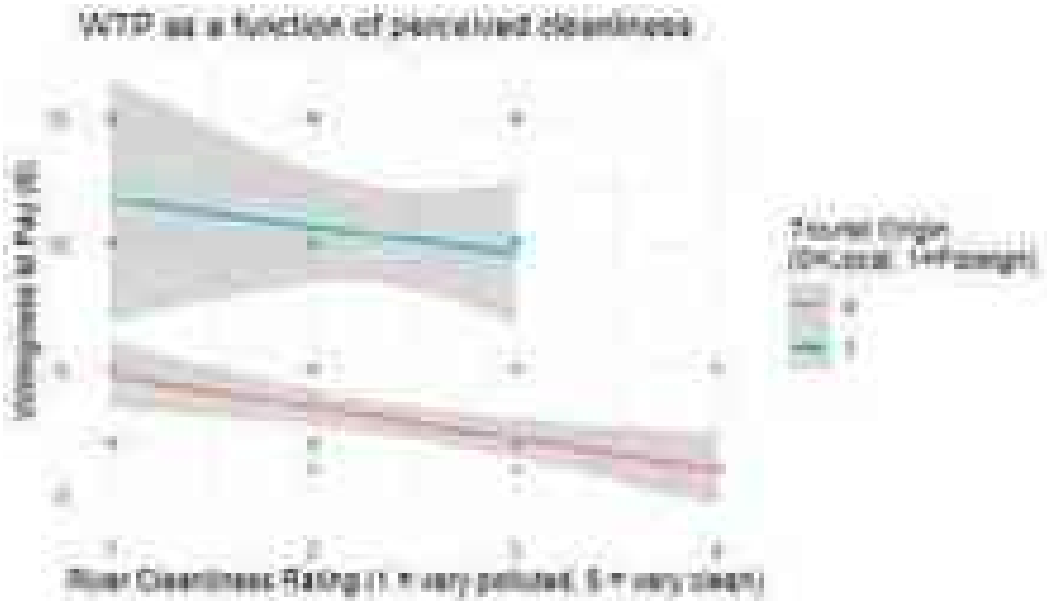


Figure 7 – Willingness to pay (WTP) as a function of perceived cleanliness (Source: Authors' calculations based on survey data, 2025).

The final model demonstrates substantial explanatory power (R^2 = 0.64), confirming that these two variables account for nearly two-thirds of the variation in WTP. Diagnostic checks further validated the robustness of the model, showing no issues with normality, heteroskedasticity, or influential outliers. Taken together, the findings underscore the decisive role of both tourist origin and perceived environmental quality in shaping willingness to pay, providing a clear statistical basis for understanding the economic dynamics of rafting tourism in Elbasan.

4. Conclusion and implications

This study examined tourists' willingness to pay (WTP) for a cleaner rafting experience on the Shkumbin River. The results confirm both the economic potential of rafting tourism and its strong sensitivity to environmental quality. Most visitors were young, stayed 1–3 days, and reported average expenditures of €100–300. Foreign tourists, particularly from Spain and Austria, showed a significantly higher WTP compared to domestic visitors. The regression analysis indicated that tourist origin and perceptions of cleanliness were the two main drivers of WTP. On average, foreign visitors were willing to pay about €7 more than locals, and those perceiving higher levels of pollution tended to contribute more. Together, these factors explained 64% of the variation in WTP, which is a relatively high explanatory power, though it should be interpreted with caution given the limited sample size. These insights highlight several important policy implications:

- Invest in river cleaning and waste management, since environmental quality directly shapes both visitor satisfaction and tourism revenues.
- Extend visitor stays through bundled packages (rafting combined with cultural, natural, or sporting activities) to increase overall tourist expenditures.

- Target high-income international markets such as Austria, Germany, and Switzerland, where tourists demonstrate higher WTP for environmental quality.
- Apply differentiated pricing policies, offering lower fees for domestic tourists and higher ones for international visitors, balancing social equity and financial efficiency.
- Engage the local community in conservation efforts, through awareness campaigns and participatory initiatives, to build ownership and strengthen sustainability.

Overall, rafting on the Shkumbin River demonstrates strong potential to combine economic development with environmental protection, while future research should expand sample size, include additional socio-economic variables, and explore other river tourism contexts in Albania and the Balkans to strengthen the generalizability of these conclusions.

Acknowledgement

This research was supported by the BeMed+ project (Beyond Plastic Med – Commit for a Mediterranean Sea Without Plastic), financed by the Fonds Français pour l'Environnement Mondial (FFEM) and implemented in collaboration with IUCN and Surfrider Foundation Europe, with INCA as the national coordinator in Albania.

Literature

[1] United Nations Environment Programme (UNEP), From pollution to solution: A global assessment of marine litter and plastic pollution, UNEP, Nairobi, 2021, 86 p.

[2] Smith M., Love D.C., Rochman C.M., Neff R.A., Microplastics in seafood and the implications for human health, Current Environmental Health Reports, Vol. 5, No. 3, Springer, Cham, 2018, pp. 375–386.

[3] McIlgorm A., Campbell H.F., Rule M.J., The economic cost and control of marine debris damage in the Asia-Pacific region, Ocean & Coastal Management, Vol. 54, No. 9, Elsevier, Amsterdam, 2011, pp. 643–651.

[4] REC Albania, Waste management in Albania: Current situation and challenges, Regional Environmental Center, Tirana, 2022, 73 p.

[5] United Nations Environment Programme (UNEP), National baseline report on plastic pollution: Albania, UNEP, Nairobi, 2021, 52 p.

[6] European Environment Agency (EEA), European environment — state and outlook 2023: Country profile Albania, EEA, Copenhagen, 2023, 24 p.

[7] Institute for Nature Conservation Albania (INCA-AL), Biodiversity impacts of infrastructure on Albanian rivers, INCA-AL, Tirana, 2024, 47 p.

[8] Williams A.T., Rangel-Buitrago N., Anfuso G., Cervantes O., Botero C.M., Litter impacts on tourist beaches: The case of the Caribbean, Marine Pollution Bulletin, Vol. 102, No. 1, Elsevier, Amsterdam, 2021, pp. 266–272.

[9] Jang Y.C., Lee J., Hong S., Mok J.Y., Kim K.S., Lee Y.J., Choi H.W., Kang D., Ra K., Shin S.C., Estimation of lost tourism revenue in Geoje Island from the 2011 marine debris pollution event in South Korea, Marine Pollution Bulletin, Vol. 81, No. 1, Elsevier, Amsterdam, 2014, pp. 49–54.

[10] Williams A.T., Tudor D.T., Litter burial and exhumation: Spatial and temporal distribution on a cobble pocket beach, Marine Pollution Bulletin, Vol. 113, No. 1–2, Elsevier, Amsterdam, 2016, pp. 477–484.

[11] Qiang M., Cheng S., Yu C., Tourists' perceptions of river pollution and their recreational choices: Evidence from China's Yangtze and Pearl Rivers, Water Resources Management, Vol. 33, No. 14, Springer, Cham, 2019, pp. 5005–5020.

[12] Jambeck J.R., Geyer R., Wilcox C., Siegler T.R., Perryman M., Andrady A., Narayan R., Law K.L., Plastic waste inputs from land into the ocean, Science, Vol. 347, No. 6223, American Association for the Advancement of Science, Washington DC, 2015, pp. 768–771.

[13] Ocean Conservancy, International coastal cleanup report 2020, Ocean Conservancy, Washington DC, 2020, 64 p.

[14] Carson R.T., Contingent valuation: A practical alternative when prices aren't available, Journal of Economic Perspectives, Vol. 26, No. 4, American Economic Association, Nashville, 2012, pp. 27–42.

[15] Abate S., Economic valuation of water quality in river-based tourism, Master thesis, Wageningen University, Wageningen, 2020, 112 p.

[16] World Bank, Municipal solid waste management in South-Eastern Europe: Albania country profile, World Bank, Washington DC, 2020, 32 p.

[17] Buckley R., Sustainable tourism: Research and reality, Annals of Tourism Research, Vol. 39, No. 2, Elsevier, Amsterdam, 2012, pp. 528–546.

[18] Schägner J.P., Brander L., Maes J., Hartje V., Mapping ecosystem services' values: Current practice and future prospects, in: Schröter M., Bonn A., Klotz S., Seppelt R., Baessler C. (eds.), Atlas of ecosystem services: Drivers, risks, and societal responses, Springer, Cham, 2017, pp. 59–63.

[19] Beaumont N.J., Aanesen M., Austen M.C., Börger T., Clark J.R., Cole M., Hooper T., Lindeque P.K., Pascoe C., Wyles K.J., Global ecological, social and economic impacts of marine plastic, Marine Pollution Bulletin, Vol. 142, Elsevier, Amsterdam, 2019, pp. 189–195.

[20] Mihai F.C., Grozavu A., Ghiurca A.A., Plastic pollution in Eastern European rivers: A review, Environmental Challenges, Vol. 7, Elsevier, Amsterdam, 2022, pp. 100–149.

[21] Kazeminia A., Altinay L., Buhalis D., Impact of tourism development on environmental sustainability: A longitudinal study, Tourism Management, Vol. 57, Elsevier, Amsterdam, 2016, pp. 1–14.

[22] Elbasan Municipality, Directorate General for Economic Development, Culture and Tourism – Directorate of Tourism and Cultural Heritage Policies, Tourism Promotion Sector, Information on tourism in Elbasan and rafting activities in the Shkumbin River, Elbasan, 2025, pp. 1–6.

[23] Struga A., Bino F., Çado D., Baseline report on plastic pollution in the Shkumbin River, ETMI, Elbasan, 2025, pp. 1–45.

[24] Surfrider Foundation Europe, Plastic Origins: Citizen-science monitoring of riverine plastic pollution in Europe, Surfrider Publications, Biarritz, 2019, 55 p.

[25] Hanemann W.M., Welfare evaluations in contingent valuation experiments with discrete responses, American Journal of Agricultural Economics, Vol. 66, No. 3, Agricultural & Applied Economics Association, Washington DC, 1984, pp. 332–341.

[26] Abate T.G., Börger T., Aanesen M., The economic impact of marine plastic pollution on tourism: Evidence from Europe, Journal of Environmental Economics and Policy, Vol. 9, No. 4, Routledge, London, 2020, pp. 439–458.

[27] Arrow K., Solow R., Portney P.R., Leamer E.E., Radner R., Schuman H., Report of the NOAA panel on contingent valuation, Federal Register, Vol. 58, No. 10, National Oceanic and Atmospheric Administration, Washington DC, 1993, pp. 4601–4614.

[28] Krejcie R.V., Morgan D.W., Determining sample size for research activities, Educational and Psychological Measurement, Vol. 30, No. 3, SAGE Publications, Thousand Oaks, 1970, pp. 607–610.

[29] Israel G.D., Determining sample size, University of Florida Cooperative Extension Service, IFAS, Gainesville, 1992, pp. 1–5.

[30] Boddy C.R., Sample size for qualitative research, Qualitative Market Research: An International Journal, Vol. 19, No. 4, Emerald Group Publishing, Bingley, 2016, pp. 426–432.

[31] Creswell J.W., Creswell J.D., Research design: Qualitative, quantitative, and mixed methods approaches, 5th ed., SAGE Publications, Thousand Oaks, 2018, 304 p.

[32] Carson R.T., Groves T., Incentive and informational properties of preference questions, Environmental and Resource Economics, Vol. 37, Springer, Dordrecht, 2007, pp. 181–210.

[33]	Buckley R., Adventure tourism management, Elsevier, Oxford, 2012, 267 p.
[34]	Sung H.H., Morrison A.M., O'Leary J.T., Segmenting the adventure travel market by activities: From the North American industry providers' perspective, Journal of Travel & Tourism Marketing, Vol. 9, No. 4, Taylor & Francis, New York, 2006, pp. 1–20.
[35]	Mitchell R.C., Carson R.T., Using surveys to value public goods: The contingent valuation method, Resources for the Future, Washington DC, 1989, 463 p.
[36]	Carson R.T., Hanemann W.M., Contingent valuation, in: Mäler K.G., Vincent J.R. (eds.), Handbook of Environmental Economics, Vol. 2, Elsevier, Amsterdam, 2005, pp. 821–936.
[37]	Togridou A., Hovardas T., Pantis J.D., Determinants of visitors' willingness to pay for the National Marine Park of Zakynthos, Greece, Ecological Economics, Vol. 60, No. 1, Elsevier, Amsterdam, 2006, pp. 308–319.
[38]	Poe G.L., Giraud K.L., Loomis J.B., Computational methods for measuring the difference of empirical distributions, American Journal of Agricultural Economics, Vol. 87, No. 2, Oxford University Press, Oxford, 2005, pp. 353–365.
[39]	Hanemann W.M., Willingness to pay and willingness to accept: How much can they differ?, American Economic Review, Vol. 81, No. 3, American Economic Association, Nashville, 1991, pp. 635–647.
[40]	Brouwer R., Langford I.H., Bateman I.J., Turner R.K., A meta-analysis of wetland contingent valuation studies, Regional Environmental Change, Vol. 1, Springer, Berlin, 1999, pp. 47–57.

The impact of immigration on the labor market of the Balkan countries

Florenca Gjorduni[1]

Leudita Ademi[2]

Resina Pllaha[3]

1 Head of Business Administration Departement, Faculty of Economie, Luarasi University, Albania
florenca.gjorduni@luarasi-univ.edu.al

2 Vc-Dean of Faculty of Economie, Luarasi University, Albania
leudita.ademi@luarasi-univ.edu.al

3 Assistent Lecture, Faculty of Economie, Luarasi University, Albania
resina.pllaha@luarasi-univ.edu.al

Abstract

The effect of diaspora on the country of origin is multidimensional, as it includes a combination of positive and negative impacts. The intensity and nature of these effects depend greatly on the economic, social and institutional context of the country of origin. In other words, emigrants stimulate employment and increase economic activity through remittances and investments; on the other hand, the departure of the workforce and dependence on remittances can create challenges for the labor market. In this paper, we aim to analyze precisely the impacts that the diaspora of the Balkan countries has on the labor market of these countries. The Balkan countries have a long history of migration which has deep traces on the developments of these countries. In fact, emigrants have been a powerful catalyst for the recovery of the economies of these countries with serious social and economic consequences in the long term. Faced with the dilemmas of the positive and negative effects generated by the massive emigration from these countries, we want to empirically analyze these implications on the labor market of these countries. In other words, this study brings to attention the impact of the diaspora and macroeconomic factors on unemployment in the Balkan countries during the period 2014–2024. Three econometric approaches were applied for the analysis: OLS regression, fixed effects model and random effects model. The empirical analysis shows that remittances increase the unemployment rate in the countries of origin, as individuals who rely on diaspora remittances are less engaged in the formal labor market. On the other hand, net migration contributes to a slight but stable decrease in unemployment, due to the departure of the labor force and the reduction of competition for jobs. The improvement in the Human Development Index (HDI) is associated with a strong reduction in unemployment, indicating the importance of investments in education and health for the development of human capital. Meanwhile, the improvement in the control of corruption is associated with an increase in unemployment, due to higher standards and increased competition in the labor market. The study highlights the need for policies that channel remittances towards productive investments and the strengthening of institutions, so that the contribution of the diaspora becomes a source of sustainable development and unemployment reduction in the region.

Keywords

Unemployment Migration, Remittances, Labor market, Balkans countries

1. Introduction

Diaspora represents a two-sided phenomenon, which brings both benefits and challenges to the country of origin. On the one hand, it has a very positive impact on the economy through remittances, investments and professional experiences that emigrants bring upon their return, thus becoming an important engine of development. Diaspora also helps to spread culture and traditions, strengthens diplomatic ties and often contributes with solidarity in times of crisis. On the other hand, mass emigration brings negative consequences such as the loss of skilled labor and young people, the creation of dependency on remittances, the weakening of the connection of younger generations with the language and culture of origin, as well as the decline in economic productivity due to the aging of the population. In this sense, diaspora remains a complex phenomenon, where positive and negative impacts must be carefully managed to maximize benefits and minimize losses. Recognizing the long migratory history of the Balkan countries but also the new phenomenon, the massive influx of immigrants from other countries to these countries, we aim to analyze how these phenomena affect the labor market. The first channel through which migrants affect the country of origin is remittances. Remittances and investments made by immigrants stimulate employment and increase economic activity, on the one hand, and on the other hand, the departure of the workforce and dependence on remittances can create challenges for the labor market. Remittances sent from the diaspora are often used for consumption, investment or financing small family enterprises. These financial revenues can contribute to increasing the demand for local goods and services, indirectly affecting the creation of jobs in the consumer sectors. They can also increase the standard of living, reducing the pressure to work for a basic income. The intensity and nature of these effects depend greatly on the economic, social and institutional context of the country of origin. In addition to the economic impact, the diaspora can exert influence on labor market-related policies and bring new professional practices and work ethics, which change the way the labor market functions. On the other hand, emigration can reduce the supply of labor in the country of origin, increasing wages for those who remain and creating changes in the structure of the labor market. Based on the above, we expect that the impact of the diaspora measured in terms of remittances and mass movements of people, in and out, from the Balkan countries will have a significant impact on the labor market of these countries. In other words, our goal in this paper is to analyze the impacts of the Balkan diaspora on the labor market, examining how remittances, returning emigrants and international networks affect the supply and demand of labor, as well as the standard of living and economic development in the region.To analyze these relationships, we used World Bank data for the period 2014-2024, including variables such as GDP, remittances, education spending, HDI, net migration, graduation rate, corruption control, foreign direct investment (FDI). The empirical analysis uses three econometric approaches such as OLS, Fixed Effects and Random Effects to examine the impact of various factors on the labor market, respectively on the unemployment rate, identifying the most important factors related to economic activity and employment in the Balkan countries.

To achieve our objective, we analyzed eight Balkan countries such as Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, North Macedonia, Serbia and Kosovo over the last ten years, the period 2014–2024. We used the Stata software for data analysis. Emigration has complex impacts on the labor market and economic development

of countries of origin. Empirical analysis conducted for Balkan countries shows that remittances, although they increase the standard of living, can discourage engagement in the formal labor market, leading to an increase in the unemployment rate. On the other hand, net migration, consisting of the departure of part of the labor force and young people, contributes to a slight but stable decrease in unemployment, due to reduced competition for jobs. Improvements in the Human Development Index (HDI) are associated with strong reductions in unemployment, demonstrating the importance of investments in education, health and living standards for human capital development. Meanwhile, strengthening corruption controls may increase unemployment rates, due to higher standards and increased market competition. These results highlight the dual nature of migration and the need for policies that maximize benefits and reduce negative consequences for the labor market and the long-term development of the region.

2. Literature review

The phenomenon of emigration, often considered a social and economic "wound" for countries of origin, has also generated a number of positive effects that cannot be neglected. Contemporary literature on migration has emphasized that this process is not simply a flow of human capital, but also an important catalyst for the economic, social and political transformation of sending countries. Authors from different countries, through their studies, have produced a vast literature that shows that emigration has multiple and interconnected impacts on the economic, social and institutional development of countries of origin.

First, remittances are an important source of financing for countries of origin. In 2023, remittance flows to low- and middle-income countries reached $656 billion, exceeding official development assistance and foreign direct investment.(Report, 2023)

Remittances represent an essential source of income for families and local economies, reducing poverty and increasing consumption. A 2023 study analyzing the Southern and Eastern Mediterranean Countries found that remittances have a positive impact on economic growth and, through increased incomes, contribute to poverty reduction. (Idris, 2023) The authors analyzed countries such as Algeria, Egypt, Jordan, Lebanon, Morocco, Tunisia, Turkey, the West Bank and Gaza for the period 2000-2018 and reached results that confirm significant effects on the development of the economies of the countries of origin. When remittances enter, they help cover basic expenses and are therefore associated with consumption smoothing (consumption stability), poverty reduction and improved household well-being.(Lwanga., et al., 2023)Other studies even find that migrant families have significant improvements compared to families that do not receive remittances: more land assets, higher incomes, and greater spending. This reflects that remittances are not only used for basic consumption, but also affect more sustainable economic dimensions.(Dey, 2024)

The migration of skilled workers helps transfer skills and technical knowledge to countries of origin. This helps increase productivity and innovation in various sectors of the economy. Furthermore, the return of emigrants can bring with them new technologies and management practices that contribute to the development of advanced sectors. (Labor migration: what's in it for countries of destination and origin?, 2024)

Migrants often create links to foreign markets, enabling the export of goods and services from their country of origin. These links can lead to increased international trade and increased foreign direct investment. (Giovannetti, Santi, & Velucchi, 2024) In 2024, Javorcik examined the relationship between the presence of immigrants in the United States and foreign direct investment (FDI) in immigrants' countries of origin. The results suggest that migration networks can facilitate FDI flows, contributing to the economic development of countries of origin.(Javorcik, 2024)

Therefore, international migration can be an effective instrument for reducing poverty and improving the well-being of families not only through direct income, but also through the accumulation of wealth and improvement of living conditions. (Ahmed, 2022)Although remittances reduce poverty, their effect is not uniform – the impact of remittances varies by country, reflecting the quality of institutions, the development of financial markets, and the structure of the economy.(Butkus, Matuzevičiūtė, & Raupytė, 2020)The authors of this study showed that public policies should encourage the use of formal transfer channels and create instruments to orient remittances towards savings, investment and local development. The maximum benefit is achieved when remittances are combined with reforms in financial and institutional systems.(Ahmed, 2022)

Remittances can be used to finance expenditures on health and education, improving the quality of life and development opportunities of individuals and communities. This investment in human capital contributes to the long-term development of the country of origin.(Ali Bare, Bani, Ismail, & Rosland, 2023)

But on the other hand, the emigration of young people and skilled individuals contributes to the aging of the population in the countries of origin. This phenomenon is particularly worrying in countries with high emigration, where the lack of young people affects the workforce and the sustainability of social and pension systems. When many individuals leave the country, the supply of labor decreases, especially in sectors where there are many low-skilled workers. This can reduce short-term unemployment, as there are fewer people competing for the same jobs.(Docquier, Ozden, & Perry, 2013)

Based on the literature described above, the effect of emigration on countries of origin appears to be very complex and multidimensional. On the one hand, migration brings significant benefits through remittances, transfer of professional skills and technology, creation of links with international markets and positive impact on social norms and family well-being (Ahmed, 2022; Butkus et al., 2020; Giovannetti, 2024; Javorcik, 2024; Solano, 2024). On the other hand, the departure of qualified individuals causes population aging, loss of labor force and the phenomenon of "brain drain", endangering the long-term development of the country and reducing economic potential (Berger, 2022; Europarl, 2025; World Bank, 2022).

Faced with the numerous dilemmas related to immigration, we aim to develop an empirical analysis of the impact of immigration on the labor market in the Balkan countries, assessing not only the short-term consequences on unemployment and labor supply, but also the long-term impacts on human capital, economic development, and the development potential of the region.

3. Data and methodology

In our analysis, we have built a database for eight Balkan countries over the period 2014-2024. Albania, Bosnia and Herzegovina, Bulgaria, Serbia, Kosovo, North Macedonia, Montenegro and Croatia – countries with a long history of migration, where the diaspora has played an important role in mitigating the economic and social crises that these countries have experienced, were selected for the study. The main objective is to assess the impact that migrants from these countries have had on the labor market of their country of origin.

The analysis is based on balanced panel data, with variables defined according to official sources (Annex 1) Our panel data are balanced, meaning that there are the same number of observations for all groups. We started our analysis by checking whether our database has multicollinearity issues. The results showed that the variables do not have a serious multicollinearity problem (VIF < 10), allowing their use in regression. (Hair et all.1995)

The normality of the model residuals was tested using the Skewness/Kurtosis test (sktest) and the Shapiro-Wilk test (swilk). Both tests showed that the residuals are normally distributed ($p > 0.05$), ensuring statistical validity. To test heteroscedasticity, the Breusch-Pagan / Cook-Weisberg and White's tests were used, which showed no evidence of heteroscedasticity ($p > 0.05$). This means that the variance of the errors is constant and the regression results are reliable. To determine the most appropriate model for the analysis of the impact of diaspora on the labor market, the Hausman test was used to compare Fixed Effects and Random Effects. The results show $chi^2 = 14.01$ with p-value = 0.039, suggesting an advantage of the Fixed Effects model.

The selection of this model was also based on the characteristics of our data: we have a balanced panel for eight countries over the period 2014–2024, which makes the fixed-effects model more appropriate and easy to interpret. Each country has its own characteristics that are invariant over the study period (e.g., historical economic structure, specific labor policies, migration traditions). The fixed-effects model ($\alpha\alpha+\mu\mu\mu\mu$) captures these characteristics by absorbing them in the intercept, avoiding their influence on the estimation of time-varying variables (remittances, net migration). Fixed effects allow us to measure only the impact of time-varying variables within each country, eliminating the "noise" from country-specific factors that do not change. Therefore, fixed effects are more reliable in capturing the real effect of remittances and migration on the labor market. Our model is presented as follows.

$$Unemployment_{it}=(\alpha+\mu i)+\beta 1\ Remittances+\beta 2\ Migration_{it}+\beta 3 Xit+\epsilon it,\ SE\ clustered\ by\ country$$

Where:

Unemployment, total (% of total labor force)for place i at time t,

$(\alpha+\mu i)$ represents the intercept specific to each location,

Remittances, received (% of GDP)is the main variable of interest,

Net migration is the main variable of interest.

Xit represents other control variables,(GDP, FDI, HDI, Control Corruption ect.)

ϵit it is the random error

This formula retains fixed effects, but adjusts standard errors for heteroscedasticity and autocorrelation within countries.

4. Description of the variables

Dependent variable: Unemployment rate (Unemployment, total % of total labor force) measures the percentage of the labor force that is currently unemployed, but actively looking for a job and available to start work. This indicator includes both genders and all age groups within the active working age, as defined by the International Labor Organization (ILO). The data are taken fromtheWorld Development Indicators (WDI) of the World Bank. Our aimis to examine the impact that migrants from the Balkan countries have on the labor market in their countries of origin.

Independent Variables

Total remittances (as % of GDP or per capita) indicate the total amount of funds sent by migrants to their country of origin, expressed as a percentage of Gross Domestic Product (GDP). Migrant remittances constitute an important financial channel that is expected to directly impact employment and unemployment levels in countries of origin. For this reason, we believe that:

H1: Emigrant remittances have a significant impact on the labor market in countries of origin.

The net migration rate measures the net change in the number of immigrants to a country, that is, the difference between the number of people entering (immigrants) and the number of people leaving (emigrants) during a given period of time. A positive value indicates more entries than exits (net immigration), while a negative value indicates more exits than entries (net emigration). In other words, we use as the variable of interest Net Migration (% of population), which indicates the difference between immigration and emigration, expressed as a percentage of the total population. Therefore, we believe that in our fixed-effects model that measures the impact on unemployment, Net Migration (% of population) is a more appropriate variable because it is a time-varying variable (fits panel data), is directly related to the labor market due to the flow of labor abroad, reflects recent changes in the labor force, and can be more directly related to unemployment or the labor market. As mentioned above, we believe that :

H2: Net migration has a direct effect on the labor force and the total effect on the labor market depends on the profile of immigrants (skilled workers vs. unemployed).

In other words, we believe that when more people leave the country (negative NetMigration), the domestic labor force decreases and consequently unemployment may decrease as the departure of workers reduces competition for jobs and vacancies remain. However, if professionals or skilled workers leave, economic growth may slow down and unemployment may increase for those who remain. Our goal is to assess how this migration dynamic is reflected in the labor markets of the Balkan countries, which have historically had large flows of immigrants. In recent years, these countries have also experienced a significant increase in immigrants entering to work, and the study aims to analyze how this phenomenon, two-way, affects the supply and demand for labor, as well as the unemployment rate.

So, to assess the impact of the diaspora on the labor market in the countries of origin, we have included remittances and net migration as variables of interest, which represent the main channels through which immigrants affect the domestic economy.

But the labor market is not only affected by the diaspora, but also by general economic development, politics and demographic structure. For this reason, we consider it important to include in our econometric analysis as control variables necessary macroeconomic factors such as GDP growth (annual %); Foreign direct investment, net inflows (% of GDP); Government expenditure on education, total (% of GDP); Control of Corruption; HDI and variables that indicate the demographic structure with the proxy used 'Percentage of population ages 25'.

Control Variables

GDP growth generates new jobs regardless of remittances. If we don't control for this, we might mistakenly think that employment increased solely thanks to the diaspora.

FDI creates jobs (especially in industry and services) and affects wages. Increased FDI brings higher employment and also better wages. So we expect that a higher level of FDI can alleviate the "labor shortage" when emigration is high.

Government expenditure on education, total (% of GDP) is an indicator that measures the percentage of total government spending on education in relation to the country's Gross Domestic Product (GDP). This indicator indicates the government's commitment to human capital and long-term development. The variable helps capture the structural effect of human capital on the labor market. A better educated workforce is more competitive, more productive, and more flexible to market demands. It helps reduce long-term unemployment, as individuals with higher education are more likely to be employed.

Demographic structure (age, percentage of young people) A young population hasmore labor force looking for work; an aging population, like Albania, is affected differently by emigration. In a country with an aging population, the departure of workers may reduce unemployment in the short term, but this is not positive, because the economy may slow down, the number of employees to pay taxes decreases, etc.

HDI - The quality of human capital is an important factor that can influence whether remittances are converted into investments or remain for consumption. We expect that a country with a high HDI index, i.e. where people are mostly at a high level of education, is more likely to use remittances for self-employment or businesses. On the contrary, if the quality of human capital is low, remittances remain mainly for consumption. So, households receiving remittances have more disposable income and as a result may no longer need to work in low-wage sectors. This may reduce the labor supply in the local market.

Corruption Control is an indicator that affects the economic climate and investment of a country, and consequently is an important indicator in the analysis of the labor market. Labor markets depend on the regulation and functioning of institutions. Corruption weakens this mechanism, increasing informality and insecurity in the labor market.

A detailed description of the variables and the sources of the data is provided in Appendix 1.

5. Results

The effect of diaspora on the country of origin is multidimensional, as it includes a combination of positive and negative impacts. In this section we want to show (in this section we present the results of our model) how these positive and negative effects are implied in the labor market in the Balkan countries.

The results of the empirical analysis show that remittances contribute positively to the increase in unemployment in the labor market of the country of origin and this may occur for several economic and social reasons.When many individuals rely on remittances to live, engagement in the formal labor market may decrease, increasing the unemployment rate. Remittances can increase the standard of living without creating new jobs in the economy. As a result, the increase in disposable income does not necessarily translate into a decrease in unemployment. On the contrary, our results show that remittances discourage the labor force from engaging in the labor market. For every additional unit of remittances from the diaspora, the unemployment rate increases by 1,072 points. Remittances can create a sense of economic security for households, reducing the incentive to look for work, which is reflected in the increase in unemployment.

Table 1– Results OLS, Fixed Effects and Random Effects Model

VARIABLES	(1) OLS	(2) Fixed Effects	(3) Random Effect Model
Remittances	1,072** (0.470)	1,072** (0.470)	1,072** (0.470)
Net_Migration	-4.83e-05** (2.09e-05)	-4.83e-05** (2.09e-05)	-4.83e-05** (2.09e-05)
HDI	-235.5*** (32.53)	-235.5*** (32.53)	-235.5*** (32.53)
Percentage_young people	0.000522 (0.0587)	0.000522 (0.0587)	0.000522 (0.0587)
Control_Corruption	21.93*** (3,739)	21.93*** (3,739)	21.93*** (3,739)
GDP	0.0658 (0.166)	0.0658 (0.166)	0.0658 (0.166)
log_FDI	-0.414 (0.784)	-0.414 (0.784)	-0.414 (0.784)
Education_Expend	1,310 (0.990)	1,310 (0.990)	1,310 (0.990)
Constant	198.2*** (28.31)	198.2*** (28.31)	198.2*** (28.31)
Observations	30	30	30
R-squared Countries	0.888	0.888	0.888
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1			

Second, our results confirm that in the Balkan countries during the period 2014–2024, the departure of a part of the population, mainly young people and the active labor force, reduces competition for jobs and consequently reduces the unemployment rate. The effect reflects changes within each country over time and shows that net migration is an important factor affecting the labor market, contributing to a slight but steady decrease in unemployment, regardless of the unchanging characteristics of each country. In other words, an increase in net migration (more people leaving the country than entering) reduces the unemployment rate. The reason is that the departure of the labor force, especially the young and able-bodied, reduces competition for jobs within the country. The coefficient shows that when net migration increases by one unit, unemployment (the dependent variable) decreases by 0.0000483 units. The effect is negative, meaning that population outflow (negative net migration) is associated with a decrease in unemployment within the country. Increased net migration (more people leaving the country than entering) reduces the unemployment rate. The reason is that the outflow of the workforce, especially the young and able-bodied, reduces competition for jobs within the country.

Third, improving human development, through education, health, and life expectancy, is associated with strong reductions in unemployment. Decisions and policies that increase the HDI contribute to the preparation of the workforce and the reduction of unemployment. A one-unit increase in the Human Development Index is associated with a large reduction of 235.5 points in unemployment. Improving education, health, and living standards contribute strongly to the reduction of unemployment.

Fourth, improved corruption control is associated with increased unemployment in this model. One possible explanation is that when corruption decreases, standards and competition in the labor market increase, causing unskilled individuals to be left out of work. For every unit improvement in corruption control, the unemployment rate increases by 21.93 points. Stronger corruption control may increase standards and competition in the labor market, leaving less skilled individuals out of work, which manifests itself as increased unemployment.

6. Recommendations

Econometric analysis shows that several factors have a significant impact on the unemployment rate in the Balkan countries, so public policies should be oriented towards their strategic management. We show that the increase in remittances from the diaspora is associated with an increase in the unemployment rate. This may seem contradictory, but it can be explained by the fact that remittances can reduce the pressure to actively seek work or create economic dependence on the families that receive them, causing some individuals not to enter the labor market. This does not deny the usefulness of remittances as an essential financial source for the economic recovery of Balkan families, but it highlights the lack of strategic plans of efficient policies to effectively channel or induce these resources in the economies of these countries. Since remittances have been shown to have an increasing effect on unemployment, Balkan countries should create mechanisms to channel these funds towards productive investments, such as the creation of small and medium-sized businesses, financing start-up projects or improving infrastructure. This would reduce dependence on remittances for consumption and turn diaspora capital into a source of long-term employment.

The results showed that net migration has an impact on reducing unemployment, as it reduces competition for jobs. However, this is not a sustainable solution, as it causes a loss of skilled labor and brainpower. Policies should focus on creating appropriate conditions for young people to find employment opportunities in the country, by providing skills development programs, promoting entrepreneurship, and foreign investment that creates quality jobs.

The decline in unemployment is strongly associated with the increase in HDI, which shows the importance of policies to improve education, health and living standards. Investments in vocational and university education, technological training and support for innovation are essential to prepare a more competitive workforce in the region.

The positive impact of corruption control on unemployment suggests that the process of cleaning up the market of unfair practices in the short term may increase the number of unemployed, as it eliminates jobs based on patronage and clientelism. However, in the long term, the fight against corruption is necessary to create a transparent business climate that attracts investment and creates sustainable jobs. Therefore, it is recommended that governments accompany anti-corruption reforms with active labor market policies and support for new employment.

In light of the above, we suggest that Balkan countries should pursue an integrated strategy for reducing unemployment, where diaspora remittances are used productively, migration is managed through return and talent retention policies, human development is promoted through investments in education and health, and the fight against corruption is combined with employment policies. Only in this way can a sustainable reduction in unemployment and long-term economic development for the region be ensured.

Literature

[1]	Ahmed, F. (2022). Does migration matter for household welfare in Bangladesh? Migration and Development, 11(3), 697-716. doi:https://doi.org/10.1080/21632324.2020.1812326
[2]	Ahmed, F. (2022). Does Migration Matter for Household Welfare in Bangladesh? Migration and Development, 11(3), 697–716.
[3]	Ali Bare, UA, Bani, Y., Ismail, WN, & Rosland, A. (2023). Does financial development mediate the impact of remittances on sustainable human capital investment? New insights from SSA countries. Applied Economics, Taylor & Francis Journals, 55(46), 5451-5463. doi:https://doi.org/10.1080/23322039.2022.2078460
[4]	Butkus, M., Matuzevičiūtė, K., & Raupytė, K. (2020). Effects of Remittances on Poverty: Evidence in CEE Countries. Organizations and Markets in Emerging Economies, 11(1), 69-82. doi:https://doi.org/10.15388/omee.2020.11.24
[5]	Dey, SR (2024). The impact of migrant remittances on poverty reduction in Bangladesh. Poverty & Public Policy, 16(3), 253-272.
[6]	Docquier, F., Ozden, Ç., & Peri, G. (2013). The Labor Market Effects of Immigration and Emigration in OECD Countries. 124(579). doi:https://doi.org/10.1111/ecoj.12077
[7]	Giovannetti, G., Santi, F., & Velucchi, M. (2024). Migrants know better": migrants' networks and FDI. Economia Politica, 41, 85–121. doi: https://doi.org/10.1007/s40888-024-00324-3
[8]	Idrissi, BI (2023). The Impact of International Remittances on Poverty: Evidence From The Southern and Eastern Mediterranean Countries.
[9]	Javorcik, BS (2024). Migrant Networks and Foreign Direct Investment. Policy Research Working Paper.
[10]	Labor migration: what's in it for countries of destination and origin? (2024). The Joint Research Centre: EU Science Hub.
[11]	Lwanga., E., N., Mwale, L., & M. (2023). Remittances, crowd-in effect, and household welfare. Scientific African. doi:https://doi.org/10.1016/j.sciaf.2022.e01521.
[12]	Report, WD (2023). Migrants, refugees and societies. World Development.
[13]	ScienceHub, E. (2024). Labor migration: what's in it for countries of destination and origin? The Joint Research Centre: EU Science Hub.

Circular Economy in action: A case study of AZ Group's sustainable practices in Albania

Frida Kuçi[1]

Sara Mara[2]

1 Master of Science, Faculty of Economy,University of Tirana
fridakuci18@gmail.com

2 Student in Master of Science, Faculty of Economy,University of Tirana
saramara1411@gmail.com

Abstract

As global focus in the last decade has shifted towards sustainability and development, circular economy (CE) emerges as a transformative idea that redefines production and consumption through engaging in the practices of reduce, reuse, recycle and recover. In this paper, we explore the practical application of circular economy principles in the context of Albania, a transition economy navigating complex environmental and economic challenges. By drawing on AZ Group, a progressive private enterprise with diverse operations, this paper looks into how businesses in emerging markets can meaningfully contribute to the sustainability goal.

Through a comparative literature review and a qualitative case study methodology, we examine how AZ Group integrates circularity across its operations. Our analysis shows that the company has developed an internal recycling system, where waste from one business unit is used as raw material in another, improving operational efficiency and promoting sustainable practices. The impact extends beyond environmental benefits to include economic gains such as cost savings and resource efficiency, as well as increased social awareness, positioning AZ Group as a noteworthy example of alignment with the Sustainable Development Goals (SDGs) and the EU Green Deal framework in Albania.

Yet, the journey toward circularity is not without friction. Regulatory gaps, market immaturity, and the limited adoption of sustainability reporting present significant challenges. This paper also offers comparative insights with regional and EU practices, to identify effective strategies and guide future progress. It underscores the importance of implementing supportive policies, investing in infrastructure, and enhancing the role of academia to foster sustainable development both within Albania and across the region.

Ultimately, the study confirms that circular economy practices, when tailored to local conditions and backed by strategic support, can drive systemic change. AZ Group serves as a strong example of how the private sector can lead Albania's journey toward sustainable development. Continued collaboration among businesses, policymakers, and academia will be essential to fully harness this potential.

Keywords

Circular economy, Private sector, Sustainable development, Sustainable Development Goals (SDGs), Transition economies

1. Introduction

The concept of the circular economy (CE) has gained increasing global attention as a response to the environmental and resource challenges posed by traditional linear production models. Unlike the "take–make–dispose" approach, the CE is based on principles of resource efficiency, waste minimization, and closed-loop systems where outputs are reintegrated into the production cycle[1]. Globally, the CE is seen as a pathway to sustainable growth, reducing dependency on finite natural resources while simultaneously generating new economic opportunities [2]. In the context of Albania, the need for sustainable development is particularly pressing. The country faces significant environmental challenges, including inadequate waste management, water and soil pollution, and vulnerability to climate change[3]. At the same time, Albania is undergoing economic transition, seeking integration into European Union markets and compliance with EU environmental directives[4]. These dynamics highlight both the urgency and the opportunity for innovative sustainability solutions.

The private sector plays a crucial role in this process. Businesses can act as drivers of sustainability by adopting CE principles, improving efficiency, and reducing ecological footprints. In Albania, AZ Group represents a pioneering example of this role. As the country's first enterprise fully based on the circular economy, AZ Group has developed a closed-loop business model that transforms animal by-products once considered waste into value-added products such as organic fertilizers, proteins, biodiesel feedstock, pet food, and pharmaceutical ingredients.[4] By doing so, the company not only contributes to reducing waste and greenhouse gas emissions but also fosters innovation, job creation, and social responsibility. The purpose of this paper is to analyse AZ Group as a case study of circular economy practices in Albania, exploring how private enterprise can address environmental challenges while driving economic development. By situating AZ Group within the broader global CE discourse and Albania's national context, the study aims to demonstrate the relevance and replicability of such models in other emerging economies.

2. Literature review

As global sustainability becomes an increasing concern in light of the current state of resource scarcity and environmental pressures, the circular economy has gained significant attention as an alternative to the traditional linear model of production and consumption. CE is no longer perceived solely as an environmental strategy but rather as an integrated framework with economic and social dimensions, including the possibility of new opportunities for innovation, efficiency and long-term economic growth. The literature reflects a rich, diverse and continually evolving body of work, ranging from the main schools of thought that have greatly influenced CE, such as industrial ecology, performance economy and cradle-to-cradle design to practical principles like the 3Rs (reduce, reuse, recycle). The Ellen MacArthur Foundation has also played a significant role in the adoption of CE, translating theory into practice, by identifying actionable strategies for businesses and governments. At the same time, research

increasingly explores how CE can be applied in different contexts, including emerging and transition economies, where local conditions and institutional settings present us with various opportunities and challenges. Building on these perspectives, this literature review examines four key areas: the contrast between linear and circular economies, the main theoretical foundations of CE, its relevance for emerging and transition economies, and its integration within the United Nations Sustainable Development Goals (SDGs). Together, these areas provide a comprehensive foundation for understanding how CE can foster long-term sustainability transitions across diverse contexts.

2.1. Circular Economy vs. Linear Economy

Linear economy and circular economy represent two opposite models of resource management and economic development that influence the industrial production process[5]. Linear economy is founded on the "take, produce, dispose" concept (Fig.1), leading to unsustainable practices and excessive waste generation[6,7]. This model relies on two fundamental assumptions: the infinite availability of resources (such as energy and raw materials) and the limitless regenerative capacity of the Earth. Regrettably when implemented these unrealistic foundations lead to overuse of resources, biodiversity loss, and ecosystem degradation. Its production processes generate significant waste and pollution that contribute to climate change and environmental crises. Inefficient waste management further increases landfill use and resource wastage[8]. Economic development under this model necessitates increasing amounts of raw materials for production while progressively generating more waste[9] thereby driving costs upward and diminishing returns. While some argue that linear economy has historically supported growth and innovation, the urgent need for sustainable alternatives underscores its shortcomings in addressing modern-day challenges.

Figure 1 – The Linear Economy [14]

Compared to linear economy, circular economy emphasizes sustainability by promoting the continuous utilization of resources through reducing, recycling and reusing (Fig.2). This approach significantly lowers the amount of waste and contributes to the conservation of natural resources, thus, promoting the environmental protection[10,11]. From an economic perspective, CE can enhance production efficiency as it decreases the reliance on the extraction of raw materials, reduces exposure to price fluctuations, and lowering overall costs[12]. Additionally, it fosters innovation, attracts investments, and generates new employment opportunities in green industries, while giving businesses a competitive edge through the optimization of the supply chain and better use of resources.

Socially, CE encourages community engagement, raises awareness of sustainability issues, and strengthen corporate reputation along with consumer trust[13]. Although these benefits highlight CE's transformative potential, implementation still faces barriers, including gaps in measurement indicators and limited consumer awareness, which must be addressed. Therefore, it is essential to continue the transition from a linear to a circular economy to ensure that society progresses in an environmentally responsible manner[14].

Figure 2 – The Circular Economy [14]

2.2. Theoretical frameworks of Circular Economy

The concept of CE has been inspired by several interconnected theoretical frameworks, each of which reflects the principles and practices of circular economy.

Industrial Ecology is widely recognized as one of the core intellectual bases for CE. It works by designing industrial systems to operate in a way that mirrors natural ecosystems. The goal is to create closed-loop processes, where waste from one process serves as input for another, thus minimizing residual by-products[15]. Practical examples include industrial symbiosis in Kalundborg, Denmark, where waste heat and by-products from power plants are used by nearby industries, and closed-loop recycling systems in the automotive sector, where scrap metal is reprocessed into new vehicle components. Essentially, industrial ecology provides the ecological rationale for CE and supports operational strategies that reduce resource use and promote sustainability.

The Performance Economy, as conceptualized by Walter Stahel, builds on this ecological perspective by focusing on economic longevity and value creation through prolonging product lifespan. Stahel (2010) advocates for reuse, remanufacturing, repair, and service-based business models, arguing that economic growth can occur independently from resource consumption[16]. This business-oriented approach on CE presents opportunities in cost savings, new revenue streams, and job creation, which have significant impact in emerging markets where resource scarcity is more pronounced.

Cradle-to-Cradle (C2C) Design, introduced by McDonough and Braungart in 2002, is another important contributor to the concept of CE. This framework models production processes as closed-loop systems where materials are continuously recovered and reused. It also highlights the importance of understanding material composition to make recycling more effective, as well as designing products that can be easily dismantled,

especially for items with short lifespans such as electronics[17]. Components can thus serve as either biological or technical nutrients for future use. Beyond materials, C2C also considers energy and water inputs and is guided by three core principles: "waste equals food," the use of renewable energy, and the celebration of diversity, all aimed at creating regenerative and sustainable production systems[15]. By promoting innovative materials and product design, Cradle-to-Cradle supports regenerative practices that reduce waste and benefit both the environment and the economy.

While Industrial Ecology, The Performance Economy and C2C Design represent some of the main schools of thought that have helped shape CE, the 3R Principles (Reduce, Reuse, Recycle) served as guidelines in implementing CE across industries. Originating from waste management policies, the 3Rs provide a hierarchy for resource efficiency: Reduce minimizes resource consumption, Reuse extends product lifecycles, and Recycle recovers materials for reintegration into production[5]. In later years more comprehensive frameworks were developed, such as the 4Rs, 5Rs or 9Rs, that incorporate additional strategies like repair, refurbish, and remanufacture.

Last but not least, the Ellen MacArthur Foundation (EMF) has played a crucial role in bringing CE into practice worldwide, ensuring it moves beyond a purely theoretical concept. EMF has developed widely adopted frameworks, guidelines, and case studies, assisting businesses and policymakers in implementing circular strategies on a higher scale. Its work bridges the gap between academic theory and actionable business and policy measures, making CE accessible to companies in both mature and emerging economies.

2.3. Circular Economy in emerging and transition economies

CE in emerging and transition economies presents unique challenges and promising opportunities. Developing markets often face infrastructure deficiencies, such as inadequate waste management systems and recycling facilities, which hinder effective material recovery and reuse. Policy frameworks may be fragmented or underdeveloped, creating uncertainty for investment and business model innovation. Furthermore, access to financing for circular initiatives can be limited due to risk perceptions and lack of tailored financial instruments[18]. Despite these hurdles, CE offers significant opportunities for green growth and further development for the remanufacturing, repair, and recycling industries. For example, countries like India and Kenya have launched pilot projects focusing on urban waste valorisation, demonstrating how locally adapted CE strategies can bring in both environmental sustainability and social inclusion[19]. These examples highlight how CE in emerging contexts is not merely an economic model but an integrated sustainable development pathway. Its implementation contributes to poverty reduction, job creation, and resilient supply chains, aligning closely with broader development goals.

2.4. Circular Economy and the Sustainable Development Goals

Paper Given its numerous advantages and systemic nature, CE is closely linked to global sustainability efforts, setting the stage for its role in advancing the United Nations Sustainable Development Goals. By encouraging sustainable consumption and production

patterns, reducing greenhouse gas emissions, and fostering inclusive economic growth, CE helps achieve several SDGs. For instance, SDG 12 (Responsible Consumption and Production) is directly supported by circular strategies that minimize waste and optimize resource use. Similarly, SDG 13 (Climate Action) benefits from reduced emissions due to lower reliance on virgin materials and energy-efficient circular processes[20].

CE also assists SDG 8 (Decent Work and Economic Growth) by creating green jobs and promoting sustainable business models. SDG 9 (Industry, Innovation and Infrastructure) is backed through the creation of innovative circular technologies and infrastructures. Additionally, urban-focused goals like SDG 11 (Sustainable Cities and Communities) profit from CE approaches through improved waste and resource management[20].

Recent studies connect CE implementation with sustainability metrics, highlighting its role in reducing environmental footprints and enhancing social equity. Global policy frameworks are increasingly recognizing CE as a helpful tool to reach these ambitious goals, reflecting a growing consensus on its strategic importance[21].

Overall, the literature suggests that CE offers a practical and necessary alternative to the linear model by reducing waste, conserving resources, and fostering innovation. While its implementation still faces various barriers, evidence indicates that collaborative efforts and proper regulations can help overcome these hurdles. As a result, circular economy has become a key pathway toward long-term sustainability and resilience.

3. Methodology

This research employs a case study approach, which is particularly appropriate for exploring the role of private enterprises in advancing sustainability. In the case of AZ Group, the circular economy model touches upon environmental, economic, and social issues, making the case study method well-suited for examining how these aspects come together in practice. The study relies on a mix of secondary data to ensure depth and reliability. Company reports and official publications from AZ Group provide key information about its sustainability strategies, operations, and certifications. These are complemented by interviews done by the company representatives, which shed light on managerial perspectives, motivations, and the challenges faced when implementing circular economy principles. Additional information comes from news articles, policy documents, and reports from NGOs, which help place AZ Group's activities within Albania's broader environmental and economic context.

AZ Group was selected as the case study because it represents a pioneering example of circular economy implementation in Albania. The company is the first in the country to adopt a fully closed-loop business model, transforming animal by-products into a range of high-value products, including organic fertilizers, proteins, biodiesel feedstock, and pharmaceutical ingredients[4]. Beyond its innovative approach, the company has received recognition for both environmental and social contributions, such as significant reductions in CO_2 emissions and compliance with international standards like ISO and HACCP. In addition, AZ Group provides an illustrative case of how a private company can drive sustainability in an emerging economy where waste management infrastructure and environmental regulation remain limited. These qualities make AZ Group a highly relevant and instructive subject for understanding how circular economy principles can be applied in practice.

4. Analysis: Circular Economy practices at AZ Group

4.1. Company profile: AZ Group

AZ Group is one of Albania's most innovative private enterprises, established with the vision of transforming waste into resources through the principles of the circular economy. Over the past decade, the company has grown into a group of interconnected businesses that operate across the food, feed, fuel, and pharmaceutical sectors. Its core subsidiaries, INCA Ltd, PetEat Ltd, AZ Rendering Ltd, and AZ Pharma Ltd, are united by a common sustainability mission: to capture animal by-products that would otherwise become waste and reintroduce them as valuable inputs into new production cycles. This mission reflects the company's broader vision of advancing a zero-waste, carbon-negative business model in line with global sustainability standards[4].

4.1.1. Design for Circularity

At the heart of AZ Group's approach is its focus on designing for circularity. By rethinking materials and production processes from the outset, the company ensures that outputs can be reused, recycled, or transformed into new products. A prime example is the use of animal by-products from slaughterhouses and fisheries, which are repurposed into proteins, fats, and organic fertilizers. In this way, materials that once contributed to waste and environmental pollution are reintegrated into productive value chains. The company's product portfolio demonstrates a commitment to durability and functionality, as in the case of pet nutrition products and natural casings that emphasize quality, safety, and extended usability. Such design choices align with the CE principle of retaining value in materials for as long as possible[1].

4.1.2. Production and Processes

AZ Group's production systems are explicitly structured around resource efficiency and waste reduction. The company operates Albania's first rendering plant, where waste materials from the meat, fish, and poultry industries are processed into inputs four other sectors. This practice reflects industrial symbiosis, where the waste of one process becomes the raw material for another, thereby reducing the need for virgin resources and minimizing environmental impacts[2]. Energy efficiency is also a central concern, with the group's operations designed to reduce emissions and maximize the use of renewable inputs. By achieving "zero technological waste," AZ Group has established itself as a rare example of a carbon-negative enterprise in the Balkan region[22].

4.1.3. Waste Management

One of the most distinctive features of AZ Group's model is its comprehensive waste management strategy. Rather than treating waste as an unavoidable externality, the company incorporates it into its business model as a primary input. For example,

fats extracted from animal by-products are refined into biodiesel feedstock, contributing to renewable energy solutions. Similarly, organic materials are processed into fertilizers that return nutrients to the soil, creating a closed-loop agricultural cycle. These practices not only reduce landfill pressure but also significantly lower methane and CO_2 emissions that would otherwise result from unmanaged organic waste[22].

4.2. Impacts and outcomes

4.2.1. Environmental Impact

The environmental benefits of AZ Group's practices are substantial. By diverting thousands of tons of organic waste from landfills and waterways each year, the company prevents significant pollution and reduces greenhouse gas emissions. For instance, AZ Rendering alone contributes to avoiding an estimated 17,500 metric tons of CO_2 emissions annually, a figure that underlines the scale of environmental impact achieved through circular operations[4]. The company's approach contributes directly to Albania's struggle with waste management challenges, where limited recycling infrastructure and weak enforcement of environmental regulations have traditionally left gaps in sustainability outcomes[23].

4.2.2. Economic Impact

Beyond environmental benefits, AZ Group has generated important economic outcomes. Its closed-loop model reduces dependency on imported raw materials, leading to cost savings and increased competitiveness for Albanian products in both domestic and international markets. The group has also created jobs across its subsidiaries, supporting local employment and contributing to regional economic development. By turning waste into value, AZ Group illustrates how sustainability can be a driver of profitability rather than a financial burden, aligning with broader research that links circular practices to long-term competitiveness[24].

4.2.3. Social Impact

The social dimension of AZ Group's activities is equally notable. The company has been recognized for fostering a family-friendly workplace, earning acknowledgment from the United Nations Population Fund (UNFPA) for its attention to employee well-being[20]. Training programs, awareness initiatives, and community engagement further extend the social reach of its business model. These practices not only strengthen employee capacity but also raise awareness about sustainable practices in the wider community. By addressing environmental, economic, and social dimensions simultaneously, AZ Group aligns its strategy with the Triple Bottom Line framework of people, planet, and profit.

4.2.4. Alignment with Global Agenda

AZ Group's practices resonate strongly with international sustainability frameworks. Its activities support several United Nations Sustainable Development Goals (SDGs), including SDG 12 on responsible consumption and production, SDG 7 on affordable and clean energy, and SDG 13 on climate action. Moreover, its efforts align with the European Green Deal, particularly in areas related to circular economy transitions and emissions reduction. This alignment not only reinforces the legitimacy of AZ Group's model but also positions it as a key player in Albania's ongoing integration with EU sustainability standards[25].

4.3. Challenges and barriers

Despite its achievements, AZ Group faces a range of challenges and barriers that are characteristic of emerging economies. One of the most significant obstacles lies in regulatory gaps. Albania's environmental legislation remains underdeveloped, and enforcement mechanisms are often weak, creating uncertainty for companies that wish to invest in advanced sustainability practices[23].

Another barrier is related to market limitations. Consumer awareness of sustainability and circular economy principles in Albania is still low, which can constrain demand for sustainable products. Additionally, the lack of a broader circular economy infrastructure, such as efficient waste collection and recycling systems, makes it difficult for companies like AZ Group to scale their efforts or rely on supportive value chains[24].

Financial and technical challenges also play a role. Circular economy models often require substantial upfront investments in technology and innovation, which may be difficult to secure in a developing economy with limited access to green finance. Although AZ Group has succeeded in building a functioning model, replicating or expanding this approach across other industries will likely demand greater institutional and financial support.

Finally, while AZ Group is a sustainability leader in Albania, it faces limitations in sustainability reporting. The company does not currently produce comprehensive public sustainability reports aligned with global standards such as the Global Reporting Initiative (GRI). This lack of transparency may hinder its ability to fully communicate its impact to international stakeholders and to benchmark progress over time. Developing a more formalized reporting system would strengthen its credibility and integration with global sustainability practices.

4.4. Comparative insight

To better understand the significance of AZ Group's practices, it is helpful to compare their approach with other CE developments in the region and the European Union (EU). The EU has been at the forefront of advancing CE through comprehensive policy frameworks such as the EU Circular Economy Action Plan (2020), which set ambitious goals on waste reduction, sustainable product design, and resource efficiency[26].

Member states have increasingly integrated CE principles into their national strategies, supported by regulatory standards, financial incentives, and innovation programs. This way CE has gradually grown from niche initiatives to mainstream policy and business practice.

By comparison, Albania, as a transition economy and EU candidate country, is still in the early stages of adopting CE principles. Regulatory frameworks remain limited, and implementation depends mainly on the initiatives of individual enterprises rather than systematic policy support. Within this context, AZ Group's efforts stand out as an important benchmark for how private sector actors can drive circularity in a market that lacks fully developed institutional and infrastructural support. Its practice of integrating waste streams across business units—where outputs from one division are reused as inputs in another—aligns closely with EU standards for industrial symbiosis and resource efficiency.

When benchmarked against EU best practices, AZ Group demonstrates notable alignment in terms of internal recycling systems, operational efficiency, and cost savings. However, areas such as formal sustainability reporting, renewable energy integration, and conformity with international CE standards are lacking. Compared with regional peers in the Western Balkans, AZ Group is relatively advanced, as many enterprises in the region still treat CE as a minor concern rather than a strategic priority.

AZ Group serves as a perfect example of how businesses in emerging and transition economies can experiment with circular practices that mirror EU-level ambitions. While gaps remain, particularly in terms of policy alignment, reporting, and scaling, its initiatives provide a useful comparative benchmark for other companies in the region seeking to transition toward circular business models.

5. Conclusions and recommendations

5.1. Conclusions

AZ Group has become a leading role model for the circular economy in Albania, demonstrating how sustainable business practices can be incorporated across operations. The company's initiatives, ranging from waste reduction and resource efficiency to product lifecycle management, illustrate the tangible environmental and economic benefits of circular approaches. In addition to operational gains, AZ Group is helping shape the business landscape in Albania, showing that circular principles can be applied effectively even in emerging market contexts. Its practices foster innovation, create value from materials that would otherwise be discarded, and strengthen the company's competitive position, while simultaneously promoting sustainability to society. AZ Group serves as a model for other enterprises in the country, highlighting the potential for CE strategies to facilitate national sustainability goals, stimulate economic development, and encourage responsible consumption and production patterns.

However, this study has several limitations. First, it focuses primarily on AZ Group and its practices, which may not be fully representative of other businesses in Albania or the region. Second, the analysis relies largely on publicly available information and case-study data, limiting the ability to generalize findings or assess long-term impacts

quantitatively. Finally, broader systemic factors, such as regulatory enforcement, consumer behaviour, and sectoral differences, were not examined in depth, which could affect the scalability and replicability of circular practices.

5.2. Recommendations

It is important to take the right strategic steps to expand and institutionalize circular economy practices. Firstly, there is a pressing need to build up policy and regulatory frameworks that will provide clear standards, reporting requirements, and incentives that encourage sustainable production, material reuse, and transparency. Secondly, infrastructure development, particularly through public-private partnerships, can be the main driving force behind the practical application of circular practices such as recycling facilities, material recovery centres, and digital platforms for tracking resource flows.

Academia can contribute significantly by fostering applied research, innovation, and knowledge transfer, helping to develop the technical expertise and evidence-based strategies needed to scale such practices. Looking forward, the focus should be on replicating successful initiatives, ensuring scalability, and establishing robust monitoring and reporting mechanisms that can demonstrate impact as well as guide through the continuous improvement process. By combining regulatory support, infrastructure investment, academic engagement, and strategic replication, Albania can create an enabling environment for circular economy adoption that is sustainable, measurable, and widely applicable across sectors.

Literature

[1]	Ellen MacArthur on the basics of the circular economy. (n.d.). [Video]. https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview
[2]	Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2016). The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production, 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
[3]	Albania Report 2023. (n.d.). Enlargement and Eastern Neighbourhood. https://enlargement.ec.europa.eu/albania-report-2023_en
[4]	Wpadmin. (2025, May 27). Industritë | AZ Group. AZ Group. https://azgroup.al/industrite/
[5]	Afteni, C., Paunoiu, V., & Afteni, M. (2022). Study on the Transition from the Linear Economy to the Circular Economy. The Annals of "Dunarea de Jos" University of Galati, Fascicle v, Technologies in Machine Building, 39(1), 49-55. http://dx.doi.org/10.35219/tmb.2021.1.08
[6]	Chung, D. K., & Le, N. P. (2023). Linear or Circular Economy: A Review of Theories, Practices, and Policy Recommendations for Vietnam. Vietnam Journal of Agricultural Sciences, 6(3), 1832–1845. https://doi.org/10.31817/vjas.2023.6.3.02
[7]	Franjić, S. (2024). Circular economy and energy. Deleted Journal, 7(1), 01-12. https://doi.org/10.55905/CONTABV7V1-001
[8]	Ellen MacArthur Foundation. (2023, February 10). What is the linear economy? Retrieved September 03, 2025, from ellenmacarthurfoundation.org: https://www.ellenmacarthurfoundation.org/what-is-the-linear-economy
[9]	Wautelet, T. (2018). Exploring the role of independent retailers in the circular economy: a case study approach. http://dx.doi.org/10.13140/RG.2.2.17085.15847
[10]	Boorová, B. (2020). Circular economy as a way of sustainable production and consumption. SHS Web of Conferences, 83. http://dx.doi.org/10.1051/shsconf/20208301004
[11]	OECD. (2020). The Circular Economy in Cities and Regions: Synthesis Report. Paris: OECD Urban Studies, OECD Publishing. https://doi.org/10.1787/10ac6ae4-en
[12]	Sariatli, F. (2017). Linear Economy Versus Circular Economy: A Comparative and Analyzer Study for Optimization of Economy for Sustainability. Visegrad Journal on Bioeconomy and Sustainable Development, 6(1), 31-34. http://dx.doi.org/10.1515/vjbsd-2017-0005
[13]	ICC & EY. (2024). Putting the circular economy into motion: From barriers to opportunities. Retrieved from www.iccwbo.org/news-publications/policies-reports/Putting-the-circular-economy-into-motion
[14]	Santander. (2024, March 13). Linear and circular economies: What are they and what's the difference? Retrieved September 02, 2025, from santander.com: https://www.santander.com/en/stories/linear-and-circular-economies-what-are-they-and-whats-the-difference
[15]	Ellen MacArthur Foundation. (2023, March 23). Schools of thought that inspired the circular economy. Retrieved September 05, 2025, from ellenmacarthurfoundation.org: https://www.ellenmacarthurfoundation.org/schools-of-thought-that-inspired-the-circular-economy

[16] Stahel, W. R. (2010). The Performance Economy (2nd ed.). Palgrave Macmillan. Retrieved from https://www.globe-eu.org/wp-content/uploads/THE_PERFORMANCE_ECONOMY1.pdf

[17] McDonough, W., & Braungart, M. (2002). Cradle to Cradle: Remaking the Way We Make Things. New York: North Point Press.

[18] Khanna, K., Kuik, S., & Ban, J. (2025). Circular Supply Chain Management: Bridging Business Innovation and Sustainability Through Best Practices. Journal of Circular Economy, 3(1). https://doi.org/10.55845/VLHS2148

[19] Collins, M. (2024, August 28). ANDE and IKEA Foundation Unveil Grants to Boost Circular Economy in Kenya and India. Retrieved September 06, 2025, from environmentenergyleader.com: https://www.environmentenergyleader.com/stories/ande-and-ikea-foundation-unveil-grants-to-boost-circular-economy-in-kenya-and-india,48378

[20] Schröder, P., & Barrie, J. (2024). How the circular economy can revive the Sustainable Development Goals: Priorities for immediate global action, and a policy blueprint for the transition to 2050. London: Royal Institute of International Affairs. http://dx.doi.org/10.55317/9781784136222

[21] SDG Action. (2024, November 13). Can the circular economy revive the SDGs? Retrieved September 08, 2025, from sdg-action.org: https://sdg-action.org/can-the-circular-economy-revive-the-sdgs/

[22] AZ Group sh.p.k. - a Western Balkan successful circular business model | Knowledge Hub | Circle Economy Foundation. (n.d.). https://knowledge-hub.circle-economy.com/article/15587?n=AZ-Group-sh.p.k.----a-Western-Balkan-successful-circular-business-model-

[23] Environmental Statement Report 2022. (2023, September 18). European Environment Agency's Home Page. https://www.eea.europa.eu/en/analysis/publications/environmental-statement-report-2022

[24] Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular Economy: evidence from the European Union (EU). Ecological Economics, 150, 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028

[25] A new approach to our environment - How the EU integration process supports local efforts to clean, recycle and protect Albania's biodiversity. (n.d.). EEAS. https://www.eeas.europa.eu/delegations/albania/new-approach-our-environment-how-eu-integration-process-supports-local-efforts-clean-recycle-and_en

[26] European Commission. (2020). Circular economy action plan: For a cleaner and more competitive Europe. Retrieved from https://eur-lex.europa.eu/: https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF

Integrating ESG factors into a business valuation model

Irseldo Meraj[1]

1 Master of Science in Finance, Faculty of Economics, University of Tirana
irseldomeraj@gmail.com

Abstract

This research aims to explore the integration of Environmental, Social, and Governance (ESG) factors into the business valuation model of a metal processing company operating in Albania. As sustainable practices are gaining increasing importance globally, the metal processing sector faces unique challenges due to its significant environmental and social impacts. This study uses the Discounted Cash Flow (DCF) model as the basis for valuing the company, adapting it to incorporate ESG factors.

Firstly, the study identifies and categorizes ESG factors that have a direct or indirect impact on the company's operations, such as carbon emissions, energy efficiency, worker health and safety, and governance transparency. These factors are used to adjust the cash flow forecasts and the discount rate (WACC) in the DCF model, reflecting both the risks and opportunities associated with the company's ESG performance

To ensure a data-driven analysis, this case study is based on secondary data collected by analyzing financial and ESG reports of the company, including revenue, expenditures, capital investments, and specific ESG performance data. The results are expected to demonstrate that effective integration of ESG factors not only improves the accuracy of business valuation but also helps identify sustainable practices that can enhance the long-term value of the business

The research concludes with practical recommendations for companies in the metal processing sector in Albania on how to integrate ESG into strategic and operational decision-making.

Keywords

Environment, Social, and Governance (ESG); DCF Model (Discounted Cash Flow); Sustainable practices; Sustainable valuation; Long-term value.

1. Introduction

This paper aims to examine the impact of the integration of Environmental, Social and Governance (ESG) factors on the valuation model of a business operating in the metal working sector in Albania. The integration of ESG factors into business valuation processes has become increasingly important to ensure that financial assessments realistically reflect the sustainable impact and long-term risks associated with the environment, society, and governance practices.

An important part of this study is the use of the Cash Flow Discount (DCF) model for business valuation. The DCF model is a popular and well-known method for valuing companies and predicts the value of a business by analyzing the future cash flows it can generate, discounting them at a certain discount rate (WACC). This model will be adapted to include ESG factors, which will influence the calculation of future cash flows and the discount rate. The use of a regulated WACC will reflect the risks and opportunities associated with ESG factors, including the risk from changes in environmental, social and governance policies. This research aims to provide a reliable and applicable model for the integration of ESG factors in business evaluation processes, contributing to the development of sustainable and responsible practices for companies operating in Albania and beyond. This paper is organized as follows. Section 1 introduces the topic and presents the study objectives. Section 2 provides a comprehensive literature review, analyzing existing theories and models for integrating ESG factors into financial valuation and highlighting the key research gaps. Section 3 describes the methodology, combining qualitative and quantitative approaches and detailing how the DCF model is adapted to incorporate ESG considerations. Section 4 presents the research findings, comparing valuation results with and without ESG integration and examining the effects of ESG factors on cash flows and the WACC. Section 5 discusses the Albanian context, identifying the challenges and opportunities for applying ESG-integrated valuation models in the country's economic environment. Finally, Section 6 offers recommendations and directions for future research.

2. Literature review

The integration of ESG factors into a business valuation model has gained crucial importance in the global financial and managerial literature, reflecting the need to incorporate environmental, social, and governance impacts into the value of companies. Eccles, Ioannou and Serafeim (2014) in their fundamental study point out that companies with good ESG performance demonstrate a more sustained growth in revenues and profits, reducing the risk of operations and improving reputation, elements that influence future cash flows. An empirical study by Khan, Serafeim and Yoon (2016) is among the most advanced in determining how ESG is integrated into CF-t and r. They used ESG performance data of US corporations and analyzed its effect on the cost of capital, using an extended Capital Asset Pricing Model (CAPM) that included a new factor for ESG risk. The results

showed that companies with better ESG performance have lower beta to systemic risks and a lower risk premium, which is reflected in a lower discount rate. In technical terms, this means that the discount rates in the DCF model can be modified in this way:

$$r_{ESG}=r_f+\beta(r_m-r_f) - \lambda \, ESG$$

Where rf is the risk-free interest rate, β is the traditional beta, r_m is the expected return of the market, and λ is the risk ratio that describes the positive impact of ESG performance on total risk reduction. This formula shows a sophisticated way to apply ESG analysis to the discount rate. They found that companies with high ESG ratings experience a significant reduction in the cost of capital, a key factor in the DCF model, as lower capital costs mean a lower cash flow discount, thus increasing the value of the business. This study also highlights the importance of using high-quality and consistent ESG data for cash flow modeling, showing that the inclusion of ESG factors in forecasting income and expenses can significantly alter the outcomes of financial modeling.

Next, Dorfleitner, Utz and Wimmer (2017) proposed a modified DCF model that includes the measurement of ESG risks and opportunities, suggesting that factors such as climate change, social regulations, and governance practices should be included in the calculation of future cash flow, while the discounting parameter should reflect the changes in systemic risk associated with these factors. They demonstrated in their analyses that incorporating ESG into the DCF model leads to a more realistic assessment of the value of enterprises and helps identify long-term opportunities for growth and risk reduction. Along these lines, Feller, Gürtler, and Kraus (2021) developed an integrated DCF-ESG model that includes a detailed analysis of social and environmental impacts outside the company (externalities), including positive and negative externalities on cash flows. They point out that their model allows for measuring the impact of ESG practices on cash flow and adjusting discounting parameters, thus creating a framework that links sustainability to financial performance in a more structured and measurable way. The approach used is probabilistic where ESG factors are treated as stochastic variables that affect the variance and presence of cash flow. They propose that CF_t and r be evaluated via Monte Carlo simulations that include the uncertainty and risk of ESG factors. This method allows to capture different scenarios for the impacts of environmental factors (e.g. natural disasters), social changes (e.g. protests or legal changes) and governance (policy change). Their extended probabilistic model delivers a range of values for the business, improving risk assessment and incorporating uncertainties that are not captured by the classic DCF model.

On the other hand, challenges in international literature include the complexity in measuring ESG impacts and defining the parameters that are included in the DCF model, as well as in determining a cost of capital adapted to ESG risk. These issues require the use of advanced statistical methods, high-quality data, and sensitivity analyses to understand real-world impacts and reduce subjectivity in modeling decisions. In addition, models should be flexible and adaptable to include factors specific to different industrial sectors and to local markets, where ESG impacts may be different. In this regard, Albania, as an emerging market with an economy in transition, faces specific challenges that require the development of special methodologies and the adaptation of international practices in a local context.

3. Methodology

This study follows a blended approach, combining qualitative and quantitative analysis to examine the impact of Environmental, Social, and Governance (ESG) factors on the business valuation model through the Cash Flow Discount (DCF) model. This approach provides a comprehensive analysis, considering both the practical and regulatory aspects of ESG, as well as their measurable impact on the financial valuation of a company operating in the metalworking sector in Albania.

In qualitative terms, the study will focus on three main approaches: Content Analysis of ESG Reports, Observation of Operating Practices, and Analysis of Policies and Regulations.

Content Analysis of ESG Reports: The ESG reports of the company being studied and similar companies operating in the metalworking sector will be analyzed. This analysis aims to identify ESG reporting best practices, the most important indicators, and how these factors are reflected in the company's financial performance.

Observation of Operating Practices: An on-site observation will be conducted on the company being studied to understand how ESG factors are applied in practice. This observation will include monitoring processes that affect environmental impact (such as waste management and energy use), social engagement (such as occupational safety and health), and governance (such as transparency practices and ethics management).

Analysis of Policies and Regulations: An analysis of the legal and regulatory framework related to ESG factors in Albania and the European Union will be carried out. This analysis aims to identify the legal requirements that metalworking sector companies must comply with and understand how these requirements affect their financial and strategic performance.

In quantitative terms, the Cash Flow Discount (DCF) model will be used to evaluate the company being studied. This model predicts the value of the business by analyzing the cash flows that are expected to be generated in the future and subtracting them to the present value through a discount rate (WACC). The DCF model will be adjusted to include the impact of ESG factors, reflecting the impact of these factors on cash flows and the discount rate.

Cash flows: Cash flows will be adjusted to reflect the impact of ESG factors. For example, the costs of meeting environmental standards (such as waste management costs or investments to increase energy efficiency) will be included as additional expenses, while savings from sustainable practices (such as reducing energy consumption) will be counted as benefits.

Discount Rate (WACC): To reflect the risks and opportunities associated with ESG factors, the WACC will be adjusted to take into account specific risks associated with the environment, society, and governance. For example, a company with poor environmental practices will face a higher regulatory risk, which will be included in the WACC through an increased risk premium.

Financial Data: The company's financial data will be collected from audited financial reports, ESG reports, and other reliable sources. This data will be used to build a detailed DCF model, including forecasting revenues, expenses, and capital investments, which will be adjusted to reflect the impact of ESG factors.

Analysis of Results: After the implementation of the ESG-adjusted DCF model, a comparison will be made between the value of the business before and after the inclusion of ESG factors. This comparison will provide a clear insight into the impact of ESG on the company's financial valuation. Also, a sensitivity analysis will be conducted to understand how changes in ESG factors affect the final valuation of the business. This methodology provides a comprehensive analysis, combining practical and regulatory knowledge related to ESG with a measurable analysis of the impact of these factors on the financial valuation of the business.

Analytical modeling is performed in the R Studio environment; due to the flexibility and accuracy it offers in the processing of numerical data and in the application of evaluation algorithms.

4. Summary of research findings

The research addresses the valuation of an Albanian metalworking business, a sector that faces significant environmental and social challenges. It adapts the traditional DCF model by incorporating ESG factors. The inclusion of ESG in the DCF model does not require a revision of the mathematical structure of the model, but an adjustment of the input assumptions and an improvement in estimates on future cash flows and the discount rate.

Free Cash Flows (FCF): Investments in ESG components (such as clean technologies, energy efficiency, or advanced social and governance standards) often increase CAPEX in the short term, but can bring operational savings to OPEX, increased productivity, and improved efficiency in the long term.

Implementing ESG practices can reduce the risk of regulatory penalties, lower insurance costs, and positively impact on the company's reputation, potentially increasing revenue and expanding the customer base.

Equation 2 – DCF's formula with ESG components

This formula suggests that financial variables (such as EBIT, CAPEX or ΔNWC) be adjusted to reflect ESG effects.

Discount Rate (WACC): Companies with good ESG performance are perceived by investors as less risky and more stable for the long term, which can lead to a lower cost of capital (for both debt and equity). The relationship between ESG and WACC can be described as: WACCESG<WACCconvetional

ESG and Terminal Value

Even the terminal value can be affected by ESG. An enterprise that builds a sustainable business model with a positive impact on the environment and society is

more likely to be competitive and sustainable in the long term. In this context, ESG affects the long-term growth rate of ggg, as well as the multiple used to calculate the terminal value:

In the lifetime growth approach (Gordon Growth Model): ESG can justify a higher long-term growth rate ggg, thus increasing terminal value. In the Multiple Exit Approach: High-performing ESG companies are often traded at multiple higher valuations (e.g. EV/EBITDA), based on the most favorable market perceptions. Despite the benefits of incorporating ESG into the DCF model, there are several challenges: Non-uniform measurement and reporting of ESG indicators, which creates difficulties in reliable comparisons and modeling. Subjective assessment of the financial impacts of ESG factors, especially if there is no long financial history for the company. The difficulty in translating ESG measures into concrete financial variables, creating the risk of insufficient or inadequate integration.

Basic financial and structural assumptions

The assumptions used in the construction of the model have been developed in harmony with international practice but also adapted to the economic and financial reality of Albania. First, for the calculation of the value of the enterprise through the DCF method, the approach with FCFF (Free Cash Flow to Firm) was used, as this allows the inclusion of the impact of the capital structure at a later stage, focusing initially on the overall value of the company's operating assets

Table 1 – Parameters for the DCF model.

Parameters	Value	Source
Projection Revenue Growth	5 % yearly	Based on historical growth and sector
Long term growth rate	2%	Based on the inflation rate and GDP in Albania
WACC	9.17%	Calculated from the current structure
Risk Free Rate	5.2%	Albanian Government Bonds
Market Return	11.7%	According to Damodaran + CRP for Albania
Beta	1.3 (rated)	Metals sector
Own capital	41%	From the balance sheet
Total debt	59%	From the balance sheet

Source: Author's calculation

Comments on the findings.

The risk-free rate is set at 5.2%, based on the yield of long-term bonds issued by the Albanian state. The market risk premium has been taken at 6.5%, based on the annual calculations published by Prof. Damodaran at NYU Stern University, while the beta coefficient is assumed at 1.1 due to the lack of a regular stock market in Albania and taking into account comparable volatilities from the metalworking sector. This leads to a required return on equity (EC) of approximately 12.65%.

For the capital structure, current data from the company's own financial statements have been used, where the ratio between equity and debt is 41% to 59% respectively. By applying the classic WACC (Weighted Average Cost of Capital) formula, including the tax rate at 15%, a final WACC of 9.17% has been calculated.

For the medium-term projections (2024–2028), a growth rate of 5% in free flows is assumed, considered stable and in line with the potential of the sector in Albania. This steady growth is expected to be driven by an increased production volume and a focus on higher value-added products, rather than just commodity price fluctuations. Benefits from the relocation of manufacturing closer to the EU (nearshoring) are expected to directly boost production output volume beyond the baseline growth rate. This increase is anticipated due to Technology and the modernization of processes, leading to greater operational efficiency.

While for the terminal value, a long-term growth rate of 2% has been used, in line with the real growth of the economy in the last decade and conservative valuation practices.

Table 1 – Overview of the components of the DCF model (2020-2030).

YEAR	EBIT	Depreciation	CAPEX	Delta_NWC	FCFF
2020	190,741,200	107,003,548	73,727,681	(8,129,211)	203,535,098
2021	525,925,500	139,070,477	99,835,200	530,003,483	(43,731,531)
2022	143,648,300	702,543,500	161,397,000	21,474,788	557,938,487
2023	177,852,600	141,601,600	907,549,000	(291,667,410)	(323,105,280)

Source: Author's calculations

Initially, the processed FCFF data for the four historical years (2020–2023) were imported, which were used as the basis for medium-term projections. Taking the value of FCFF for 2023 as a starting point, it turned out to be a methodological problem, as the inflow for that year was negative due to significant capital investments. To overcome this anomaly, a technique called "free flow normalization" was applied, taking the average of positive years to build a stable initial value per projection.

The projection free flows for each year with an increase of 5% are calculated below, which are discounted through the respective WACC factors for each year. For the last year of the projection (2028) a terminal value has been calculated, which has also been discounted to the current value. The results are summarized in a total consisting of: (i) the actual value of the projection flows, and (ii) the actual value of the terminal value.

The final value of the company according to this model was about 5.76 billion ALL, which is a reasonable assessment of the company under the current conditions. This result comes as a result of a balanced analysis between historical performance, growth potential, capital structure and cost of capital.

DCF model with the integration of ESG factors

In the last decade, the valuation of enterprises has started to increasingly take into consideration not only traditional financial factors, but also parameters related to environmental, social and governance (ESG – Environmental, Social and Governance)

sustainability. These factors affect the risk perception, access to financing, and long-term sustainability of the enterprise. In this context, this section analyzes the impact of a concrete ESG-related investment on the value of the enterprise, using the free cash flow discount (DCF) model for the firm.

In 2020, the company in question made an investment dedicated to meeting environmental criteria, in the amount of 500,000 euros. The investment was financed through a loan with favorable interest (6.5%), aiming at improvements in energy efficiency and reduction of pollutant emissions. This investment represents a first step towards incorporating ESG considerations into the company's development strategy, albeit on a relatively modest scale. To assess the impact of this investment on the company's value, a conservative scenario has been constructed, maintaining a cautious and realistic approach to financial assumptions. The main principles of this scenario are:

No increase in operational performance (FCFF) has been assumed as a result of ESG investing. This implies that future net flows are projected based on financial history, without reflecting any direct improvement in revenue or costs.

The FCFF for 2020 has been reduced by the value of the investment, to reflect the net effect of cash outflow as a result of capital expenditure. The capital structure has been updated to include new ESG debt, while maintaining the existing proportion of equity and existing debt. The introduction of this debt with a lower interest rate has affected the average reduction of the cost of debt.

The WACC (Weighted Average Cost of Capital) has been reduced minimally, by 0.2 percentage points, to reflect the limited impact of this investment on the overall financial structure of the enterprise. This symbolic decrease reflects the slight improvement in the company's risk profile due to the inclusion of sustainability elements, without exceeding the real weight of the investment.

The purpose of this scenario is to give a realistic assessment of the impact of ESG, avoiding overestimating the effect that a single and relatively small investment can have on the value of the company. In a context like the Albanian one, where financial markets and ESG instruments are still evolving, a careful analysis is more representative of reality. This scenario provides a basis for comparing how the gradual incorporation of sustainable practices can affect the value of the enterprise, not only through improved operating flows, but also through lower capital costs and more favorable perceptions from the market and financiers.

Table 1 – Overview of the components of the DCF model (2020-2030).

Parameter	Without ESG	With ESG	Difference	Comments
WACC	9.17%	8.97%	0.2%	ESG debt rate lowers the average debt cost
FCFF 2020	203,535,098ALL	143,535,098ALL	60,000,000	Reduction as a result of CAPEX
The average cost of debt	8%	7.24%	0.76%	Combination of existing debt with lower ESG rate
Debt burden	59%	62%		ESG debt temporarily increases total debt
Growth rate	2%	2%		Same in both scenarios, not affected by ESG investment

The impact of ESG on the value of the enterprise is moderate, with an increase of about ALL 184 million or +3.2%, representing a credible and justifiable effect for an investment of this size. This scenario aims to avoid overvaluations and maintain a consistency between financial valuation theory and the operational reality of the enterprise.

Following the inclusion of this ESG investment in the valuation model, its impact has been measured through two components: the reduction of free cash flow in 2020 and the minimal reduction of the WACC. The FCFFs for the projection period (2024–2028) have not been changed, maintaining a stable estimate based only on historical data.

These interventions have led to a moderate increase in the value of the enterprise, reflecting the real and limited impact that such an investment can have on the value of a company, when it is at an early stage and does not yet have a maturable operational impact.

This result aligns with the purpose of the analysis: to provide a realistic and careful assessment of the impact of ESG on a small market and with new sustainability practices, creating a model that can be used for comparison in more advanced cases of ESG integration into the strategy and financing of enterprises.

5. Discussion of Albanian Context

Based on the international and Albanian literature, important research questions arise, such as: How can the DCF model be adapted to effectively include ESG factors in the assessment of Albanian businesses? What are the impacts of ESG factors on cash flows and cost of capital for companies operating in Albania? How prepared is literature and local practice to empirically and measurably integrate ESG factors into valuation financial models? What are the main barriers for a practical application of these models in Albania and how can they be overcome? What is the effect of improving ESG performance on the value and risk of Albanian enterprises? How can the modified DCF model be used to reflect these changes accurately and reliably? The answers to these questions are essential for the further development of financial literature and practices in Albania.

Overall, the international and Albanian literature highlights the need for a holistic approach to business valuation that incorporates ESG factors beyond traditional financial analysis, to improve risk management, value enhancement and long-term sustainability. International studies suggest the use of advanced DCF models that modify cash flows and discount parameters in line with ESG performance, taking into account social, environmental and governance impacts. The Albanian literature, although evolving, emphasizes the importance of this integration and the challenges of the lack of data and standards. This creates a wide space for empirical research and methodological development in Albania, especially in adapting DCF models to ESG factors and testing them in real Albanian companies.

International and Albanian literature show that the integration of ESG factors in the business valuation model, especially in the DCF model, is an area with great development potential. While international studies provide models and empirical evidence for the efficacy of this approach, the Albanian literature needs a significant advancement, especially in the use of real data and the development of methods adapted to the local context. This integration is vital for increasing investor credibility and for making more sustainable and informed decisions for business development in Albania.

6. Recommendation and Future Research

In this context, future research should focus on the collection and analysis of reliable ESG data in Albania, the development of indicators and parameters appropriate for valuation models, and the empirical testing of the effect of ESG factors on the value and risk of domestic enterprises. It is also important to develop national guidelines and standards for the reporting and measurement of ESG factors, which will enable their systematic integration into financial models and business management practices. This will contribute to the sustainable development of the private sector and to the increased competitiveness and credibility of investments in Albania.

It is clear that the inclusion of ESG factors in financial valuation models is no longer an alternative, but a necessity for businesses aiming for sustainable growth and an improvement in market perception. In this context, recommendations should not only be addressed to individual companies, but also to institutional actors, regulators and the academic community.

First, Albania needs a genuine legal and institutional framework that supports and promotes the integration of ESG into business decision-making. While in European Union countries, ESG reporting is becoming a mandatory part of corporate transparency, in Albania this dimension still remains voluntary and fragmentary. This creates a huge gap between the need for a sustainable economy and the real capacities of businesses to adapt. In this sense, concrete intervention is needed from public institutions – especially the Ministry of Finance and the MFA – to provide standard and applicable guidelines for ESG reporting.

Second, the Albanian financial system needs to be transformed to reflect the importance of ESG performance in financing processes. Currently, lending conditions rely largely on traditional financial risk analysis, neglecting factors that may represent much deeper risks in the long term, such as exposure to pollution, lack of governance, or social instability. Banks need to evolve towards the sustainable financing model, offering more favorable interest rates to companies that report ESG performance and that pursue environmentally and socially responsible policies.

Another important recommendation is related to human capacity building. In the absence of experts and trained professionals in the field of ESG, even businesses that have the will to change often encounter difficulties in designing and implementing concrete policies. Albanian universities, including the Faculty of Economy, should play a more active role in integrating ESG into study programs, as well as in providing specialized training to current private sector professionals.

Finally, companies themselves need to understand that ESG is not a cost, but an investment. Enterprises that consider sustainability as part of their strategy, that strive to be transparent to stakeholders, and that invest in improving their environmental and social impact, are the ones that not only survive, but also thrive in an increasingly complex and challenging economy. While this requires a change in culture and approach, it is clear that the path to a sustainable economy passes through enterprises that see value not only in financial terms, but also in their long-term impact on society and the planet in which they operate.

Literature

[1] Berg, F., Fabisik, K., & Sautner, Z. (2020). Rewriting History II: The (Un)Predictable Past of ESG Ratings.SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3722087Wikipedia+1Wikipedia+1.

[2] Brooks, C., & Oikonomou, I. (2018). The effects of environmental, social and governance disclosures and performance on firm value: A review of the literature in accounting and finance. The British Accounting Review, 50(1), 1–15. https://doi.org/10.1016/j.bar.2017.11.005Wikipedia

[3] Damodaran, A. (2012). Investment Valuation: Tools and Techniques for Determining the Value of Any Asset (3rd ed.). Wiley .Wikipedia

[4] *Feller, A., Gürtler, M., & Kraus, M. (2021).* Integrating ESG risks into discounted cash flow valuation: A stochastic modeling approach. Journal of Sustainable Finance & Investment, 11(1), 37–57. https://doi.org/10.1080/20430795.2020.1782815

[5] Henisz, W., Koller, T., & Nuttall, R. (2019). Five Ways that ESG Creates Value. McKinsey Quarterly.https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our

[6] Eccles, R. G., Ioannou, I., & Serafeim, G. (2014). The Impact of Corporate Sustainability on Organizational Processes and Performance. Management Science, 60(11), 2835–285 https://doi.org/10.1287/mnsc.2014.198

[7] Senadheera, S. S., Withana, P. A., Dissanayake, P. D., Sarkar, B., Chopra, S. S., Rhee, J. H., & Ok, Y. S. (2021). Scoring environment pillar in environmental, social, and governance (ESG) assessment Sustainable Environment, 7(1), 1960097 .https://doi.org/10.1080/27658511.2021.1960097 Wikipedia

[8] World Bank. (2022). Albania Country Environmental Analysis. Washington, DC: The World Bank. https://documents.worldbank.org

[9] Shleifer, A., & Vishny, R. W. (1997). A Survey of Corporate Governance. The Journal of Finance, 52(2), 737–783. https://doi.org/10.1111/j.1540- 6261.1997.tb04820.x

[10] Ministry of Finance and Economy. (2023). National Strategy for Sustainable Development and ESG. Tirana, Albania. https://financa.gov.al

Calculation and management of the environmental footprint in Albanian businesses: practices, challenges and impact on risk decision-making

Kendi Cara[1]

Julia Dado[2]

1 Master Student in Risk Management
kendicara02@gmail.com

2 Master Student in Risk Management
julia.dad09@gmail.com

Abstract

This paper studies the calculation and management of the environmental footprint in Albanian businesses, focusing on practices, challenges, and their impact on risk-related decision-making. It explores how companies measure and report emissions, integrate international standards, and prepare for compliance with directives such as the CSRD, which will also influence Albania during its EU integration.

The environmental footprint is presented as a key element of sustainability and corporate governance, strongly connected to ESG (Environmental, Social, Governance) practices. Measuring and reporting it is shown to affect strategic policies, competitiveness, and reputation in global markets. Literature and international standards confirm that proactive environmental management improves financial and economic performance, while reactive approaches generate costs.

The paper combines secondary sources with primary data from interviews and questionnaires, revealing that while limited funds, expertise, and regulatory support remain challenges, interest in sustainability reporting is growing. A case study of Maccaferri Balkans SHPK illustrates how adopting recyclable materials, advanced technologies, and international certifications can reduce operational risk and enhance long-term value.

The paper concludes that accurate carbon footprint measurement, transparent reporting, adoption of global standards, and integration of sustainability into corporate strategies are essential for Albanian businesses to reduce negative impacts, gain competitive advantage, and support sustainable development.

Keywords

Environmental Footprint, CSRD, ESG, Sustainable Reporting, Maccaferri Shpk

1. Literature review

In recent years, there has been a lot of discussion on the connection between risk, sustainability, and corporate environmental management. Corporate Social Responsibility (CSR) and its extension into Environmental, Social, and Governance (ESG) frameworks are seen as essential for mitigating negative externalities caused by economic activities while also improving competitiveness. According to stakeholder theory, businesses should take stakeholder interests into account when making choices in order to achieve their social responsibilities [1]. This strategy emphasizes how ESG is becoming more and more important in corporate governance in response to growing social and environmental issues [2].

From an economic standpoint, while environmental measures may result in higher expenses, they can also provide a competitive edge through resource efficiency and innovation. The "revisionist stance" contends that adopting environmental technology and making efficient use of resources can reduce compliance costs and enhance business performance [3]. Porter's idea, according to which well-crafted environmental rules can spur technical innovation and improve both environmental and financial performance, is closely related to this point of view [4].

Numerous studies offer practical support for various interpretations of the connection between financial performance and environmental factors. While some discover U-shaped or inverted U-shaped connections, indicating an ideal level of environmental sustainability beyond which competitiveness may deteriorate, others find linear positive effects, where higher environmental performance boosts profitability [5-6]. Proactive environmental initiatives frequently result in cost savings and competitive benefits in highly polluting industries, and they are linked to increased operational performance in the service sector [7].

International principles and frameworks play a key role in harmonizing environmental footprint measurement. The GHG Protocol, ISO 14064, PAS 2050, and Life Cycle Assessment (LCA) provide structured methodologies for quantifying emissions and environmental impacts [8]. These standards enhance comparability, transparency, and credibility in environmental reporting, which is increasingly demanded by regulators, investors, and consumers. With the introduction of the Corporate Sustainability Reporting Directive (CSRD) in the European Union, even candidate countries such as Albania face mounting pressure to align with international reporting norms [9].

Recent literature also highlights the growing role of innovation in sustainable business strategies. Green innovation, including eco-friendly products, recyclable materials, and renewable energy use, is identified as a key point of long-term competitiveness [10]. Companies that integrate ESG factors into their strategy often gain access to new markets, benefit from lower capital costs, and improve their corporate image [11]. Conversely, firms that rely on "greenwashing" practices risk losing credibility and investor confidence [12].

Case-based evidence reinforces these findings. Research shows that firms adopting proactive sustainability measures are more resilient to crises and better able to manage operational and reputational risks [13]. For example, case studies in the construction sector demonstrate how the use of recyclable materials, green certifications, and advanced technologies can reduce environmental impacts while ensuring financial benefits [14].

1.1. Laws and standards of environmental footprint

The legal and regulatory aspect of environmental footprint management is defined through a combination of national laws and international standards that set obligations and procedures for businesses. Law No. 10431/2011 "On Environmental Protection" in Albania, established the basis for environmental responsibility and requires businesses to assess and mitigate their impacts.

Key international standards like ISO 14064, PAS 2050, and the GHG Protocol, provide methodologies for calculating emissions, assessing product life cycles, and ensuring comparability of data. Their adoption is essential for Albanian businesses aiming to align with European practices and access global markets.

A central focus is placed on the Corporate Sustainability Reporting Directive (CSRD), which introduces mandatory non-financial reporting in the EU. As Albania advances in its integration process, CSRD is expected to shape future corporate reporting obligations. The European Green Deal is important for its influence on national strategies and private sector practices

2. Methodology

The methodology of this paper is based on a mixed approach that combines both primary and secondary data sources in order to give a complete analysis of how Albanian businesses calculate and manage their environmental footprint. The goal is to confirm that the findings reflect both the theoretical foundations from the literature and the practical realities of the private sector in Albania.

2.1. Data collection

To provide a full analysis, the paper included both primary and secondary data. The basis was secondary research, which drew from scholarly sources including books, journal articles, theses, and conference papers that could be found on sites like Research Gate and Google Scholar. Furthermore, official papers from institutions such as the World Bank, OECD, and European Commission were used to place the findings in the perspective of global sustainability frameworks. These resources included information about established techniques for measuring carbon footprints (GHG Protocol, ISO 14064, PAS 2050, LCA), integrating ESG, and pertinent Albanian laws, such as Law No. 10431/2011 "On Environmental Protection."

In addition, semi-structured interviews with company officials and structured questionnaires were used to collect primary data. The surveys focused on measuring techniques and collected both quantitative and qualitative data. The questionnaires focused on methods of measuring and managing environmental footprints, main sources of emissions, challenges in adopting sustainable practices, and the role of reporting in strategic decision-making. Interviews provided managerial perspectives, organizational capacities, and the readiness of firms to comply with international standards such as the CSRD.

2.2. Case study approach

This paper studies Maccaferri Balkans SHPK, a construction company chosen for its use of green technologies, recyclable materials, and international certifications. This case provided insight into how environmental footprint management can reduce impacts while supporting efficiency and value creation. Data from questionnaires were used to measure carbon footprint indicators and cost-benefit outcomes, while interviews and literature were analysed thematically to identify key challenges and practices. The combined approach offered a clear view of both quantitative results and qualitative insights, highlighting opportunities and barriers in integrating sustainability into corporate strategy.

2.3. Limitations

This paper acknowledges limitations including reliance on self-reported data from company representatives, potential lack of uniformity in measurement methods across firms, and restricted access to comprehensive datasets due to limited disclosure practices in Albania. Despite these challenges, the combination of multiple data sources strengthens the reliability and validity of the research findings.

3. Study case: Maccaferri SHPK

Maccaferri is an Italian company with over 140 years of tradition in civil, geotechnical and environmental engineering solutions, present in over 70 countries. It has been operating in Albania since 2009, with production plants in Vora and Shijak, contributing to major infrastructure projects such as the Korçë–Ersekë road and the Rrëshen–Kalimash highway. Its portfolio includes gabions, geosynthetics, rockfall protection systems, hydraulic works and coastal protection. In addition to infrastructure, the company is also engaged in supporting culture, such as sponsoring the Albanian Pavilion at the 2024 Venice Biennale. These initiatives have positioned Maccaferri as a key player in the sustainable development and modernization of the country.

Maccaferri Balkans has implemented green policies to reduce its environmental impact, such as the use of recycled materials, renewable energies and water recycling systems. Its new factory in Albania is ISO 14001, ISO 45001 and EPD certified, ensuring transparency in the environmental impact of its products. An example of innovation is PoliMac® gabions, which offer a lifespan of up to 120 years, reduce CO_2 emissions by up to 40% and improve biodiversity, representing a much cleaner alternative to traditional concrete structures. These measures not only reduce long-term maintenance costs, but also strengthen the company's reputation as a leader in sustainable engineering and environmental responsibility.

3.1. Calculation of the environmental footprint for the polimac gabion:

The FootprintCalculator platform was used to calculate the carbon footprint. Below is the entire process, from entering the data into this platform, adjusting it to find the environmental factor, and presenting the result.

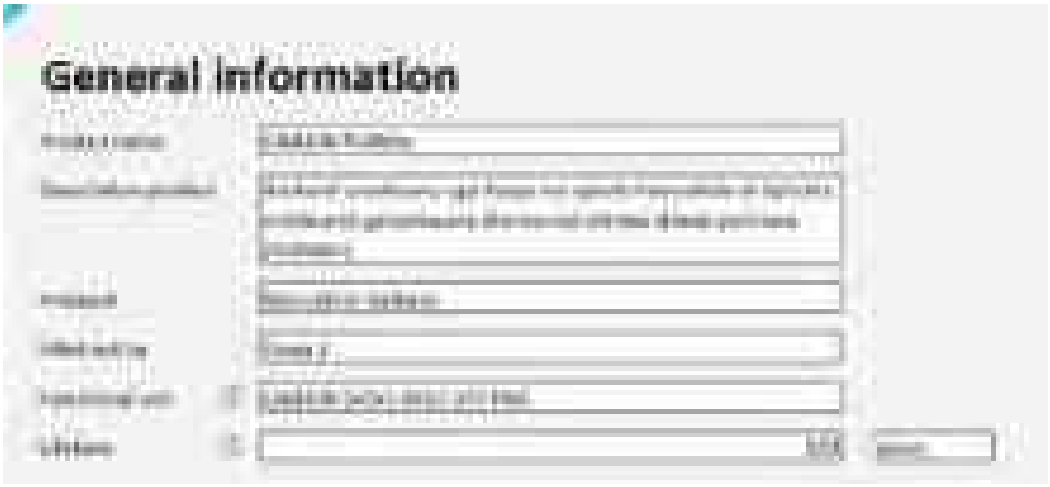


Figure 1 – Footprint Calculator

The gabion life cycle starts with the raw material supplier (A1) (steel wire and plastic) and is then transported to the Maccafferri Balkans production lines (A2) where the wires are coated with plastic and woven to create the gabions (A3). The finished product is transported and installed at the location requested by the customer (A4-A5). At the end of the product life cycle, if it is damaged or has completed its full life cycle (120 years), the gabions are dismantled and the waste is transported to landfills where the steel is recycled and the plastic is incinerated (C1-D).

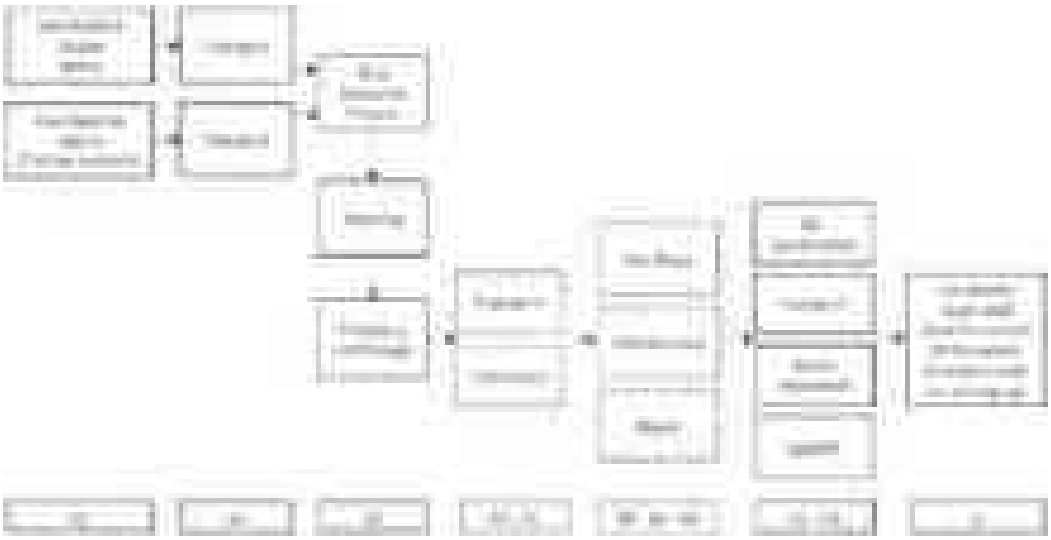


Figure 1 – Process

3.2. Materials

Gabions covered with PoliMac are CE marked in accordance with Regulation (EU) 305/2011, according to EAD 200039 and EAD 200019. The products are made of galvanized steel wire (diameter 2.7 mm for mesh wires and 3.4 mm for edge wires), covered with PoliMac (cover thickness 0.5 mm).PoliMac is a polymer with high resistance to abrasion and UV radiation, extracted from metal wire and specially developed by Maccaferri.

Figure 2 – Raw Materials

As shown below, the carbon emissions for gabion raw materials result in 0.633 kg of CO2 emissions from steel and 0.162 kg of CO2 from plastic.

Figure 3 – Materials in Process

3.3. Production process

The process that Maccaferri Balkans carries out in the production of PoliMac Gabions begins the moment the raw materials arrive at the company's production lines. We have defined two main processes for the production of gabions on which we have also measured carbon emissions.

- Plastic coating of wires (extrusion - production site)
- Wire Mesh Forming (since the platform did not offer this process as an impact factor, Rolling was selected as a similar process to replace it).

Initially, the plastic materials (HDPE) are heated and melted in an extrusion machine. The steel wires pass through the extruder, where the plastic melts and wraps the wire uniformly. After the wire passes through the extruder and is wrapped in plastic, it enters a cooling system that stabilizes and hardens the plastic. Thus, a protective plastic layer is created that fits tightly around the steel wire and provides durability and protection against environmental factors.

These wires are then woven to create the gabions (baskets). The carbon emissions for each process result in 0.311 kg CO2 and 0.150 kg CO2.

Figure 4 – Production Process

3.4. Transport

Regarding emissions from transport, the following have been taken into consideration:

- Transport: Supplier - Maccaferri Balkans
- Transport: Maccaferri Balkans - Client

Some generalizations have been made for the calculation of CO2 from this activity:

1. The vehicle used for all transport is a Scania R560 truck (shown in the photos below).

2. Distances (km) have been calculated based on the information we were told during the company visit as an average of distances (the raw material is provided by the steel processing plant in Elbasan and the product is transported inside and outside the territory of Albania such as: Kosovo, North Macedonia, Montenegro, etc.).

Figure 6 – Distribution

3.5. Usage

Once installed, Gabions do not require any maintenance or extra costs for their proper functioning, so this part of the product life is considered to have zero carbon emissions.

3.6. End of product life

According to experts, since gabions are used as structural components for retaining walls, channel layers, hydraulic control structure protection, erosion protection, shear systems that control and prevent rockfall and loose pile flow, finger systems and earth retaining structures: they are intended to be permanently incorporated into the engineering works where they are used. For this reason, it is assumed that the end of life is equal to zero. Therefore, it is taken into account that the reuse of materials brings a reduction in carbon emissions since the amount of emissions that would come from extracting the same material from scratch would be many times higher. Regarding the end-of-life of the packaging components, the following scenarios were applied:

The plastic component at the end of life was associated, for conservative purposes, with incineration. The end-of-life of the wooden pallet was not taken into account (biodegradable material with high administrative costs for data provision). The steel packaging component at the end of life is recycled (taking into account an approximate amount of steel packaging needed for 1 kg of gabion).

Figure 7 – Recycling

3.7. Results

As can be seen from the data presented below, the total carbon emission calculated for 1 kg of Gabion Polimac is 1.32 kg CO2 equivalent. While the environmental cost results in 0.32 euro/kg.

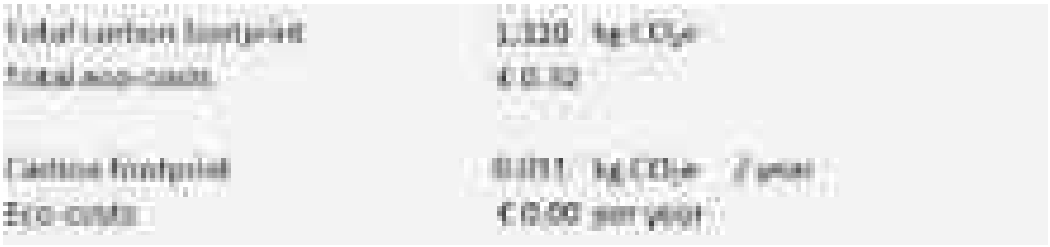


Figure 8 – Results

The highest weight of emissions in the life cycle of gabions is accounted for by the raw material with 60% and their production process with 35% of the total emission. The other two components, transport (3%) and product disposal (2%), have an almost negligible weight.

Figure 9 – Carbon Footprint

Maccaferri Balkans has a very positive approach to the environment, showing special care for its protection and the production of products as ecological as possible, as specified above. The company has taken initiatives to reduce the negative impact on the environment, including the investment in photovoltaic panels, which now provide the company with about 50% of the energy needed to carry out its activities. The rest of the electricity is provided by the grid, but in general, both of these energy sources (photovoltaics and hydroelectric power plants) provide clean energy. So Maccaferri does not have much to do in terms of energy saving, except to provide a technology with higher energy savings. As can be seen below, the materials used as raw materials also produce the highest emissions, especially plastic, which is associated with CO2 emissions even at the end of the cycle, since the combustion process is used to destroy it. So changing the type of plastic from PoliMac high-density poly(ethylene) (HDPE) to another type of plastic

Polypropylene (PP) or Polyester (PET) plastic with similar characteristics would significantly reduce carbon emissions. But we should not overlook the fact that the lifespan of the gabion would be reduced due to their lower performance against environmental factors, including UV radiation and extreme conditions compared to HDPE.

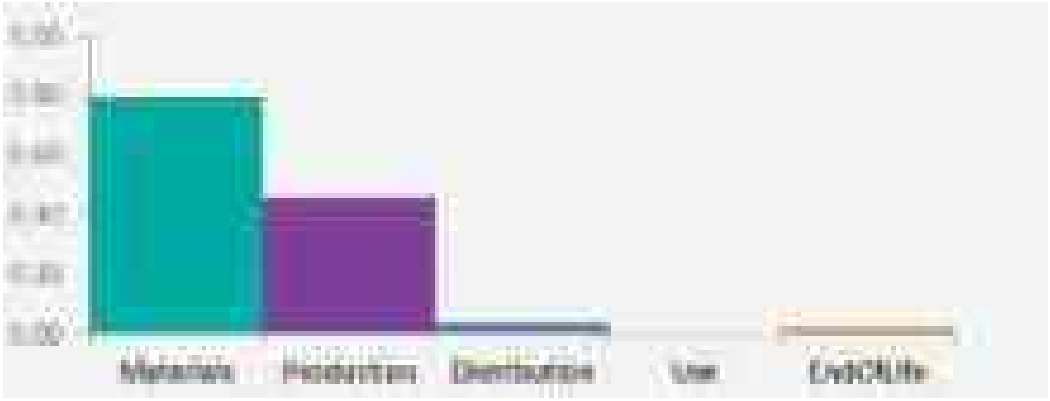


Figure 10 – Raw material process

On the other hand, the use of steel wires created from 100% scrap would lead to a reduction in emissions in the 'material' component but is almost impossible to achieve. First, it does not depend entirely on the initiative of the company but comes as a result of the well-functioning of a wide industrial system from the collection of scrap to its industrial processing to create steel wires.

Maccaferri Balkans gabions can be considered ecological products due to all the commitment made by the company itself so that the gabions are in harmony with nature to have a minimal impact. The measures taken within the framework of environmental protection or the undertaking of other social initiatives and not only positions Maccaferri Balkans well in the construction and infrastructure industry, making it a very competitive company in the market. The fact that today the need to take measures in the framework of environmental protection, pollution reduction and emissions is urgent turns the entire investment of the company in such policies into a strong point for it as well as a valuable and positive contribution in the fight against climate change.

3.8. Comparison of results

Maccaferri Balkans during 2024 has carried out the EPD report for the most important products, including gabions, within the framework of environmental responsibility. According to this report, the CO2 emission for the entire life cycle of the product results as follows:

GWP-total (1.59 kg CO2 equivalent):

According to our calculations, the total emission results in 1.32 kg CO2 equivalent. A difference of 0.27 kg CO2 between our calculations and those of EPD experts may be due to the following factors:

1. The FootprintCalculation platform did not contain specific processes used for the production of gabions, therefore, as explained above, approximate processes were used.

2. The averaging of distances is associated with a margin of error, but the analysis of all deliveries and transports made by the company during 2024 requires extra time and administrative costs from the company.

3. The amount of steel materials used for packaging is approximate in the absence of specific data.

4. Conclusions

The analysis shows that environmental risk management in modern businesses has evolved from a fragmented approach into a strategic and integrated process, where ESG principles have become central to long-term sustainability and competitiveness. Measuring and reporting the environmental footprint, particularly carbon emissions, is no longer simply a regulatory requirement but a decisive factor for market positioning, investor confidence, and corporate reputation. Although the implementation of green technologies and practices often entails high initial costs—especially for small and medium enterprises—the long-term benefits in terms of financing opportunities, market value, and stakeholder trust make such investments indispensable.

The case of Maccaferri Balkans SHPK illustrates how proactive environmental and operational risk management can create tangible value. By integrating renewable energy, recyclable materials, and internationally recognized certifications, the company has minimized its environmental footprint and strengthened its resilience in the construction sector. This demonstrates that sustainability and innovation are not merely ethical imperatives but also effective business strategies.

Looking ahead, companies are encouraged to adopt ESG frameworks as a pathway to improved performance, to invest in precise methods for measuring their carbon footprint, and to integrate environmental management into their core strategic planning. Public institutions, on their part, should ensure consistent enforcement of environmental laws and create supportive mechanisms for businesses transitioning toward clean energy and green technologies. Ultimately, aligning corporate practices with global sustainability standards and the EU Green Agenda is not only a legal or moral duty, but also a strategic opportunity to enhance resilience, competitiveness, and long-term value creation for both business and society.

Literature

[1]	Freeman R., Strategic Management: A Stakeholder Approach, Pitman, Boston, 1984, 292 p.
[2]	Christensen H., Hail L., Leuz C., Corporate Responsibility and Sustainability Reporting: Definitions and Concepts, Journal of Accounting and Economics, Vol. 70, No. 2–3, Elsevier, 2021, pp. 101–120.
[3]	De Haas R., Popov A., Finance and Environmental Sustainability, Journal of Financial Economics, Vol. 138, Elsevier, 2020, pp. 409–429.
[4]	Porter M., van der Linde C., Toward a New Conception of the Environment-Competitiveness Relationship, Journal of Economic Perspectives, Vol. 9, No. 4, 1995, pp. 97–118.
[5]	Grewatsch S., Kleindienst I., When Does It Pay to be Good? Moderators and Mediators in the Corporate Sustainability–Corporate Financial Performance Relationship, Journal of Business Ethics, Vol. 145, Springer, 2017, pp. 383–416.
[6]	Matsumura E., Prakash R., Vera-Muñoz S., Firm-Value Effects of Carbon Emissions and Carbon Disclosures, The Accounting Review, Vol. 89, No. 2, 2013, pp. 695–724.
[7]	Pereira-Moliner J., Gil I., Environmental Practices and Hotel Performance: The Role of Competitive Advantage, Tourism Management, Vol. 75, Elsevier, 2019, pp. 286–296.
[8]	ISO 14064, Greenhouse Gases – Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals, International Organization for Standardization, Geneva, 2018.
[9]	European Commission, Corporate Sustainability Reporting Directive (CSRD), Brussels, 2020.
[10]	Chen Y., Wang Y., Green Innovation and Firm Performance: Evidence from Emerging Economies, Technological Forecasting and Social Change, Vol. 174, Elsevier, 2022, pp. 121–139.
[11]	Eccles R., Youmans T., Materiality in Corporate Sustainability: The Role of ESG Factors in Investment Decisions, Harvard Business Review, 2015, pp. 1–15.
[12]	Kim E., Lyon T., Greenwash vs. Brownwash: Exaggeration and Undue Modesty in Corporate Sustainability Disclosure, Organization Science, Vol. 26, No. 3, INFORMS, 2015, pp. 705–723.
[13]	Adomako S., Amankwah-Amoah J., Danso A., Environmental Sustainability Orientation and Performance of Family and Non-Family Firms, Business Strategy and the Environment, Vol. 30, Wiley, 2021, pp. 2346–2360.
[14]	Case study reference from thesis: Maccaferri Balkans SHPK, Company Sustainability Report, Tirana, 2025.

Integrating advanced technologies and circular economy practices for sustainable business transformation

Ljiljana Popović[1]

Nenad Medić[2]

Suzana Draganić[3]

1 Associate professor, University of Novi Sad, Faculty of Technical Sciences, Department of Industrial Engineering and Management
ljiljana.popovic@uns.ac.rs

2 Assistant professor, University of Novi Sad, Faculty of Technical Sciences, Department of Industrial Engineering and Management
medic.nenad@uns.ac.rs

3 Assistant professor, University of Novi Sad, Faculty of Technical Sciences, Department of Civil Engineering and Geodesy
suzanav@uns.ac.rs

Abstract

The escalating pressures of climate change and resource scarcity demand innovative business models that align technology with sustainability. Circular economy practices, such as closedloop systems, product life cycle extension, and waste minimization, offer a promising path forward. However, the role of advanced technologies in enabling these practices and translating them into measurable sustainability outcomes remains insufficiently explored. This paper presents a conceptual model linking key digital technologies (i.e., artificial intelligence, Internet of Things, blockchain, and big data analytics) with circular economy practices to enhance sustainability performance and business resilience. The core research problem addresses the gap between digital innovation and its effective application in circular business strategies. The model is structured around three levels: technological enablers, circular economy practices as mediators, and sustainability outcomes including environmental performance, ESG alignment, and organizational resilience. Using a qualitative, theory-building approach, this study integrates findings from sustainability science, digital transformation, and industrial systems. It also considers moderating factors such as organizational digital maturity, policy environment, and academia–industry collaboration. The model offers a roadmap for future empirical research and practical application. It supports cross-sector collaboration aimed at accelerating the green transition and advancing the Sustainable Development Goals through data-driven, circular strategies.

Keywords

Circular economy, advanced technologies, sustainability, digital transformation, ESG, business resilience, SDG.

1. Introduction

The global economy is facing unprecedented challenges arising from environmental, social, and economic pressures. Climate change, biodiversity loss, pollution, and resource scarcity have escalated into systemic risks that threaten the stability of societies and markets alike [1]. Urgent transitions are required across energy, production, and consumption systems in order to meet international climate targets and prevent irreversible environmental damage [2]. Against this backdrop, businesses are increasingly expected to move beyond incremental improvements and adopt transformative strategies that embed sustainability at their core [3].

Traditional business models, rooted in the linear economy, are no longer fit for purpose. The extract–produce–consume–dispose paradigm drives inefficiency, generates massive waste streams, and relies on the unsustainable depletion of natural resources [4]. In contrast, the circular economy (CE) has gained traction as a paradigm shift that promotes closed material loops, resource efficiency, waste prevention, and product life cycle extension. CE practices not only support environmental goals but also open avenues for new business models, such as product-as-a-service systems, which can strengthen competitiveness and resilience in volatile markets [5].

Parallel to these sustainability imperatives, digital transformation has emerged as a defining force in the 21st-century economy. Advanced technologies—including artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics—are reshaping how industries manage operations, resources, and customer relationships [6]. These technologies provide capabilities for real-time monitoring, predictive decision-making, transparency, and traceability. When strategically deployed, they can serve as powerful enablers of CE principles, supporting businesses in reducing waste, optimizing resource use, and complying with increasingly stringent Environmental, Social, and Governance (ESG) standards.

Despite this potential, the integration of advanced technologies with CE practices remains uneven and insufficiently studied. Much of the existing literature explores either digital transformation or sustainability in isolation, while fewer contributions investigate the synergies between them [7]. As a result, there is a fragmented understanding of how digital technologies function as enablers of circular strategies, and under what conditions they produce measurable sustainability outcomes. This knowledge gap is particularly critical in emerging economies and transitional regions, where resource efficiency and resilience are vital to sustainable growth.

This paper seeks to address this gap by proposing a conceptual model that links advanced technologies with CE practices to achieve sustainability outcomes. The model emphasizes the mediating role of CE in translating technological capabilities into practical environmental and business benefits. Furthermore, it highlights the importance of moderating factors such as organizational digital maturity, policy frameworks, and academia–industry collaboration in shaping the effectiveness of digital–circular integration.

The study contributes both theoretically and practically. From a theoretical perspective, it advances interdisciplinary research by combining sustainability science, digital innovation, and industrial systems thinking. From a practical standpoint, it provides a roadmap for businesses, policymakers, and academic institutions to collaborate in building digitally enabled circular solutions. In doing so, the research supports progress toward the United Nations Sustainable Development Goals (SDGs), particularly SDG 9 (i.e., Industry, Innovation, and Infrastructure) and SDG 12 (i.e., Responsible Consumption and Production).

2. Methodology

This research employs a qualitative, theory-building methodology designed to address the emerging and interdisciplinary nature of the study. Since the intersection of advanced technologies and circular economy practices is still underexplored, a conceptual approach is most appropriate for establishing foundational insights and guiding future empirical research.

The starting point of the study was a comprehensive review of the existing literature across three key domains: sustainability science, digital transformation, and circular economy frameworks. Academic sources, policy reports, and case studies were systematically examined to identify recurring concepts, key drivers, and gaps in current knowledge. This review provided the empirical and theoretical grounding necessary for constructing a model that integrates technological innovation with sustainability strategies.

Following the literature review, the study adopted a systems thinking approach to map interdependencies among technological enablers, circular practices, and sustainability outcomes. Systems thinking was selected because it allows researchers to move beyond linear cause-and-effect assumptions and instead capture the dynamic feedback loops that characterize both digital and sustainable transitions. For example, the adoption of IoT technologies not only enables real-time monitoring of resources but also creates new opportunities for predictive analytics, which in turn influence how firms design circular strategies.

Building on these insights, the research proceeded with the development of a conceptual model. The model was structured around independent variables representing technological enablers (AI, IoT, blockchain, and big data analytics). These were linked to mediating variables in the form of circular economy practices, including closed-loop supply chains, product life cycle extension, and waste minimization. The model also identified sustainability outcomes as dependent variables, with particular emphasis on environmental performance, ESG alignment, and business resilience.

Finally, the model incorporated contextual moderators to account for variability across firms and sectors. Organizational digital maturity, supportive policy environments, and cross-sector collaboration between academia and industry were recognized as crucial conditions that influence how effectively technologies can support circular transitions.

Through this methodological process, the study develops a conceptual framework that not only advances theoretical understanding but also provides a practical roadmap for future empirical testing. The narrative approach adopted here ensures that the methodology remains flexible, reflective, and adaptable to the complex and evolving challenges of sustainability and digital innovation.

3. Results and discussion

The conceptual research model (Figure 1) demonstrates how advanced technologies act as enablers of CE practices, which in turn mediate sustainability outcomes. The model also highlights the importance of moderating factors—such as organizational digital maturity, policy environment, and academia–industry collaboration—in shaping the effectiveness of these interactions.

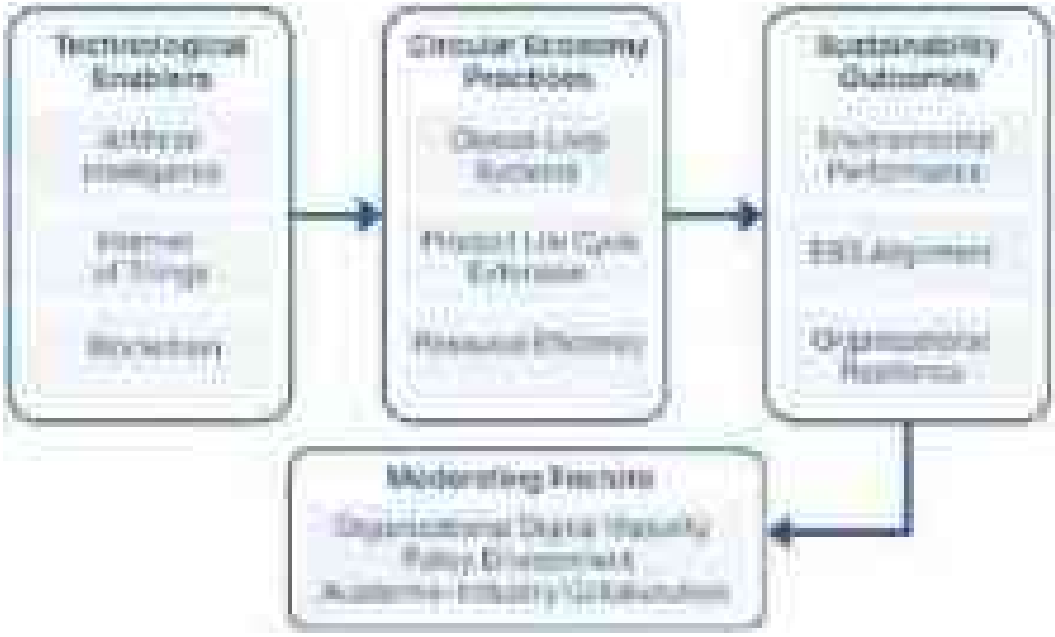


Figure 1 – Conceptual research model

The conceptual research model developed in this study provides a theoretically grounded framework for examining the interplay between advanced technologies and CE practices, and for understanding how these dynamics contribute to sustainability outcomes. The model confirms what recent scholarship has suggested: while digital technologies hold great promise for sustainability transitions, their efficacy is highly dependent on the extent to which they are embedded within systemic circular strategies [4][6].

The findings highlight that technologies such as AI, IoT, blockchain, and big data analytics act as enabling mechanisms rather than standalone solutions. Their capacity to generate value emerges only when aligned with CE principles. For example, AI's predictive capabilities facilitate resource optimization and maintenance strategies that extend product lifespans, while IoT-based monitoring enhances the traceability of material flows, enabling effective closed-loop processes. Blockchain reinforces trust and accountability in supply chains, a prerequisite for recycling and reverse logistics, and big data analytics provides firms with the ability to analyze patterns of inefficiency, identify opportunities for recirculation, and report transparently on sustainability performance.

By placing CE practices at the core of the model, this study illustrates the mediating role they play in translating technological potential into sustainability outcomes. Closed-loop supply chains, product life cycle extension, and resource efficiency serve as the operational pathways through which firms can realize reductions in waste and emissions. This aligns with prior research arguing that the CE is not only an environmental imperative but also a strategic approach to competitiveness and resilience in uncertain markets [5].

The outcomes identified in the model are threefold: improvements in environmental performance, alignment with ESG standards, and enhanced organizational resilience. Firms that successfully integrate advanced technologies with CE practices demonstrate superior environmental metrics, including lower carbon emissions and reduced resource intensity. They also show stronger ESG alignment by leveraging technologies such as blockchain and analytics for transparent reporting and compliance. Perhaps most significantly, these firms exhibit greater resilience, as the capacity for real-time monitoring and predictive management enables them to adapt more effectively to climate risks, market fluctuations, and regulatory change.

Nevertheless, it must be acknowledged that these benefits are not automatically realized and are contingent upon contextual factors. The model emphasizes the moderating influence of organizational digital maturity, which determines a firm's readiness to absorb and deploy advanced technologies. Regulatory and policy environments also play a decisive role, either accelerating adoption through supportive incentives and standards or constraining it through fragmented frameworks. Academia–industry collaboration emerges as particularly significant, offering opportunities for co-creation, experimentation, and the diffusion of best practices. In transitional and emerging economies, such collaboration can compensate for gaps in infrastructure and accelerate knowledge transfer.

Taken together, this research points to a critical insight: the pursuit of sustainability through technology cannot be understood as a linear process of adoption but must instead be conceptualized as a systemic integration of enablers, practices, and contexts. Digital technologies amplify the possibilities of CE, but it is only through institutional support, organizational commitment, and multi-stakeholder collaboration that their transformative potential can be fully realized. This study thus contributes to the academic discourse by offering not only a conceptual model but also a holistic perspective on how advanced technologies and CE practices can jointly underpin the sustainable business models required to address the challenges of the twenty-first century.

4. Conclusion

This study has advanced the discourse on sustainable business transformation by articulating a conceptual model that links advanced technologies with circular economy practices and demonstrates how these interactions produce sustainability outcomes. The model contributes to theoretical development by clarifying the mediating role of circular practices in translating technological capabilities into tangible environmental and organizational benefits. It further underscores the moderating influence of contextual factors such as digital maturity, policy environments, and academia–industry collaboration, which collectively determine the effectiveness of this integration.

The findings support a critical insight: digital technologies are necessary but insufficient for sustainability transitions. Their transformative power emerges only when embedded within systemic frameworks that prioritize circularity and are reinforced by institutional support and organizational commitment. By situating technology as an enabler rather than an end in itself, this research challenges reductionist narratives of digital innovation and instead emphasizes the importance of systemic integration for achieving meaningful change.

From a practical standpoint, the model offers policymakers, business leaders, and academic institutions a roadmap for action. It highlights the need to build digital capabilities, design regulatory environments that incentivize circular practices, and cultivate partnerships that bridge research and practice. By doing so, stakeholders can accelerate the alignment of business strategies with environmental imperatives and societal expectations.

Future research should empirically validate and refine the proposed model across diverse industries and regional contexts. Such investigations will deepen our understanding of how advanced technologies and circular economy practices interact

under varying conditions and will provide evidence-based guidance for scaling solutions. In conclusion, the integration of advanced technologies with circular economy practices represents not merely a technical adjustment but a paradigm shift toward resilience and sustainability. If pursued collaboratively and systematically, this integration has the potential to reshape business models, strengthen competitiveness, and contribute decisively to the achievement of the Sustainable Development Goals.

Literature

[1]	J. Rockström et al., *"A safe operating space for humanity,"* Nature, vol. 461, no. 7263, 2009, 472–475, ISSN 1476-4687
[2]	IPCC, Global Warming of 1.5°C: *An IPCC Special Report*, Intergovernmental Panel on Climate Change, 2018. [Online]. Available: https://www.ipcc.ch/sr15/
[3]	van Vuuren, D. P., Stehfest, E., Gernaat, D. E., Doelman, J. C., van den Berg, M., Harmsen, M., Hof, A. F., *"Alternative pathways to the 1.5 °C target reduce the need for negative emission technologies,"* Nature Climate Change, vol. 8, 2018, 391–397, ISSN 1758-6798
[4]	M. Geissdoerfer, P. Savaget, N. M. P. Bocken, and E. J. Hultink, *"The Circular Economy – A new sustainability paradigm?,"* Journal of Cleaner Production, vol. 143, 2017, 757–768, ISSN 1879 - 1786
[5]	N. M. P. Bocken, I. D. Pauw, C. Bakker, and B. van der Grinten, *"Product design and business model strategies for a circular economy,"* Journal of Industrial and Production Engineering, vol. 33, no. 5, 2016, 308–320, ISSN 2168-1015.
[6]	M. A. Moktadir, A. Kumar, S. M. Ali, and S. K. Paul, *"Critical success factors for a circular economy: Implications for business strategy and the environment,"* Business Strategy and the Environment., vol. 29, no. 8, 2020, 3611–3635, ISSN 0964-4733.
[7]	S. Rajput and S. P. Singh, *"Connecting circular economy and industry 4.0,"* International Journal of Information Management, vol. 49, 2019, 98–113, ISSN 0268-4012

Circular economy and Millennium goals

Mirjana Laban[1]

Olivera Bedov[2]

Suzana Draganić[3]

Ljiljana Popović[4]

1	Full Professor, University of Novi Sad, Faculty of Technical Sciences *mlaban@uns.ac.rs*
2	Teaching Assistent, University of Novi Sad, Faculty of Technical Sciences *olivera.bukvic@uns.ac.rs*
3	Assistant Professor, University of Novi Sad, Faculty of Technical Sciences *suzanav@uns.ac.rs*
4	Asociated Profesor, University of Novi Sad, Faculty of Technical Sciences *ljiljana.popovic@uns.ac.rs*

Abstract

The 17 Sustainable Development Goals (SDGs) are the world's best plan to build a better world for people and our planet by 2030. Adopted by all United Nations member states in 2015, the SDGs are a call to action by all countries – poor, rich and middle-income countries – to promote prosperity while protecting the environment.

For this purpose, we need new business models and innovative product design that makes use of non-toxic materials which can be endlessly recycled. The circular economy shifts wealth and prosperity from our current means of consumption to a system that is continuous and long-lasting. It is a system that is regenerative by design, where the needs of all citizens are provided within the natural means of the earth.

Working on a circular economy means working on most SDGs, not as a cost, but as a business model. In some parts of the world, actions take place within SDGs; in other countries, climate issues are the dominant driver of action. Some focus on measures that create sustainable and economically profitable cities, while there are regions like ours that have started to move towards a circular economy.

The strongest relationships and synergies between circular economy practices and SDG targets lie within: SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land), which have high scores both for direct and for indirect contributions.

Improvement of higher education in WB countries was done in line with established needs, but not only through courses curricula revision: 1Future project anticipated new tailor made short intensive courses, new learning material and teaching methods as well.

Keywords

Sustainability, Circular Economy, Millennium goals

1. Introduction

As nations continue their urbanisation and industrialization, the use of natural materials resources has been tripled over the last fifty years: the global middle class expands; there is a corresponding accelerated rise in material use, waste, emissions, as well as water and land consumption. The global average of material demand per capita was 8.4 tonnes in 1970 and grew to 12.2 tonnes per capita in 2020, and with the current growth rates and population increase rates, global demand for resource use will be up by 60 per cent from 2020 levels by 2060 [1]. Our current deeply unsustainable systems of consumption and production will cumulate in catastrophic impacts on the earth systems and ecological processes that underpin human well-being and the diversity of life on our planet (Fig. 1). Current increase in demand, limited supply of certain resources and disrupted supply chain cause a significant increase in prices and threaten to give rise to a new economic crisis, demonstrating the fact that the current models of the use of resources are far from being sustainable, while they may potentially cause instability.

To prevent catastrophic consequences of accelerated resource consumption for the humanity, societies and economies across the world have been adopting structural changes in order to reduce their environmental impact. With its 2020 Green Deal [2], the EU puts climate change in the epicentre of their long-term development plans: the first climate-neutral continent by 2050, at least 55% less net greenhouse gas emissions by 2030, compared to 1990 levels and 3 billion additional trees to be planted in the EU by 2030. European Climate Pact [3] is part of the European Green Deal and is helping the EU to meet its goal to become climate-neutral by 2050. Transition to circular economy is an important element of this plan.

At the historic UN General Assembly Summit in September 2015, the 2030 Agenda for Sustainable Development was adopted by the UN's 193 member states [4]. The 17 Sustainable Development Goals (SDGs) and their 169 targets are part of this agenda. The Sustainable Development Goals are a bold, universal agreement to end poverty and all its dimensions and craft an equal, just and secure world – for people, planet and prosperity.

Working on the circular economy means working on the majority of SDGs, not as a cost item but as a business model. In some areas of the world, action takes place under the framework of the SDGs; in other countries, climate issues are the dominant driver for action. Some focus on measures that are creating sustainable and economically viable cities, while there are also regions such as ours which set out on the transition towards a circular economy.

The Sofia Summit in 2020 represented a milestone for the Western Balkan region that should galvanise a shift in development paradigm and bolster the region to undertake a major transformation and to properly and timely address the growing environmental and climate challenges by putting sustainable development, resource efficiency, nature protection and climate action in the centre of all economic activities and turn those challenges into opportunities.

Action Plan for the Implementation of the Sofia Declaration on the Green Agenda for the Western Balkans 2021-2030 [5] represents one of the outputs of the Sofia Declaration on the Green Agenda for the Western Balkans [6] and is used as a tool to guide its implementation. It embodies the "putting words into actions" paradigm by identifying concrete steps and supporting organisations, as well as defining an indicative timeframe for each implementable measure. It sets the framework to coordinate and support its proper implementation and monitor the progress in this regard.

In *'The relevance of circular economy practices to the Sustainable Development Goals'*, Patrick Schroeder et al. [7] studied the 17 SDGs and 169 targets in a comprehensive mapping exercise. The study showed that the strongest relationships and synergies between circular economy practices and SDG targets lie within SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG12 (Responsible Consumption and Production) and SDG 15 (Life on Land), which have high scores both for direct and for indirect contributions.

This paper represents the results of 1Future Erasmus+ project based on all the above findings on the background for needs for improvement of Western Balkan countries' higher education programmes.

2. The basic principles of Circular economy

The core principles of the CE are reflected in 10 strategies (Fig. 1):

- In the production and distribution phase, four strategies (1–4) focus on maximising the use of renewable resources and minimising value losses along the value chain.
- In the consumption phase, six strategies (5–10) are directed at reducing value leakage by keeping products and materials at their highest utility level through practices such as sharing, reusing, repairing, remanufacturing, and recycling.
- At the end-of-life stage, products typically lose value, since valuable by-products are not recovered for further use. Instead of discarding them, the circular economy prevents this value loss by ensuring their productive reintegration, thereby creating additional value.

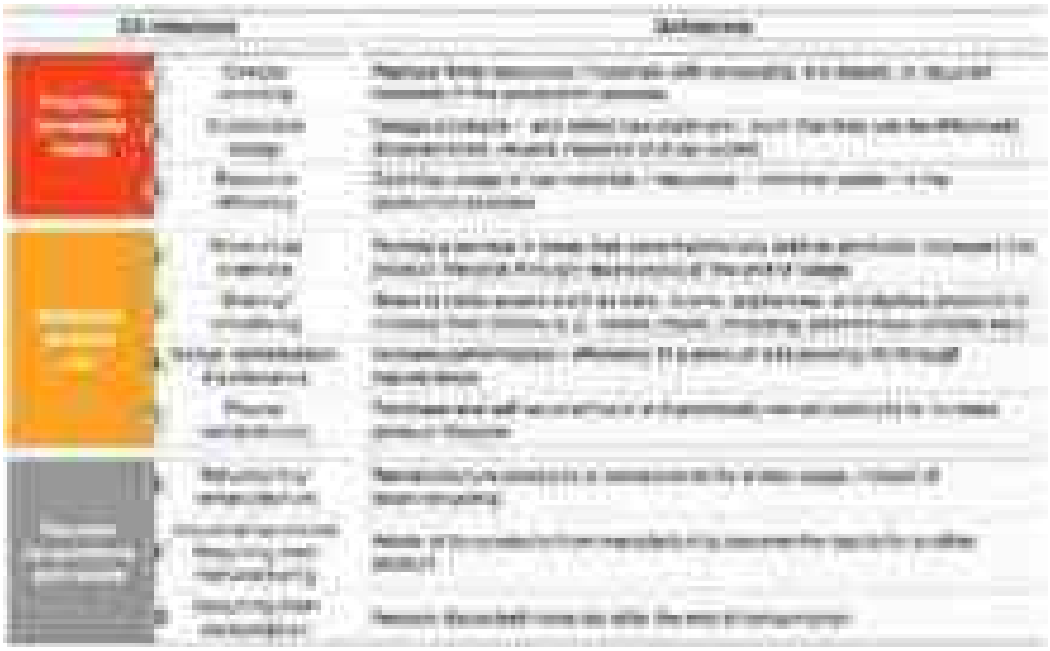


Figure 1 – Ten strategies of CE [7]

3. Millennium goals and Circular economy synergies

Circular economy practices are essential for achieving the Sustainable Development Goals (SDGs) by promoting resource efficiency, reducing waste and pollution, and fostering sustainable consumption and production (Fig. 2). These practices, which emphasize reusing, repairing, remanufacturing, and recycling materials, directly support several SDGs, including those related to responsible consumption and production (SDG 12), climate action (SDG 13), and life below water (SDG 14) [8].

Figure 2 – The 11 priority SDGs that are connected with the circular economy, according to [8]

Circular economy practices contribute to specific SDGs:

1. Sustainable Consumption and Production (SDG 12):

Reducing waste and pollution: Circular economy principles prioritize designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

Resource efficiency: By focusing on reuse, recycling, and remanufacturing, the circular economy reduces the need for virgin materials and minimizes the environmental impact of resource extraction and processing.

Extending product lifecycles: Repairing, refurbishing, and remanufacturing products extend their lifespan, reducing the overall demand for new products and associated resource consumption.

2. Climate Action (SDG 13):

Reducing greenhouse gas emissions: Circular economy practices, such as reducing waste, reusing materials, and transitioning to renewable energy, help to lower greenhouse gas emissions associated with material production and consumption.

Conserving natural resources: By minimizing waste and promoting resource efficiency, the circular economy reduces the need for resource extraction, which often contributes to deforestation and habitat loss, both of which exacerbate climate change.

3. Life Below Water (SDG 14) and Life on Land (SDG 15):

Reducing plastic pollution: Circular economy initiatives focused on reducing plastic waste and promoting alternatives to single-use plastics directly benefit marine ecosystems and coastal communities, addressing SDG 14.

Protecting biodiversity and ecosystems: By reducing resource extraction and promoting sustainable land management practices, the circular economy helps to protect terrestrial ecosystems and the species that inhabit them, supporting SDG 15.

4. Other Relevant SDGs:

SDG 8 (Decent Work and Economic Growth): The circular economy can create new jobs in areas like recycling, remanufacturing, and repair services, while also fostering innovation and economic growth.

SDG 9 (Industry, Innovation, and Infrastructure): Circular economy principles encourage the development of new technologies and business models that are more sustainable and resourceefficient.

SDG 11 (Sustainable Cities and Communities): By promoting sustainable consumption and production patterns, the circular economy helps to create more sustainable and resilient cities and communities.

SDG 17 (Partnerships for the Goals): The transition to a circular economy requires collaboration and partnerships among various stakeholders, including governments, businesses, and individuals.

By adopting circular economy principles, countries can accelerate progress towards multiple SDGs simultaneously, creating a more sustainable, inclusive, and prosperous future.

3. Millennium goals and Circular economy synergies

The Western Balkans is among the European regions most severely affected by climate change, a trend expected to persist. Projections indicate temperature increases between 1.7°C and 4.0°C, and potentially above 5.0°C by the end of the century, depending on the extent of global efforts to reduce greenhouse gas emissions [9].

Circular public governance is essential for laying the foundations of circular development. *The Green Agenda for the Western Balkans* [10] represents a new growth strategy for the region, aiming to shift from a traditional economic model to a sustainable one, in line with the European Green Deal. It identifies five key areas for action:

- *Decarbonisation:* climate, energy, mobility,
- *Circular economy,*
- *Depollution:* air, water & soil,
- *Sustainable food systems & rural areas* and
- *Biodiversity:* protection & restoration of ecosystems.

It provides concrete recommendations to unlock the potential of the circular economy, among other areas.

The Action Plan for the Sofia Declaration, signed in 2021, serves as the key framework for future cooperation and planning of the circular economy transition in the Western Balkans. Guided by green sustainability criteria, each country in the region is expected to design its own pathway for implementing circular economy activities and to identify potential priority sectors.

In November 2020, Serbia committed to the European Union's requirements by signing the Green Agenda for the Western Balkans, thereby linking the European Green Deal with the region's strategic development. To outline the goals and next steps in the transition to a circular economy, the *Roadmap for Circular Economy in Serbia* was developed [11]. Furthermore, the Industrial Policy Strategy of the Republic of Serbia (2021–2030) [12] serves as a key pillar for building a modern economy based on circular and high-value principles. It highlights the promotion of the circular economy, fostering investment in circular and low-carbon solutions as growth drivers, and improving the efficient use of material resources and energy in industrial processes.

Although Montenegro has not yet established formal circular economy policies, efforts are being made within the public system to support the development of eco-sustainable business, particularly following the adoption of the Smart Specialization Strategy of Montenegro (2019-2024) [13] and the development of the *Roadmap Towards the Circular Economy in Montenegro* [14]. The Roadmap highlights five priority areas - food and forest systems, the built environment, tourism, and manufacturing - which are strongly interconnected. By applying the principles of industrial symbiosis and synergies, these areas can drive systemic transformation. It further identifies key drivers of this transition, including resilience and self-sufficiency, innovation and economic growth, the use of untapped green financing, environmental protection and restoration, as well as societal development and the creation of green jobs.

Economic growth and rising consumption in Albania are expected to drive higher demand for raw materials, posing risks to reducing environmental pressures and limiting opportunities to strengthen economic competitiveness and resilience. Although resource productivity doubled between 2016 and 2021, the economy still relies on a relatively high volume of physical resources per unit of GDP. These trends intensify challenges in critical areas such as waste management, which threatens Albania's ecosystems and exacerbates existing climate vulnerabilities. While waste generation remains about 30% below the EU average, growing consumption suggests a worsening trajectory, with issues linked to unmanaged and illegal landfills, widespread littering, and inadequate waste management practices. As a result, the recycling rate of municipal waste remains low (around 17%), and high levels of plastic leakage contribute significantly to marine pollution.

A Roadmap towards Circular Economy of Albania was adopted in 2024 [15]. According to an OECD analysis, based on multi-criteria assessment and stakeholder consultations, three priority areas have been identified where circular economy reforms could generate significant impact: *(1) applying economic instruments to foster sustainable consumption and production, (2) promoting circular business models among small and medium-sized enterprises (SMEs), and (3) improving the plastics value chain, with particular emphasis on reducing marine litter.*

Policy measures defined within the five priority areas are expected to advance circular practices by tackling overarching challenges such as municipal waste management and by strengthening awareness of the circular economy. Their implementation can further support North Macedonia in meeting climate change mitigation targets, given that a substantial share of greenhouse gas emissions stems from material production and consumption.

The *Circular Economy White Paper of Bosnia and Herzegovina* [16], developed in 2022, outlines five priority areas for action: *improving legislation regulating the circular economy, introducing fiscal incentives, ensuring the full pricing of waste management costs, promoting green public procurement, and implementing education and awareness-raising programmes to encourage sustainable consumption.*

The Circular Economy Roadmap for Bosnia and Herzegovina is currently under development. Key obstacles to its implementation include limited knowledge and experience, insufficient financing, and the absence of an adequate legal and strategic framework. Circular economy initiatives are often confined to waste management or, occasionally, energy efficiency, and are generally not reflected in national regulations. Nevertheless, despite the lack of a comprehensive plan, the number of circular economy projects and initiatives in BiH has increased significantly in recent years, particularly following the adoption of the EU Green Deal and the Green Agenda for the Western Balkans.

The top rated green measures, already adopted by companies in WB countries [17], with adoption levels, are listed in Table 1. All companies have some top-rated measures in common: environmental protection measures, reducing pollution measures, energy saving measures and engagement in community based environmental initiatives.

Table 1 – Green measures adoption across WB countries

Country and company size	Green business measures	Level of adoption
Albania - all companies	Implement measures to protect the environment	56.3%
	Estimate the level of energy consumption/savings/losses	67.1%
	Implement measures to reduce pollution	81%
	Have a green transport plan/procedure (for staff, customers, freight)	72%
	Have adopted a national/international environmental certificationprogram	79,1%
B&H - all companies	Engage in community-based environmental initiative	44.4%
	Estimate the level of energy consumption/savings/losses	49.3%
	Implement measures to reduce pollution	64.7%
	Send delegates to environmental conferences/activities; Estimate the level of energy consumption/savings/losses	62.8%
	Engage in community-based environmental initiatives	65.7%
Montenegro - all companies	Engage in community-based environmental initiatives	52. 8%
	Implement measures to reduce pollution	75.5%
	Implement measures to protect the environment	81.9%

Despite varying policy frameworks across the region, the main barriers to implementing the circular economy in the Western Balkans are [18]:

- limited knowledge and skills,
- low awareness of potential benefits,
- uncertainty about where and how to begin, and
- a shortage of multidisciplinary expertise and professional skills.

The higher education development and improvement have been made towards circular economy practise and millennium goals in the scope of 1Future project. Revision of content and methodology of selected courses was done according to the needs analysis; partners of WB countries have identified specific teaching lessons where reform of current curricula is needed in order to make the course more interesting and responding to the needs for a climate resilient society. There were 61 courses revised in total, which offer a new perspective of sustainability to 2808 students enrolled in revised courses in the academic year 2024-2025, at 6 WB HEIs.

4. Conclusion

At the halfway point of the 2030 Agenda for Sustainable Development, the world is far off track as shown in the Global Sustainable Development Report 2023 [19]. Without urgent course correction and acceleration, humanity will face prolonged periods of crisis and uncertainty – triggered by and reinforcing poverty, inequality, hunger, disease, conflict and disaster.

The circular economy helps to achieve the Sustainable Development Goals in many ways: circular examples from various market segments that are closely linked with SDGs such as food, manufacturing and the built environment are included next to cross-sectorial topics such as consumer goods or plastics.

The transition to the circular economy requires systemic change and asks for collaboration. A local government can set the ambition (urgency), define boundary conditions and nurture experimentation. Researchers and knowledge institutes can develop new insights and tools, validate ideas and boost awareness. Local entrepreneurs have the guts and imagination to take risks, accelerate change and deliver scale. Meaningful participation by citizens and residents is also crucial, as is educating the leaders, employees and consumers of the future.

Improvement of higher education in WB countries was done in line with established needs, research on actual practices in business sector and contemporary scientific achievements.

Above all, the cooperation developed between science, industry and society is aimed to initiate concrete collaboration between parties, such as joint projects, internships, research activities, and more.

Literature

[1] United Nations Environment Programme (2024): Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes. International Resource Panel. Nairobi. https://wedocs.unep.org/20.500.11822/44901

[2] EU Commission, The European Green Deal - Striving to be the first climate-neutral continent, 2019, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[3] EU Commission, European Climate Pact
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0788

[4] UN General Assembly, Resolution adopted by the General Assembly on 25 September 2015: Transforming our world: the 2030 Agenda for Sustainable Development
https://docs.un.org/en/A/RES/70/1

[5] Regional Cooperation Council, Action Plan for the Implementation of the Sofia Declaration on the Green Agenda for the Western Balkans 2021-2030
https://www.rcc.int/download/docs/Action%20Plan%20ENG%20ver%20l%20(1).pdf/d6b170df3ed1b06973f02675e474d661.pdf

[6] Sofia Declaration on the Green Agenda for the Western Balkans
https://www.rcc.int/download/docs/Leaders%20Declaration%20on%20the%20Green%20Agenda%20 for%20the%20WB.pdf/196c92cf0534f629d43c460079809b20.pdf

[7] Schroeder, Patrick and Anggraeni, Kartika and Weber, Uwe, The Relevance of Circular Economy Practices to the Sustainable Development Goals (February 2019). Journal of Industrial Ecology, Vol. 23, Issue 1, pp. 77-95, 2019; available at SSRN: https://ssrn.com/abstract=3344675 or http://dx.doi.org/10.1111/jiec.12732

[8] NL Netherlands Platform, Netherlands Enterprise Agency, Holland Circular Hotspot. 2018. Circular Economy & SDGs - How circular economy practices help to achieve the Sustainable Development Goals.p.76

[9] Vuković A., Vujadinović Mandić, M., Study on climate change in the Western Balkans region, 2018, Regional Cooperation Council Secretariat, Sarajevo, Bosnia and Herzegovina, https://www.rcc.int/download/docs/2018-05-Study-on-Climate-Change-in-WB-2alowres.pdf/06af8f7432484a6ce384ebcb8c05e8d7.pdf

[10] EU Commission, Guidelines for the Implementation of the Green Agenda for the Western Balkans, Brussels, 6.10.2020 https://enlargement.ec.europa.eu/system/files/2020-0/green_agenda_for_the_western_balkans_en.pdf

[11] UNDP & RS Ministry of Environmental Protection, ROADMAP for circular economy in Serbia, Sector for Strategic planning and Projects, 2020, https://www.undp.org/serbia/publications/roadmapcircular-economy-serbia

[12] The Government of Republic of Serbia, Industrial policy strategy of the Republic of Serbia from 2021 to 2030., https://privreda.gov.rs/sites/default/files/documents/2021-08/Industrial-Policy-Strategy-2021-2030.pdf

[13] Montenegro Ministry of Science, Smart specialization strategy of Montenegro 2019 – 2024., https://www.gov.me/dokumenta/ea1d661e-922a-4d42-af8d-ae55bc53988e

[14] The United Nations Development Programme in Montenegro and The Chamber of Economy of Montenegro, Roadmap Towards the Circular Economy in Montenegro, (2022) https://circulareconomy.europa.eu/platform/en/strategies/roadmap-towards-circular-economymontenegro

[15] OECD (2024), A Roadmap towards Circular Economy of Albania, OECD Publishing, Paris, https://doi.org/10.1787/8c970fdc-en

[16] OECD (2024), A Roadmap towards Circular Economy of North Macedonia, OECD Publishing, Paris, https://doi.org/10.1787/1973c88c-en

[17] Centre for Policy and Governance, Bosnia and Herzegovina Circular Economy White Paper, 2022, https://zelenaekonomija.komorabih.ba/wpcontent/uploads/2023/10/White_Paper_Publication_28042022.pdf

[18] Laban M. et al., *Building capacity and interdisciplinary knowledge for a sustainable and resilient society*, 21st International Symposium of MASE, Ohrid, North Macedonia, 24-27 September 2025, Proceedings of 21st International Symposium of MASE, Macedonian Association of Structural Engineers & Faculty of Civil Engineering, Skopje, 2025, pg. 1218-1223

[19] Western Balkan Countries on the road to the circular economy, https://cirekon.rs/wpcontent/uploads/2023/01/Com_.-analysis-of-needs-asses.-in-Western-Balkan-countries.pdf

[20] Independent Group of Scientists appointed by the Secretary-General, Global Sustainable Development Report 2023: Times of crisis, times of change: Science for accelerating transformations to sustainable development, (United Nations, New York, 2023).

Management problem of olive pomace generated as a waste by-product during the olive oil production. case of three-phase olive oil mill in Elbasan County, Albania

Entela Çobani[1]

Xhuana Xhika[2]

Denisa Selimi[3]

1 Dr. Entela Çobani, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania
entela.cobani@fin.edu.al

2 BSc. Xhuana Xhika, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania
xhuana.xhika@fin.edu.al

3 BSc. Denisa Selimi, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania
denisa.selimi@fin.edu.al

Abstract

The olive sector is one of the most important agro-industrial sectors in the world and especially for the Mediterranean region, as it is the largest producer and consumer in the world, where about 95% of global production is concentrated there, with Spain as the biggest producer. In the recent years (2000s-2010s) the cultivation of olive trees has grown in Albania, where about 100,000 farmers (one third of total farmers in Albania) are involved in olive growing and olive processing. However, the production of olive oil also generates solid and liquid wastes, which have great impacts on the environment, if not treated, including surface and groundwater contamination, air pollution and soil degradation. These wastes are generated in large quantities during a short period of time, of around 4 months (October-January) leading to serious management problems. The main wastes coming from olive processing are Olive Mill Wastewater (OMWW) and Olive Pomace (OP), which depending on the type of olive oil mill (pressing or centrifugation), take on different physicochemical characteristics but essentially all wastes are characterized by phenolic compounds, fats, high organic load and acidic pH of 4.8-5.2. In this paper, we will focus only on the solid waste, where we will calculate the amount of olive pomace produced by olive mills in Albania and Elbasan County (the third largest county producer in national level in Albania for olive oil and table olives) for olive production year of 2022, we will see the three possible scenarios of olive pomace treatment and management plans and finally we will present a case study of a three-phase olive oil mill in Elbasan County which has implemented a solid waste treatment unit for this waste by-product as a solution for the management problem of olive pomace.

Keywords

Olive mills, olive pomace, olive waste by-products, phenolic compounds

1. Olive oil production in Albania & Elbasan County

Like every other Mediterranean country, the olive cultivation in Albania represents an important, traditional and old agricultural activity, with an important economic, social and historical significance. The olive cropping area in Albania is situated in the western coastal region, which represents 36,2 % of the country territory and where about 60 % of the population lives. It extends from the northern border of Shkodër to Konispol to the south, by penetrating the mainland towards the east, through river valleys, creating a continuum of olive groves [2].

Olive cultivation is important for the Albanian agrifood sector as represented by the fact that about one-third of the farmers operate in the olive sector. Currently the number of olive trees is estimated at around 11 million and the olive area is estimated at about 54,000 ha. However, compared to other mediterranean countries, the olive sector in Albania is far behind in terms of the number of plants per capita (around 3.5 compared to 4-10 plant per capita in Italy, Spain and Greece), as well as in terms of yield per plant and overall product quality. Some of the problems that Albania has in the olive oil sector are very small orchards at a competitive disadvantage, the difficulty of mechanization because of steep land, lack of pruning, irrigation and phytosanitary measures and lack of basic technical skills on processing [2].

Table 1 – Olive production in Albania (source: Institute of Statistics of Albania)

Year	2014	2013	2015	2016	2017	2018	2019	2020	2021	2022
Production (000 ton)	92	98	96	99	107.8	117.6	98.3	132	110.2	157.7

Olive cultivation for the olive oil production is highly concentrated in the counties of Fier, Berat, Vlore and Elbasan, which together cover 80% of total production. Most of the olive processors (olive oil mills) are also located in these regions [1].

Elbasan is the third most important region in terms of olive production, especially the olives for olive oil production.This area has 19,598 lands spread over 9,763.216 ha, where about 2,370.999 olive trees are planted, where the typical variety for the Elbasan area is “Mixani i Elbasanit”. The area with the highest productivity in the Elbasan region is the Dumrea area with Belsh City as its center. This region is because it has some advantages:

1. Large land areas, around 0.35-0.4 ha per capita, among the highest in Albania.
2. Dumrea is rich in water, with abourt 85 karst lakes.
3. There are many immigrants or seasonal workers in Greece, who have brought their knowledge here, creating their own businesses in the field of olive cultivation.

All these factors combined have led to a large increase in olive plantations, olive mill factories and olive oil, as well as an increase in the generation of olive wastes and by-products [1].

1.1. Olive oil mills

There are currently three different types of olive mill factories: traditional factory, two-phase system factory and three-phase system factory.The first type of factory is based on the pressing process, while the other two are based on the centrifugation process for olive oil exctraction. Pressing process for olive oil exctraction has existed since the ancient times, and it still exists today but as an outdated method, which continues to be preferred by some countries such as Greece.

The three-phase system factory was first created in the 70s, which today has a fairly wide use in our country. The products at the end of the centrifugation process in factories with a three-phase system are: olive pomace or olive husk (with moisture 40-45%), olive mill wastewater and olive oil. A very important disadvantage of the three-phase system is the increase in the amount of wastewater generated, due to the increased water consumption at the centrifugation process [3].

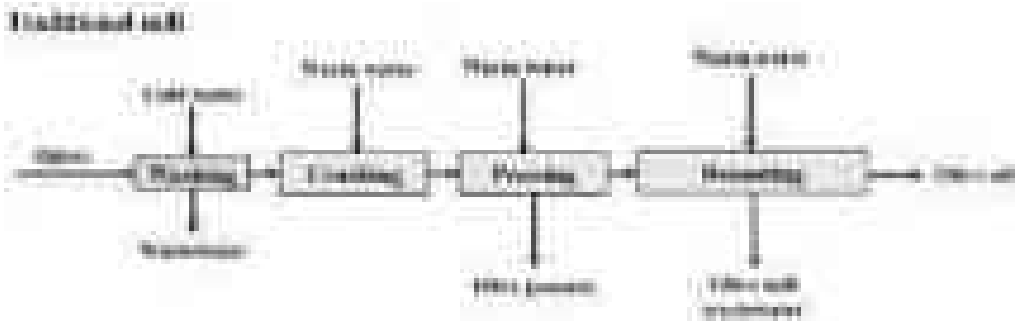


Figure 1 – Scheme of traditional factory [3]

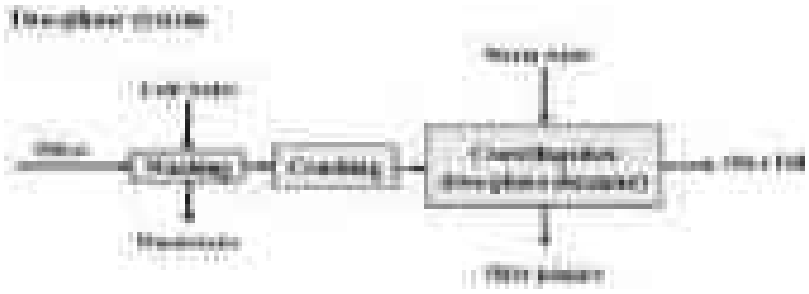


Figure 2 – Two-phase system [3]

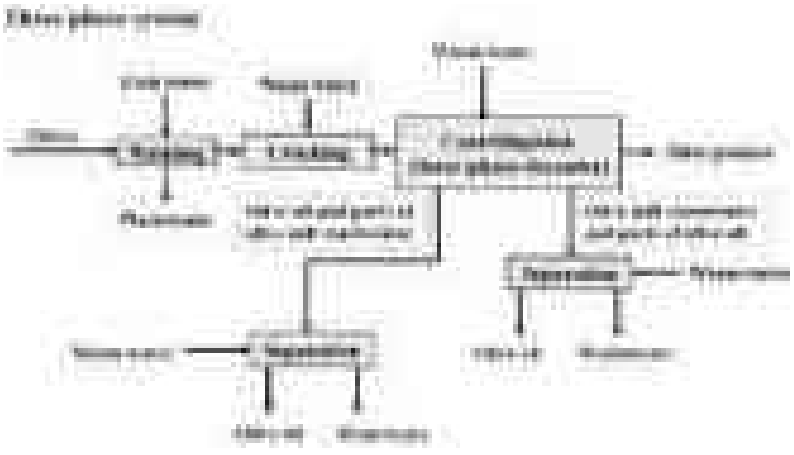


Figure 3 – Three-phase system [3]

In the early 90s, several companies promoted new types of centrifuges that could separate olive oil and olive pomace from the source without the need to add water. This type of centrifuge is used in factories with a two-phase system, which is characterized as ecological due a reduced water consumption and is called two-phase system since two products are produced: olive oil and olive pomace with a moisture content of 55-70%.

In Europe, Spain has completely replaced three-phase systems with two-phase systems, while there are many countries like Albania, where the three-phase system prevails. The main disadvantage of two-phase systems is the increased moisture content of the solid product, which makes it difficult to manage it, transport it and treat it.

Table 2 – Inputs and Outputs

	Inputs		**Outputs**	
Traditional pressing	Olives	1000 kg	Olive oil	~200 kg
	Water for olive washing	0.1-0.12 m^3	Olive pomace	~400 kg
	Energy	40-63kWh	Olive mill wastewater	0.4-0.6 m^3
Three-phase process	Olives	1000 kg	Olive oil	~200 kg
	Water for olive washing	0.1-0.12 m^3	Olive pomace	~500-600 kg
	Water for centrifugation	0.5-1 m^3	Olive mill wastewater	1-1.2 m^3
	Energy	90-117 kWh		
Two-phase process	Olives	1000 kg	Olive oil	~200 kg
	Water for olive washing	0.1-0.12 m^3	Olive pomace	~800-950 kg
	Energy	<90-117 kWh	Olive mill wastewater	0.085-0.11 m^3

1.2. Characteristics of olive pomace

At the end of the olive oil processing, factories produce solid waste from two sources. The first source is the olive leaves and stems that come from the olive washing at the beginning of processing, and the second source is the pits that come after the pressing and centrifugation process. A determining parameter for the mass and volume of olive pomace is the moisture content of the olive fruit, the higher the moisture content, the greater the volume of waste produced.

Another factor that affects the volume of olive pomace generated is the system the olive mill factory uses. The solid waste produced often contains a high % of moisture and oxygenated compounds such as phenols, consequently these affect the reduction of the calorific value of the olive pomace. Other compounds found in olive pomace that have polluting potential are amounts of Cl (HCl, furan or dioxin), as well as the potential to lower the pH of soils by turning them acidic and increasing soil salinity and making soil hydrophobic, as inflitration decreases [3].

As mentioned earlier, different olive oil production methods produce residues with different compositions. The table below shows the physical and chemical parameters of solid waste from olive factories with three different production methods. Based on the table, it is found that factories that use the two-phase production system produce solid waste with the highest percentage of moisture, compared to other olive oil production methods.

Table 3 – Characteristics of olive pomace for three different olive mills [3]

Characteristics	Pressing	Three-phase	Two-phase
Moisture (%)	27,2 ± 1,048	50,23 ± 1,935	56,80 ± 2,188
Fats-Oils (%)	8,72 ± 3,254	3,89 ± 1,449	4,65 ± 1,736
Proteins (%)	4,77 ± 0,024	3,43 ± 0,017	2,87 ± 0,014
Saccharides (%)	1,38 ± 0,016	0,99 ± 0,012	0,83 ± 0,010
Celulose (%)	24,1 ± 0,283	17,37 ± 0,203	14,54 ± 0,170
Ash content (%)	2,36 ± 0,143	1,70 ± 0,105	1,42 ± 0,088
N-organic (%)	0,71 ± 0,010	0,51 ± 0,007	0,43 ± 0,006
P (%)	0,07 ± 0,005	0,05 ± 0,004	0,04 ± 0,003
Phenolic compounds (%)	1,14 ± 0,06	0,326 ± 0,035	2,43 ± 0,15
K (%)	0,54 ± 0,045	0,39 ± 0,033	0,32 ± 0,027
Ca (%)	0,61 ± 0,059	0,44 ± 0,043	0,37 ± 0,036
TOC (%) – Total Organic Carbon	42,9 ± 3,424	29,03 ± 2,317	25,37 ±2,025
C/N	60,7 ± 5,352	57,17 ± 5,033	59,68 ± 5,254
C/P	588,7 ± 51,25	552,9 ± 48,20	577,2 ± 50,31

Due do the high organic load, phenolic compounds, oil content, acidic pH the olive pomace has great impacts in the environment if not managed or treated such as: harmful emissions if it is burned, soil contamination, increasing soil salinity, decreases soil infiltration etc.

1.2.1. The olive pomace generated in Albania and in Elbasan County for 2022 olive crop year

Based on table 4 (olives in tons for oil production) and 5 (olive pomace produced by the type of factory), we will calculate the amount of olive pomace produced for the three-phase and two-phase factory in Albania and Elbasan County for the year 2022.

Table 4 – Olives used for oil production in crop year 2022

Agricultural production in tons of olives used for oil production (2022)	
In Albania	**In Elbasan County**
157,700 ton	25,564 ton

Table 5 – Olive pomace generated for two and three-phase process [3]

Type of centrifugation	Olive pomace generated from 1000 kg of olives
Two-phase process	950 kg/ton
Three-phase process	600 kg/ton

Olive pomace produced in Albania in 2022:

1 . Two-phase process:
$[OP]_{produced}$ = mass $_{olives}$ x $OP_{two\text{-}phase}$ =157,700 ton x 950 kg/ton =149,815 ton

2. Three-phase process:
$[OP]_{produced}$ = mass $_{olives}$ x $OP\ t_{hree\text{-}phase}$ =157,700 ton x 600 kg/ton =94,620 ton

Olive pomace produced in Elbasan County in 2022:

1. Two-phase process:
$[OP]_{produced}$ = mass $_{olives}$ x $OP_{two\text{-}phase}$ =25,564 ton x 950 kg/ton =24,285.8 ton

2. Three-phase process:
$[OP]_{produced}$ = mass $_{olives}$ x $OP_{three\text{-}phase}$ =25,564 ton x 600 kg/ton =15,338.4 ton

1.2.2. Three possible scenarios of olive pomace treatment and management plans

The treatment techniques for olive pomace include two methods: *biological methods* and *thermal methods*. Biological methods include anaerobic digestion and composting. Anaerobic digestion uses microorganisms which, in absence of oxygen, break down complex compounds into simpler compounds. At the same time, this process is accompanied by the methanization process, which produces the gases that make up biogas. After biogas production, it can be used in boilers for heating systems in households or olive mills boiler, but it can be also used to produce electricity that covers the expenses of the olive mill. Composting is another method that it can be used for the olive pomace treatment, when the final product is effectively composted into a valuable organic fertilizer and soil conditioner, and it can be applied in soils that are degraded or nutrient-deficient [3],[5].

In the thermal methods there are a lot of techniques, including: pyrolysis, incineration, gasification etc. All these methods use temperature to treat olive pomace, but depending on the needs, requirements, costs they are applied in different cases. For example, in Greece there are some plants called olive pomace treatment plants, that use temperature and hexane for olive pomace oil extraction and olive husk producing. Due to extremely high costs, treatment of olive pomace is neglected and is often deposited in the environment without any criteria, causing a lot of environmental problems and that is the main reason we need to manage and treat it properly.

For the olive pomace management and treatment there are three possible scenarios that can be applied in: *individual level*, *common level*, or *central level*. The individual level means that every olive mill factory needs to implement a special unit for olive pomace

treatment, but taking into consideration, that most of the factories are with three-phase system, which means that besides the solid waste they have to manage and treat the olive mill wastewater, they usually deal only with the wastewater and the olive pomace is deposited in the ground around the mill area without any criteria or treatment. This happens because the amount of solid and liquid wastes for an olive season produced by the mill is exceptionally large, which is associated with high costs for treatment units. In other words, is exceedingly difficult for a mill factory to properly treat its wastes, because even if it has a treatment unit, this unit will have a low-cost technique but not necessarily effective [4].

Figure 4 – Olive pomace dumped in soil (source: oikologicarodiaka.wordpress.com)

The central level refers to a big treatment unit that collects all the wastes produced by factories in a region, a county etc. The main benefit of large treatment plants is the use of advanced technologies such as anaerobic digestion (biogas production) for electricity or a big olive pomace drying center, associated with olive mill wastewater treatment or not. The central treatment of olive wastes is an expensive and voluminous solution, in addition to the fact that olive oil factories only operate 4 months a year, so the costs of construction, waste transportation, maintenance, and operation are very high [4].

The third plan (the most effective) concerns small plant units, where groups of olive processing factories are located in close proximity to each other and can transport and collect easily their waste for treatment. To avoid transportation costs, it is recommended that the treatment unit be located within the territory of their factories or near them.

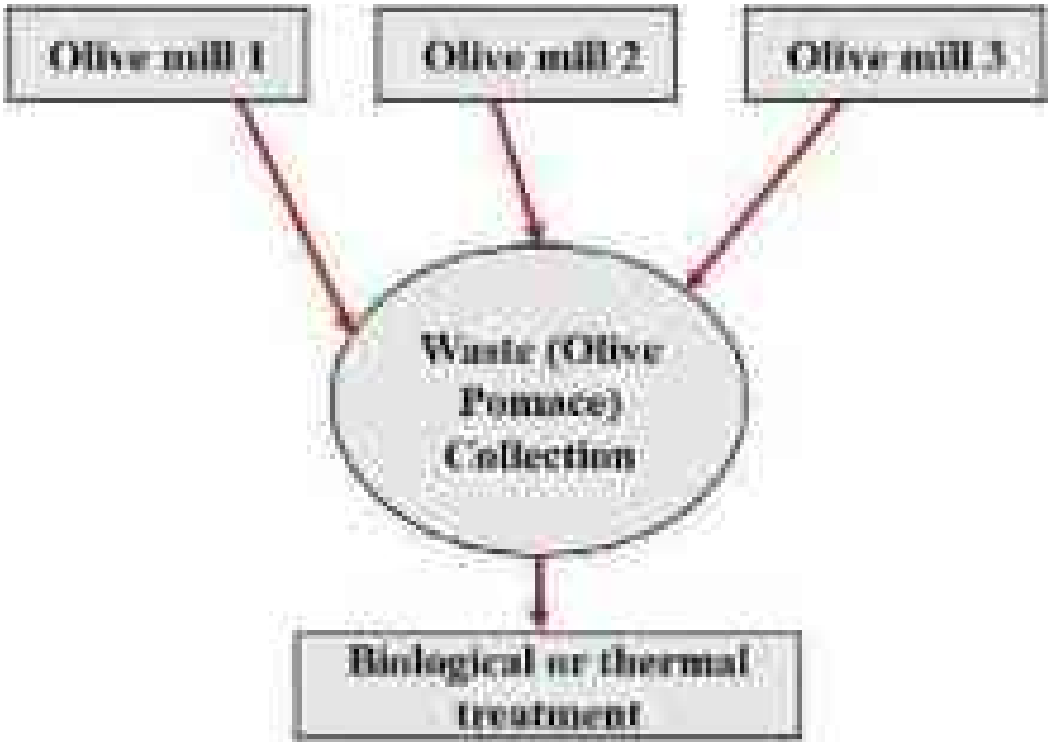


Figure 5 – Scheme representation of common level treatment

1.3. Case of olive mill factory located in Elbasan County, Albania

Figure 6 – Satellite image of the olive oil mill (photo withdraw from Google Earth).

Figure 7 – Olive pomace dryer

As a case study is taken an olive oil processing factory, built in 2021, in the village of Selita, approximately 33 km from the city of Elbasan and 18 km from the city of Cerrik. The coordinates of the mill are X= 40.886314 and Y= 19.979095. The mill has a three-phase centrifugation process, with three products at the end. In 2023, this mill saw the need to implement a unit for the treatment of olive pomace due to the large amount produced and the lack of storage space. Therefore, it installed a pomace dryer with a drying capacity of three tons/hour, thus solving the pomace management problem. Now this dried pomace is used for the factory boiler and sold for residential heating systems, thus compensating the excessive cost of installation.

Conclusions and recommendations

Although the olive sector is a very important agro-industrial sector in Albania, it is associated with a large amount of OP produced. According to physicochemical properties of OP, it was observed that it contains substances with a polluting potential such as phenols and polyphenols. Through the calculations we saw that for the crop year 2022 if all olive mill factories had two-phase systems, the amount of OP generated in Albania and Elbasan County was: 149,815 ton and 24,285.8 ton. The high costs of treatment, lack of knowgledge, negligence of various operators have caused OP in most cases to be thrown into the ground without being treated and without any criteria. Knowing the negative effects that olive pomace has on the environment, it is necessary to treat it, but starting from the high costs of installing treatment units, we analyzed three possible management scenarios and concluded that the best scenario is the cooperation of two to three factories to treat their waste jointly. In this way, costs can be shared between factories and a satisfactory treatment technique is chosen, depending on the factories' requirements. In the case of Albania, as a country where the economy relies on agriculture and toursim, the biological method of composting will be recommended, which is considered on of the low-cost methods.

Another problem that is often encountered in Albania is the drying of olive pomace in the open air, on unprotected ground and then using it in factory biomass boilers or for heating systems in households. In other European countries such as Greece, Italy and Spain, this is prohibited because olive pomace still contains olive pomace oil, which is then burned and causes air pollution. This is due to the lack of normatives acts for the management and treatment of olive waste. To avoid ths problem it is recommended that the olive pomace used in heating systems of mill boilers to be dryed in olive pomace dryer as the example of the mill that we took as a case study in Elbasan County.

Literature

[1]	Drini I., Shkreli E.: *"Olive oil sector study report"*, Albania Agribusiness Support Facility (AASF), Tirana, 2019.
[2]	P. Pugliese., G. Cardone., S. Madzaric., P. Pasko., (CIHEAM-Bari) D. Panajoti (Albania).: *"Sustainable Development of the Olive Sector in Albania-ASDO", Tirana*, 2018.
[3]	Ελενη Χ.Κουτρουλη.:"Βιοτεχνολογικη Αξιοποιηση Αποβλητων Ελαιοτριβειων για Παραγωγη Υδρογονου", PhD thesis, 2008, pages 3-21.
[4]	I. Foteinopoulos., E. Darakas.: *"Olive Mill Waste Management-The Case of Messenia Area"*, Thessaloniki, 2018.
[5]	D. Mondelli.: *"Management of olive mill by-products-ASDO Project"*, Agicultural Ministry of Albania, Tirana, 2018.

T2

Environmental justice and equity in public policies

CPR 305/2011 and CPR 2024/3110 – Comparative analysis and implications for sustainability and the circular economy

Miloš Knežević[1]

Ana Andabaka[2]

1 Full Professor, University of Montenegro
knezevicmilos@hotmail.com

2 Ass. Professor, University of Zagreb
aandabaka1@net.efzg.hr

Abstract

The paper presents a comparative analysis of Regulation (EU) 305/2011 and the new Regulation (EU) 2024/3110 on construction products. The starting point is the historical development of legislation from Directive 89/106/EEC to CPR 2011, which achieved harmonization of the EU internal market, but without significant consideration of sustainability issues. The new regulation, adopted in 2024, integrates the construction sector into the broader political and climate framework of the European Union, including the European Green Deal, the Fit for 55 package, the Circular Economy Action Plan, and the Renovation Wave initiative. By analyzing instruments such as the Declaration of Performance (DoP), Digital Product Passports (DPPs), emission thresholds, and mandatory Life Cycle Assessment (LCA), it is shown that the regulation is transforming from a technical-market instrument into a strategic regulatory instrument of sustainability. Particular emphasis is placed on the expanded obligations of manufacturers, the digitalization of CE marking, and the inclusion of circular economy models such as take-back schemes. The paper also considers the implications for small and medium-sized enterprises, the interlinkage with other EU policies, and the challenges of harmonization in Montenegro. It is concluded that the success of the new regulation will depend not only on the legal framework but also on the readiness of industry, state institutions, and coordinated European policies to enable the achievement of the ambitious climate neutrality goals by 2050.

Keywords

Construction products; CPR 305/2011; CPR 2024/3110; European Union; sustainability; circular economy; Digital Product Passport; CE marking; climate neutrality; Montenegro.

1. Introduction and objectives

The regulatory framework for construction products in the European Union has evolved through three key phases. The first phase was marked by Directive 89/106/EEC on construction products (Construction Products Directive – CPD), adopted in 1988, which set the primary objective of removing technical barriers to trade in construction products. This directive was a typical internal market instrument of the EU, intended to ensure the free movement of goods through the harmonization of national technical requirements and standards. However, as a directive, it required national transposition into domestic legislation, which left significant room for divergent interpretations and inconsistent application in the process of creating a truly harmonized internal market.

The second phase began with the adoption of Regulation (EU) No. 305/2011 (Construction Products Regulation – CPR), which replaced the Directive precisely to avoid contradictions and inconsistent interpretations. Unlike a directive, a regulation has direct legal effect in all Member States, which allowed for a higher degree of legal certainty and consistency. The key innovations of CPR 305/2011 were the introduction of the Declaration of Performance (DoP) and clearly defined procedures for CE marking, thereby ensuring a uniform approach to construction products within the EU internal market.

The third and most recent phase of the development of the legislative framework is marked by the adoption of Regulation (EU) 2024/3110, which enters into force at the end of 2024. Unlike its predecessor, whose primary objective was market harmonization, the new regulation is developed within a broader political and climate context. Its adoption is directly linked to the European Union's strategic documents, most notably the European Green Deal (2019), which sets the target of climate neutrality by 2050, and the Fit for 55 package (2021), which commits to reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. In addition, the Circular Economy Action Plan (2020) identified the construction sector as a priority area, given its share in overall resource consumption and waste generation.

The new regulation, therefore, does not merely represent a continuation of internal market policy but rather a transformation of the legal instrument into a strategic tool of the EU's climate and sustainability policy.

2. General objectives

In comparison with the previous regulatory framework, the differences between Regulation (EU) 305/2011 and Regulation (EU) 2024/3110 are clearly reflected in their general objectives. While CPR 305/2011 was primarily aimed at harmonizing the construction products market, removing technical barriers, and ensuring the free movement of goods within the EU internal market, the new 2024 regulation significantly expands its normative horizon. In addition to the market dimension, it introduces an ecological-political framework, making the construction sector a key instrument in achieving the European Union's climate and sustainability objectives.

The first general objective of the new regulation is reflected in highlighting the economic and social importance of the construction sector. With a contribution of

approximately 10% to the European Union's gross domestic product and employment of more than 25 million people across different segments of the value chain, this sector represents one of the pillars of the European economy. The construction sector, including buildings and infrastructure, accounts for approximately 40% of the EU's final energy consumption and around 36% of greenhouse gas emissions related to energy use. This disproportion between economic significance and environmental burden places the sector at the center of European climate policy.

The second general objective of CPR 2024/3110 is the alignment of the legislative framework with the EU's climate commitments for 2030 and 2050. The European Union has committed to reducing greenhouse gas emissions by at least 55% by 2030 and to achieving climate neutrality by 2050. In this context, the new regulation introduces mandatory declaration of environmental performance of products, the establishment of CO_2 emission thresholds in certain industries (e.g., the cement industry), as well as the obligatory application of the Life Cycle Assessment (LCA) methodology. In this way, construction products are no longer viewed merely as market goods but also as elements of the broader climate and energy system.

The third significant objective relates to small and medium-sized enterprises (SMEs) producing construction materials. Considering that SMEs represent the majority of the production base in the EU construction industry, the new regulation provides mechanisms for mitigating administrative burdens. These include the digitalization of processes through Digital Product Passports (DPPs), the possibility of simplified procedures for micro-enterprises, and a centralized database that reduces the costs of repeated testing and certification. This aims to achieve a dual effect: on the one hand, fostering innovation and competitiveness among smaller producers, and on the other, ensuring their integration into the new system of sustainability and transparency without creating disproportionate administrative burdens.

Overall, the general objectives of Regulation 2024/3110 go beyond the framework of technical harmonization and represent a strategic orientation toward a sustainable, digital, and climate-neutral economy, in which the construction sector plays a prominent and responsible role.

3. Instruments (DoP, DPP, Thresholds, LCA)

One of the key differences between Regulation (EU) 305/2011 and Regulation (EU) 2024/3110 concerns the set of instruments used to ensure transparency, performance monitoring, and compliance of construction products with the EU legislative framework. While the earlier system focused predominantly on the Declaration of Performance (DoP) and CE marking, the new regulation expands the toolkit to include digital tools, environmental thresholds, and mandatory life-cycle assessment of products.

3.1. Declaration of Performance (DoP)

The DoP remains the basic mechanism by which the manufacturer assumes responsibility for the product. In practice, this means that the manufacturer must clearly state the performance of a construction product in relation to its essential characteristics defined by harmonized standards.

Example from practice: a concrete producer specifies in the DoP the load-bearing capacity of a concrete element, frost resistance, fire-resistance classification, and CO_2 emissions associated with its production. For steel, the DoP may include data on mechanical strength, ductility, and the level of recycled content.

With CPR 2024/3110, the Declaration of Performance (DoP) is merged with the Declaration of Conformity (DoC) into a single declaration with a harmonized structure and mandatory digital availability. This unified form must be available in a digital, machine-readable format, enabling direct linkage with European databases and digital tools such as BIM platforms, thereby achieving greater transparency and interoperability in the construction sector.

3.2. Digital Product Passports (DPPs)

The Digital Product Passport (DPP) represents the most significant innovation introduced by Regulation 2024/3110. Its function is to provide transparent, reliable, and permanently accessible product data throughout its entire life cycle.

- *Database structure:* The DPP will be integrated into a centralized EU database, maintained by the European Commission. This database will be available in a standardized IT format and linked to a unique identification code of each product.
- *Purpose and benefits:*
    - For designers – enables material selection based on proven environmental performance.
    - For contractors – provides reliable information on installation, maintenance, and product compatibility.
    - For investors and building owners – ensures transparency of life-cycle costs and facilitates compliance assessments with the EU taxonomy and green finance.

In this way, the DPP becomes a tool not only for monitoring and regulation but also for strategic planning and investment decisions.

3.3. Environmental Thresholds

The new regulation introduces mandatory environmental thresholds for certain categories of products, particularly cement and other materials with a high carbon footprint. For specific product groups with significant impacts, such as cement and steel, the Commission is empowered to set binding environmental thresholds (e.g., CO_2 emissions per ton of product) through delegated acts, which are expected to be gradually tightened in line with EU climate goals. Such thresholds represent a shift from voluntary declarations to binding regulatory limits, marking a significant regulatory innovation with direct implications for industrial competitiveness.

The thresholds are not limited to cement but also apply to steel, glass, thermal insulation materials, and other high-carbon products. Thus, thresholds become a mechanism for industry transformation.

3.4. Life Cycle Assessment (LCA)

In the new CPR, LCA is introduced as a mandatory methodological framework for assessing the environmental performance of products.

- *Methodologies*:
    - EN 15804 – European standard for preparing Environmental Product Declarations (EPD).
    - ISO 14040 and ISO 14044 – international standards for life cycle assessment.
- *Mandatory application:* Manufacturers will have to document the impacts of their products across all life-cycle phases: raw material extraction, production and transport, installation and use, and finally dismantling, recycling, or disposal.
- *European Commission support:* The Commission has announced software support for calculating LCA parameters, with pre-defined characterization factors, which should reduce the administrative burden for SMEs and ensure data comparability.

The instruments of the new regulation – DoP, DPP, thresholds, and LCA – constitute an integrated system through which construction products are placed at the service of sustainability, digitalization, and EU climate objectives. The DoP ensures manufacturer responsibility, the DPP provides transparency and access to data, thresholds guarantee minimum environmental standards, while the LCA ensures a holistic assessment of product impacts throughout their life cycle. Together, they form the basis for the transition from market harmonization to a climate-policy instrument, representing a fundamental change compared to CPR 305/2011.

4. Standards and CE Marking

4.1. The Role of Standards in CPR 305/2011

Within Regulation 305/2011, standardization was primarily entrusted to the European standardization bodies – CEN and CENELEC – whose task was to develop harmonized technical specifications. These specifications served as the basis for issuing the Declaration of Performance (DoP) and for affixing the CE marking to construction products. The role of the European Commission was indirect and related to granting mandates for the development of standards and publishing references in the Official Journal of the EU. This model was intended to remove technical barriers and enable the free movement of goods in the internal market.

4.2. Changes Introduced by CPR 2024/3110

With CPR 2024/3110, the role of standards and CE marking is significantly redefined. The European Commission now has the authority to more directly request, amend, or replace harmonized standards and, in cases of delay, to adopt Common Technical Specifications (CTS), which have the same legal effect. This ensures greater adaptability of the regulatory framework to technological innovations and sustainability needs.

Key innovations include:

- **Proactive role of the European Commission:** The Commission now has the ability to reject or amend standards that are not aligned with the objectives of climate neutrality, the circular economy, and environmental protection. In this way, standardization is placed directly in the service of achieving EU political objectives, and not only market harmonization.
- **Mandatory nature of standards:** Certain standards may be granted the status of mandatory harmonized standards, thereby avoiding divergent application in Member States and ensuring a uniform method of performance assessment.
- **Interoperability with digital systems:** Standards are now developed with the aim of being compatible with Building Information Modelling (BIM) platforms and other digital tools, enabling automated retrieval of data from DoP and DPP systems.

4.3. CE Marking – From Physical to Digital Mark

- Regulation 305/2011: The CE mark was a physical label that had to be affixed to the product or its packaging. Its meaning was twofold: it confirmed that the product had undergone a conformity assessment and that the manufacturer had issued a DoP in accordance with harmonized technical specifications.
- Regulation 2024/3110: The CE mark acquires a digital dimension. It is no longer just a visual symbol on the product, but is linked to the Digital Product Passport (DPP) and the centralized EU database. This means that the CE mark now provides direct access to all information on the product's performance, environmental characteristics, and compliance.

In addition, the new regulation explicitly prohibits the use of other markings that may cause confusion or diminish the value of the CE mark. In this way, CE becomes the sole recognized conformity marking in the EU for products covered by harmonized technical specifications.

Whereas in CPR 305/2011 standardization had a technical-market role, in CPR 2024/3110 it is transformed into a regulatory-political instrument. Standards are no longer neutral technical documents, but become direct carriers of the EU's climate, environmental, and digital objectives. The CE mark, on the other hand, moves from the domain of physical labeling into the sphere of digital identification and transparency, thereby gaining a new function – linking market harmonization with the goals of sustainable development.

5. Circular Economy and Secondary Products

5.1. Limitations of the Old Framework (CPR 305/2011)

Regulation 305/2011 created a framework for take-back schemes, allowing manufacturers or consortia to organize the collection, recycling, and re-use of construction products after the end of their service life. This approach resembles existing practices in sectors such as electronics and packaging, but its application in construction is more complex due to the scale, weight, and heterogeneity of building materials. Nevertheless, pilot schemes in the steel, timber, and glass sectors demonstrate the feasibility of closed-loop systems, where materials are reintroduced into the production cycle with a reduced environmental footprint.

5.2. Limitations of the Old Framework (CPR 305/2011)

In contrast, Regulation 2024/3110 explicitly integrates the principles of the circular economy into the regulatory framework. It recognizes that the construction sector generates around 35% of total waste in the EU, and that the existing linear model of production and consumption is unsustainable. For this reason, it introduces a wide range of instruments aimed at extending product lifespans, re-use, and material recycling.

5.3. The "Take-back Scheme" and Producer Obligations

One of the central innovations is the so-called take-back scheme, which requires manufacturers to take back into ownership products that are unused, surplus on construction sites, or unsold.

- This obligation aims to reduce waste and reintegrate materials into the production cycle.
- For example, a glass panel manufacturer is obliged to take back unused panels, which can then be recycled or re-marketed.
- A similar principle applies to the steel and timber industries, where secondary material streams are already well developed.

5.4. The "Take-back Scheme" and Producer Obligations

- Steel: As a material with a high recycling rate, steel is a paradigm of the circular economy. The new regulation encourages the use of steel with a high percentage of recycled content and its re-use after building demolition.

- Timber: In the context of the biological cycle, the regulation emphasizes the importance of quality control of secondary timber to ensure safe use.
- Glass: Take-back and recycling of glass present particular challenges due to logistical costs and the need for sorting, but the potential benefits in reducing emissions and raw material consumption are significant.

5.5. Barriers and Implementation Challenges

Although the concept of the circular economy in construction opens up major opportunities, the new regulation also recognizes a series of practical obstacles:

- Logistics and costs: Transporting secondary products can be more expensive than using new raw materials.
- Quality standardization: Re-use of materials requires clear standards to ensure the safety and functionality of construction products.
- Market incentives: In the absence of financial instruments (e.g., tax incentives), manufacturers may resist additional obligations related to take-back and recycling.

CPR 2024/3110 brings the circular economy into the very core of construction products regulation. The take-back scheme model, the obligation to establish secondary material flows, and the strengthening of producer responsibility represent a shift from a linear market logic to a sustainable, circular model. In this way, the construction sector, which traditionally generates enormous material waste, is transformed into a potential driver of recycling and resource-efficient practices, fully aligned with the objectives of the European Green Deal and the Circular Economy Action Plan.

6. The Role of Manufacturers and Market Implications

6.1. Manufacturer Obligations under CPR 305/2011

Within Regulation 305/2011, manufacturers of construction products had the basic obligation to:

- prepare the Declaration of Performance (DoP),
- ensure product compliance with harmonized technical specifications,
- ensure, where applicable, the availability of spare parts, maintenance information, and repair options,
- affix the CE marking to the product, thereby assuming responsibility for compliance with declared performance.

This framework was largely limited to technical and market requirements, while issues of sustainability, digital transparency, and long-term manufacturer responsibility were secondary.

6.2. Expanded obligations under CPR 2024/3110

The new Regulation significantly expands manufacturer obligations by introducing the concept of extended responsibility. It regards the manufacturer not only as an economic operator placing a product on the market but also as a custodian of information, sustainability, and the post-market life cycle of the product.

Key obligations include:

- Digital databases: manufacturers are required to enter and maintain up-to-date data within Digital Product Passports (DPP), including technical characteristics, environmental performance, and instructions for re-use or recycling.
- Service and technical information: manufacturers must ensure the availability of documentation enabling maintenance, repair, and refurbishment of products throughout their life cycle.
- Spare parts: manufacturers must provide the availability of spare parts and components for a period of at least 10 years, thereby extending product lifespans and reducing the need for complete replacement.
- Liability for inaccurate data: legal responsibility is introduced for inaccurate or misleading declarations of performance and compliance, including potential sanctions at the EU level.

6.3. Market implications

The expanded manufacturer obligations have multiple consequences for the construction products market:

- Increased production costs: manufacturers will need to invest in digital systems, software for LCA analyses, and logistics for product take-back. This may increase product prices, especially for materials with a high carbon footprint (e.g., cement, steel).
- Strengthened competitiveness: data transparency and digital availability of information create a market where the most sustainable products will have an advantage. Competition thus shifts from “lowest price” to “best balance of sustainability and quality.”
- Innovation incentives: obligations to reduce emissions and maintain secondary material flows stimulate research and development of new technologies (e.g., eco-cement, timber composite structures, low-emission steel).

- Impact on small and medium-sized enterprises (SMEs): while large manufacturers can more easily implement the new obligations, SMEs will face additional costs. The Regulation provides certain relief measures (e.g., simplified procedures for micro-enterprises), but the challenge remains how to ensure their market sustainability.

In the new regulatory framework, the role of manufacturers shifts from the passive function of "declaring products" to the active function of managing the entire product life cycle. The market implications of this approach are reflected in higher costs but also in the creation of new market niches and innovation potential. In this way, CPR 2024/3110 transforms manufacturers from ordinary market actors into key partners in achieving the objectives of sustainability, digitalization, and the circular economy.

6.4. Interconnections with other EU Policies

One of the key features of Regulation (EU) 2024/3110 is its interoperability with the broader legislative and strategic framework of the European Union. Unlike CPR 305/2011, whose primary goal was to remove technical barriers and ensure a unified market, the new regulation positions construction products at the center of European policies on sustainability, digitalization, and climate neutrality.

6.5. Link with the Ecodesign Regulation 2024/1781

Regulation 2024/3110 directly builds upon the Ecodesign for Sustainable Products Regulation (ESPR) of 2024. While Ecodesign represents a horizontal framework applying to a wide range of products, CPR 2024/3110 serves as a specialized sectoral instrument for construction products. In practice, this means that:

- for energy-related products (e.g., pumps, ventilation systems, heating units), the provisions of the Ecodesign Regulation will take precedence, while CPR will act complementarily;
- in cases of contradiction, CPR 2024/3110 prevails as lex specialis for construction materials.

6.6. Link with the Ecodesign Regulation 2024/1781

The construction sector has been recognized as one of the key sectors in the EU taxonomy, the instrument defining criteria for sustainable investments. By introducing Digital Product Passports (DPP) and mandatory declaration of environmental performance, CPR 2024/3110 creates the preconditions for investors and financial institutions to easily assess whether a given product or project meets sustainability criteria. This ensures that capital markets are directed toward environmentally sound construction solutions, while at the same time reducing the risk of so-called "greenwashing," i.e., false or misleading claims about product sustainability.

6.7. Zero Pollution Action Plan

The new regulation is also linked with the Zero Pollution Action Plan (2021), which aims to reduce air, water, and soil pollution. CPR 2024/3110 contributes to these objectives through:

- mandatory application of the LCA methodology for measuring emissions and environmental impacts of construction products,
- establishing thresholds for CO_2 and other pollutant emissions in production,
- promoting recycling and waste reduction through circular models.

6.8. Renovation and initiative

In 2020, the European Commission launched the Renovation Wave, aiming to renovate 35 million buildings in the EU by 2030 in order to reduce energy consumption and emissions. CPR 2024/3110 provides the regulatory framework for implementing this initiative by:

- obliging manufacturers to declare the environmental performance of products, thereby facilitating material selection for energy-efficient renovations,
- promoting the use of recycled and low-carbon materials in the renewal of the building stock,
- ensuring digital accessibility of data (DoP and DPP), which allows for faster and more accurate preparation of renovation projects.

CPR 2024/3110 does not function in isolation but is structurally connected with key European policies in sustainable development, environmental protection, and energy. Its alignment with the Ecodesign Regulation, EU Taxonomy, Zero Pollution Action Plan, and Renovation Wave initiative demonstrates the EU's intent to transform the construction sector into a strategic driver of the climate transition. In this way, the new regulation goes beyond the boundaries of sector-specific legislation and becomes part of the broader architecture of the EU's green and digital legislation.

7. National Framework (Montenegro)

7.1. Exhisting legislation

Montenegro is in the process of accession to the European Union and its legislation is already largely aligned with the EU acquis. The Law on Construction Products ("Official Gazette of Montenegro", No. 018/14 of 11.04.2014, 051/17 of 03.08.2017) transposed the provisions of Regulation (EU) 305/2011, thereby establishing the basis for harmonization of the national market with the rules of the EU internal market. The law defines the obligations of manufacturers, distributors, and importers, the procedures for conformity assessment, as well as the conditions for affixing the CE marking to construction products.

In practice, CE marking is already applied to a wide range of construction products on the Montenegrin market that are imported from the EU. Local manufacturers are certified and production in factories is monitored.

However, local manufacturers, especially small and medium-sized enterprises (SMEs), still face challenges in meeting all technical and administrative requirements.

7.2. Challenges of harmonization with CPR 2024/3110

The new Regulation 2024/3110 introduces qualitatively different requirements compared to the previous one, which opens a number of challenges for the Montenegrin regulatory framework:

- Data digitalization: the introduction of Digital Product Passports (DPP) requires the establishment of compatible national IT systems and the training of administrative capacities for data management.
- Environmental thresholds: the setting of mandatory limit values for CO_2 emissions and other environmental parameters requires the development of local infrastructure for laboratory testing and verification, thereby creating the need for investments in national institutes and accredited bodies.
- Circular economy: the implementation of the "take-back scheme" principle presupposes a logistical system for take-back and recycling, which in Montenegro is still insufficiently developed. This particularly affects manufacturers with limited market capacity.
- SME capacity: small and medium-sized construction material producers face the risk of increased costs due to the obligation to maintain digital records, carry out LCA analyses, and sustain secondary product flows. Without systematic state support, there is a risk that part of the domestic producers will lose competitiveness.

7.3. Obligations of manufacturers and importers in the region

In a broader regional context, Montenegro will need to align its practices with Western Balkan countries that are also in the process of European integration. This includes:

- the obligation for importers of construction products from third countries to provide DPP and CE marking before placing products on the market,
- the harmonization of national accreditation and notification bodies with European networks,
- coordination with neighboring countries in developing infrastructure for recycling and re-use of construction materials.

For Montenegro, alignment with CPR 2024/3110 represents a significant step forward in the process of European integration. While the transposition of CPR 305/2011 ensured formal harmonization with EU market rules, the new regulation requires a substantive transformation of the regulatory and economic system – from digitalization and strengthening of laboratory capacities to building the logistics of the circular economy. In this sense, the successful implementation of CPR 2024/3110 will be a test of Montenegro's institutional readiness to integrate sustainable, digital, and innovative policies into the construction sector.

The implications of the Construction Products Regulation extend beyond the EU and are highly relevant for candidate countries such as Montenegro. As part of the accession process, Montenegro is required to progressively harmonize its legislation with the EU acquis, including the regulatory framework for construction products.

8. Conclusion

The comparative analysis of Regulation (EU) 305/2011 and Regulation (EU) 2024/3110 shows that the European Union has made a significant step forward – from technical market harmonization to a strategic regulatory framework oriented toward sustainability, digitalization, and the circular economy. Nevertheless, although the new regulation represents a normatively ambitious step, the question remains how realistically these goals can be achieved in practice.

First, industrial resistance and implementation costs may significantly slow down or limit the effectiveness of the regulation. High-emission sectors, such as the cement and steel industries, face major investments needed to meet the new CO_2 emission thresholds. In this context, there is a risk that some producers may resort to "greenwashing" or that a dual market may emerge in which large players profit from innovation while small and medium-sized enterprises remain burdened with costs.

Second, digitalization through DPPs and integration with BIM platforms carries the potential for transparency and efficiency but also raises a series of technical and legal issues: interoperability of IT systems across all Member States, the capacity of small producers to provide digital data, as well as the risk of cybersecurity threats.

Third, the connection of the CPR with broader EU policies (Ecodesign, EU Taxonomy, Renovation Wave) ensures coherence of the legislative framework but may lead to complexity and administrative burdens for businesses. This raises the question of whether the regulation will accelerate the green transition or, on the contrary, slow down innovation in certain segments due to bureaucratic requirements.

Finally, for candidate countries such as Montenegro, the new regulation does not only mean adopting the EU acquis but also entails a profound transformation of the system of standardization, accreditation, and market surveillance. In practice, this requires significant institutional and financial capacities, which are currently not fully developed.

All of this indicates that CPR 2024/3110 represents an important strategic instrument, but its success will not depend solely on the normative text. It will depend on the readiness of industry, the support of state institutions, and coordinated European policies that will make it possible to translate ambitious climate and sustainability objectives into measurable and achievable results

Acknowledgment

This article is based upon work from COST Action CA21103—Implementation of Circular Economy in the Built Environment (CircularB), supported by COST (European operation in Science and Technology).

Literature

[1] European Parliament and Council, Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC, Official Journal of the European Union, L 88, 2011.

[2] European Parliament and Council, Regulation (EU) 2024/3110 of the European Parliament and of the Council of 13 February 2024 on construction products and amending Regulation (EU) 2019/1020, Official Journal of the European Union, L 2024/3110, 2024.

[3] Council of the European Communities, Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products, Official Journal of the European Communities, L 40, 1989.

[4] European Commission, The European Green Deal, COM(2019) 640 final, Brussels, 2019.

[5] European Commission, "Fit for 55": delivering the EU's 2030 Climate Target on the way to climate neutrality, COM(2021) 550 final, Brussels, 2021.

[6] European Parliament and Council, Regulation (EU) 2024/1781 on Ecodesign for Sustainable Products, Official Journal of the European Union, L 2024/1781, 2024.

[7] European Parliament and Council, Regulation (EU) 2020/852 on the establishment of a framework to facilitate sustainable investment (EU Taxonomy), Official Journal of the European Union, L 198, 2020.

[8] European Commission, Zero Pollution Action Plan: Towards zero pollution for air, water and soil, COM(2021) 400 final, Brussels, 2021.

[9] European Commission, A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives, COM(2020) 662 final, Brussels, 2020.

[10] European Committee for Standardization (CEN), EN 15804:2012+A2:2019 – Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products, Brussels, 2019.

[11] International Organization for Standardization (ISO), ISO 14040:2006 – Environmental management – Life cycle assessment – Principles and framework, Geneva, 2006.

[12] International Organization for Standardization (ISO), ISO 14044:2006 – Environmental management – Life cycle assessment – Requirements and guidelines, Geneva, 2006.

[13] F. Pacheco-Torgal, Eco-efficient Construction and Building Materials. Cambridge, UK: Woodhead Publishing, 2014.

[14] United Nations Environment Programme (UNEP), Global Status Report for Buildings and Construction 2022. Nairobi, 2022.

[15] McKinsey & Company, Net-zero buildings: Decarbonizing the construction sector. New York, 2023.

[16] CEN/CENELEC, Standards and sustainability in construction sector – Policy Paper. Brussels, 2022.

Adaptive governance for coastal thresholds: Negotiating sustainability in times of climate crisis

Vittoria Ridolfi[1]

1 PhD student, IUAV University of Venice
vridolfi@iuav.it

Abstract

Coastal areas are emblematic territories of today's climate and planning challenges. They are increasingly affected by environmental pressures such as sea level rise, coastal erosion, saline intrusion, and extreme weather events, while simultaneously facing intense anthropogenic pressure from urbanisation, infrastructure, tourism, and economic development. This overlapping of ecological fragility, strategic functions, and conflicting land uses turns coastal zones into highly contested spaces, where institutional fragmentation and competing interests hinder long-term planning and effective climate adaptation.

This paper draws on an ongoing doctoral research project that reinterprets the coast not as a linear boundary between land and sea, but as a threshold: a dynamic, porous, and hybrid space that challenges conventional planning categories. The research proposes three interrelated conceptual lenses—coast as a space of conflict, of threshold, and of negotiation—through which to investigate the spatial, political, and ecological tensions shaping coastal territories.

Focusing on the Italian context, the study critically explores the limitations of current governance frameworks, highlighting the lack of coordination between spatial planning and climate policies, the dominance of sectoral approaches, and the absence of adaptive tools capable of dealing with uncertainty and long-term transformation. The paper introduces a framework for adaptive coastal governance grounded in the concepts of trading zones and boundary objects, aiming to foster negotiation among diverse actors, values, and institutional languages.

In this perspective, sustainability is not reduced to legal ownership but is redefined as the collective ability to ensure accessibility, ecological care, and shared responsibility for coastal futures. By bridging environmental justice, climate adaptation, and participatory governance, the paper outlines new conceptual and operational directions for embedding sustainability into coastal planning agendas.

Keywords

Coastal governance, climate adaptation, trading coastal zone, sustainability, mediterranean areas, planning climate change, environmental justice

1. Introduction: A preliminary exploration of coastal dynamics

In recent years, the coastal zone has gained growing attention across multiple scientific disciplines and within contemporary public debate, increasingly recognized as a space of extreme fragility, conflict, and global relevance. Due to its nature as a boundary between land and sea, the coast is particularly subject to multiple transformations and intensifying pressures, representing a delicate and highly interconnected ecological, socio-economic, and geomorphological context [1], [2]. This growing complexity calls for a renewed effort to investigate the conceptual foundations of the coastal domain, its modes of governance, and the future scenarios it may face.

To initiate an exploration of the coastal question, it is necessary to examine the factors that historically have made the coast a key area of concern. First, from an ecological standpoint, coastal areas represent a critical transition zone between two environmental domains—land and sea. These liminal geographies are inherently dynamic and morphologically diverse, hosting rich biodiversity and complex interactions between abiotic and biotic components. As such, coastal ecosystems provide essential ecosystem services and are central to environmental equilibrium. For instance, in Italy there are currently 29 Marine Protected Areas and 2 submerged parks, safeguarding around 228,000 hectares of marine territory and approximately 700 kilometres of coastline [3]. These protected areas not only conserve habitats and endangered species, but also support scientific research, environmental education, and sustainable practices such as eco-tourism and responsible fishing.

However, the ecological value of coastal zones is coupled with significant fragility due to the cumulative stressors they face—particularly anthropogenic and socio-economic pressures, as well as increasing exposure to extreme environmental conditions [4], [5]. Given their position at the intersection of land and sea, coastal territories are affected by a double exposure to human activities and environmental change, operating simultaneously across terrestrial and marine domains [4]. According to a 2022 ISTAT report focused on coastal areas, approximately one-third of Europe's population lives within 50 km of the coastline, and over 200 million citizens reside in coastal or insular regions. This trend is also reflected in the Italian context, where a significant share of the population lives in coastal municipalities.

34.4% of Italy's population lives in municipalities located directly on the coast or where at least 50% of the municipal territory lies within 10 kilometres of the sea. These municipalities account for only 18.8% of the national land area, highlighting an intense demographic concentration in relatively small zones. This concentration is further underscored by population density data: coastal municipalities average 360 inhabitants per square kilometre, compared to the national average of 198. As of January 1, 2019, Italy counted 1,166 coastal municipalities, representing 14.7% of the national total and distributed across 15 regions with a maritime coastline.

Such data clearly illustrate the historical and ongoing relationship between urbanization and the coastal system. Coastal areas have long represented natural settlement sites due to their accessibility to water resources and fertile lands. From ancient Greece to the present day, the coast has been seen as a socio-economically strategic territory, shaped by the dual presence of residents and seaborne arrivals. This idea of coastal connectedness and maritime interaction, particularly in the Mediterranean context,

has been emphasized by Bultrighini [6], underlining the embeddedness of coastal regions in regional and global circulation. In addition to these long-standing dynamics, contemporary coastal areas are increasingly exposed to the cross-cutting impacts of climate change. Key marine hazards include sea-level rise, coastal erosion, storm surges, and saltwater intrusion. From the land side, hazards such as river flooding and flash floods further amplify coastal vulnerability, highlighting the often-neglected connection between coastal and inland systems. The rising frequency and intensity of climate-related extreme events, alongside the gradual rise in sea levels, have led to severe environmental and socio-economic consequences, disproportionately affecting coastal communities and infrastructure.

Among these emerging risks, coastal erosion has become particularly acute, resulting in the gradual and often irreversible loss of land. According to the Osservatorio CittàClima, 41.1% of 1,732 recorded climate events in Italy occurred in coastal municipalities, with a strong spatial concentration along the coastline. Sea-level rise, driven by glacial melting and oceanic thermal expansion, further exacerbates this vulnerability, threatening the structural stability of coastal ecosystems, homes, and economic activities. According to a recent study by ENEA, by 2100 at least 40 areas along the Italian coast may be at high risk of permanent inundation, affecting a total area of 5,686.4 km^2 and over 385 km of shoreline [7].

These data underscore the urgency of rethinking how we govern and manage coastal areas, particularly considering the growing centrality of climate as a variable of spatial transformation. If the goal is to advance more effective and equitable approaches to coastal management, then it is imperative to reflect critically on how the very concept of "coast" is defined and delineated. Only by examining the origins of coastal vulnerability and their links to disciplinary framings can we develop governance tools capable of responding to the real, hybrid, and fluid nature of these territories.

2. Definitions and disciplinary approaches to a moving system

The definition and delimitation of the coastal zone represent a complex challenge that has long engaged the international scientific community. Various disciplines and geographical contexts have proposed often diverging definitions, reflecting the hybrid and multidimensional nature of these transitional spaces between land and sea.

At the international level, the US Commission on Marine Science, Engineering and Resources (1969) defined the coastal zone as "the part of land influenced by proximity to the sea and the part of the sea affected by proximity to land, up to the point where human activities conducted on land have a measurable impact on the chemistry and ecology of marine waters." [8] Likewise, the US Coastal Zone Management Act (16 U.S.C. 1453. Definitions, 1972) described the coastal zone as "comprised of coastal waters and the adjacent shorelands, including transitional and intertidal areas, salt marshes, wetlands, and beaches" [9]. Similarly, UNEP (2006) offered a general and variable definition, based on the influence of the sea on land: "The coastal zone is a narrow strip of land dominated by the influence of tides and marine aerosols; the marine area is defined by the depth of light penetration" [10]. In the European context, the European Environment Agency

(EEA, 2006) proposed a definition focusing on the terrestrial portion of the coastal zone: "the environment resulting from the coexistence of two margins, namely the terrestrial edge of the continent and the coastal waters as the littoral section of shelf seas. Its terrestrial portion is defined as the area extending 10 km inland from the coastline" [11]. Although this definition omits the marine component, it has the advantage of being consistent and measurable. EUROSTAT, in turn, defines coastal regions as those "with a border on the sea and with at least half of their population living within 50 km of the coastline" [12].

At the European and Italian levels, the ICZM Protocol (2008) defines the coastal zone as "the geomorphological area located on both sides of the shoreline, where the interaction between marine and terrestrial components is expressed through complex ecological systems and resources composed of biotic and abiotic elements coexisting and interacting with human communities and their socio-economic activities" [13]. Furthermore, ISPRA [14] emphasizes that "the coast is the physical location where land and sea meet, giving rise to a transitional area between continental and marine environments characterized by extremely complex phenomena."

These definitions highlight the hybrid and multidimensional character of the coastal zone as a space of interaction between terrestrial and marine processes, between human activities and natural systems. They also underscore the difficulties in clearly framing and governing such a space. The variety of definitions leads to diverging spatial delimitations, drawing overlapping geographies that often fail to coincide and sometimes describe entirely different spaces. As noted by Guadagno and Grasso [15], the fluid nature of coastlines presents significant governance challenges. The management of these areas goes beyond administrative boundaries, creating a substantial gap between scientific analyses and current policy tools [16]. It is precisely due to this "mobile" essence that coastal territories emerge as complex and difficult to govern, particularly considering the intense anthropogenic pressures they face [17].

Moreover, climate impacts themselves do not respect administrative borders, making it even more urgent to investigate climate vulnerability in coastal zones. This analysis must precede—and challenge—the artificial need to contain such spaces within fixed boundaries. Understanding how climate change affects these fluid systems is therefore a priority, requiring the development of new governance tools that go beyond static territorial classifications.

3. Governance tools for coastal management: From regulation to adaptation

Considering the increasing pressures and vulnerabilities affecting coastal zones, a central challenge today lies in developing governance tools that can embrace the complexity of these territories. Coastal zones are not only ecologically and geomorphologically dynamic—they are also politically fragmented and institutionally contested. Their governance requires flexible, contextsensitive instruments that can respond to environmental uncertainties, negotiate competing land-sea uses, and promote long-term sustainability. Over the past decades, numerous regulatory frameworks and planning instruments have emerged across different geographical contexts. Many of these tools have focused on limiting urban sprawl and protecting fragile ecosystems. For instance,

the Loi Littoral (1986) in France introduced strict land-use restrictions along the coastal strip, aiming to contain uncontrolled development and preserve natural areas. Supported by the Conservatoire du Littoral, this legal framework has contributed to the long-term preservation of vulnerable coastal lands through direct public acquisition and management [18]. Similarly, Spain's Ley de Costas (1988) established a protection belt along the coastline, limiting construction and promoting the recovery of degraded areas [19].

While these regulatory approaches have had significant impacts, their effectiveness is often constrained by weak enforcement, fragmented institutional mandates, and a lack of continuous monitoring. As emphasized by Alterman and Pellach [20], legal frameworks alone are not sufficient to address the socio-ecological complexities of coastal governance. A shift is needed—from static regulation toward more adaptive and participatory governance models that integrate local knowledge, scientific expertise, and cross-scalar coordination.

In this context, Integrated Coastal Zone Management (ICZM) has emerged as a globally recognized approach, promoting holistic, multi-level, and intersectoral strategies. ICZM frameworks have been successfully implemented in countries such as the Netherlands, Australia, and Canada— each adapting the approach to its own institutional and geographic specificities. The Delta Programme in the Netherlands, for example, exemplifies how adaptation to sea-level rise can be embedded into a comprehensive and participatory planning process that combines infrastructure, ecosystem restoration, and spatial foresight [21]. However, even ICZM frameworks have shown limitations when confronted with deeply rooted governance fragmentation, conflicting land uses, and limited financial or administrative capacities—especially in Southern European contexts such as Italy. Here, despite the formal ratification of the ICZM Protocol of the Barcelona Convention, coastal planning remains largely sectoral, reactive, and unevenly applied across regions [13], [22]. This gap between ambitious policy frameworks and practical implementation reflects a broader governance dilemma: how to translate international commitments and national legislation into locally rooted, operational tools that reflect the lived realities and contested geographies of the coast. Addressing this challenge requires not only technical innovation but also a rethinking of institutional architectures, power relations, and the role of communities in shaping coastal futures.

In recent years, community-based and participatory approaches have gained momentum as a response to these limitations. Recognising the situated knowledge and adaptive capacity of coastal communities, these approaches emphasize local agency, social equity, and collaborative learning. In British Columbia, Canada, coastal governance frameworks have explicitly incorporated Indigenous knowledge systems, enabling more inclusive and resilient planning processes [23]. Similarly, bottom-up initiatives across the Mediterranean—such as local pacts, river basin contracts, and landscape charters—illustrate the potential of negotiated instruments to foster place-based governance and epistemic pluralism in highly diverse and politically sensitive coastal areas. As climate change accelerates and inequalities deepen, coastal governance can no longer rely solely on top-down regulation or technocratic planning [24]. What is needed is a new generation of governance tools—hybrid, experimental, and transdisciplinary—that acknowledge the coastal zone as a public, dynamic, and negotiated space. This shift implies moving from control to co-evolution, from sectoral policies to integrated visions, and from normative certainty to procedural flexibility.

4. Theoretical framing: conflict, threshold, negotiation

Coastal areas, as outlined above, embody a condition of intrinsic complexity and instability, shaped by the interaction of ecological processes, human activities, and climate dynamics. In this context, rethinking coastal governance requires not only a reform of planning instruments, but also a conceptual shift in how the coast is understood and governed. This paper adopts a theoretical framework based on three interrelated assumptions: the coast as a space of conflict, of threshold, and of negotiation. These assumptions provide a multi-dimensional lens to read coastal transformation and explore the limitations—and potential—of existing governance systems.

4.1. The coast as a space of conflict

Coastal zones are marked by multi-layered and persistent tensions among actors, interests, and spatial functions. As Cicin-Sain and Knecht [2] note, the coast is simultaneously an ecological system, an economic resource, and a socio-political frontier. In practice, this means that coastal spaces often host incompatible land uses and competing claims: environmental conservation, residential and touristic development, maritime industries, infrastructure, and cultural heritage protection. These overlapping interests result in territorial frictions that manifest both at the local scale—through land-use disputes and access conflicts—and at the institutional level, through the fragmentation of competences and policy goals [15]. In many cases, the physical transformation of the coastline is directly tied to underlying governance conflicts: regulatory gaps, overlapping jurisdictions, and the lack of coordination between spatial and environmental planning exacerbate tensions rather than resolve them [16]. Furthermore, the progressive privatisation and commodification of the littoral zone restrict public access and intensify conflicts between public and private interests. These dynamics contribute to the erosion of coastal publicness, not only in terms of legal ownership, but also as a broader condition of collective accessibility, responsibility, and care for the coastal commons [25], [26].

Framing the coast as a space of conflict does not imply a negative condition to be eradicated. Rather, it reveals the inherently political nature of coastal governance, which cannot be fully captured by technical or normative instruments alone. Recognising this conflictual is essential for the development of tools that can operate within disagreement, enabling cohabitation and negotiation rather than seeking definitive consensus.

4.2. The coast as a space of threshold

Beyond its contested character, the coast is a liminal geography—a threshold between land and sea, subject to constant reconfiguration by both natural forces and human interventions. This transitional condition is not merely spatial, but also temporal, ecological, and institutional. The coastline shifts over time due to erosion, sedimentation, and sea-level rise, challenging the stability of planning categories and property regimes. At the same time, the coast functions as a regulatory boundary, where terrestrial and

marine jurisdictions often clash or fail to align [17], [14]. Conceptually, seeing the coast as a threshold invites a departure from static and zoned approaches to spatial planning. It suggests instead a reading of the coast as a dynamic interface—a zone of gradients, flows, and mutual influences between systems that are traditionally managed in isolation [1]. This relational view resonates with recent ecological and geographical scholarship that conceives thresholds as spaces of potentiality and transformation, rather than mere margins or limits [27], [28].

From a governance standpoint, acknowledging the threshold nature of coastal areas calls for adaptive, temporally aware instruments. Static regulations are ill-suited to environments that are in continuous flux. Instead, planning needs to embrace uncertainty, iteration, and processualism, allowing the governance of the coast to evolve in response to changing conditions. The coast, in this sense, becomes a laboratory of transitions, where new forms of co-evolution between human systems and environmental dynamics must be tested.

4.3. The coast as a space of negotiation

Building upon the notions of conflict and threshold, this research ultimately frames the coast as a space of negotiation. If coastal zones are both contested and in flux, then governance must be re-imagined not as a top-down mechanism of control, but as a situated practice of mediation among actors, values, and temporalities. In this regard, the concepts of trading zones [29] and boundary objects [30] provide valuable insights. Trading zones are conceptualised as spaces where actors with diverging goals and epistemologies can still collaborate, not through full consensus but through the construction of intermediate languages and partial agreements. As applied to coastal governance, this suggests a shift from the ideal of integrated, unified planning towards a more plural, pragmatic, and iterative approach, in which differences are acknowledged rather than erased [26]. Negotiation becomes a tool not to dissolve conflict, but to transform it into a productive force, enabling shared experimentation and situated solutions.

In parallel, boundary objects are entities—documents, models, or practices—that hold interpretive flexibility, meaning different stakeholders can engage with them in different ways, while still coordinating their actions. In the coastal realm, such objects might include participatory maps, adaptive zoning instruments, or multi-actor charters. Their strength lies in their capacity to mediate across scales and sectors, allowing actors to act collectively without requiring a unified worldview.

Together, these concepts lay the foundation for a new grammar of coastal governance—one that recognises the coast as a public, negotiated, and adaptive space, and seeks to develop tools that are structurally open, epistemically inclusive, and territorially responsive. Rather than offering definitive solutions, this framework aims to foster institutional creativity and cultivate a planning culture attuned to the complexity of coastal realities.

5. Towards a negotiated governance: Trading zones and boundary objects as conceptual lenses

Considering the increasing pressures affecting coastal areas, the concepts of trading zones and boundary objects offer valuable analytical tools for rethinking coastal governance in an era of profound climatic, ecological, and socio-political transformation. As territories marked by dynamic processes and overlapping jurisdictions, coastal zones cannot be effectively governed through static, sectoral, or overly technocratic approaches. Rather, they call for a governance model that acknowledges the coast as a negotiated space—a site of continuous interaction between heterogeneous actors, perspectives, and forms of knowledge. Originally proposed by Galison in the context of scientific collaboration, the notion of a trading zone has been fruitfully adapted to the field of urban and territorial planning by Balducci, who interprets it as a space of interaction among actors with divergent goals, competencies, and languages [29], [26], [31]. Within this space, collaboration does not rely on full consensus or shared values, but rather on the construction of a common language—a hybrid or "pidgin"—that enables the partial alignment of interests and the coproduction of situated responses. Applied to coastal governance, this concept illuminates the possibility of fostering inclusive, flexible, and plural negotiation arenas, where adaptation strategies are not imposed from above but emerge through iterative dialogue.

Complementing this, the concept of boundary objects [30] highlights the importance of shared tools or frameworks that—while interpreted differently by distinct social groups—are sufficiently robust to ensure coherence, coordination, and operational functionality. In the coastal domain, potential boundary objects might include spatial plans, climate adaptation frameworks, zoning tools, or even the concept of publicness itself. When appropriately designed, these tools can serve as interfaces between environmental strategies, collective rights, and spatial planning instruments, enabling the translation of abstract objectives into context-sensitive actions.

This dual conceptual framework—trading zones as spaces of negotiation and boundary objects as mediating instruments—allows us to reposition the coastal zone not merely as a site of vulnerability, but as a laboratory for democratic experimentation and adaptive governance. It challenges the traditional dichotomies between land and sea, public and private, conservation and development, suggesting instead a paradigm of co-evolution and negotiated sustainability. Crucially, this perspective opens the way for a reframing of climate adaptation itself. Rather than being understood as a technical add-on or an exogenous constraint, adaptation becomes a political and procedural lever —a means to question existing power dynamics and regulatory arrangements, while co-constructing plural visions for the future of coastal territories [32]. If interpreted as a boundary object, adaptation can activate cross-sectoral coalitions and participatory processes, reinforcing the publicness of the coast as both a shared resource and a collective responsibility.

In conclusion, the application of these theoretical lenses invites a shift in the way we conceptualize and govern the coastal space: from fixed territorial entities to relational and evolving interfaces, from rigid management regimes to processual and inclusive models. This research does not claim to offer definitive solutions, but rather to open a reflective space—a trading zone in itself— where new alliances, tools, and imaginaries can emerge to shape more just and resilient coastal futures in the face of climate crisis.

Literature

[1]	Vallega A.: Geografie del mare, Carocci, Roma, 1999, 197p.
[2]	Cicin-Sain B., Knecht R.W.: Integrated Coastal and Ocean Management: Concepts and Practices, Island Press, Washington DC, 2013, 543p.
[3]	Ministero dell'Ambiente e della Sicurezza Energetica – MASE: "Aree Marine Protette italiane", Ministero dell'Ambiente, Roma, 2021.
[4]	Halpern B.S., Walbridge S., Selkoe K.A., et al.: "A global map of human impact on marine ecosystems", Science, 319(5865), 2008, 948–952.
[5]	Crain C.M., Halpern B.S., Beck M.W., Kappel C.V.: "Understanding and managing human threats to the coastal marine environment", Annals of the New York Academy of Sciences, 1162, 2009, 39–62.
[6]	Bultrighini I.: Storie di mare. Mediterraneo e navigazione nel mondo antico, Edizioni ETS, Pisa, 2013, 215p.
[7]	ENEA: "Le aree costiere italiane a rischio inondazione permanente al 2100", in Clima e territorio, ENEA Report, Roma, 2023.
[8]	U.S. Commission on Marine Science, Engineering and Resources: "Our Nation and the Sea", Washington DC, 1969, 305p.
[9]	U.S. Congress: Coastal Zone Management Act, 16 U.S.C. §1453, 1972.
[10]	UNEP: "Marine and coastal ecosystems and human wellbeing: A synthesis report", Nairobi, 2006.
[11]	European Environment Agency: "The changing faces of Europe's coastal areas", EEA Report No 6/2006, Copenhagen, 2006, 107p.
[12]	EUROSTAT: "Coastal regions", Statistics Explained, Eurostat, 2023.
[13]	UNEP/MAP: Protocol on Integrated Coastal Zone Management in the Mediterranean, Barcelona Convention, Madrid, 2008.
[14]	Bovina G., Sinapi L.: "La fascia costiera: definizioni, dati e criticità", in: ISPRA, Rapporto Ambiente – Stato dell'Ambiente 2022, Roma, 2022, p. 133-145.
[15]	Guadagno S., Grasso D.: "Coastal adaptation in Italy: gaps and perspectives", Journal of Coastal Research, 38(2), 2022, 389–399.
[16]	Cantasano N., Pellicone G., Ietto F.: "Integrated coastal management and governance fragmentation in Italy", Ocean & Coastal Management, 146, 2017, 27–35.
[17]	Kildow J.: "The changing dynamics of the U.S. coastal zone", Coastal Management, 25(1), 1997, 45–66.
[18]	Robert M., Bille R., Michel D.: "La loi Littoral: évaluation, controverses, avenir", Éditions Quae, Versailles, 2015, 176p.

[19] Smith H., Ortega A., Roca E.: "Shifting sands: evaluating the effectiveness of Spain's coastal law", Land Use Policy, 116, 2022, 106060.

[20] Alterman R., Pellach S.: "The limits of regulatory planning in coastal zones: A comparative view", Planning Theory & Practice, 22(4), 2021, 593–614.

[21] Hein C.: "Adaptive planning and the Delta Programme: A model for climate-resilient planning?", Planning Theory & Practice, 21(1), 2020, 23–40.

[22] Di Venosa L., Manigrasso M.: "Le sfide della pianificazione costiera in Italia: criticità e prospettive", Territorio, 100, 2022, 56–67.

[23] Jones R., Hansen L., Garfin G.: "Co-producing actionable science for sustainable coastal communities", Sustainability Science, 13(4), 2018, 1209–1221.

[24] Ferrarese A., Maragno D., Musco F.: "Territori d'acqua e co-pianificazione locale: esperienze e prospettive", in: INU Edizioni (a cura di), Rigenerare l'acqua, Roma, 2021, p. 83–98.

[25] Healey P.: "Collaborative planning: Shaping places in fragmented societies", UBC Press, Vancouver, 1997, 317p.

[26] Balducci A.: "Pluralismo cognitivo e costruzione negoziale della città", in: Urbanistica, 147, 2011, 5–11.

[27] Ingold T.: "Being Alive: Essays on Movement, Knowledge and Description", Routledge, London, 2011, 256p.

[28] Viganò P.: "Urbanisms of the In-Between", in: Dehaene M., De Cauter L. (Eds), "Heterotopia and the City", Routledge, London, 2009, p. 244–257.

[29] Galison P.: "Image and Logic: A Material Culture of Microphysics", University of Chicago Press, Chicago, 1997, 850p.

[30] Star S.L., Griesemer J.R.: "Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39", Social Studies of Science, 19(3), 1989, 387–420.

[31] Balducci A.: "Urban Planning and Democracy: A Trading Zone for Dialogue", in: Sanyal B. et al. (eds.), Planning Ideas That Matter: Livability, Territoriality, Governance, and Reflective Practice, MIT Press, Cambridge, 2011, pp. 259–277.

[32] Fainstein S.S.: The Just City, Cornell University Press, Ithaca, 2010, 208p.

Strategies for climate transition in Italian cities: Collective governance for adaptive and resilient territories

Vittoria Ridolfi[1]

Elena Ferraioli[2]

Filippo Magni[3]

Giulia Lucertini[4]

1	PhD Student, IUAV University of Venice *vridolfi@iuav.it*
2	PhD, IUAV University of Venice *eferraioli@iuav.it*
3	Assitant Professor, IUAV University of Venice *fmagni@iuav.it*
4	Assistant Professor, IUAV University of Venice *glucertini@iuav.it*

Abstract

Climate change has become an urgent priority, demanding new tools for urban and territorial governance. In Italy, local authorities are increasingly mobilizing to strengthen climate adaptation through innovative and collective approaches. This paper presents the experience of the Strategie di Transizione Climatica (STC), developed within the "Strategia Clima" call by Fondazione Cariplo, which supports small and medium-sized municipalities in defining longterm policies and concrete actions for climate transition. The STCs aim to mainstream climate issues into planning tools while fostering collaborative governance, multi-level coordination, and civic participation. Drawing from case studies in the Lombardy region— such as the strategies La Brianza Cambia Clima, AgriCiclo2030, and ACE3T-CLIMA in the Mantua area— this research highlights the importance of shared methodologies, updated knowledge bases, strategic visioning, and operational measures. These strategies promote resilient, human-centered urban environments by creating synergies across municipal boundaries and institutional sectors. Moreover, they illustrate how adaptation and mitigation can be integrated into planning processes to ensure long-term transformation. By connecting local action to broader sustainability goals, these experiences contribute to the advancement of the 2030 Agenda and the Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals). The STC process thus emerges as a replicable model to support territorial resilience, inclusive governance, and climate justice across European cities.

Keywords

Climate adaptation; strategic planning; local governance; territorial resilience; SDGs.

1. Introduction: Climate change as a driver for sustainable and just territorial transformation

In recent decades, climate change has emerged not only as a planetary emergency but also as a transformative challenge that redefines the way societies conceive and govern their territories. The accumulation of greenhouse gases in the atmosphere has now reached its highest concentration in the last 800,000 years, with the scientific community linking this critical trend primarily to anthropogenic factors such as fossil fuel consumption and unsustainable models of economic development [1]. The effects of this acceleration are increasingly visible at local scales, where extreme weather events, environmental degradation, and social inequalities intersect, undermining the quality of life and the adaptive capacity of communities [2][3].

Against this backdrop, the notion of sustainability must be rearticulated through practices of territorial justice, ecological awareness, and participatory governance. Urban and regional planning is called to play a strategic role in this reconfiguration, not only by mitigating emissions and reducing vulnerability, but also by creating enabling environments for innovation, cooperation, and structural change [4][5]. A growing body of literature emphasises the need for integrated approaches capable of aligning planning instruments with climate targets, while mobilising local knowledge and multilevel coordination frameworks [6][7]. However, despite the centrality of cities and regions in climate governance, many municipalities—especially small and medium-sized ones—remain underequipped to address the complexity of the ongoing transition. In the Italian context, this gap is particularly acute. While large metropolitan areas and regional administrations have begun to develop long-term climate strategies, smaller municipalities often struggle to access data, funding, technical expertise, and institutional support, which hampers their ability to activate climate adaptation pathways autonomously [8].

To address this disparity and promote a more inclusive and distributed climate action framework, Fondazione Cariplo launched in 2019 the programme F2C – Fondazione Cariplo per il Clima, including the funding initiative Strategia Clima. This programme was conceived as a systemic response to climate change, explicitly grounded in the principles of sustainability, equity, and territorial cohesion. Rather than offering one-size-fits-all solutions, Strategia Clima has supported the co-design of locally tailored Climate Transition Strategies (Strategie di Transizione Climatica, STC), empowering municipalities to develop integrated responses that combine spatial planning, nature-based solutions, civic participation, institutional innovation, and capacity-building.

These strategies are not limited to technical interventions or isolated mitigation actions. They represent a new governance paradigm where environmental challenges are addressed as opportunities for territorial reconfiguration and collaborative decision-making. In doing so, they contribute to several Sustainable Development Goals (SDGs), particularly Goal 11 on sustainable cities and communities, Goal 13 on climate action, and Goal 17 on partnerships for the goals.

This paper explores the Italian experience of STCs as a promising model of adaptive, placebased, and collaborative climate governance. It presents a set of intermunicipal strategies promoted within the Strategia Clima call, focusing on their innovative planning approaches, governance mechanisms, and capacity to catalyse structural

change in under-resourced territories. By examining their methodological trajectories, planning tools, and operational outputs, the paper contributes to the broader debate on how to make climate transition socially inclusive, territorially grounded, and institutionally transformative.

2. Climate strategies in northern Italy

In the northern Italian context, with the aim of fostering adaptive territories and climate-proof communities, several local actors—including medium-sized cities and aggregations of small municipalities—have embarked on the development of Climate Transition Strategies (Strategie di Transizione Climatica, STC), as part of the "Strategia Clima" call launched by Fondazione Cariplo. This funding programme has provided a crucial opportunity for local governments to experiment with sustainable, multi-scalar planning tools that integrate climate adaptation into urban development, and to initiate spatial transformations that enhance the habitability, equity, and ecological resilience of their territories.

Rather than promoting isolated or sectoral measures, the call has encouraged the design of coherent, cross-cutting strategies capable of aligning local action with climate targets, while activating long-term cooperation among public institutions, civic actors, and technical partners. These strategies serve as experimental frameworks for climate governance at the local level, enabling municipalities to develop context-specific responses through integrated spatial planning, nature-based solutions (NBS), and collaborative approaches. As such, they represent a concrete pathway toward the implementation of Sustainable Development Goals (SDGs), in particular SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals), while contributing to a more equitable distribution of climate resources across territories.

Among the funded initiatives, three cases stand out for their strategic vision, methodological coherence, and governance innovation: Brianza Cambia Clima, AgriCiclo2030, and ACE3T Mantova. Each strategy has been developed through extensive territorial alliances and places-based diagnostics, combining urban planning, environmental stewardship, and community engagement. The following paragraphs present an in-depth analysis of these cases, beginning with the two Brianzan experiences and continuing with the STC of the Mantuan territory.

2.1. The Brianza cases

In the western area of Brianza, a highly urbanised region at the edge of the Milan metropolitan area, two intermunicipal alliances were formed with the aim of developing shared climate strategies. These partnerships brought together local governments, environmental management bodies, and third-sector organisations, resulting in the elaboration of two distinct but complementary STCs: Brianza Cambia Clima (2021) and AgriCiclo2030 (2022). Both strategies are grounded in a collaborative planning framework, informed by a comprehensive vulnerability assessment and oriented towards long-term resilience and sustainability.

The Brianza Cambia Clima strategy was developed by the municipalities of Cesano Maderno, Bovisio Masciago, Meda, and Varedo, in collaboration with the Groane and Brughiera Briantea Regional Park, the Cesano Maderno Civil Protection Association, InnovA21, and the Fondazione Lombardia per l'Ambiente (FLA). The strategy targets key climate-related vulnerabilities such as soil sealing, urban heat, and hydrological risk, promoting actions like urban depaving, hydraulicforestry interventions, and the enhancement of ecological connectivity. It also established a permanent coordination structure among the municipalities and initiated participatory processes aimed at raising public awareness and building institutional capacities for climate adaptation.

The AgriCiclo2030 strategy, led by the municipality of Lentate sul Seveso in partnership with Barlassina, the Groane and Brughiera Briantea Park, and InnovA21, adopts a distinct approach focused on the agroecological landscape and peri-urban mobility. Key interventions include the creation of intermunicipal cycling corridors, functioning both as sustainable transport infrastructure and ecological greenways, alongside the restoration of agricultural areas to promote carbon sequestration, biodiversity, and local food systems. The strategy also supports the development of short supply chains, integrates green space planning with adaptive land use policies, and fosters cross-sectoral synergies between mobility, agriculture, and climate resilience.

Together, these two STCs illustrate how even small and medium-sized municipalities can activate effective forms of supralocal governance, enabling them to jointly define strategic goals, coordinate planning instruments, and implement climate-oriented spatial transformations. Through their shared vision, robust partnerships, and action-oriented frameworks, Brianza Cambia Clima and AgriCiclo2030 demonstrate that the climate transition can be pursued in ways that are socially inclusive, territorially grounded, and institutionally innovative.

2.2. The ACE3T-CLIMA strategy in the Mantova area

Among the many Climate Transition Strategies (STCs) developed within the Strategia Clima programme, the ACE3T-CLIMA Strategy in the province of Mantova offers a paradigmatic example of how inter-municipal cooperation, territorial vision, and operational pragmatism can be combined into a coherent and transformative adaptation pathway. The initiative, formally approved in 2021, was promoted by the Municipality of Mantova and co-developed with the Parco del Mincio, the Municipalities of San Giorgio Bigarello, Marmirolo, Porto Mantovano, Curtatone, and the Unione dei Colli Mantovani, in collaboration with the association Alkémica. The project received funding from both Fondazione Cariplo and Regione Lombardia, positioning itself within the broader objectives of the F2C programme.

The name ACE3T—Acqua, Calore ed Energia: 3 pilastri per la Transizione Climatica del Mantovano—highlights the three interrelated pillars around which the strategy is organised: water, heat, and energy. These thematic axes were not chosen arbitrarily; rather, they emerge from a situated reading of territorial vulnerabilities and potentials, where hydraulic risk, heat waves, and energy dependency intersect with urban fragility, ecological degradation, and socio-economic inequalities. ACE3T-CLIMA thus interprets climate change not only as a technical challenge but as a systemic driver

for spatial reconfiguration, cross-sectoral innovation, and inter-institutional learning. The strategic vision is structured around three programmatic axes (Pi), each of which articulates a specific set of goals, actions, and expected impacts:

- **Pi 1 – Blue Permeability:** This axis tackles the challenge of hydrogeological risk by enhancing water retention, reconnecting ecological corridors (blue and green), requalifying urban and peri-urban areas near water bodies, and fostering a broader ecological valorisation of water. Actions under this axis combine structural interventions (e.g., floodable parks, naturalised riverbanks) with planning tools for buffer zones and ecosystem restoration, thus integrating climate adaptation with biodiversity protection.
- **Pi 2 – Green Inclusion:** This dimension focuses on increasing ecological continuity and social inclusiveness, by promoting biodiversity in urban, peri-urban, and agricultural contexts. It fosters the recognition of productive landscapes as multifunctional systems, enhancing ecosystem services, reducing land fragmentation, and supporting agroecological transitions. Special attention is paid to marginal areas and vulnerable groups, with the aim of designing adaptive and just environments.
- **Pi 3 – Resilience and Decarbonisation of Territorial Systems:** The third axis aims to improve environmental quality and adaptive capacity through infrastructural interventions and energy efficiency strategies. It encompasses measures for enhancing urban accessibility, reducing emissions, and improving the performance of public buildings and mobility networks. Nature-based solutions, such as urban green infrastructures and cool islands, are deployed to reduce urban heat island effects and promote environmental justice.

Beyond the coherence of its planning structure, ACE3T-CLIMA is particularly noteworthy for its multilevel and multi-actor governance model. The strategy not only brings together municipalities of different sizes, but also integrates the role of the regional park, civic associations, and technical offices, creating a collaborative ecosystem that reflects the goals of Strategia Clima: fostering strategic territorial alliances, promoting innovative and replicable initiatives, and supporting the redefinition of long-term policies for sustainable development. The operational outputs of ACE3T-CLIMA extend across multiple scales and domains: from planning guidelines to specific pilot projects, from awareness campaigns to training programs for public officials and technicians. This multiplicity of actions reinforces the idea that climate transition is not a sectoral issue, but rather a transversal challenge that must permeate all dimensions of territorial governance—planning, design, management, communication, and funding.

Finally, the strategy positions itself as a generative process: not simply a static document, but a dynamic platform to mobilise future investments, strengthen institutional capacity, and engage local communities in climate action. By leveraging synergies between climate mitigation and adaptation, ecological regeneration and social cohesion, ACE3T-CLIMA contributes meaningfully to Sustainable Development Goals (SDGs) 11, 13 and 17, and exemplifies how non-metropolitan areas can become laboratories of sustainable territorial transformation.

2. Conclusions: Collective governance and territorial resilience as pillars for a just climate transition

The Climate Transition Strategies (STCs) analysed in this paper offer a compelling illustration of how local climate action can become a catalyst for deeper, systemic transformations in planning, governance, and spatial justice. Far from being isolated experiments, these strategies embody a broader rethinking of how territories can adapt to climate change while preserving their ecological, social, and institutional integrity. Through integrated diagnostics, shared strategic visions, and cross-sectoral alliances, they point to an emerging paradigm of collective climate governance, in which adaptation becomes a relational and place-based process, rather than a merely technical fix. One of the most significant contributions of the Strategia Clima programme lies in its capacity to mobilise complex partnerships across different administrative levels and sectors. The experiences of Brianza and Mantova reveal how small and medium-sized municipalities, when adequately supported, can play an active role in structuring climate responses that are both territorially coherent and socially inclusive. These strategies are not confined to infrastructure or emergency preparedness. Rather, they are grounded in a long-term territorial vision that aligns ecological objectives with social justice, planning tools with community needs, and climate targets with institutional capacity-building.

The methodological framework underpinning these initiatives is particularly noteworthy. Developed and refined through the iterative work of municipalities, environmental authorities, civil society organisations, and technical partners, the STCs are based on a shared and replicable model that can be adapted to other contexts across Italy and beyond. This model is characterised by five key components:

- an organic and clearly defined coordination structure to manage intermunicipal collaboration;
- an updated and cross-sectoral knowledge base built through vulnerability assessments and participatory processes;
- a shared strategic vision and set of objectives, enabling alignment across institutions and stakeholders;
- a synergic and actionable framework of interventions, ranging from spatial to social and ecological measures;
- and the mainstreaming of climate concerns into statutory planning instruments, ensuring long-term coherence and institutionalisation.

By embedding climate adaptation within existing planning frameworks—rather than treating it as an external or exceptional issue—the STCs contribute to a profound shift in governance culture. They support municipalities in moving from reactive, fragmented measures to proactive, coordinated climate strategies, grounded in the specific identities, landscapes, and social fabrics of each territory.

The STCs not only contribute substantively to several Sustainable Development Goals (particularly SDG 11 on sustainable cities and communities, SDG 13 on climate action, and SDG 17 on partnerships), but also offer a generative platform for further experimentation, learning, and replication. Their value lies in the process as much as in the

outputs: they foster a governance culture that is more dialogic, adaptive, and capable of addressing uncertainty. In the broader European and global context, the Italian experience represents a valuable model of decentralised climate governance, capable of informing other regions where institutional asymmetries and territorial inequalities hinder effective climate action. By prioritising co-creation, territorial knowledge, and intermunicipal cooperation, the STCs show that the climate transition can be made more just, more democratic, and more structurally embedded in how we imagine and govern the future of our territories.

As the climate crisis continues to unfold with increasing urgency, the need for territorial transformation becomes ever more apparent. The STCs provide an example of how this transformation can be designed collectively—through participatory governance, methodological innovation, and strategic integration—thereby activating a long-term trajectory of change that is not only sustainable, but also equitable, place-sensitive, and future-oriented.

Literature

[1]	IPCC: "Climate Change 2014 – Synthesis Report", Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, 2014, 151p.
[2]	IPCC: "Climate Change 2021 – The Physical Science Basis", Sixth Assessment Report, Working Group I, Cambridge University Press, Cambridge, 2021, 2391p.
[3]	Leichenko R.: "Climate change and urban resilience", Current Opinion in Environmental Sustainability, 3(3), Elsevier, 2011, 164-168, ISSN 1877-3435
[4]	Brugmann J.: "Financing the resilient city", Environment and Urbanization, 24(1), 2012, 215-232, ISSN 0956-2478
[5]	MacKinnon D., Derickson K.D.: "From resilience to resourcefulness: A critique of resilience policy and activism", Progress in Human Geography, 37(2), 2013, 253-270, ISSN 0309-1325
[6]	Jabareen Y.: "Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk", Cities, 31(1), 2013, 220–229, ISSN 0264-2751
[7]	Lawrence J.: "Urban planning in the age of climate change", Urban Design International, 12(2-3), 2007, 61–63, ISSN 1357-5317
[8]	Litt G., Ferraioli E., Lucertini G., Magni F.: "Metodi e strumenti innovativi per la transizione climaticaa livello locale. L'esperienza mantovana: dalle linee guida 'Mantova resiliente' a una strategia di transizione climatica sovralocale", In: La città come laboratorio di apprendimento permanente, Anteferma, October 2022, p.33 *Main design of Union Bridge in Podgorica*, Faculty of Civil Engineering, University of Montenegro, 2001-2002

T3

The role of technology and innovation in sustainability

Information technology and humanitarian response efficiency: A case study of the red cross society of Bosnia and Herzegovina

Abdurahman Aljic[1]

Edisa Nukic[2]

Jelena Marković[3]

1 MSc, Red Cross of the Federation of Bosnia and Herzegovina
abdurahman.aljic@ckfbih.ba

2 PhD, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Bosnia and Herzegovina
edisa.nukic@untz.ba

3 PhD, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Bosnia and Herzegovina
jelena.markovic@untz.ba

Abstract

The Red Cross Society of Bosnia and Herzegovina, as the oldest and most widespread humanitarian organization in Bosnia and Herzegovina, carries out a large number of humanitarian operations in response to natural disasters, migrant crises, and other humanitarian, program, and project activities. Current approaches to data collection and processing are often not sufficiently applicable in the field as they don't allow quick data management. This can lead to inadequate planning, delayed decision-making, hindered resource allocation, and even pose risks to volunteers and professionals on the ground.

Insufficient application of modern information technologies presents a significant challenge for the organization regarding preparedness for humanitarian response and real-time monitoring of humanitarian operations.

This paper examines how the adequate application of information technologies and systems could improve the BH Red Cross's capacities for timely humanitarian response. The research focuses on use of advanced information tools such as KoBo Collect, Power BI, and QGIS, which enable more efficient data collection, analysis and visualization.

The use of Power BI enables data analysis on the number of services provided by the Red Cross, while KoBo Collect was used for field data collection and QGIS as a tool for spatial analysis.

Keywords

Red Cross Society, Information technologies, Power BI, KoBo Collect, QGIS

1. Introduction

The Red Cross Society of Bosnia and Herzegovina (RCS BiH) is the only Red Cross organization operating throughout the entire territory of Bosnia and Herzegovina, consisting of the Red Cross of the Federation of Bosnia and Herzegovina, the Red Cross of Republika Srpska, and the Red Cross of Brčko District BiH with their organizations, and has the status of a national society with recognizable and accepted programs. The Red Cross of Tuzla Canton (RC TC), whose activities are analyzed in this paper, is part of the RCS BiH structure. RCS BiH is an organization that achieves its humanitarian goals and tasks through a range of humanitarian activities aimed at providing support to vulnerable population categories. The key humanitarian activities implemented in Bosnia and Herzegovina are: training citizens in first aid provision, organizing voluntary blood donation campaigns and promoting voluntary blood donation, preparation and response to natural and other disasters, tracing service and restoration of family links, public health education, humanitarian-social activities, information and dissemination, youth work, and land mine risk awareness.

Traditional approaches to data collection and processing are often not sufficiently applicable in the field, i.e., they do not provide possibility of rapid data management, which can lead to inadequate planning, delays in decision-making, hindered resource allocation, and pose risks to volunteers and professionals in the field. Insufficient application of modern information technologies presents a challenge for the Organization in terms of preparedness for humanitarian response, as well as monitoring humanitarian operations in real-time.

This paper examines the possibilities of improving the Red Cross's capacities for timely humanitarian response by implementing appropriate information technologies and systems. The research [1] was conducted using quantitative research methods and utilizing internal information systems of RCS BiH, which enabled a holistic approach to analyzing the impact of information technologies on humanitarian response with a focus on areas of operation: migration, humanitarian mapping and establishment of service user databases, as well as for keeping records of the organization's implemented activities.

2. Information technologies in humanitarian activities of RCS BiH

As early as 2013, the International Federation of Red Cross and Red Crescent Societies (IFRC) report titled "Focus on Technology and the Future of Humanitarian Action" [2] focused on the rapid expansion of technologies, especially information and communication technologies, which are transforming humanitarian action. The same year, OCHA published a report titled "Humanitarianism in the Network Age (HINA)" [3] which presents some of the most important features of new technologies and identifies opportunities and difficulties in their application. Globally, the most commonly used information technologies in humanitarian activities include the use of tools for rapid field data collection, analysis and visualization, such as: KoBo ToolBox, QGIS and Microsoft PowerBI. Therefore, these tools were implemented to improve RCS BiH's planning and response to humanitarian challenges.

RCS BiH and organizations in its structure first began applying these tools during the onset of the migrant crisis in Bosnia and Herzegovina in 2019. The first such information system in the RCS BiH structure consisted of a questionnaire for daily reporting on services provided to migrants/refugees in Bosnia and Herzegovina and a Microsoft PowerBI dashboard for analyzing collected data. As part of this activity, training was conducted on the method of use and reporting for RC mobile team members.

2.1. Advantages of Using Information Technologies

In social research that relies on field surveys, the questionnaire is one of the key instruments for data collection. Dauenhauer et al. (2019) and Tayal et al. (2015) note that paper questionnaires have a number of challenges, including high costs, the need for physical distribution, processing and return of results, and a high possibility of errors [4]. The processing takes a long time, as data must be entered manually and only then can be statistically analyzed, which is a long and complex process. Also, paper questionnaires allow surveyors to provide qualitative answers in quantitative sections, which can lead to unexpected data. The only advantage of paper questionnaires is that no special training is required for their use. The comparative advantage of using information technologies is that they require less time and facilitate the conduct of research/surveying. Additionally, if data collection needed to be repeated due to an error, the traditional method would require having backup questionnaires, and sending data from the field to the researcher's location would take additional time.

In response to these challenges, researchers use KoBoCollect/Toolbox, a free platform developed and created for creating questionnaires for data collection and analysis. The platform consists of a set of web and mobile applications that enable the creation of complex forms, data collection using mobile devices, data analysis and storage. An important advantage, which is particularly relevant for the context of work in inaccessible terrain, lies in the fact that this information technology enables data collection in online and offline mode, i.e., with and without access to the internet network. Due to its practicality and ease of use, KoBoToolbox is widely used during work in crisis situations, field surveys, research projects and other activities that require rapid data collection. The technology is adapted to the non-governmental sector and humanitarian organizations, which is

why a large number of international and domestic organizations/agencies use this tool as a basic work tool, i.e., use leased servers with the aim of a more transparent management and data protection process.

RCS BiH uses the paid server of the International Federation of Red Cross and Red Crescent Societies (IFRC), which ensures a higher level of security and data protection, with all IFRC members having access to it. The tool enables the integration of various instruments such as: paper questionnaires, GPS devices, cameras, audio recorders and other tools into one instrument that can be used via smartphone. It also simplifies the research process by automating data and enables adaptation of data format to research needs. Deniau et al. (2017) believe that KoBoCollect reduces research costs, saves time and enables precise recording of research location coordinates [5].

Key features of the implemented QGIS include: compatibility with various operating systems such as Windows, MacOS, Linux, BSD and Android; tools for spatial search, geospatial processing and geographic analysis; ability to create high-quality maps with customizable symbologies and layout options; an active community that contributes to continuous updates and improvements. QGIS is an open-source GIS application that enables visualization, management, editing and analysis of geospatial data. It is available on almost all platforms. QGIS can be freely modified to perform various tasks, and its basic functionality can be extended using numerous plugins developed using C++ or Python programming languages, which is its greatest advantage.

Visualization and analysis of data through the third applied tool - PowerBI dashboard enables the Red Cross to plan, monitor and improve its activities more efficiently. Additionally, PowerBI provides the ability to store large amounts of data from previous years, and the ability to filter them as needed for making informed decisions. Microsoft Power BI is a set of services and applications that transform mutually unconnected data sources into clear, visualized and interactive insights. Data networked using Power BI tools can come from a wide range of sources, such as Excel spreadsheets, OneDrive repositories, cloud and on-premise data warehouse systems.

3. Areas of information technology implementation

3.1. Area of migration

RCS BiH has been actively involved in the humanitarian response to the needs of people on the move through Bosnia and Herzegovina since 2018. This response is reflected in the organization of mobile teams whose task is to provide first aid services, restore family links, psychosocial support and distribution of food and non-food packages. In order to establish a unified reporting system, monitor trends and analyze data, with the aim of informed humanitarian response planning, an electronic reporting system is being introduced. The established system is based on daily reporting by mobile teams on the type and number of services provided through the KoBo Collect questionnaire, which enables monitoring of field conditions in real-time, as well as visualization and analysis of data using Microsoft PowerBI tools.

Figure 1 – PowerBI dashboard home page

The created reporting questionnaire includes data on types of services and their users, namely: demographic data (age, gender and national structure of users), type and number of services provided (first aid, psychosocial support, family links restoration), type and number of distributed items (food, non-food items, hygiene), number and location of referred persons, locations where user presence was observed.

After mobile teams complete their daily reports, all data submitted in the report are stored on the IFRC server. The final step of this information system is connecting the collected data and importing them to the Microsoft PowerBI platform, where a system for their clearer understanding and analysis has been previously established (Figure 1).

It is important to emphasize that this method of data collection and sorting enables quick and simple data management, whereby it is possible to filter data in seconds depending on needs, according to: type of donor; mobile team that provided services; day, month, year or time interval; gender; age structure; user nationality; micro-location of service provided; macro-location of service provided; type of service provided, etc. Mobile teams have the task and possibility, using information technology (KoBo Collect), to enter coordinates where migrant presence was observed as part of daily reporting, thus achieving precise determination of locations where it is necessary to plan and organize the organization's humanitarian response (Figure 2).

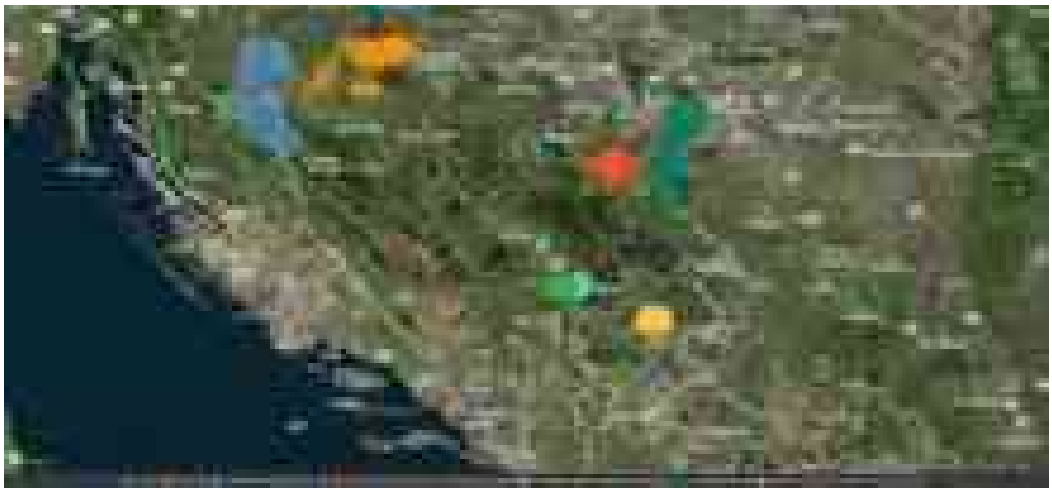


Figure 2 – Geolocations of RCS BiH mobile team operations

The information system established in the migration program is summarized on 12 pages, with each page providing detailed analysis of a specific type of service provided by mobile teams, namely: general data, first aid, food, hygiene, psychosocial support, restoration of family links, trainings and meetings, referral mechanism, operational geolocations and donors.

Figure 3 – First aid services and distribution data

As can be seen (Figure 3), each dashboard page provides insight into the total number of services provided, the time period when the need for providing a certain service was particularly expressed, the precise type of injury, as well as the item that was distributed. All this greatly facilitates key actors in planning humanitarian response and making informed decisions.

3.2. Humanitarian Mapping of RC Service Users

Information technologies can play a crucial role in the process of mapping populations affected by natural disasters due to the possibility of quick and simple data collection, as well as their unified transmission. After the floods that affected 5 municipalities in the territory of Bosnia and Herzegovina in October 2024, with the aim of gaining insight into the number of affected households, as well as planning the humanitarian response, the process of mapping affected households was initiated. For the purpose of field data collection, a KoBo questionnaire for humanitarian mapping was created containing information about: data collection method; organization collecting data; name and surname of household head; type of affected settlement (urban/rural); type of residential building; data on damage, evacuation and household income; household needs; information on received assistance; data on vulnerable population categories.

Figure 4 – Quick overview of flood-affected households

After completing the humanitarian mapping process, the collected data were processed through Microsoft PowerBI tools, as well as prepared in the form of lists of flood-affected populations, which provided RCS BiH with prerequisites for starting a coordinated humanitarian response (Figure 4). Also, the collected data contributed to a clearer understanding of the scale of natural disasters that affected Bosnia and Herzegovina at that time. The implemented information technologies also determined the geolocations of flood-affected households (Figure 5).

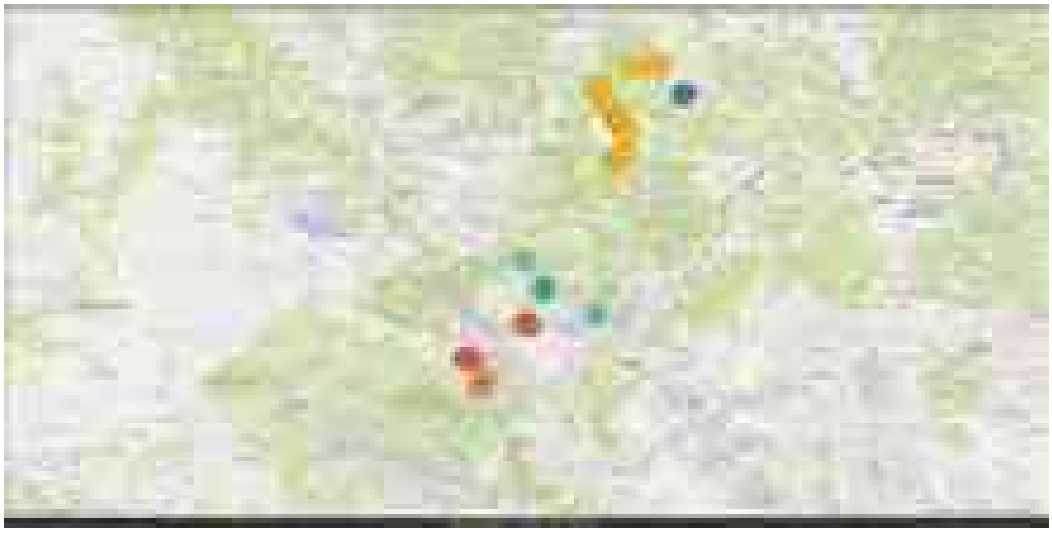


Figure 5 – Geolocations of flood-affected households

Through these activities, it can be concluded that the application of information technologies and systems in the humanitarian sector enables more efficient collection, processing and sharing of data with other key actors, thereby improving the organization's operational efficiency, as well as coordination with other humanitarian actors. Additionally, information technologies and systems contribute to improved coordination

of field activities and strengthen communication capacities in interaction with affected communities. Also, the integration of information systems increases transparency and accountability in the process of humanitarian goods distribution.

3.3. Establishment of User Database

RCS BiH is an organization with a widespread structure of organizations working with a large number of service users, with a focus on socially vulnerable populations. User databases, established using KoBo Collect and Microsoft PowerBI tools, enable systematic management of information and data about users with whom organizations work or cooperate. Accordingly, the integration of information technologies into the work of organizations enables a unified approach to the method of registering new users and managing user data. Questions in the registration questionnaire are adapted to the context of the RC TC organization, which simplifies and speeds up the data entry process by the person registering the new user. Optional data about the household in which the service user lives are also displayed, simultaneously providing broader information about the user's social profile, i.e., needs depending on household size, type and ownership of the building in which the user lives, as well as the social category to which the user belongs. This method of data collection with the aim of creating a unified user database enables precise determination of user needs. Also, with the help of geospatial determination of user coordinates, it is possible to determine the exact location of the user's residence (Figure 6).

Figure 6 – Dashboard - RC TC User Database

Figure 6 shows the first page of the PowerBI dashboard that provides the possibility of viewing general data about service users. Also, it is possible to quickly filter data, and in a short period of time it is possible to determine the number of individual user categories, depending on the needs and requirements of the organization/donor.

3.4. Promotion of Implemented Activities

Since the Red Cross is an organization that largely depends on donor support, it pays great attention to promoting implemented activities, as well as visibility and transparency of work in public. One solution for recording activities in public information services is the use of KoBo Collect and Microsoft PowerBI tools. Primarily, a KoBo questionnaire was created that all RC TC employees/volunteers fill out after appearing in a particular information service. The following are recorded: name and surname of the person who appeared, date of appearance, topic that prompted the appearance and media outlet where the appearance took place. In this way, it is possible to obtain a simple insight into the number of media appearances of the organization, the most interesting topics of appearances, broadcasting houses where appearances were most frequent and the schedule of appearances by media (Figure 7).

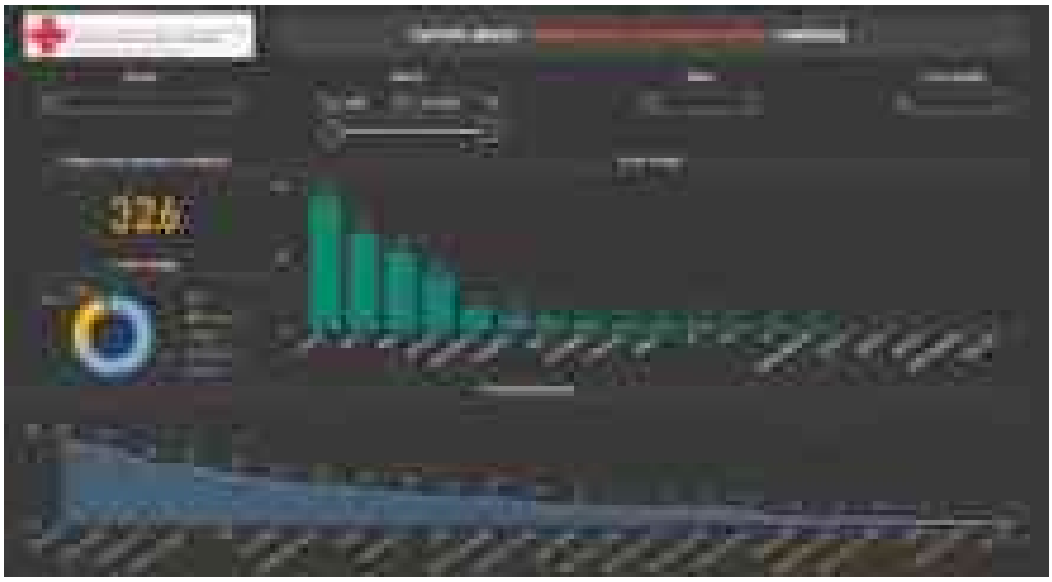


Figure 7 – Dashboard - Media Appearances

Based on the collected data (shown on the dashboard), it is possible to analytically draw a number of conclusions with which the organization can improve its work and visibility in the public media space. Also, this method of recording activities provides opportunities for using collected data and information when preparing annual reports and bulletins of the organization.

4. Conclusion

The implementation of modern information technologies and systems enables faster assessment of field needs, better coordination of volunteers and more efficient information exchange, which contributes to timely and higher quality humanitarian response. Their application facilitates data collection, processing and visualization, which

significantly improves the decision-making process and activity planning. One of the key advantages of using information tools is building a database that enables drawing conclusions based on previous experiences. Large amounts of data can be efficiently filtered according to current needs, thus creating a basis for a systematic approach to humanitarian operations.

Within the research, the KoBo Collect tool was used for field data collection, Power BI for analyzing the number of services provided by the organization, and QGIS for spatial analysis. The results indicate a significant role of information technologies in the areas of migration, humanitarian mapping and monitoring of field activities. Despite numerous advantages, the challenge is the credibility of data collected digitally, as well as the need to protect user privacy, especially vulnerable groups. Therefore, it is necessary to additionally invest in staff education and development of information systems that ensure high standards of information security.

Literature

[1] Aljić A.: *" The Impact of Information Technologies on the Efficiency of the Humanitarian Response of the Red Cross Society of Bosnia and Herzegovina"*, Master thesis, Faculty of Mining, Geology and Civil Engineering, University of Tuzla, Tuzla, 2025

[2] World Disasters Report 2013: Focus on technology and the future of humanitarian action, International Federation of Red Cross and Red Crescent Societies, ISBN 978-92-9139-197-4

[3] Humanitarianism in the network age: including world humanitarian data and trends 2012, UN. Office for the Coordination of Humanitarian Affairs. Policy Development and Studies Branch, New York: 2013-04

[4] Wayan Nampa et al., *"The KoBoCollect for Research Data Collection and Management (An experience in Researching the SocioEconomic Impact of Blood Disease in Banana)"*, SOCA Jurnal Sosial Ekonomi Pertanian, Vol. 14, No. 3, September 2020, page 545 - 556 ISSN: 2615-6628 (E), ISSN: 1411-7177 (P)2020, https://www.researchgate.net/publication/342740543

[5] Deniau, C., Gaillard, T., Mbagogo, A., Réounodji, F., & Le Bel, S. *"Using the KoBoCollect tool to analyze the socio-economic and socio-cultural aspects of commercial hunting and consumption of migratory waterbirds in the Lakes Chad and Fitri (Chad)"*, Conference Proceedings of 2017 EFITA WCCA Congress: European Conference Dedicated to the Future Use of ICT in the Agri-Food Sector, Bioresource and Biomass Sector (https://agritrop.cirad.fr/585572/), 2017

Design terazzo tiles implementing life cicle assesment

Faton Spahiu[1]

Vladimir Vitanov[2]

Ana Trombeva-Gavriloska[3]

Teodora Mihajlovska[4]

1	PhD student, Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, Skopje, North Macedonia
2	Prof., Ss. Cyril and Methodius University in Skopje, Faculty of Civil engineering, Skopje, North Macedonia *v.vitanov@gf.ukim.edu.mk*
3	Prof., Ss. Cyril and Methodius University in Skopje, Faculty of Architecture, Skopje, North Macedonia *agavriloska@arh.ukim.edu.mk*
4	Assist., Ss. Cyril and Methodius University in Skopje, Faculty of Civil engineering, Skopje, North Macedonia *mihajlovska.teodora@arh.ukim.edu.mk*

Abstract

The construction industry is a major contributor to global environmental degradation, prompting the need for sustainable material choices. Construction waste have a great impact on environmental pollution that results in significant economic losses at the same time. In the mean of a sustainable environment, construction waste should be properly stored or recycled and reused to prevent environmental pollution in order to utilize waste materials in the manufacturing process of new products offering both direct and indirect benefits to environmental sustainability, instead of the practice that the construction waste should be released into nature without control.

In order to accomplish the goals for sustainable environment and growing emphasis on sustainable development, construction industry develops methods to reduce the negative impact of construction waste by using it as fillers for building materials. Such a example of material is terrazzo, a composite material that consist several components: raw ingredients, binders and pigments.

This paper applies Life Cycle Assessment (LCA) methodology to evaluate the environmental performance of terrazzo tiles, from raw material extraction to end-of-life. Findings suggest that terrazzo, especially when made from recycled aggregates, offers significant environmental benefits over conventional tiles, particularly in terms of embodied carbon and resource efficiency.

Keywords

Sustainability, Life cycle assessment, Terrazzo tile, Construction waste

1. Introduction

Construction waste have a great impact on environmental pollution that results in significant economic losses at the same time. In the mean of a sustainable environment, construction waste should be properly stored or recycled and reused to prevent environmental pollution in order to utilize waste materials in the manufacturing process of new products offering both direct and indirect benefits to environmental sustainability, instead of the practice that the construction waste should be released into nature without control.

In the construction sectors the marble industry is among the sectors that produce the highest amount of waste, keeping in mind that the production and development of marble is in grow, especially concerning to mining and process stages. Considering that during the process of marble fabrication, nearly 50% of a marble block's volume is turned into waste. It could be concluded that marble waste gathered in open area is increased, creating serious health and environment problems, such as fertility of the soil, water and rivers contamination, as well as air pollution, [9], Figure 1.

Figure 1 – Effect of marble waste on the environment

In order to accomplish the goals for sustainable environment and growing emphasis on sustainable development, construction industry develops methods to reduce the negative impact of construction waste by using it as fillers for building materials. That lead to reducing of construction waste and cost for materials in one hand, as well as developing a new material with improved properties in other hand, [11].

Such a example of material is terrazzo, a composite material that consist several components: raw ingredients, binders and pigments. In the process of manufacturing as binders usually is used cement, while as raw ingredients are used marble powder, granite, glass or quartz particles, waste from the specific industry. Terrazzo products could be poured in place or prefabricated and they are primarily used for floors and stairs due to the rough surface that has exceptional anti-slip qualities and weather-resistant property, [5].

Environmental impact of waste production, treatment, and its disposal could be evaluated by using Life Cycle Assessment (LCA) as a critical tool implemented for the entire life cycle of industrial processes and products, by analyzing inputs and outputs from material extraction, production, use, and end-of-life stages. Integrating, LCA into waste management plans is crucial to identify environmental hotspots and opportunities for promoting cleaner production, for waste minimization, resource recovery and recycling, [7]. LCA industries create a multiple benefit including reducing carbon footprint, waste reduction, conservation of natural resource, low material costs, energy savings and improving material properties.

The main focus of the presented research is on producing a sustainable product, terrazzo tile, by using construction waste from the process of marble fabrication. This paper applies Life Cycle Assessment (LCA) methodology to evaluate the environmental performance of terrazzo tiles, from raw material extraction to end-of-life. Findings suggest that terrazzo, especially when made from recycled aggregates, offers significant environmental benefits over conventional tiles, particularly in terms of embodied carbon and resource efficiency.

2. Terazzo systems

The historical use of terrazzo can be traced back to ancient times, with the earliest identifiable terrazzo floors dating between 10,000 and 8,000 BC. Civilizations such as the Ancient Greeks, Romans, and Egyptians improved terrazzo methods by incorporating mixtures of crushed limestone and marble to produce both decorative and resilient flooring for residences, bathrooms, and public structures, [6]. In the 19th-century the origin use of terrazzo is from Italy, spreading worldwide by the Italian craftsmen influencing on the use of this material on the architecture, [15], Figure 2.

Figure 2 – The Application of Terrazzo in in the Early 20th Century

The terrazzo has a polished and ground surface made mostly of tiny stone fragments (up to 10 mm) such as river bed stone, granite or marble as aggregates mixed with white or grey portland cement, either with or without pigments, Figure 3.

Figure 3 – Terrazzo tile with Cement Base

Instalment of terrazzo material could be done by using various methods, such as sand cushion, bonded or monolithic systems, Figure 4. The sand cushion system is composed of several distinct layers of materials, each serving a specific function. Bonded terrazzo system is constructed as a portland cement topping and at least 50 mm thickness in underbed totaling. Monolithic system involves pouring of the material all at once onto a concrete base without the need for an underbed. Monolithic and bonded systems are installed directly on the concrete slab, while sand cushion systems is installed independently of the concrete slab.

a) b) c)

Figure 4 – Types of terazzo system: a) Sand Cushion System; b) Bonded Terrazzo; c) Monolithic System

3. Literature review

Demand for use of the sustainable materials in construction industry, initiate use of marble powder to be re-considered not as waste, but as a valuable resource in building products, such as bricks, tiles and concrete. Use of a construction demolition waste and glass waste in concrete can produce a sustainable terrazzo material. Especially application of the construction waste such as marble powder, lime or glass in combination with cementitious composites in terrazzo material has been confirmed by numerous studies.

Yifru & Mitikie presented that Partial replacement of sand up to 67% with scoria and marble waste can improve by 30% the compressive strength of concrete and decrease cost up to 4.5% compared to traditional concrete [14]. Quality and strength of concrete by using waste of marble powder are confirmed by results presented in the study of Singh et al. [12], in which is pointed that the use of marble slurry can generate financial and environmental benefits. The potential of the waste from marble powder in manufacturing the concrete products is presented by Mansor et all [2], complaining with requirements for the fresh qualities of Self Compacting Concrete with up to 50% marble powder instead of cement. The potential of industrial and quarrying waste from marble sand in concrete as replacement for fine aggregates is presented in the experiments done by Hebhoub et al. [9], showing that marble waste, which has similar properties of cementitious, is economical and eco-friendly material as replacement of fine aggregate and natural sand increasing the strength of concrete in comparison to conventional concrete. The impact of marble powder waste materials on the mechanical properties of concrete is presented by Abbas & Muntean, [1], confirming that by substitution of cement with marble powder up to 15% mechanical properties of the concrete could be improved, particularly tensile and compressive strength. Andreani et al., [4], in their research confirmed that replacement of cement with an up to 10% of marble powder in mortar production increase in comprehensive strength.

Regarding to incorporating waste of limestone powder as a filler in epoxy coatings, according to Chowaniec-Michalak et al., [6], leads to increased hardness of the epoxy coating simultaneously reducing both tensile and flexural strength, by reducing the costs and decreasing the overall use of epoxy resin, contributing to a more sustainable development.

Research of Stabile et al, [13], highlights that managing a waste, especially high volume of waste, in manufacturing the terrazzo tile products will provide the benefits for local economy, as well as that from an environmental perspective, the LCA revealed significant benefits in terms of reduced carbon emissions, energy consumption, and raw material depletion due to the use of recycled glass and construction demolition waste.

On the basis of the literature review the overarching aim of this research is to investigate the viability and potential of using locally sourced bio materials to develop a sustainable terrazzo tile product in order to contribute to the ongoing efforts towards achieving sustainability in the building industry.

4. Selection of materials for terrazzo tile and relations to LCA

The Based on standard ISO 14040 Life Cycle Assessment (LCA) plays a critical role to assess the true potential sustainability benefits of reusing marble powder, particularly in building construction as sustainable material. From reusing marble waste LCA offers a comprehensive evaluation of the environmental implications, considering the energy consumption, the emissions, and resource use from extraction to disposal.

The marble industry, particularly in countries with large-scale quarrying and processing operations, generates substantial quantities of marble waste, including fine marble powder or marble dust. Marble powder is generated during quarrying, cutting, polishing, and shaping of marble slabs which is often discarded in open areas or landfills leading to serious negative environmental effect like water and air pollution, [3].

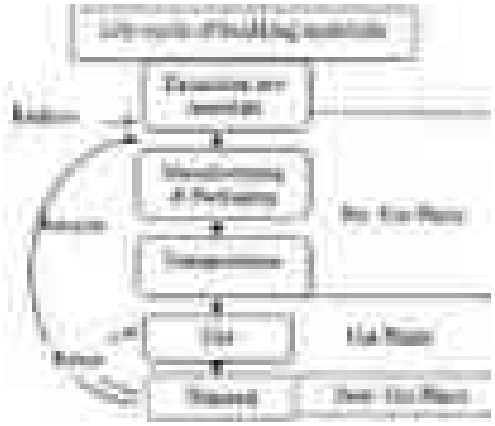


Figure 3 – Process of life cycle building materials

The life cycle of a terrazzo tile made with marble powder, cement, marble chips, marble glass, and sand consists of several distinct stages, from raw material extraction to end-of-life is shown on Figure 5, [10].

4.1. Raw material extraction and processing

For the purposes of this study, the life cycle assessment approach was implemented in the production process of terrazzo tiles for the use of construction waste from the Western Balkan countries. All components for the production of terrazzo tiles, shown in Figure 6, are local materials from North Macedonia and Kosovo. The life cycle assessment analysis is reviewed according to all points of the methodology outlined in [10].

Figure 6 – Components for producing terrazzo tiles: 01)Sand, 02) Cement, 03) Lime, 04) Marble Powder, 05) Marble Chips

Extracting the raw materials have been done from different regions of North Macedonia and Kosovo, Figure 7, on the base of their availability and quality for use, Figure 6. Marble powder and marble chips are extracted from Prilep Marble, within the marble formation that belongs to the Pelagonian metamorphic complex. Dolomite type of marble, known as Sivec, characterized with high content of magnesium carbonate is used due to its whiteness and the fined grain structure.

a) b)

Figure 7 – Extracting raw materials: a) marble powder; b) lime stone

Limestone from Gllareva region near Klina, Kosovo is the second used material. A sedimentary rock, composed primarily of calcium carbonate ($CaCO_3$), with a light gray color that, due to its layering, acquires a unique texture, making it a popular material for architectural and design purposes. Sand and cement, as some of the main components in the terrazzo material, are local materials from deposits in Kosovo, namely from excavations near Pristina and Sharrcem – Hani e Elezit, respectively.

4.2. Tile manufactoring

All aggregates (marble chips, marble powder, glass chips, and sand) are precisely proportioned and combined with cement and water. The mix ratio and composition can be alteredfor specific properties or eco-efficiency.

Forming process started by the mixture which is poured into molds (or “pans” for tile production) and vibrated or pressed to eliminate air pockets and achieve the desired density and surface quality. Tiles are cured naturally, which is essential to ensure the strength and durability of the finished product. Once cured, the tiles are ground and polished to expose aggregate surfaces and create a smooth, glossy finish. Additional finishing treatments may include sealing to improve stain resistance.

Figure 8 – Process of preparation of tile

4.3. Transportation and installation, use phase and end-of life (post use)

Finished tiles should be packed and transported to construction sites in order to be installed. Transportation and installation stages could contribute to the overall environmental impact if the construction site is located closely to the manufacturing, otherwise their impact is smaller compared to the stage of extraction and use of raw materials.

Terrazzo tiles are highly durable and with minimal maintenance, such as regular cleaning and occasional resealing, their lifecycle could extent several decades, often more than 25 years.

At the end of their service life, terrazzo tiles could be removed and recycled as construction and demolition waste. As a demolished material they could be reused as aggregate for manufacturing new tiles or other building material. By using demolition waste of terrazzo tiles as recycled aggregate could be closed the material loop reducing the need for original resources and reducing the environmental footprint.

5. Conclusion

Use of the life cycle assessment methodology of a particular construction product could contribute in addressing the challenges of waste management and environmental risks. The use of construction waste as a raw material as a replacement of original materials in the production of new products could contribute to reducing the use of natural resources and reducing overall carbon emissions, if construction waste is effectively reused or recycled.

Key points synthesized from recent LCA studies and reports are that the recycling of construction materials could support a circular economy by feeding back into the production loop, minimizing landfill waste and preventing additional environmental burdens. In this paper the life cycle assessment is implemented on use of construction waste in the process of manufacturing terrazzo tiles with the key focus on sustainability optimizations. The emphasis is on reduction on the cement content by maximizing use of recycled material and efficient production processes to minimize gas emissions and resource use.

Using construction waste from manufacturing, especially use of marble powder and lime in production of terrazzo tiles could be decreased the amount of used cement, that reduce the material costs, carbon emissions, and conserve natural resource. Through the use of bio materials, which are sourced locally and renewable, there is an opportunity to reduce the reliance on non-renewable materials, such as sand, and to minimize the environmental impact.

This study is the first stage of the research that will consist a combination of experimental testing and numerical modelling of developing a sustainable building product such as composite tiles by using locally waste materials.

This led to conclusion that manufacturing of terrazzo tiles by using construction waste create a sustainable and eco-effective material that could be used in building and renovation projects. Considering that terrazzo tiles as a material contain the most aggregate, it can be concluded that their potential to recycle and reuse at the end of life belong to the principles of circular economy and it could be classified under Cradle-to-Cradle approach.

Literature

[1]	Abbas, M. M., & Muntean, R. (2025). Marble Powder as a Sustainable Cement Replacement: A Review of Mechanical Properties. Sustainability (Switzerland), 17(2), 1–28.
[2]	Ali M. Mansor, Asaad A. Elshab, Ruben P. Borg, & Ahmed M. M. Hamed. (2018). *Effect of Marble Powder Waste on the Properties of Self-Compacting Concrete*. October, 165–170.
[3]	Alyamaç, K. E., & Ince, R. (2009). A preliminary concrete mix design for SCC with marble powders. *Construction and Building Materials, 23*(3), 1201–1210.
[4]	Andreani, A. S., Taopan, H. V. R., Banunaek, F. S., & Nurkhaliza, F. (2024). Impact of Waste Marble Powder as A Partial Alternative Material for Cement. *Jurnal Sains Materi Indonesia*, 26(1), 81–91. https://doi.org/10.55981/jsmi.2024.4569
[5]	Asif, Laraib, and Waqas Malik. 2023. "Effect of Marble Powder on Concrete : A Review." 2 Nd International Conference on Engineering , Natural and Social Sciences, 166–71.
[6]	Chowaniec-Michalak, A., Czarnecki, S., & Sadowski, Ł. (2025). Towards the Use of Waste Limestone Powder as a Filler for Epoxy Coatings in Floors: Research on Mechanical Properties. In *Springer Proceedings in Materials* (Vol. 61). Springer International Publishing. https://doi.org/10.1007/978-3- 031-72955-3_36
[7]	Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., & Suh, S. (2009). Recent developments in life cycle assessment. Journal of Environmental Management, 91(1), 1–21.
[8]	Grossutti, J. P. (2021). From guild artisans to entrepreneurs: the long path of Italian marble mosaic and terrazzo craftsmen (16th c. Venice–20th c. New York City). *International Labor and Working-Class History*, 100, 60–86.
[9]	Hebhoub, H., Aoun, H., Belachia, M., Houari, H., & Ghorbel, E. (2011). Use of waste marble aggregates in concrete. *Construction and Building Materials, 25*(3), 1167–1171. https://doi.org/10.1016/j.conbuildmat.2010.09.037
[10]	Ishak, N. I., Mustafa Kamal, E., & Yusof, N. (2017). The Green Manufacturer's Compliance With Green Criteria Throughout the Life Cycle of Building Material. *SAGE Open*, 7(3), 1–12. https://doi.org/10.1177/2158244017725446
[11]	Nemerow, Nelson L, Franklin J Agardy, Patrick J Sullivan, and Joseph A Salvato. 2009. Environmental Engineering: Environmental Health and Safety for Municipal Infrastructure, Land Use and Planning, and Industry. John Wiley & Sons.
[12]	Singh, M., Choudhary, K., Srivastava, A., Singh Sangwan, K., & Bhunia, D. (2017). A study on environmental and economic impacts of using waste marble powder in concrete. J*ournal of Building Engineering*, 13, 87–95. https://doi.org/10.1016/j.jobe.2017.07.009
[13]	Stabile, P., Radica, F., Ranza, L., Carroll, M. R., Santulli, C., & Paris, E. (2021). Dimensional, Mechanical and LCA Characterization of Terrazzo Tiles along with Glass and Construction and Demolition Waste (CDW). Recent Progress in Materials, 3(1). https://doi.org/10.21926/rpm.2101006
[14]	Yifru, B. W., & Mitikie, B. B. (2020). Partial replacement of sand with marble waste and scoria for normal strength concrete production. *SN Applied Sciences, 2*(12), 1–11. https://doi.org/10.1007/s42452-020-03716-9
[15]	Zhang, D. (2023). Introduction of Terrazzo from Italy to the United States. International Journal of Frontiers in Engineering Technology, 5(7), 13–23. https://doi.org/10.25236/ijfet.2023.050703

Diesel engine without EGR

Ibrahim Mustafić[1]

1 Head of technical service, Centar za cestovni promet d.o.o.Sarajevo, Bosnia and Herzegovina
sarajevograd11@gmail.com

Abstract

The general progress of human civilization entails various types of pollution as a side effect. Thus, with the increase in the number of inhabitants on planet Earth, the number of motor vehicles inevitably increases. In the world, vehicles with internal combustion engines that use diesel fuel are largely used, especially in cargo programs. This paper presents the author's idea of increasing the combustion efficiency of diesel engines with certain modifications to the engine and exhaust system. It is known that combustion in an IC engine will be good only if it burns fuel and air, in a given air/fuel ratio (approx. 14.7:1), without admixture of exhaust gases from the previous cycle. Through EGR, the current system actually disrupts this combustion ratio and only increases the number of particles that clog the DPF even faster. The main innovation is that the EGR valve is eliminated in the exhaust system, the task of which was to reduce NOx emissions in diesel engines, because the return of a part of the exhaust gases lowers the combustion temperature in the engine. A lower combustion temperature means a reduction in NOx emissions from the IC engine. The second change is to reduce the compression ratio from the current most common 16-19 to 15, 14 or 13. This change also results in a lower temperature at the end of the compression stroke, and therefore a lower final combustion temperature in the IC engine with a reduction in the amount of fuel injected per cycle. The third change is that the IC engine volume in passenger cars does not go below 2,000 cc, with a reduction in the maximum engine speed of approx. 3,500-4,000 min^{-1} (current 5,000-6,000 min^{-1}), and that the channels in the cylinder head are made with gradual transitions from the inlet to the outlet. High-quality surface treatment of that channels is obligatory and that the intake manifold and exhaust manifold have optimal pipe curvature radii in accordance with the well-known recommendations for the hydraulic radius R_h=A/O, with as minimum flow resistance as possible. The fourth change is a new DPF design. Other suggestions can be found in the text of the paper.

Keywords

EGR, DPF, NOx emission, silencer/muffler

1. Introduction

The human desire to protect the environment has become inevitable, especially when considering the increase in the number of people on earth and the increasing needs for the use of motor vehicles for the transport of people and goods. The development of electric vehicles and their greater application in everyday life is conditioned primarily by the development of energy storage technologies (batteries, capacitors, chargers), as well as the infrastructure necessary for the establishment of a network of public chargers, which in their current state are insufficient to meet all the needs of man on earth. Sales of new commercial vehicles by powertrain in 2023 shows that we are far away from wide usage of electric vehicles as shown in Figure 1. [1]

Figure 1 – Sales of new commercial vehicles by powertrain in EU in 2023

Figure 1. also shows that city buses are more convenient to electric technology than other vehicles because of better supply of chargers in urban area.

The main reason for the use of electric vehicles is that their use results in zero emissions of environmental pollution and can be used in urban and rural areas. Secondly, in order to mass use of such vehicles (first, need to lower their price), constant development of IT technology is needed, along with the development of technology for the production of new and lighter materials for the manufacture of both transducers and sensors, as well as for the manufacture of vehicle body structures. In here, the greater support from the government with finances is needed. Third, the design of new, better, lighter and more economical batteries for electric vehicles with a greater range of movement per battery charge. Fourth, is the increase in the number of jobs, with the dosed application of robotization in the production process, where legislation at the European Union level should be included in order to protect human jobs. This protection of jobs should prevent the employer from thinking only about increasing profits, and from introducing robots into the production process too much.

The paper continues with a literature review that presents information on the representation of vehicle types in operation in the previous 4 years in the EU, followed by a methodology with listed ideas that should be undertaken in relation to the topic of this paper, followed by an analysis of the steps with details of what and how, followed by a discussion and conclusion of the paper.

2. Literature review

The market penetration of electric vehicle for each country depends on many factors, like regulatory settings, social acceptance, and its purchase prices. It is expected that EVs' market share in Europe is going to increase over the coming years since delaying disadvantages are assumed to decline at the same time. In that research is applied some model to describe accepted projections. They developed and applied such a model for each of the considered European countries; additionally, they incorporated the effect of political decisions forbidding the sale of conventional cars from a certain year. Some functions were parameterized for each country based on expert judgments considering both the current number of EV registrations and the economic conditions of the included countries. The number of EVs in Europe reaches approximately 159 million in 2050 in mid-trajectory, which corresponds to about 56% of the passenger car fleet of the corresponding country groups in 2019 (European Automobile Manufacturers Association, 2021). Germany, the UK, and France will have the highest number of EVs in 2050. In contrast to the unregulated situation in Germany, France and the UK proscribe sales of conventional combustion cars from 2035 to 2040, respectively. Correspondingly, the number of EVs in 2050 is rather independent of the considered trajectory in these countries. Overall, EVs are mainly registered in North-western Europe in line with the socio-economic characteristics of these countries. Integrating EVs in an electricity market modelling framework poses several challenges. Notably, there are three major uncertainties that influence the impact of EVs on the electricity system:

- The EVs' market penetration and the total capacity of their batteries
- The driving behaviour and thus the temporal consumption patterns of individual EVs
- The availability to charge (i.e., being connected to the grid) as well as the charging (and discharging) power of EVs. [2]

Contrary to expectations, looking at Figure 1 shown in the introduction, it can be concluded that the mass use of electric vehicles is much lower than we would like to. Therefore, and until these changes for the better, it is necessary to try to improve the currently most common diesel engine in motor vehicles, so that its use results in the lowest possible emissions of exhaust gases.

Analysing the results of CO_2 emissions [3] based on available technologies applied on the market of internal combustion engine vehicles (ICEVs) for new vehicles in EU as

shown in Figure 2 it's that emission are still high and far from the desired limits which have been changed (postponed) when 2018/2019 emission testing changed from NEDC[1] to WLTP[2] [4] and RDE[3]. [1], [5]

Therefore, it is necessary to try to "improve" ICEs (both diesel and gasoline) so that the fuel burned in them produces as little exhaust gases as possible. This paper is an attempt in that direction.

Figure 2 also shows that for new vehicles PHEV technology shares about 9%, HEV about 10%, BEV about 16%, Diesel about 18% and Petrol shares about 47% in 2023 in EU. Knowing that PHEV and HEV vehicles also runs on internal combustion engine big proportion of time, then it can be realised that in 2023 on EU roads were added 84% (PHEV+HEV+Diesel+Petrol) of vehicles that produces exhaust emission.

Also, that situation confirms an estimated vehicle fleet that is in 2023 in circulation on Europe's roads of approximately 285.8 million vehicles including 249 million cars and 36.8 million commercial vehicles and buses (30.1 million vans, 6 million medium and heavy commercial vehicles, 679,802 buses). Despite battery-electric cars making a big progress on EU market, they only represent 1.8% of passenger cars on EU roads, showcasing just how further EU government must go to make zero-emission mobility a reality. The number of vans, trucks, and buses on roads is also rising and buses lead the way, with almost a 2.5% share being battery-electric vehicles. [6]

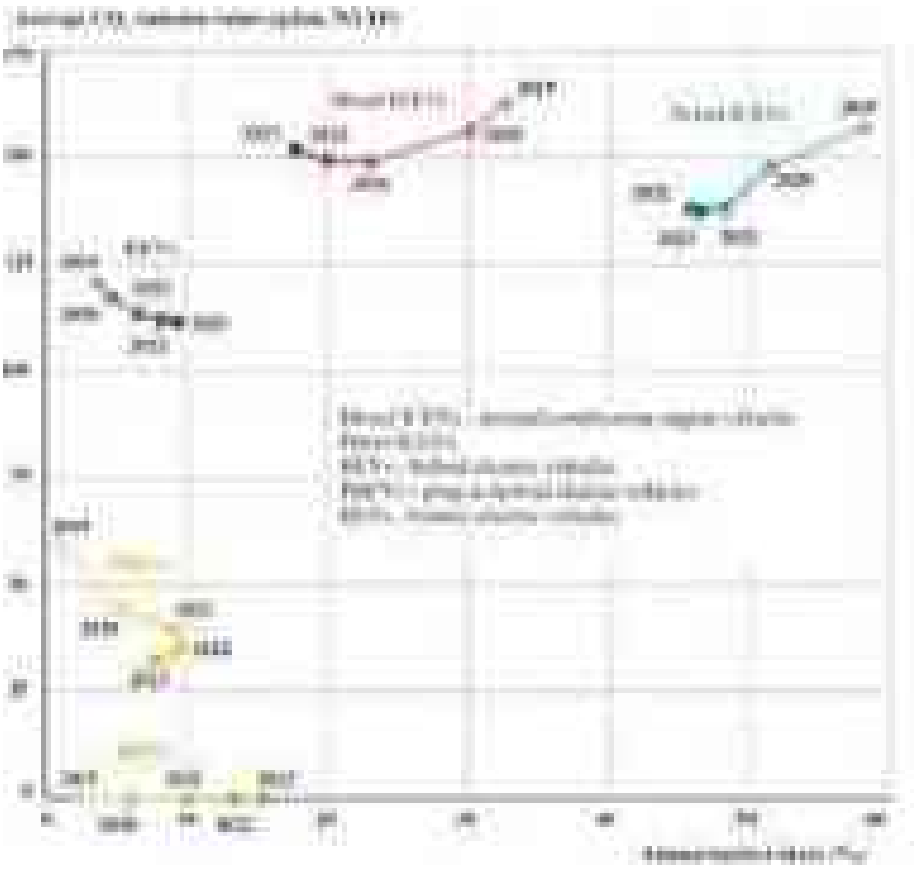


Figure 2 – Annual average CO2 emissions and market share per fuel and powertrain technology in EU for new vehicles, 2019–2023

[1] NEDC – New European driving cycle; Old lab test procedure
[2] WLTP – Worldwide Harmonised Light-Duty Vehicles Test Procedure is laboratory test. It replaces the previous NEDC standard, providing more realistic and standardized data on vehicle fuel consumption and CO2 emissions for consumers and manufacturers
[3] RDE – Real Driving Emissions is reliable emissions tests in real driving conditions

It is known that combustion in an IC engine will only be good if it burns air and fuel, in a given air/fuel ratio (approx. 14.7:1 or λ=1), without the addition of exhaust gases from the previous cycle. The recommendations given in this paper primarily applies to diesel engines, but the same analogy can be applied to gasoline (petrol) engines as well, especially gasoline direct injection engines (GDI). In order to reduce exhaust emissions, motor vehicle manufacturers have started by reducing engine displacement to around 1000 cc and adding turbochargers to obtain high-rpm engine power that meets the needs of customers. This high-rpm engine power comes at a price, and that is higher exhaust emissions (NOx, soot, ...).

The possibility of increasing engine power can be analysed through the expression for the effective engine power P_e (W), which is [7]:

(1)

were:

P_e (W) – effective engine power is the power which engine delivers to the flywheel,
p_e (N/m^2) – the mean effective pressure in cylinder,
n (s^{-1}) – engine speed,
T – number of strokes (2 or 4),
V_H (m^3) – displacement of one cylinder,
z – total number of cylinders in engine.

From expression (1) it can be concluded that there are 3 parameters on the basis of which the desired engine power can be obtained, namely the total engine displacement ($z \cdot V_H$), the mean effective pressure (pe) ($p_e = p_i - p_m$, p_i – mean indicated pressure in the cylinder, p_m – mean pressure of mechanical losses in the engine) and the engine speed (n).

Engines with a small displacement (e.g., 1,000 cc) can obtain greater power by increasing the compression ratio (ε), increasing the amount of fuel burned in one cycle (which causes an increase in the mean effective pressure p_e) and increasing the engine speed (n).

Diesel engines have a higher compression ratio compared to gasoline engines and it currently most often ranges from ε=15-19 for diesel and ε=9-12 for gasoline engines.

A higher compression ratio in combination with a larger amount of fuel per cycle causes greater mechanical and thermal stresses in IC engines. This results in thicker engine block walls, a larger engine cooling system, and a larger engine lubrication system, which contributes to an increase in the total vehicle mass, which is unfavourable because the vehicle's performance is then reduced. This also causes high combustion temperatures and high formation of NOx.

In order to reduce NOx emissions in IC engines, the idea was to return a part of the exhaust gases (usually 20-30%) [8] or most often 20-40% [9] back to the cylinder to be burned a second time (Exhaust Gas Recirculation system – EGR). This amount of exhaust gases is mixed with clean air entering the cylinder through intake ports and in this way the combustion temperature in the cylinder is reduced, which results in a NOx reduction.

The usage of EGR after a certain time, causes clogging the intake channels/ports, EGR itself, EGR cooler which causes poor air supplying to the cylinder, which primarily results in an increase in soot emissions from the engine, and also clogs the DPF (Diesel Particulate Filter) faster, as well as a reduction in engine power. The reason for the reduction in engine power is that a clogged DPF prevents the engine from "breathing" normally, increasing the engine's thermal load because the heat from the exhaust gases

is retained in the engine compartment, thereby placing additional strain on the entire engine (e.g., all moving parts in the IC engine, as well as the lubrication system and cooling system in the engine, which further reduces the engine's service life). [10]

3. Methodology

The following actions need to be taken on the diesel engine for its better functioning – reducing exhaust emissions:

- Reducing compression ratio,
- Increase the displacement of the IC engine,
- Remove the EGR and all the equipment with it from the IC engine,
- New DPF design,
- New silencer/muffler design.

All of these actions are the ideas of the author, and need to be proven in laboratory test, and everyone are allowed to do so.

4. Analysis of the steps

Here will be presented more detailed information about every idea mentioned in previous methodology.

4.1. Reducing compression ratio

In diesel IC engine reduce compression ratio (ε) from the current most common 16-19 to 13-15, which will directly affect the reduction of the material required for the production of the engine block and cylinder head, and in addition, it is proposed to reduce the amount of fuel per cycle so that the fuel can burn as well as possible. That will cause lower temperature at the end of the compression stroke (Figure 3.) and because of that reducing the temperature at the end of the combustion process in cylinder. The consequence of these measures is lower NOx production, and a smaller cooling system and a smaller lubrication system will be required. And all this leads to lower material consumption and ultimately a lighter car, which increases its performance for the same engine power. [11]

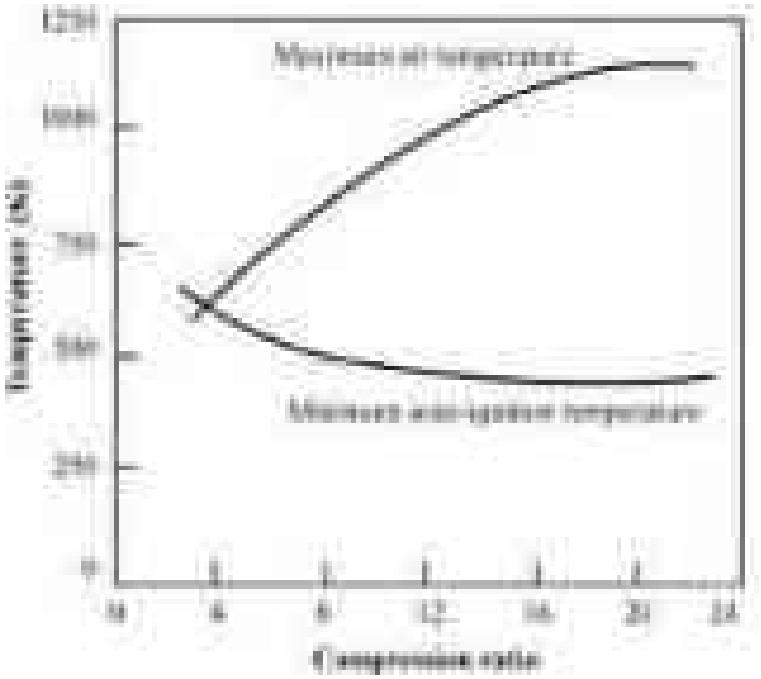


Figure 3 – Effect of compression ratio on maximum air temperature and minimum auto ignition temperature

4.2. Increase the displacement of the IC engine

The displacement of IC engines in passenger cars should not go below 2,000 cc, with a reduction in the maximum speed so that the maximum value is approx. 3,500-4,000 min^{-1} (current 5,000-6,000 min^{-1}).

It is necessary for manufacturers of motor vehicles for everyday vehicles to focus on obtaining enough power from the IC engine, which, in combination with the transmission (e.g., i_1=4, i_2=3, i_3=2.1, i_4=1.4, i_5=0.9, i_{MT}=4, r_D=0.35 m) (i_1-i_5 – gear ratios in the gearbox, i_{MT} – gear ratio of the main transmission, r_D – dynamic radius of the average tire for passenger car) can be delivered to the drive wheels of the car with the lowest possible exhaust emissions. At the same time, maximum speeds should not be the focus of general attention, because maximum speed on the highway are most often limited to 130 km/h, and therefore vehicles with maximum speeds over 150 km/h do not make sense, except that they contribute to an increased risk of traffic accidents. Those who like high speed cars, that's what sports-oriented vehicles are for.

This change allows more time for one cycle in the cylinder to be completed (better combustion), which results in exhaust emission reduction (primarily less NOx). With a reduced compression ratio and lower engine speed, the engine will be less thermally exposed (less heating of the piston, piston rings, cylinders, ...).

Also, channels in the cylinder head should be made with gradual transitions from the inlet to the outlet. High-quality surface treatment of that channels is obligatory and that the intake manifold and exhaust manifold have optimal pipe curvature radii in accordance with the well-known recommendations for the hydraulic radius Rh=A/O (where A is the cross-sectional area of the flow and O is the wetted perimeter), with as minimum flow resistance as possible.

4.3. Remove the EGR and all the equipment with it from the IC engine

EGR and its additional installation further complicates and increases the mass of the engine and the vehicle, but so far it has served to reduce NOx emissions in diesel engines (also in gasoline direct injection (GDI) engine). However, by enlarging engine displacement and reducing the engine speed rpm, the conditions are created for a smaller amount of fuel to be burned per cycle and for more time to be available for better combustion of the air/fuel mixture (λ) thereby reducing NOx.

It is known that diesel engines generally operate with excess of air, i.e., they operate in the range λ>1, where the largest amount of NOx is formed, shown in Figure 4. [12] It need to be considered that the mass air flow sensor (MAF) measures the amount of air that enters the cylinder and the engine ECU regulates the amount of fuel injected in one cycle according to that information. Over time, MAF sensor becomes dirty and it reads a smaller value of air than actually enters the cylinder, which causes the aforementioned problems in diesel and GDI engines.

Figure 4 – NOx-soot map of conventional Diesel, PPCI, and HCCI combustion

4.4. New DPF design

It is proposed that the openings/channels in the DPF (Diesel Particulate Filter) should not be flat as it is now, but that a recess be made in several places into which soot particles can fall, so that there is always a part of free space for exhaust gases to pass through the DPF. On this way the IC engine could operate better (Figure 5.). It is additionally proposed to examine all combinations when the walls are porous and the end wall is porous, but also to examine the behaviour of the DPF when the walls and the end wall of the DPF are not porous. And just as important is that the entire DPF is heated with a special electric heater (AC/DC) so that it is always ready to "burn" the soot particles contained in it.

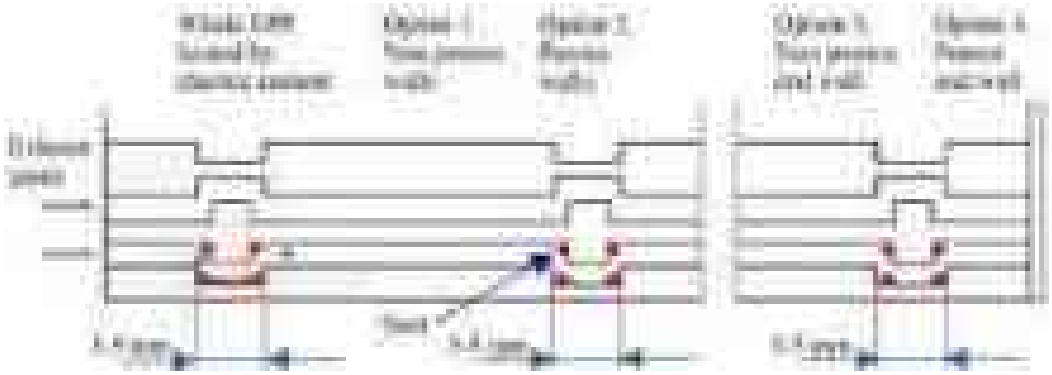


Figure 5 – New DPF design

In this way, the DPF could perform the regeneration function without additional fuel consumption (because even that fuel, when burned creates new soot particles).

To remember, there are two ways of DPF regeneration during IC engine operation, which is passive and active regeneration.

Passive DPF regeneration is performed during a long drive on an open road or highway, by stable driving at an increased engine speed, and active DPF regeneration is initiated by the vehicle's ECU based on a certain pressure drop limit on the DPF.

In both cases, DPF heating is performed through increased fuel consumption, which is partly burned in the DPF itself. It would be optimal that entire DPF were heated evenly in the axial and radial directions, so that all soot would be removed during the regeneration process, but this is currently not possible. [13]

4.5. New silencer/muffler design

In the rear silencer/muffler, a new design is proposed, shown in Figure 6. In the central part of the silencer, there are obstacles that serves to reduce the intensity of the noise produced by the exhaust gases and reduces its speed. The outer part of the silencer is divided into several parts with passages that are spirally arranged with the intention of forming a swirl effect and creating a negative pressure at the exit of the silencer, in order to improve the flow of exhaust gases and to remove them from the IC engine as quickly as possible.

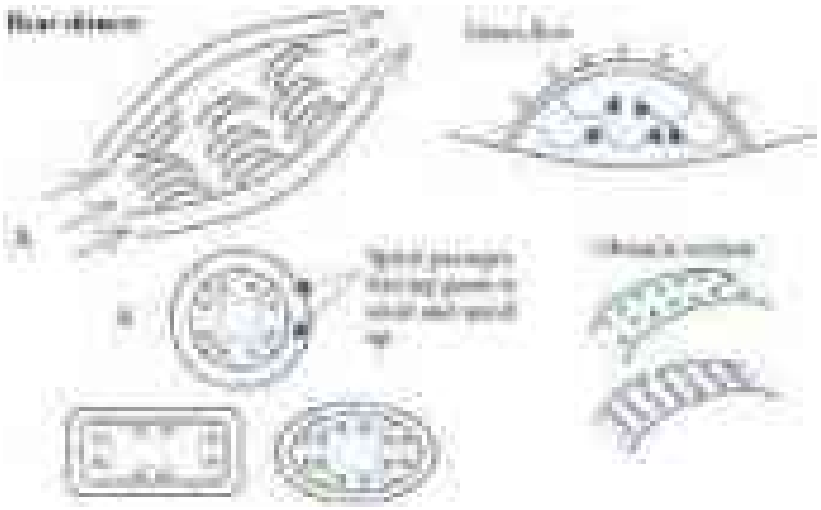


Figure 6 – New silencer design

5. Discussion

Based on the information presented in the literature and the well-known problems of clogged DPF and EGR, now is the ideal time to explore something new. It is necessary to examine a new approach to diesel engine operation (chapter 4.), which should result in lower NOx emissions. This NOx would still be treated in the catalyst with AdBlue fluid.

In addition, a new DPF design and a new silencer design are presented, all of which are ideas from the author.

This paper presents ideas, which should be applicable maybe with slightly design corrections, which the author believes should be useful for diesel and gasoline engines. Anyone interested can use this information.

6. Conclusion

The main reason for the ideas presented in this paper is that in the last few years one can often see on the web comments about problems related to DPF and EGR in diesel engines. Most of these EGR valves, their coolers, and air intake ducts are very dirty with grease and soot particles. And as soon as the EGR is dirty, too much soot enters the cylinder, which disrupts normal combustion, and thus the DPF clogs even faster. Knowing the principle of operation of the IC engine, the author came to a conclusion and suggested several items that motor vehicle manufacturers should examine in order to improve the operation of diesel engines.

The author didn't make any laboratory or computer model testing of suggestions mentioned in this paper, but really believes that it could be useful in diesel or petrol engine and everyone are allowed to do so.

Literature

[1]	EUROPEAN VEHICLE MARKET STATISTICS, *"Pocketbook 2024/25"*, The international council on clean transportation, January 2025, p.3-4
[2]	https://theicct.org/publication/eu-co2-standards-cars-vans-may23/ (accessed 20.08.2025)
[3]	https://unece.org/transport/documents/2021/02/standards/un-regulation-no-154-worldwide-harmonized-light-vehicles-test
[4]	https://unece.org/transport/documents/2024/03/standards/un-regulation-no-168
[5]	European Automobile Manufacturers' Association (ACEA), *"VEHICLES ON EUROPEAN ROADS"*, January 2025, p.3-4
[6]	https://www.scribd.com/doc/176824495/Mahalec-Luli%C4%87-Kozarac-Motori-s-unutarnjim-izgaranjem0 (accessed 20.08.2025)
[7]	*Effect of Exhaust Gas Recirculation (EGR) on Performance and Emission characteristics of a Three Cylinder Direct Injection Compression Ignition Engine*, December 2012, Alexandria Engineering Journal 51(4): 241–247, doi: 10.1016/j.aej.2012.09.004
[8]	*Effect of Exhaust Gas Recirculation (EGR) on Performance and Emission characteristics of a Three Cylinder Direct Injection Compression Ignition Engine*, December 2012, Alexandria Engineering Journal 51(4):241–247, doi: 10.1016/j.aej.2012.09.004
[9]	Rak H. S., Haeng M. c.: "A study on engine performance of EGR valve problem in Hybrid vehicles", September 2015, Journal of Energy Engineering 24(3):34-39, doi: 10.5855/ENERGY.2015.24.3.034
[10]	Gerald B., Roland B., Christoph W.: "The impact of electric vehicles on the future European electricity system – A scenario analysis", House of Energy Markets and Finance, University of Duisburg-Essen, Universitätsstr. 12, 45141, Essen, Germany, https://doi.org/10.1016/j.enpol.2021.112751
[11]	Barh A. M.: *"Lecture notes in engine design"*, February 2024, doi: 10.13140/RG.2.2.35721.21609
[12]	Miao X., Zhang G, Ju Y., Wang X., Hong J., Zheng J., Qiao X., Huang Z.: *"Study on Premixed Combustion in a Diesel Engine with Ultra-Multihole Nozzle"*, Hindawi Publishing Corporation, Journal of Combustion, Volume 2011, 2011, Article ID 471648, 16p., doi: 10.1155/2011/471648
[13]	*Experimental Study and Numerical Interpretation on the Temperature Field of DPF during Active Regeneration with Hydrocarbon Injection*, April 2018, SAE Technical Papers, doi: 10.4271/2018-01-1257

Adoption of Artificial Intelligence in the Economy and Business

Jonida Bekteshi[1]

Zhaklina Dhamo[2]

1 Doctor, Department of Finance and Banking, University of Luarasi
jonida.bekteshi@luarasi-univ.edu.al

2 Doctor, Department of Finance and Banking, University of Luarasi
zhaklina.dhamo@luarasi-univ.edu.al

Abstract

Over the past few decades, technological innovation has reshaped the foundations of economies and transformed how businesses operate in a digital and interconnected environment. Among the most influential developments, artificial intelligence (AI) has emerged as a decisive factor, evolving from a theoretical concept into a practical and widely implemented tool. AI refers to the ability of machines to perform tasks requiring human intelligence, including data-driven learning, reasoning, and autonomous decision-making.

The integration of AI into economic and business practices has generated significant improvements in productivity, operational efficiency, and cost reduction. By automating repetitive processes and enhancing analytical capabilities, AI empowers organizations to respond more effectively to market changes and develop innovative strategies. Beyond efficiency, AI adoption creates new opportunities for competitive advantage, disruptive business models, and long-term growth.

At the macroeconomic level, AI is driving structural transformations, influencing labor markets, and redefining the skill sets required for future employment. While these developments offer considerable potential, they also present challenges related to ethics, data governance, regulation, and social inclusivity. Businesses and countries that invest in AI are more likely to maintain competitiveness and resilience, whereas those that lag risk diminished relevance in the global economy. As AI technologies advance further, their role in shaping both organizational strategy and economic development will intensify, making it essential to design approaches that balance innovation with responsibility, inclusiveness, and sustainable progress.

Keywords

Artificial Intelligence, Economic Transformation, Business Innovation, Data Analysis, Automation.

1. Introduction

Recent developments in artificial intelligence (AI) have enabled machines to perform tasks traditionally associated with human cognition, such as data analysis, pattern recognition, forecasting, and strategic decision-making. Within organizational contexts, AI contributes to enhanced operational efficiency by automating complex workflows and tailoring services to meet individual customer needs. To fully capitalize on the transformative potential of AI, organizations must invest not only in technological infrastructure but also in cultural adaptation. This includes fostering digital competencies among employees, encouraging critical thinking, and promoting meaningful interaction with intelligent systems.

2. Research Objective

The primary objective of this study is to examine how artificial intelligence is transforming business practices and economic structures, to identify the challenges and opportunities it presents, and to assess the level of its adoption within the region.

3. Research Methodology

This study employs a mixed-methods approach, combining qualitative and quantitative analyses to examine AI adoption in the economic and business sectors of the Western Balkans. Data were collected from international reports, media articles, regional statistics, national strategies, and academic studies. The literature review covers peer-reviewed journals, conference proceedings, and book chapters up to 2025, ensuring a comprehensive overview of regional AI trends and challenges.

4. Applications of Artificial Intelligence in the Economy and Business

AI has become a key driver of economic development and business practices worldwide, enhancing efficiency, reducing costs, and supporting strategic decision-making (Zakaria & Mohammed, 2025). AI enables process automation, advanced data analysis, and improved decision support, reshaping global business landscapes.

In the Western Balkans, adoption varies across countries. Albania and Serbia show notable progress in practical implementations and national strategies, while other nations remain in early phases. Key sectors include public administration, healthcare, education, and industry.

Challenges persist, such as limited technological infrastructure, a shortage of skilled workforce, and insufficient legal frameworks. To leverage AI's full potential, policymakers must focus on sustainable development, invest in education and innovation, and promote regional cooperation. These measures are essential to foster effective AI utilization and drive economic growth in the region.

Table 1 – Various sectors using AI in the Balkan Region

No.	Sectors of AI services	Scope of use	Balkan Region
1.	**Public administration and government services**	Automation of services; Procurement management and the fight against corruption; Optimization of the decision-making process;	**Albania / Serbia**
2.	**Healthcare**	Used in diagnosing diseases with the help of AI; Analyzing medical data for more effective treatments. Telemedicine and remote monitoring;	**North Macedonia/ Bosnia & Herzegovina**
3.	**Agriculture**	Crop monitoring and production optimization; Weather forecasting and natural resource management; Automation of agricultural processes for increased efficiency.	**Serbia**
4.	**Education and training**	Intelligent and adaptive learning platform; Content personalization and automatic assessment; Training for the development of digital and AI skills;	**Albania/ North Macedonia**
5.	**Business and Industry**	Automation of production and logistics processes; Market analysis and digital marketing; Customer management and customer services (chatbots);	**Albania / Serbia**
6.	**Finance and Banking**	Risk analysis and fraud prevention; Banking automation and customer support; Financial markets and trading algorithms;	**Bosnia & Herzegovina**
7.	**Energy and Environment**	Energy network management and consumption optimization; Monitoring of air quality and natural resources; Renewable energy and environmental sustainability projects;	**Montenegro / Serbia**
8.	**Security and Defense**	Security monitoring and crime prevention; Cyber threat detection; Data analysis for civil protection and emergencies;	**Albania / Serbia**

5. Benefits and Challenges of Artificial Intelligence in Economics and Business

AI presents significant opportunities for growth, innovation, and efficiency in modern economies and business practices (Al-Mamary, 2025). By enabling process automation, advanced data analytics, and strategic decision-making, AI is reshaping production models, service delivery, and overall market behavior.

Key benefits of AI adoption include enhanced:

1. Enhanced operational efficiency
2. Improved decision-making and strategic support

3. Personalized customer experiences
4. Cost reduction
5. Development of innovative business models
6. Better risk management
7. Facilitation of labor market transformation
8. Automation of routine tasks
9. Analysis of large datasets for informed strategies and consumer forecasting

Despite these benefits, AI adoption also presents challenges, including ethical considerations, workforce impacts, and technical complexities in implementation and integration. Balancing technological advantages with social responsibility, digital equity, and ethical practices is essential to ensure sustainable and effective AI utilization.

Overall, AI is becoming a critical enabler of digital transformation, competitiveness, and long-term economic growth, highlighting the need for strategic planning and investment across both public and private sectors.

Figure 1 – Challenges related to AI in the economy and business

AI adoption presents significant social, ethical, and institutional challenges, including job displacement, skill shortages, data privacy risks, and algorithmic biases. These issues require coordinated responses and clear policies to ensure responsible use. A balanced approach that manages risks while promoting equitable benefits is essential. Collaboration among public institutions, private enterprises, and academia is crucial to foster economic growth, transparency, and long-term sustainability.

6. Adoption of Artificial Intelligence in Business and Economy across the Balkans (2020–2025)

The comparative table presents an overview of the development and integration of AI in the economic and business sectors across five Balkan countries. Generally, AI adoption in the Balkans remains in its early stages, with varying degrees of progress among the countries. Between 2020 and 2025, Balkan states have made diverse efforts to incorporate AI into their economies and business environments, yet the level of advancement differs considerably.

Albania is making significant progress, especially regarding AI use in business and the development of human capacities through IT professional training. However, challenges persist, including the lack of specific legislation and infrastructural issues in certain areas. Serbia leads the region with advanced national AI strategies, well-developed digital infrastructure (including 5G), and a strong startup ecosystem supported by investments.

Countries such as Montenegro, North Macedonia, and Bosnia & Herzegovina have experienced slower growth due to structural challenges, limited expertise, and low investment levels. This is largely due to the absence of clear AI strategies, shortages in skilled professionals, and insufficient financial support.

The Balkan region faces several challenges that slow the integration of AI into the economy and private sector. One major obstacle is the lack of clear and well-implemented AI development policies, which creates institutional uncertainty and a lack of long-term vision. Another significant issue is the shortage of qualified human resources, as many countries suffer from a deficit of experts in technology and AI, making sustainable development difficult.

Table 2 – Adoption of Artificial Intelligence in Business and Economy across the Balkans (2020–2025)

Country **Aspects**	**Albania**	**Montenegro**	**Serbia**	**North Macedonia**	**Bosnia & Herzegovina**
Implementing AI technologies in Business	Approximately 12% of businesses use AI	Around 5-7% growth trend	8-10% more developed regionally	5-7% slow growth	4-6% Minimal utilization
National Strategy and Policy	Digital strategy and EU initiatives	There is a strategy in development	International strategy and active AI	National strategy for digitalization	Emerging stage without a solid plan
Digital Infrastructure	Significant improvement 4G/5G in development	Stable connectivity and infrastructure in progress	Very developed, 5G in some cities	Gradual improvement	Unstable infrastructure
Human Capacities	More IT professionals are coming out of universities	Significant lack of experts	Stronger universities and training	Improving despite a lack of experts	Lack of advanced skills
Private Investments/Startups	Private investments are increasing, and startups are growing	Lower investment level	More developed ecosystem, large investments	Small investments	Minimal investment
Adoption of New Technologies	Swift implementation of AI and data analytics	Slow adoption	Good adoption, wide use of AI in companies	Limited adoption	Slow adoption
Major impediments	Insufficient statutory framework and physical infrastructure in specific areas	Human and financial capacities	Bureaucracy and the cost of technologies	Lack of funds and experts	Weak infrastructure and support

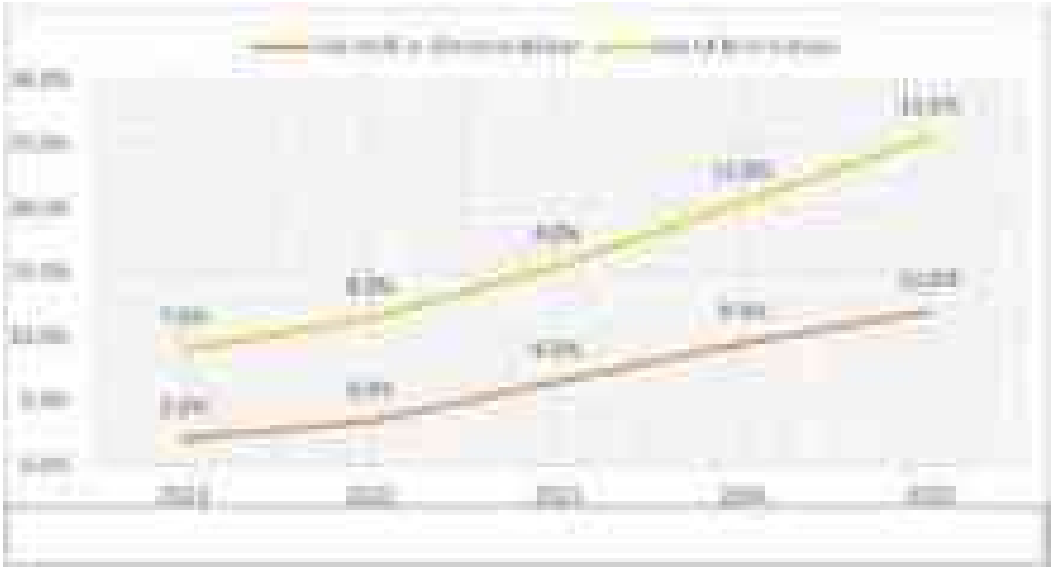
Graph 1 – Use of AI in Economy & Business in Western Balkans

AI is gradually transforming economies and businesses in Albania, Serbia, Montenegro, Bosnia and Herzegovina, and North Macedonia. Adoption rates are 5–12%, mainly among larger, tech-driven companies (RCC, 2023). Businesses use AI for data analysis, customer management, task automation, and operational efficiency, while the public sector explores digital governance. Challenges include limited infrastructure, skill shortages, and regulatory gaps, which governments are addressing through education, incentives, and the development of ethical frameworks. AI adoption is essential for enhancing competitiveness, innovation, and economic growth in the region.

Graph 2 – Use of AI in Economy & Business in Europe

AI is transforming European economies and businesses, with 13.5% of EU companies using AI by 2024, especially in information and communication (Eurostat). Businesses apply AI for data analysis, customer service automation, predictive maintenance, and marketing optimization. The European Commission promotes AI through policies, funding, and research initiatives, led by countries like Germany, France, and the Netherlands.

Challenges include skill shortages, limited data access, and regulatory and ethical concerns. AI adoption continues to enhance efficiency, innovation, competitiveness, and the future growth of European markets.



Graph 3 – Comparison between the Western Balkans and Europe in AI use

AI adoption is higher in the EU (13–14% of companies) due to strong infrastructure, skilled professionals, and clear regulations, especially in ICT, finance, and manufacturing. In the Western Balkans (5–12%), adoption is mainly among larger firms, while smaller businesses face infrastructure, skill, and regulatory challenges. Regional initiatives and national strategies promote education, pilot projects, and ethical frameworks. Strategic investments in infrastructure, talent, and regulation could help the Western Balkans close the gap. AI has the potential to drive economic growth, innovation, and long-term regional transformation.

7. Conclusions

AI has numerous practical applications in the economic and business sectors, reshaping operations, decision-making, and customer engagement. It enhances efficiency, fosters innovation, and strengthens competitiveness. However, AI integration also poses challenges requiring careful attention from policymakers, business leaders, and academics. Ensuring equitable and sustainable benefits demands a balanced approach that addresses associated risks. The Balkan region has significant potential for AI development, but realizing it requires strategic planning and close regional cooperation.

8. Recommendations

First and foremost, each country should develop and implement clear national strategies that define the directions and priorities for the development of Artificial Intelligence (AI). Equally important is investment in education and vocational training, aimed at strengthening human capital and preparing a skilled workforce to meet the demands of the evolving technological market.

In addition, creating a favorable environment for attracting private investment is essential. This can be achieved by supporting startups and establishing innovation incubators. Another key priority is the enhancement of digital infrastructure, particularly in underdeveloped areas, to ensure equitable access to technology across regions.

Finally, the development of a comprehensive legal and policy framework is crucial to ensure the safe, ethical, and efficient use of AI. Such a framework would contribute to building a sustainable and trustworthy ecosystem for technological advancement throughout the region.

Literature

[1] Leka, A., & Shyti, E. (2020). *Ethical Considerations in the Use of AI in Albania's Public Sector*. Balkan Journal of Ethics and Technology.

[2] Meta, D., & Xhafa, F. (2021). *Application of AI in the Albanian Economy: Challenges and Opportunities*. International Journal of Economics and Technology.

[3] Lityaykina, A. I. (2021). Artificial intelligence and its role in human life. *Kontentus, 3*, 34–42. https://doi.org/10.24412/2658-6932-2021-3-31-37

[4] Zhang, C., & Lu, Y. (2021). Artificial intelligence and economic growth: A review of recent literature. Technological Forecasting and Social Change, 165, 120533.

[5] Korinek, Anton & Stiglitz, Joseph. (2021). Artificial Intelligence, Globalization, and Strategies for Economic Development. SSRN Electronic Journal. 10.2139/ssrn.3785787.

[6] Hoxha, E., & Caka, S. (2022). *The Impact of Artificial Intelligence on Digital Transformation in Albanian Public Administration*. Journal of Digital Innovation.

[7] Vitvitskaya, O. V., & Tarasova, T. V. (2022). The impact of artificial intelligence technologies on the economy and business. *International Journal of Applied Science and Technology "Integral"*, 5, 1509–1522.

[8] World Bank (2022) – "Digital Economy Assessment: Albania".

[9] Kolleshi, M., & Golemi, E. (2023). *Impact of Artificial Intelligence on the Albanian Banking System*. Interdisciplinary Journal of Research and Development, 10(2), 105–113.

[10] Dialogo AI. (2023). *Albanian AI-powered communication platform*. Retrieved from https://f6s.com/company/dialogo

[11] Kuzin, M. A. (2023). Assessing the impact of AI development on the financial sector of the economy. *The Eurasian Scientific Journal*, 15(4), 118–123

[12] Melnik, O. V. (2023). Artificial intelligence and its application in economics. *International Scientific Journal "Vestnik Nauki,"* 4(12), 1121–1127

[13] OECD (2023) – "AI adoption and the digital transformation in SMEs".

[14] UNDP Albania (2023) – "Digital transformation and inclusion: Opportunities and barriers in Albania"

[15] Tugar-ool, P. E., Saaya, A. A., & Mongush, D. O. (2024). The impact of artificial intelligence on the global economy. *Modern Scientific Research and Innovations, 1*(153), 65–72.

[16] BalkanEngineer. (2024). *Shqipëria investon 10 milionë euro në startup të inteligjencës artificiale*. Retrieved from https://balkanengineer.com

[17] INSTAT & AKEP (2024) – Raporte vjetore mbi përdorimin e internetit dhe shërbimeve digjitale në Shqipëri

[18] European Commission (2021-2024) – "AI Watch" dhe "Digital Economy and Society Index (DESI)"

[19]	MIA (2024). *Transformimi i administratës publike përmes inteligjencës artificiale*. mia.gov.al
[20]	UAMD & LAIA Project (2024). *Zhvillimi i laboratorëve të inteligjencës artificiale në Shqipëri*.
[21]	Hasan, R., & Ojala, A. (2024). *Managing Artificial Intelligence in International Business: Toward a Research Agenda on Sustainable Production and Consumption*. Wiley Online Library.
[22]	Olson, P. (2024). *Supremacy: AI, ChatGPT and the Race That Will Change the World*.
[23]	Gondauri, D. (2025). *Deciphering the AI Economy: A Mathematical Model Perspective*. arXiv.
[24]	IMF. (2025). *The Global Impact of AI: Mind the Gap*. International Monetary Fund.
[25]	Zakaria Mohammed, M. M. (2025). *Artificial Intelligence Applications in Economics: Opportunities and Challenges*. Posthumanism Journal
[26]	Sunki, Rakesh & Dendi, Naveen. (2025). Redefining Work and Leisure in the Age of AI: A Theoretical Framework. European Modern Studies Journal. 9. 122-128. 10.59573/emsj.9(4).2025.13.

Assessment of pollution load from coal mines on the Modrac multipurpose water reservoir: ecological and socio-economic implications

Maja Kin[1]

Zvjezdan Karadžin[2]

Edisa Nukić[3]

Jelena Marković[4]

1	MSc CE, JP "Spreča" dd Tuzla *jomaja@gmail.com*
2	Associate professor, Faculty of Mining, Geology, and Civil Engineering, University of Tuzla *zvjezdan.karadzin@untz.ba*
3	Associate professor, Faculty of Mining, Geology, and Civil Engineering, University of Tuzla *edisa.nukic@untz.ba*
4	Full time professor, Faculty of Mining, Geology, and Civil Engineering, University of Tuzla *jelena.markovic@untz.ba*

Abstract

The Modrac water reservoir, located in northeastern Bosnia and Herzegovina, is a vital water resource that supplies industry, agriculture and the population. However, the ongoing mining activities of the Đurđevik and Banovići brown coal mines present a significant pollution burden. This paper systematically analyzes the impacts of wastewater discharges rich in fine coal fractions and heavy metals on the physicochemical characteristics of water and sediment, the hydrological regime and the ecological stability of the reservoir. Using field research, laboratory analyses and hydrological modelling, a significant reduction in the useful volume of the reservoir (about 40% of the designed volume) and deterioration of water quality were confirmed. The research identified critical sedimentation zones and pointed to serious ecological and socio-economic consequences, including the threat to water supply and fish stocks, and the reduction of recreational potential. Specific technical-technological, organisational and administrative measures are proposed to mitigate these impacts and ensure the long-term sustainability of the Modrac reservoir.

Keywords

Modrac reservoir, Đurđevik and Banovići coal mines, water pollution, heavy metals, sedimentation, Spreča river, ecological risk, hydrological modeling

1. Introduction

The Modrac water reservoir, built in 1964 on the Spreča River in Bosnia and Herzegovina, is an essential infrastructural and ecological resource for the Tuzla Canton. Its primary function includes providing water for industrial processes (chemical, thermal energy, mining industries), water supply for the population, flood protection, and recreation and fishing. With an area of approximately 17 km^2 and a maximum depth of 20 meters, the reservoir is of vital importance for regional development and ecological balance.

However, decades of intensive mining activities in its basin, primarily from the Đurđevik and Banovići brown coal mines, pose a continuous threat to its functionality and ecological stability. The coal upgrading processes in these mines, which rely on wet separations, generate significant amounts of wastewater. These waters, rich in suspended coal particles (fractions 0-3 mm) and heavy metals, are discharged directly or indirectly into the Gostelja and Oskova rivers. These rivers are tributaries of the Spreča River, which then transports pollutants directly into the Modrac reservoir, causing significant ecological damage.

This scientific work aims to conduct a comprehensive assessment of the pollution load coming from coal mines to the Modrac multipurpose reservoir. Through a detailed analysis, the work seeks to:

- Identify and quantify key pollutants generated by mining activities.
- Analyze the dynamics of pollutant transport and their impact on water and sediment quality in the reservoir.
- Assess the ecological and socio-economic consequences of reservoir degradation.
- Propose specific technical-technological, organizational and administrative measures to reduce pollution and ensure sustainable management of the Modrac reservoir.

The work is based on a critical analysis of the available literature, the results of field research, laboratory analyses and the application of advanced models, providing a basis for making informed decisions in the field of environmental protection and water resources management.

2. Researched area and characteristics of mining activities

2.1. Location and general characteristic of Modrac reservoir

The Modrac Reservoir is located in the northeastern part of Bosnia and Herzegovina, within the Tuzla Canton, between Lukavac and Živinice. A dam on the Spreča River, built in 1964, created this reservoir. Its key dimensions include an area of approximately 17.1 km^2 and a maximum depth of 20 m in the dam zone. The functions of the reservoir are multiple and vital for the region, including water supply for the population and industry, hydropower, irrigation, recreation and fishing. Priority uses are prescribed by the Law on the Protection of the Modrac Reservoir, with an emphasis on water supply and industrial needs.

Hydrographically, the reservoir belongs to the Black Sea basin. The main tributaries are the rivers Spreča and Turija, with their numerous smaller tributaries, which together form a catchment area of 1189 km^2. The woodiness of the area and the configuration of the terrain (average slope 23%, height difference 211 m) contribute to erosion and the input of sediments. Current estimates indicate that the useful volume of the reservoir has been reduced from the projected 100 million m^3 to around 64 million m^3, which is a consequence of long-term sedimentation. [1] ; [2]

2.2. Brown coal mines Đurđevik and Banovići

The brown coal mines Đurđevik and Banovići represent two key mining operations in this part of the region, with significant production of brown coal.

Đurđevik coal mine: Established in 1936, with an annual production of approximately 500,000 tons. The exploitation is carried out on surface (the "Višća" surface mine) and underground operations. The key problem is the technological process of wet coal separation, where water is used to separate the fractions. The wastewater from this separation, with a share of coal particles of 0-3 mm, is discharged into the Gostelja River. Analysis of the chemical composition of the ash shows the presence of iron, aluminum, calcium and sulfur. The shortcomings of the existing technological process include high water consumption, low energy efficiency of the plant and an insufficiently efficient wastewater treatment system. [3]

Banovići coal mine: One of the largest coal mines in the region, with an annual production of between 1.3 and 1.5 million tons. Like Đurđevik, Banovići uses wet separation, with the wastewater containing fine coal fractions, heavy metals, and even oils. This water is discharged into the Oskova River. The chemical composition of the Banovići coal ash shows the presence of calcium, silicon, iron, and aluminum. It is estimated that about 35,000 tons of fine coal fractions are discharged annually from the Banovići separation, and about 15,000 tons

from Đurđevik, for a total of about 50,000 tons per year into the Modrac reservoir. The shortcomings of the technological process at Banovići are similar to those at Đurđevik, including insufficient separation efficiency, high water consumption, and inadequate tailings management. [4]

2.3. Impact on the hydrography of the basin

The Gostelj and Oskova rivers, after receiving mining wastewater, become significantly polluted and carry this load into the Spreča River. The "Black Spreča", as it is popularly called, brings all this wastewater directly to the Modrac reservoir. The problem has been ongoing for 70 years, culminating in the reservoir, where pollutants settle. Studies indicate that about 80% of the sediments in the reservoir originate from mining activities. [5]; This leads to water turbidity, changes in pH, a decrease in biodiversity and the accumulation of toxic substances.

3. Research methodology

The research was conducted using a multidisciplinary approach, combining field, laboratory, statistical and modeling techniques.

3.1. Data collection and analysis

Water and sediment samples were collected at strategic locations along the Gostelje, Oskova, Spreča rivers and within the Modrac reservoir (tributary mouths, central part, dam zone). Sediment samples (correr and dredge) were taken at several locations in Modrac under the influence of the Spreča river, especially in zones up to 4 meters deep, where sedimentation is most intense. [6]

Visual inspections and observations were conducted at mining separation units, settling ponds and tailings ponds of the Đurđevik and Banovići coal mines.

Physico-chemical parameters of water were then analyzed: pH value, turbidity, electrical conductivity, dissolved oxygen concentration, suspended solids, heavy metals (Fe, Mn, Zn, Cu, Pb, Ni, Cd, As, Mo, Hg), nutrients (phosphorus, nitrogen compounds) and organic/inorganic pollutants. Standardized methods were used, e.g. for heavy metals ICP-MS. [7]

Sediment: Granulometric composition, coal and mineral component content, and heavy metal concentrations were analyzed. Petrographic tests were used to compare samples from the reservoir with those from the coal mine.

Hydrological data: Long-term data on river flow, precipitation and water levels from measuring stations were used, as well as water quality data from the monitoring of the Sava River Basin Agency (period 2011-2021).

3.2. Hydrological modeling and analysis of sediment transport

Advanced software tools were used to model the dynamics of pollutant spread and sediment transport:

ArcGIS: It was used for the preparation of geospatial data, mapping of the reservoir basin and visualization of the spatial distribution of pollution.

ArcSWAT: It is applied for hydrologic-hydraulic calculations. This model simulates hydrological processes on a daily basis for each hydrological unit (HRU) using the soil water balance equation:

Equation 3.1

where:
SWt – total soil water content (mm)
SWo – initial soil water content (mm)
Rday – daily precipitation (mm)
Qsurf – daily surface runoff (m3/s)
Ea – daily evapotranspiration (mm)
Wseep – percolation (extraction) – groundwater level rise (mm)
Qgw – groundwater volume (mm)

Universal equation of soil and sediment erosion (Williams, 1995):

$$sed = 11.80 \times (Qsurf \times qpeak \times areahru) 0.56 \times Kusle \times Cusle \times LSusle \times CFRG$$

Equation 3.2

where:
sed – sediment volume (t/day)
Qsurf – surface runoff volume (mm)
qpeak – peak surface runoff rate (m3/s)
areahru – area of the hydrological unit HRU (ha)
Kusle – soil erosion factor (taken: 0.013 t/ha)
Cusle – land cover and management factor
LSusle – topographic factor
CFRG – coarse fragment factor

3.3. Environmental risk assessment and impact visualization

The Environmental Risk Assessment (ERA) model was used to assess the risks, which systematically identifies, analyzes, and evaluates potential negative impacts. [8] Key elements of the ERA model include:

Hazard identification: Identifying mining waste, 0-3 mm coal, coal dust, and waste rock as sources of pollution.

Exposure analysis: Assessing the contact of the reservoir ecosystem with the identified pollutants.

Consequence analysis: Evaluating the severity of potential impacts such as water pollution, biodiversity loss, and eutrophication.

Risk prediction modeling: Monte Carlo simulations were used to assess uncertainty in the risk model.

4. Results and discussion

4.1. Physicochemical characteristics of water and sediment

Laboratory analyses of water and sediment samples confirmed the significant load of pollutants originating from mining activities on the Modrac reservoir. Table 4.1 clearly shows dramatic increase in suspended matter in the Litva River (a tributary of the Oskovo River) after leaving the Banovići coal mine area; values jumped from 51.00 mg/l to 7874.00 mg/l (11.5.1973), or from 0.61 mg/l to 66.90 mg/l (2010) immediately after the separation outlet. [9]; These high concentrations of suspended matter in the Gostelja and Oskova rivers are directly transferred to the Spreča River and then to the Modrac reservoir. Consequently, there is an increased turbidity of the water in the reservoir, a decrease in the penetration of sunlight and a negative impact on the process of photosynthesis of aquatic plants, which disturbs the primary production in the ecosystem.

Sediment analyses, especially the exploratory drilling shown in Figure 4.2, revealed the accumulation of heavy metals such as iron, manganese, zinc, copper, lead, nickel, cadmium, arsenic and mercury. [7]; Concentrations of mercury (Hg) up to 36 mg/kg in some sediment samples inside the reservoir, as well as in the settling basins of the Banovići mine, are particularly worrying. These discoveries were supported by petrographic tests that confirmed the identity of the mineral components of the sediment samples from Modrac with those from the Đurđevik and Banovići coal mine separations, which unequivocally points to coal mining activities as the main source of pollution. The accumulation of heavy metals in sediments represents a long-term risk, because under anaerobic conditions they can be released again into the water column, entering the food chain and endangering the aquatic ecosystem and human health. Changes in pH values, although not always extreme, indicate anthropogenic pressure and disruption of the natural buffering capacity of the water system.

Table 4.1 – Data on watercourse measurements showing the impact of the Banovići coal mine separation.

Sampling location	Date	Flow (m^3/s)	Suspended matter (mg/l)	Transport (t/dan)
Litva above Banovići	11.5.1973	0.27	51.00	1.21
	1.8.1973	0.09	104.00	0.80
	13.11.1973	0.16	657.00	8.85
	14.2.1974	0.26	88.00	1.95
	2010	0.35	0.35	0.01
Litva below Banovići	11.5.1973	0.38	8.00	0.26
	1.8.1973	0.22	16.00	0.30
	13.11.1973	0.53	18.00	0.82
	14.2.1974	0.47	0.00	0.00
	2010	0.61	0.61	0.03
Litva behind the separation outlet	11.5.1973	0.48	7874.00	329.39
	1.8.1973	0.31	8991.00	241.25
	13.11.1973	0.62	3042.00	163.76
	14.2.1974	0.56	7650.00	370.69
	17.10.1980	0.23	6109.00	121.40
	23.9.1981	0.35	1616.00	49.01
	2010	0.86	66.90	4.97

Figure 4.2 – Location of exploratory drilling spots

4.2. Sedimentation and reduction of storage capacity

One of the most critical long-term impacts of mining activities on the Modrac reservoir is the progressive reduction of its useful volume due to intensive sedimentation. The data from Table 4.3, which compares the morphometric characteristics of the reservoir from 1964 to 2022, dramatically illustrates this trend. The projected volume was 100 million m^3 in 1964, while preliminary data from 2022 is estimated at approximately 64 million m^3. This represents a loss of as much as 36% of the useful storage volume over a period of 58 years. [2]

Table 4.3 – Relationship between measured data in 1964 and data measured in 1985, 2012 and preliminary data in 2022.

	1964.	1985.	2012.	2022.
Surface	17,10 km^2	16,75 km^2	16,69 km^2	16,658 km^2
Total Volume	98 x 10^6 m^3	88 x 10^6 m^3	102 759 630 m^3	102 756 630 m^3
Useful Volume	86 x 10^6 m^3	76 x 10^6 m^3	87 739 727 m^3	87 073 407 m^3
Deposit Volume			15 019 903 m^3	15 686 223 m^3
Maximum Depth	18,0 (10,0) m	18,0 (10,0) m	14,94 m (kota dna)	15,09 m
Average Depth	5,7 m	5,2 m	5,32 m	5,27 m
Maximum Length	10 700 m	10 400 m	10 475,72 m	10 367,33 m
Maximum Width	1 600 m	1 780 m	2 411,17 m	2 294,33 m
Coast Length	33 250 m	31 700 m	42 537,63 m	36 583,25 m

The main cause of this reduction is the continuous intake of small fractions of coal and sludge from the Đurđevik and Banovići mines via the Oskova, Gostelja and Spreča rivers, as well as soil erosion from the catchment area and industrial and municipal waste. Sedimentation is most pronounced in the "dead zones" of the reservoir, such as the mouth of the river Spreča, where a "dead plate" with an estimated area of 4.5 km^2 has already been created. These areas become shallow, muddy and unsuitable for aquatic organisms, and in dry periods they can dry out completely. Quantification of sediment transport by means of hydrological models, as described by equation (3.2), confirmed a significant intake of silt and coal, especially during torrential flows.

4.3. Hydrological, climatic and seasonal influencing factors

Hydrological factors play a key role in the dynamics of pollutant spread and deposition. Although the Modrac reservoir has a relatively high flow rate

Annual average water flows of the main tributaries of Lake Modrac [10]

- Spreča River with Qsr= 13.22 m^3/s
- Turija River with Qsr= 3.08 m^3/s

which allows for a complete water exchange 5-6 times a year, this is not sufficient to prevent the accumulation of pollutants in specific zones. Modelling of the dynamics of pollutant spread has shown that pollution is mostly retained in zones with slower water circulation, such as bays, shore zones and immediate areas of river mouths.

Climatic factors, especially changes in the precipitation regime, further affect the condition of the reservoir. Intense precipitation leads to the leaching of pollutants from mining dumps and eroded soil, increasing the input of suspended solids into the reservoir. In contrast, dry periods cause a decrease in flow, which results in an increase in the concentration of pollutants in the water and favors sedimentation. Seasonal variations also play a role; lower temperatures in winter can slow down the biological processes of pollutant degradation, while high temperatures in summer and reduced water flow favor the formation of anoxic or hypoxic zones, which is extremely harmful to fish stocks and other aquatic organisms. The results of microbiological surveys (e.g. coliform bacteria) show seasonal fluctuations in pollution, with higher levels in summer.

4.4. Environmental and socio-economic consequences

The environmental consequences of pollution are multiple and serious. The long-term presence of pollutants leads to:

- *Ecosystem degradation and loss of biodiversity*: The presence of heavy metals and organic pollutants negatively affects phytoplankton, zooplankton and bottom fauna. Research has shown the poverty of zoobenthos species (dominance of Oligochaeta and Diptera) due to the muddy bottom.
- *Eutrophication:* Increased nutrient input (primarily from agriculture and municipal waters, but also from mining wastewater) contributes to excessive algae growth, which reduces the concentration of oxygen in the water and leads to mass fish kills.
- *Threatening fish stocks:* Detection of toxic substances in fish species and a decrease in the total fish stock has direct economic consequences for fishing.
- *Socio-economic consequences* of pollution directly affect the quality of life of the local population and the regional economy.

- *Water supply:* Increased concentration of pollutants requires more expensive and complex water purification processes for drinking water and industrial use. Industrial users (e.g. Tuzla Thermal Power Plant) face problems of intrusions and shell fractions in pipe transport systems due to polluted water.
- *Recreation and tourism:* Polluted water, unpleasant odors and visually degraded environment drastically reduce the recreational and tourist potential of the reservoir. The fact that there is not a single well-maintained beach on the 41 km of coastline speaks volumes about the problem. The 2025 World Float Fishing Championship, which was held on Modrac, required significant efforts in preparing the lake.
- *Management costs:* Continuous cleaning of the reservoir from floating debris (e.g. on the protective net at the dam) represents a significant operating cost, which, although it does not solve the original pollution problem, maintains minimal functionality.

Visualization of the impact of mining activities clearly shows the chain reaction: mining activities (surface exploitation, tailings, separation units) generate wastewater (fine coal, heavy metals, acid drainage), which leads to pollution of rivers (Spreča, Gostelja, Oskova), and then the Modrac reservoir. The consequences are manifested through sedimentation, eutrophication, loss of biodiversity, and impact on water supply, tourism and agriculture.

5. Measures for pollution reduction and risk management

Based on the conducted research and identified problems, a comprehensive package of measures is proposed to reduce the pollution load and ensure sustainable management of the Modrac reservoir. These measures cover technical, organizational and administrative aspects.

5.1. Recommended technical measures

- ***Modernization of wastewater treatment plants in the Đurđevik and Banovići mines:***

  Physical-chemical treatment: Installation of advanced filter systems (e.g. membrane filters, sand filters, active carbon) for the removal of suspended particles (especially the 0-3 mm coal fraction) and the application of coagulants/flocculants for more efficient removal of heavy metals.

  Biological treatment: Development and implementation of biological treatments (e.g. bioreactors, phytoremediation) for the degradation of organic pollutants.

  Water recirculation: Maximizing the recirculation of process water within mine separation units to reduce the volume of wastewater discharged.

- ***Construction and optimization of sedimentation basins:***

  Establishment of additional, larger and more efficient sedimentation basins near mine separations to maximize the settling of suspended particles before discharge into natural watercourses.

  Regular and systematic cleaning and maintenance of these basins, with adequate disposal of the collected sediment.

- ***Wastewater discharge control:***

  Installation of online measuring stations at all mine discharge points for continuous monitoring of the quantity and quality of discharged water.

  Implementation of automated discharge closure systems (automatic gates) in case the permitted limit values are exceeded.

- ***Stabilization of tailings and industrial waste landfills:***

  Covering landfills with impermeable materials (geo-membranes) and recultivation of degraded areas to prevent erosion and leaching of pollutants into waterways.

  Introducing a system for collecting and purifying leachate from landfills.

- ***Revitalization of the shore zones of reservoirs and tributaries:***

  A forestation and planting of indigenous vegetation in erosion areas along the banks of rivers and reservoirs to reduce soil erosion and filter pollutants before they enter the water.

  Construction of natural filter barriers (wetlands, reed beds) at the mouths of tributaries and in critical zones of the reservoir.

- ***Sediment treatment within the reservoir:***

  Research and implementation of methods for removing contaminated sediment (e.g. hydraulic excavation) from critical zones of the reservoir (e.g. Spreča estuary) or in-situ sediment stabilization to prevent the release of pollutants.

5.2. Organizational and administrative measures

- ***Introduction of stricter legal regulations and standards:***

  Revision and updating of existing legal acts (e.g. Law on Protection of Modrac Reservoir, Law on Waters of FBiH) with the aim of defining stricter limit values for discharges of all types of pollutants from mining and industrial facilities.

  Introduction of the “polluter pays” principle in full, with mechanisms for compensation for damage and financing of remediation activities.

- ***Strengthening inspection supervision and application of sanctions:***

  Increasing the number and frequency of inspection controls of mines and other industrial facilities in the reservoir basin.

  Implementation of stricter sanctions, including high fines, temporary closure of facilities or revocation of operating permits in case of repeated violations of regulations.

- ***Establishment of a specialized body for the management of the Modrac reservoir:***

  Formation of a multidisciplinary body that will include experts in the fields of hydrology, ecology, mining, law and economics, with clear powers and responsibilities for integrated reservoir management.

  Improving coordination and communication between different levels of government (cantonal, municipal), public companies, mines and non-governmental organizations.

- ***Education and awareness programs:***

  Organize continuous educational workshops, seminars and campaigns for local residents, employees in mines and industry, and decision-makers on the importance of preserving the reservoir and the harmfulness of pollution.

  Regularly inform the public about monitoring results, the status of implementation of measures and planned activities.

- ***Development of comprehensive risk management plans:***

  Develop detailed scenarios for emergency interventions in the event of major incidents (e.g. separation accidents, spills of large quantities of pollutants).

  Establish rapid response protocols, including alarms, resource mobilization and public notification.
  Regularly update plans based on new data and risk assessments.

- ***Financial support and incentives:***

  Provide significant financial resources from state, cantonal and municipal budgets for the modernization of treatment infrastructure.

  Explore opportunities to attract international funds and donors for environmental protection projects.

  Introduce tax breaks or subsidies for industrial entities investing in green technologies and pollution reduction.

5.3. Environmental monitoring and monitoring plan

The establishment of a robust monitoring system is key to monitoring the effectiveness of implemented measures and timely recognition of new threats. Suggested:

- ***Continuous online monitoring:***

  Installation of a network of automatic sensors along the rivers (Gostelja, Oskova, Spreča) and inside the reservoir (mouth, center, dam zone) for continuous measurement of key parameters of water quality (pH, turbidity, dissolved oxygen, temperature, electrical conductivity) and concentration of heavy metals.

  Placement of sensors to measure the transfer of sediments at strategic points.

- ***Periodic sampling and laboratory analyses:***

  Regular (monthly, quarterly, annual) sampling of water and sediments from defined locations.

  Extended laboratory analyzes on a wide range of organic and inorganic pollutants, microbiological parameters and specific toxicological analyses.

- ***Monitoring of biological indicators:***

  Systematic monitoring of phytoplankton, zooplankton, benthos and ichthyofauna populations to assess ecosystem changes and pollutant bioaccumulation.

  Identification and monitoring of types of indicators that indicate ecosystem health.

- ***Integrated GIS data management system:***

  Development of a centralized GIS database that will integrate all collected data from monitoring (physical-chemical, biological, hydrological), modeling results and pollutant locations.

  Regular updating of spatial maps of pollution and critical zones.

- ***Seasonal and annual reports:***

  Preparation of transparent and publicly available reports on the state of water quality, sediments and ecosystems, with analysis of trends and comparison with reference values and standards.

- ***Modeling of pollution dynamics:***

  Continued use and calibration of hydrological and transport models (eg HEC-RAS, MIKE 21) to predict the spread and deposition of pollutants, especially under conditions of seasonal changes and extreme hydrological events (floods, droughts).

6. Conclusion and recommendations

The research presented in this paper unequivocally confirms that the mining activities of the Đurđevik and Banovići brown coal mines represent the dominant source of pollution of the Modrac multipurpose reservoir. The discharge of wastewater with fine coal fractions and heavy metals has resulted in a significant deterioration of water quality, the accumulation of toxic sediments and a drastic reduction in the useful volume of the reservoir (as much as 36% loss). These changes have serious ecological consequences, disrupting biodiversity and ecosystem functionality, and direct socio-economic implications, threatening water supply, fisheries, agriculture and recreational potential.

It is concluded that the current protection measures are insufficient and inadequate. The lack of modernized infrastructure for wastewater treatment in mines, weak implementation of regulations, insufficient inspection supervision and a fragmented monitoring system contribute to the continuous deterioration of the situation. Urgent and integrated action by all stakeholders is imperative.

After detailed research, recommendations were made for further multidisciplinary research and action:

- *Research and implementation of advanced treatment technologies:* Focus on the application of innovative solutions such as nanotechnology, phytoremediation and membrane filtration for highly efficient removal of coal fines and heavy metals from mine wastewater.
- *Detailed study of sedimentation dynamics and remediation options:* Quantification of the volume and composition of contaminated sediment and research and testing of methods for its removal (e.g. hydraulic excavation) or in-situ stabilization to restore the useful volume of the reservoir and reduce the risk of secondary pollution.
- *Long-term ecological monitoring and biodiversity research:* Continuous monitoring of ecosystem health, with a special emphasis on bioindicators, genetic monitoring and analysis of long-term toxicological effects of pollution on aquatic organisms and human health.
- *Analysis of the impact of climate change in synergy with mining pollution:* Development of more sophisticated models that will predict the cumulative effects of increased frequency of extreme precipitation and dry periods on the spread and concentration of pollutants in the Modrac reservoir.
- *Economic-political analysis and feasibility studies:* Quantification of economic losses caused by reservoir degradation and assessment of the economic justification of proposed measures, taking into account investment costs and long-term benefits for the community and industry. It is necessary to develop financial models that will include "green" investments in the mining sector.
- *Public-private partnerships and international cooperation:* Actively seek financing models through public-private partnerships and apply for international funds and projects that support water resource protection and sustainable development.

The practical application of the results of this research lies in providing concrete guidelines for decision-makers, industry managers and local communities. Only through an integrative approach, which includes modernization of technologies, strict law enforcement, effective monitoring and strong cooperation of all stakeholders, can the long-term sustainability and functionality of the Modrac water reservoir, as an irreplaceable resource for the Tuzla Canton, be ensured.

Literature

[1]	MIG d.o.o.Slavonski Brod: "Elaborate on periodic geodetic recording of the reservoir and shore lines", 2012
[2]	BN PRO d.o.o. Sarajevo: "Elaborate on periodic geodetic recording of the reservoir and the coast", 2022
[3]	d.o.o. Đurđevik: "Study on the technical and economic justification of investments in the Brown coal mine Đurđevik", 2019
[4]	Rudnik mrkog uglja Banovići: "Study on the technical and economic justification of investments in the Banovići coal mine", 2019
[5]	Babić-Mladenović M.: "Watercourse regulation, publishing house Institute for Water Management Jaroslav Černi", Belgrade, 2018
[6]	Đozić, A.: "Pollution analysis of Lake Modrac and the Spreča and Turije rivers", Center for Ecology and Energy, Tuzla. 2021
[7]	Đozić, A.: "Analysis of physical and chemical parameters and the presence of heavy metals in Lake Modrac and the Spreča river", Center for Ecology and Energy, Tuzla, 2021
[8]	Nurkanović Z. ,Demirović- Garić M.: "Selected chapters of mathematics", publishing house PrintCom Tuzla, 2016
[9]	Study Energy Sector in Bosnia and Herzegovina: "Final Report, Module 8 – Coal Mines", 2008.
[10]	Green home: "Ecologically acceptable flow", Guide for the application of the rulebook in practice, 2014.

Education and communication in contemporary society: A study in Bosnia and Herzegovina

Mirzo Selimić[1]

Hadžib Salkić[2]

Samir Ščetić[3]

Nermin Palić[4]

1 Doc.dr., University College "CEPS - Center for Business Studies" Kiseljak
mirzo.selimic@ceps.edu.ba

2 Prof.dr., University College "CEPS - Center for Business Studies" Kiseljak
hadzib.salkic@ceps.edu.ba

3 MA., University College "CEPS - Center for Business Studies" Kiseljak
samir.scetic@ceps.edu.ba

4 Doc.dr., University College "CEPS - Center for Business Studies" Kiseljak
nermin.palic@ceps.edu.ba

Abstract

This paper examines the multifaceted relationship between education and communication in Bosnia and Herzegovina, emphasizing both digital and interpersonal communication practices within higher education institutions. In a rapidly evolving educational landscape, effective communication is recognized as a key factor influencing teaching quality, student engagement, and overall academic achievement. To explore these dynamics, a quantitative research method was employed, utilizing a structured questionnaire administered to a diverse sample of 520 respondents, including students, teachers, and university participants from multiple cantons and entities across BiH.

The study assessed several dimensions: levels of digital literacy among both students and teaching staff, the frequency and effectiveness of digital tool usage in the learning process, and the perceived quality of teacher–student communication. Findings reveal a significant correlation between effective communication practices and higher academic performance, suggesting that communication is not merely a supportive element but a core component of educational success. Moreover, the results highlight pronounced disparities between urban and rural contexts, particularly regarding access to digital technologies, consistency in communication practices, and the inclusivity of the learning environment.

Building on these insights, the paper offers a set of actionable recommendations tailored to the BiH context. These include the systematic training of teachers in digital and intercultural competencies, the standardization of digital tools across institutions to ensure equal learning opportunities, and the promotion of inclusive communication strategies that address regional and institutional inequalities. By strengthening communication capacities within education, Bosnia and Herzegovina can foster a more equitable, innovative, and effective higher education system that aligns with European and global standards.

Keywords

Education, communication, digital literacy, teaching process, Bosnia and Herzegovina, research, students, teachers.

1. Introduction

In contemporary society, marked by rapid technological development and digital transformation, education and communication represent two key components that determine the success of the educational process and the social integration of individuals. [1] Educational institutions, as the bearers of social and intellectual development, increasingly rely on digital tools and platforms not only to improve methods of knowledge transfer but also to ensure high-quality and timely communication between teaching staff, pupils, and students. [2] In the context of Bosnia and Herzegovina, a country with a complex administrative-political structure and pronounced regional differences, it is particularly important to understand how the education system responds to the challenges of modern communication. The lack of standardization in the application of digital resources, varying levels of digital literacy, and unequal access to educational resources between urban and rural areas further hinder the achievement of equal educational opportunities for all participants in the system. [3] The aim of this research is, through a quantitative approach, to examine the state of educational and communication practices in BiH, and to identify the key factors influencing the effectiveness of teaching and interpersonal interaction within educational institutions. The research encompasses a sample of 520 respondents from different parts of BiH, including pupils, students, and teaching staff, thereby ensuring the representativeness of the results. A particular focus is placed on digital literacy, the frequency of digital tool usage, and the quality of communication, with the aim of formulating concrete recommendations for improving educational practice in the country.

2. Research methodology

This study applied a quantitative research approach with the goal of systematically collecting and analyzing numerical data related to levels of digital literacy, communication patterns, and the use of digital tools in educational institutions in Bosnia and Herzegovina. [4] Such an approach makes it possible to identify patterns and correlations among the variables of interest and provides a basis for formulating recommendations based on statistically relevant findings.

2.1. Research instrument

Data collection was carried out using a structured questionnaire specifically designed for the purposes of this study. The questionnaire included closed-ended questions with multiple-choice answers and a Likert scale in order to quantify respondents' opinions, attitudes, and habits regarding the topic of education and communication.

The questionnaire covered the following thematic areas:

- Basic sociodemographic characteristics of respondents (gender, age, level of education, place of residence),
- Level of digital literacy and frequency of digital tool usage in education,

- Perceptions of the quality of communication between teaching staff and pupils/students,

Attitudes about the role of digital and interpersonal communication in the educational process.

2.2. Data collection, processing and analysis

The survey was conducted both online and in person, depending on the technical possibilities and accessibility of the respondents. All participants were informed about the purpose of the research and the voluntary nature of participation, while their anonymity and data confidentiality were guaranteed.

The collected data were analyzed using descriptive and inferential statistics. Software tools for statistical processing (e.g., SPSS or Excel) were applied, including:

- frequency analysis,
- percentage distribution,
- arithmetic mean,
- correlation analysis (e.g., Pearson's coefficient) to determine relationships between variables such as digital literacy and quality of communication

The analysis was based on data collected through a structured questionnaire from a total of 520 respondents, divided into three main categories: pupils of primary and secondary schools; students of higher education institutions; teachers and professors (Table 1).

Table 1 – Data collected for the questionnaire

Category of respondents	Number of respondents	Note
Pupils of primary and secondary schools	210	Pupils from different cantons of BiH
Students of higher education institutions	160	Students from public and private universities
Teachers and professors	150	Representatives of primary, secondary, and higher education

Table 2 – Sample structure by location

Respondent's Place of Residence	Number	Share (%)
Urban areas (cities)	310	59,6%
Rural areas	210	40,4%

Table 3 – Demographic data

Characteristic	**Categories**	**Share (%)**
Gender	Male (42%) Female (58%)	
Age	<18 years (38%) 18–25 years (34%) 26–55 years (28%)	
Level of Education	Primary, Secondary, Higher	According to respondent categories
Internet Usage	Daily (82%) Occasionally (13%) Rarely/Never (5%)	

Thematic variables from the questionnaire:

1. Level of Digital Literacy

- Self-assessment of knowledge of basic and advanced digital tools
- Ability to use digital learning platforms (Google Classroom, Zoom, Moodle, etc.)

2. Frequency of Digital Tool Usage in Education

- How often computers, projectors, e-mail, e-diaries, and platforms are used

3. Quality of Communication

- Assessment of communication between teachers and pupils/students (clarity, accessibility, interactivity)
- Preferred communication channels: in-person, e-mail, messaging, LMS platforms

4. Challenges and Barriers in Communication

- Technical equipment of schools and households
- Lack of teacher training
- Overload of digital content

These data will be statistically analyzed (e.g., by gender, place of residence, respondent status) to identify relationships and differences between groups, with the aim of formulating recommendations for improving the educational and communication process in Bosnia and Herzegovina.

Table 4 – Variables used in the study

Variable Name	Description	Measurement Scale	Data Type
Gender	Respondent's gender (male, female)	Nominal	Categorical
Age	Age in years or categories (e.g., <18, 18–25, etc.)	Ordinal	Numerical / Grouped
Place of Residence	Urban or rural area	Nominal	Categorical
Respondent Status	Pupil, student, teacher	Nominal	Categorical
Level of Education	Primary, secondary, higher	Ordinal	Categorical
Frequency of Internet Use	Daily, occasionally, rarely	Ordinal	Categorical
Digital Literacy	Self-assessment of knowledge of digital tools (1–5)	Interval (Likert)	Numerical
Use of Digital Tools	Frequency of using tools in teaching (1–5)	Interval (Likert)	Numerical
Quality of Communication	Assessment of communication with pupils/students (1–5)	Interval (Likert)	Numerical
Preferred Communication Channel	In-person, e-mail, messaging, platforms	Nominal	Categorical
Technical Equipment	Assessment of the institution's technical equipment (1–5)	Interval (Likert)	Numerical
Barriers in Communication	Yes/No responses regarding the listed barriers	Nominal (binary)	Categorical
Need for Staff Training	Is there a need for additional training? (1–5)	Interval (Likert)	Numerical
Overall Satisfaction with Communication	Global assessment (1–10)	Interval	Numerical

To analyze differences between groups (pupils, students, teachers), the following methods were used [5]:

- Descriptive Statistics – calculation of the mean (M), standard deviation (SD), minimum, and maximum values.
- Analysis of Variance (ANOVA) – to examine whether there are significant differences in digital literacy and communication quality among the groups.
- Pearson Correlation – to investigate the relationship between digital literacy and the assessment of communication quality.

These are the equations used:

- Mean (M):

- Standard Deviation (SD):

- One-way ANOVA (F-test):

- Pearson Correlation (r):

The results are given in the Table 5.

Table 5 – Descriptive statistics by group

Group	N	Digital Literacy (M ± SD)	Communication Quality (M ± SD)
Pupils	210	3,5 ± 0,8	3,2 ± 0,7
Students	160	3,8 ± 0,7	3,5 ± 0,6
Teachers	4,2 ± 0,6	150	4,2 ± 0,6

***Scale from 1 (low) to 5 (high)**

The graphical representation is shown in the following figures:

- Bar Chart: Digital Literacy by Group [6]

X-axis: Respondent Group
Y-axis: Mean Digital Literacy Score

Figure 1 – Bar Chart: Digital Literacy by Group

- Line Chart: Communication Quality by Group [7]]

  X-axis: Group
  Y-axis: Mean Communication Quality Score

Figure 2 – Line Chart: Communication Quality by Group

3. Conclusion

The results of the study clearly indicate a significant relationship between digital literacy and the quality of educational communication in Bosnia and Herzegovina. Differences were observed among respondents of different status—teachers demonstrated the highest level of digital literacy and the most positive perception of communication, while pupils showed lower values in both areas. Students occupied an intermediate position, with a strong awareness of the importance of digital tools, but also with certain deficiencies in interpersonal communication with teaching staff. Urban areas were characterized by better technical equipment and more regular use of digital resources in teaching, whereas rural areas still faced barriers in access to and quality of digital infrastructure.

Despite these differences, all respondents recognized the importance of digital competencies and quality communication as key factors for a successful educational process. Based on the findings, the following measures are recommended:

- Continuous training of teaching staff in digital literacy,
- Standardization of digital tools in educational institutions,
- Strengthening interpersonal and intercultural communication through structured programs.

By improving communication skills and the digital capacities of the educational system, Bosnia and Herzegovina can take a significant step toward modernizing education and building a competent, connected, and inclusive society.

Literature

[1] Agency for Preschool, *"Primary and Secondary Education of BiH"*, ICILS 2023, 2024

[2] Birt Katić D., et al.: *"Digitalna inkluzija u obrazovanju – 2u1 Priručnik za student učiteljskih studija i škola"*, DIGITclue

[3] Vashchenko V.: *"Teachers of Bosnia & Herzegovina: the driving force behind the digital transformation in education"*, UNICEF BiH, 2024

[4] Bećirović S., Dervić M.: *"Students' perspectives of digital transformation of higher education in Bosnia and Herzegovina"*, The Electronic Journal of Information Systems in Developing Countries, 2022, e12243, https://doi.org/10.1002/isd2.12243

[5] Karagözoglu, N., Gezer U.: *"An Investigation of the Relationship Between Digital Literacy Levels and Attitudes Towards Distance Education Among Social Studies Teacher Candidates"*, Educational Policy Analysis and Strategic Research, 2022, Vol.17, No.1, 222–229. Retrieved from https://files.eric.ed.gov/fulltext/EJ1334602.pdf

[6] Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E.: *"Multivariate Data Analysis"*, Cengage, 8th ed., 2019

[7] Healey, J. F.: *"Statistics: A Tool for Social Research"*, Cengage Learning, 10th ed., 2014

T4

Engineering, Energy and Resource Management

Post Disaster Needs Assessment, legal perspective, Albania earthquake 2019 case

Agim Alia[1]

Anni Dasho Sharko[2]

Geron Kamberi[3]

1 Assistent Lecturer, Faculty of Information Technology and Innovation, Luarasi University, Albania
agim.alia@luarasi-univ.edu.al

2 Associate Professor, Dean of Faculty of Information Technology and Innovation, Luarasi University, Albania
anni.dasho@luarasi-univ.edu.al

3 Assistent Lecturer, Faculty of Information Technology and Innovation, Luarasi University, Albania
geron.kamberi@luarasi-univ.edu.al

Abstract

Albania is a country that faces prominent level of disaster risks, such as earthquakes floods, forest fires, droughts. In response to this Albanian government has taken concrete measures to provide the legislation based on the international legal framework and to apply tools to measure and mitigate the impacts of disasters. Post-Disaster Needs Assessment (PDNA) is a crucial framework for understanding and addressing the impacts of disasters. From a legal perspective, PDNA ensures compliance with international standards, strengthens domestic disaster response frameworks, and facilitates resource mobilization.

This paper examines Albania's experience of earthquake 2019, the PDNA, focusing on the integration and transposition of legislation and methodologies in Albanian legislation and mechanisms in disaster recovery and resilience-building efforts. The paper explores the alignment of Albania's legal framework with the Sendai Framework and EU legislation for Disaster Risk Reduction (DRR), emphasizing the role of national legislation in promoting coordinated responses across governmental levels. Key legal challenges are analyzed in this paper. Recommendations include enhancing legal capacity for PDNA execution, promoting participatory governance in recovery planning, and ensuring legal mechanisms are adaptive to Albania's seismic risk profile.

The study highlights the importance of harmonizing national and international frameworks to ensure coherence in disaster recovery strategies. It also underscores the necessity of building institutional capacity and legal expertise to effectively operationalize PDNA in practice. The paper contributes to the broader discourse on disaster law, resilience, and sustainable recovery in the Western Balkans.

Keywords

Disaster Risks, Post Disaster Needs Assessment (PDNA) earthquake, legislation, Sendai Framework

1. Introduction

Albania has taken some moderate steps in Post Disaster Needs Assessment, reflecting on the legislative and institutional framework. Exposed to various natural hazards including earthquakes, floods, mudflows, landslides, forest fires and droughts, Albania faces one of the highest levels of disaster risk in Europe. Over the period 1995-2015, an average of 30,000 people were affected annually by natural disasters, and more than 95 per cent of Albanian municipalities were affected by at least one disaster. In 2019, an earthquake of magnitude 6.4 hit the country, affecting over 200,000 people in eleven municipalities, including Tirana and Durres. According to the Post-Disaster Needs Assessment (PDNA), the earthquake caused damages equal to 6.4 percent of the 2018 gross domestic product (GDP), and losses equal to an additional 1.1 percent. Left unchecked, the impacts of disasters could further increase as a result of the growing economy, and climate change may increase the severity and/or frequency of weather-related disasters, such as floods, wildfires, and droughts [1]. As part of this, Albania did a comprehensive review on the current practice and related legislation for risk-related data collection and management, and post-disaster damage and loss assessment.

The Government of Albania, answering to the globally accepted obligations as part of the Sendai Framework, as a full member country of the EU Civil Protection Mechanism (EU CPM) and aspiring to become a future EU member state but most importantly wanting Albania to become a disaster resilient country, is strongly supporting the development of National Disaster Risk Reduction Strategy (NDRRS). Even though the preconditions in terms of existing national level framework and expertise were there it needs to be noted that the turning point directing changes in how the DRR system was perceived in Albania was the 26 November 2019 earthquake. It was then when the Government of Albania considered this major disaster as an opportunity to strengthen the overall DRR system, both in terms of capacity and strategic planning. This entire DRR strengthening process is something that the Government of Albania could be and is willing to internationally present as a best practice example. The Albanian DRM Strategy, approved by Albanian government with Council of Ministers Decision (CMD) [2] is fully aligned with the national development plans and Sendai Framework for DRR. Albania made progress in the area of civil protection since it joined the EU Civil Protection Mechanism in 2022, and it has prepared a national disaster risk reduction strategy and action plan for 2023-2030. Albania needs to continue working to further improve its civil protection system [3].

The main purpose of this paper is to analyze the reaction of Albania after the earthquake in 2019, and what are the challenges ahead. The research explores the legislative framework and its harmonization with the UN and World Bank methodology and acquis communitaire, identifying main achievements in this area. The methodology of this paper takes the form of depth desk research on the matter, including primary data from official sources, such as different reports and experts' views expressed in different academic and research papers.

1.1. Albanian legal framework on PDNA

In order to approximate the national legislation with the EU Law, and UN and World Bank methodologies Albania adopted a new Law [4]. This law provides a solid framework for promoting disaster risk reduction and requires the adoption of a national

disaster risk reduction strategy. The purpose of this Law is to reduce disaster risks and achieve civil protection in order to guarantee the protection of human life, livestock, property, cultural heritage, and environment by strengthening the civil protection system. This Law governs the functioning of the civil protection system defining the responsibilities of the institutions and structures of this system, international cooperation, the rights and obligations of citizens and private entities, education, training, and inspection.

The adoption of this law implemented the principles of the Sendai Framework into Albanian national legislation, and the NCPA shall have the task to develop and implement the methodology for drafting plans for civil emergencies. In the article 3 of this law, it is given the definition of "Disaster Loss Database", *"which shall be a set of systematically collected information about disasters, damages, losses and their impacts"*. The law in the article 22, point 2 provides that: *"The ministries and central institutions shall have the following tasks and duties: to create, within 2 years from the entry into force of this law, the Disaster Loss Database for their area of responsibility, which they maintain, update and exchange information with NCPA"*. Also, the article 28, point 2, provides that: *"In addition to the tasks and duties set out in the Law on the District Prefect, the District Prefect shall also have the following duties: to set up, within 2 years from the entry into force of this Law, the District Disaster Loss Database, which shall maintain and update, as well as exchange information with the National Civil Protection Agency (NCPA) and, as appropriate, with the Prefects of the neighbouring districts".*

Article 30 of the law provides that: *"The municipalities shall have the following tasks and duties: to set up, within 2 years from the entry into force of this law, the Disaster Loss Database for the Municipality's territory, which they maintain and update, as well as exchange information with the District Prefect and the National Civil Protection Agency"*. Article 48 of the law provides that: *"The public institutions and private entities, at the request of the National Civil Protection Agency, shall have the duty to provide disaster risk reduction and civil protection data. The Disaster Loss Database shall be set up and operates within the National Civil Protection Agency, according to the method defined for collecting and managing the disaster loss data, made by a decision of the Council of Ministers, upon proposal of the Minister."* The article 67 of the law provides that: *"Inspection of state institutions and structures and private entities for implementation of this Law on Civil Protection shall be conducted by NCPA inspectors, according to the legal provisions into force for inspection. During inspections, the inspectors shall examine in particular: creation, maintenance and updating of the Disaster Loss Database in their area of responsibility and the exchange of information with the National Civil Protection Agency."*

1.2. Post Disaster Needs Assessment – UN and World Bank methodology, transposing these methodologies in Albanian legislation

The Post-Disaster Needs Assessment (PDNA) is a globally recognized framework used by governments, with support from the United Nations (UN), the European Union (EU), and the World Bank (WB), to evaluate disaster impacts and prioritize recovery efforts. The methodology ensures a comprehensive, sectoral, and inclusive approach to post-disaster recovery planning. "Sendai Framework for Action on Disaster Risk Reduction 2015-2030, Priority 2: S*trengthening disaster risk governance to manage disaster risk national and*

local levels, provides that in order to achieve this, it is important to establish and strengthen government coordination forums composed of relevant stakeholders at the national and local levels, such as national and local platforms for disaster risk reduction, and a designated national focal point for implementing the Sendai Framework for Disaster Risk Reduction 2015–2030 [5]. The development of national and local disaster risk reduction strategies is one of the seven targets of the Sendai Framework for Disaster Risk Reduction 2015–2030. Albania has prepared a national disaster risk reduction strategy and action plan for 2023-2030.

The revised UN Plan of Action should provide the principles, priority commitments, practical guidance, and targets for the UN system to reduce the loss of disasters and support countries and communities in implementing the Sendai Framework for Disaster Risk Reduction 2015-2030 [6]. Standardization, although the majority of the databases surveyed use a standardized methodology (DesInventar), lack of universally accepted standards affects data comparability and aggregation. Standardization issues include how the parameters for loss and damage data are collected, defined and how loss and damages are attributed to hazard events [7]. Disasters and their impacts represent major losses for governments and communities. The information system provides improved access to national and regional disaster data and enables to monitor, analyse and disseminate information on key hazards and vulnerabilities. The information system uses the DesInventar methodology [8]. A calendar of all such activities, including sufficient details about their implementation, the distribution by geographical areas and targeted population groups, is considered part of the assessment. The governments of affected countries normally use this type of assessment and post-disaster programs, first, to define their short-term interventions to lessen and shorten immediate disaster impacts and to initiate economic recovery and, second, to define and obtain the required international assistance that goes beyond their domestic capacities, thus ensuring successful implementation of recovery, reconstruction and management of risk. [9]

The World Bank's guidelines for assessing damage, losses and reconstruction needs are based on the ECLAC methodology. There are two distinct potential uses of the results of a damage and loss assessment: in the short term, to define government interventions for the immediate aftermath of the disaster, which aim to lessen people's suffering and to initiate economic recovery. In the medium to long term, the assessment is used to define the required financial needs to achieve overall recovery and reconstruction. In addition to revealing the magnitude of effects caused by a disaster, the damage and loss assessment provides information to define effects and impacts on most geographical areas and sectors of the economy, as well as on overall economic performance. [10]. To achieve a comprehensive estimation of needs for recovery and reconstruction, an assessment of disaster effects, impacts and needs should be all-encompassing, it should cover all sectors of social and economic activities. To be fully credible and reliable, needs should be estimated on a solid quantitative basis of disaster effects and impacts. The estimation of financial requirements must be made so that the different actors or stakeholders clearly understand the manner in which they have been assessed (this includes presentation in appropriate language), enabling the assignment of scarce resources to the recovery and reconstruction activities [11].

Albania, with support from international partners, continues to refine its disaster recovery frameworks. The National Strategy for Civil Protection (2020–2030) explicitly mentions the adoption of international best practices, including PDNA methodologies, as a key goal. Through legislative amendments, institutional reforms, and capacity-building efforts, Albania is progressively embedding PDNA methodologies into its legal and operational systems, ensuring better-preparedness and resilience for future disasters.

Yet, there are challenges in transposition such as Challenges in Transposition, Institutional Capacities: Limited expertise and resources to conduct comprehensive PDNAs, Inter-Agency Coordination: Challenges in ensuring cooperation among multiple sectors and levels of government, Data Gaps: Insufficient baseline data for accurate damage and loss assessments.

1.3. Legal framework, the adoption of new legislation

Experience of Albania demonstrate the need for developing a systemic approach to managing potential disasters' risks. Government of Albania, in recognition of the threat natural disasters, pose to its development, has worked to strengthen its DRR capacities, often in concert with international organizations and conventions. In developing and implementing the DRM System in Albania, the following key documents were taken into account. The Law "On Civil Protection" adopted by the Assembly of the Republic of Albania, UN Sustainable Development Goals: "Transforming Our World - the 2030 Agenda for Sustainable Development" and UN Sendai Framework for Disaster Risk Reduction, 2015 – 2030 [12].

Albania has made substantial improvement in developing its DRM Strategy. The main aim related to legislation was to update and strengthen related legislation, in line with EU standards. Albania made progress in the area of civil protection since it joined the EU Civil Protection Mechanism in 2022, and it has prepared a national disaster risk reduction strategy and action plan for 2023-2030. Albania needs to continue working to further improve its civil protection system. On civil protection, Albania made progress in building its civil protection capabilities and has undergone a comprehensive reorganization of its national civil protection system. In 2022, it joined the EU Civil Protection Mechanism (UCPM), demonstrating its commitment to contribute to the Mechanism and make further progress on civil protection. Albania also prepared a national disaster risk reduction strategy and action plan for 2023-2030. Nevertheless, the country should work on further improving its civil protection system. Considering the increased frequency of national disasters in the last decade and the intensified impacts of climate change, Albania should review its emergency plans and increase its operational capacities, infrastructure and systems for early warning, prevention, preparedness, and response. Albania needs to build efficient civil protection and disaster risk reduction (DRR) systems, to increase the country's resilience to natural disasters and crisis. The country should improve its management of flood risks in accordance with the EU floods Directive and formulate new measures to reduce the damage caused by flooding. [13]. Another issue is that the NCPA should accelerate the complete the bylaws of Law 45/2019 as other documents such as SOP/SOG7, guidelines, manuals, regulations, continuity of operations plans (COOP) and continuity of Government (COG) in the ministry and other security and protection institutions.

Another law to be approved is the law on critical infrastructure. Provided in law 45/2019 of chapter V "Protection of critical infrastructure and cultural heritage" is a first and important step for strengthening the resilience of critical infrastructure. However, a Law on Critical Infrastructure is necessary to be drafted as soon as possible which will transpose the EU legislation on critical infrastructure such as EU Council Directive 2008/114 of December 8, 2008. In addition, it is necessary for the NCPA to coordinate the work to carry out the assessment of the critical and public infrastructure

resilience, based on which the neediest objects will be prioritized, their project will be designed, and the rehabilitation works will be carried out. Another key document produces by Albanian government is the National Plan for Civil Emergencies [14].

These efforts reflect a strategic approach by the Albanian government to build resilience through improved risk management infrastructure and policies. Another development in preparing the sublegal acts was the Decision No. 747, dated 20.11.2019, that defines the organization and functioning of the National Civil Protection Agency (AKMC) in Albania. This agency operates under the Ministry of Defense and is tasked with coordinating efforts in risk reduction, preparedness, and response to disasters throughout the country [15]. Further steps to be taken by the Albanian government are the adoption of three CMD: Decision No. 1020, dated 16.12.2020, establishes the composition, operation, and responsibilities of the Technical Advisory Commission for Disaster Risk Reduction in Albania [16]. Decision No. 923, dated 19.11.2020, outlines the organization and functioning of the Civil Protection Committee and regulates inter-institutional cooperation within Albania's civil protection system [17]. Decision No. 53, dated 01.02.2023, defines the criteria and procedures for allocating funds to implement preventive and rehabilitation measures in response to disasters. This decision applies to damaged infrastructure and other activities related to civil protection [18].

1.4. Major disaster context – introduction

The PDNA for the earthquake that hit Albania in November 2019 was prepared through collaborative efforts, excellent cooperation, and committed engagement of the Government of Albania and its international partners: the European Union, the United Nations agencies, and the World Bank. [19]. The document also contains recommendations for improving disaster risk management in Albania. As a result of the disaster, a total of 202,291 people were affected in the country, 47,263 directly, and 155,029 indirectly. The earthquake caused fifty-one fatalities and injured at least 913 people.

The assessment reveals that the total effect of the disaster in the eleven municipalities amounts to 985.1 million EUR (121.21 billion ALL), of which 843.9 million EUR (103.84 billion ALL) represents the value of destroyed physical assets, and 141.2 million EUR (17.37 billion ALL) refer to losses. (See sector-specific damages and losses in Table 1).

Table 1 – Damages and losses, sector and sub-sector specific [19]

Sectors	Sub-sectors	Damages	Losses	Total
			In million EUR	
Health		8.02	1.91	9.93
Education		63.59	8.76	72.35
Housing		662.30	34.00	696.30
Productive		70.82	79.66	150.48
Business and Employment		47.48	5.47	52.95
Tourism		16.71	73.53	90.24

Sectors Sub-sectors	Damages	Losses	Total
		In million EUR	
Cultural Heritage	5.31	0.44	5.75
Agriculture	1.32	0.22	1.54
Infrastructure	30.41	3.01	33.42
Community Infrastructure	6.06	0.16	6.22
Roads	4.83	0.43	5.26
Water and Sanitation	0.35	0.00	0.35
Communication	0.92	0.16	1.08
Public Buildings	10.07	2.26	12.33
Energy	8.18	0.00	8.18
Social Protection	-	0.62	0.62
Civil Protection and DRR	8.75	13.22	21.97
Total	843.89	141.17	985.06

The earthquake has made very visible a number of vulnerabilities of the population and economy that need special attention and require the reduction of disaster risks. It needs direct action by the government to tackle these issues. The harmonized definitions of human and economic impact indicators and recommendations regarding their inclusion in loss databases provide guidance for the future development of national and sub-national databases as well as the reconciliation of indicators in existing loss databases [19]. The earthquake is estimated to have caused effects that are equivalent to 6.4% of the 2018 Gross Domestic Product (GDP) in damages and to 1.1% of GDP in losses. Damages amount to 26.4% of gross fixed capital formation indicating a limited capacity of Albania to achieve full reconstruction in a short to medium timeframe. In terms of losses, the hardest-hit economic sectors were tourism and real estate, but significant damages were also inflicted on education, health, public infrastructure, manufacturing and trade, and agriculture [20].

1.5. Recovery strategy in Albania after the earthquake

Albania Post-Earthquake Needs Assessment report has two volumes, whereby the Volume B includes only the full-fledged Sectorial and Sub-sectorial and the recovery strategy. Whereas in Volume A you can find the following sections: an executive summary, the whole introduction with a description of the pre-disaster context of the country and of the affected area including a brief description of the 26th of November 2019 event and the population affected, and the initial response undertaken. A summary of each of the

sectorial and sub-sectorial reports. The impact of the disaster on the macro-economic and human development indicators. Finally, the recovery strategy comprising the proposed interventions by sector split into short-, medium- and long-term implementation, including the overall vision, the overall guiding principles and the implementing arrangements, and the proposed financial mechanisms [20].

Another key step taken by the Albanian government is the adoption of National Disaster Risk Reduction Strategy. The main purpose of the National Disaster Risk Reduction Strategy in Albania (Strategy) is to guide Albania's future disaster risk management activities and investments in a comprehensive and inclusive manner. Albania has identified the most relevant national natural and human-caused hazards that could cause a disaster and analysed and assessed the disaster risk in the 2022 National Risk Assessment. The action plan refers to the management activities of a total of six risks defined for the purposes of drafting the Strategy until 2030. For each risk, several activities have been determined that will be implemented as a priority by the end of 2026. In addition to individual risk management activities, the Action Plan includes groups of activities that simultaneously affect the level of all or more risks at once: activities to strengthen disaster risk management. [20]. It was observed that almost three years after the enactment of the Law 45/2019 On Civil Protection many of the prescribed reforms and initiatives have not occurred yet and local authorities and national institutions still face several challenges in meeting their responsibilities defined by the Law.

According to the Law, risk and disaster loss data shall exist in three levels - municipalities, prefectures, ministries, and central institutions, and shall be managed on a national level by AKMC. In practice, an integrated national digital database for risk-related and post-disaster data with a clearly defined structure, standards and IT infrastructure for collection and processing of data is not available. The National Geoportal, developed and operated by ASIG [21], is currently the digital database for georeferenced information but it still is in its initial phase of structuring and harmonization, with a limited number of datasets and functionality that needs improvement.

As for the disaster data, the only unified database currently used in Albania is DesInventar Sendai. The use of DesInventar, however, is not regulated by Law 45/2019 or related legislation, thus the rules for update and data entries are not defined. Separate disaster reports are occasionally prepared, communicated and stored by municipalities and prefectures but they are not systematically collected and managed across all municipalities. As for disaster loss and damage assessment, a comprehensive national methodology for consistent application across Albania is not available. Referring to Albania Summary Report there are only two assessments conducted based on the PDNA methodology – after the flood in November 2015 and after the November earthquake in 2019. Deficiencies were identified also with the organization and management of the assessment process. In many cases the coordination was inefficient, the involved people did not have the needed training, nor experience, ministries were not prepared, the collection of data was not well-planned, the collected data was not verified, and the results were not transparent.

1.6. Conclusion, main findings

The PDNA methodology is a common framework for collecting and monitoring data on damages and losses due to disasters is also a contribution to the development of operational indicators for the implementation of the Sendai Framework in Albania,

as they enable the improvement of the quality of national database with the aim of monitoring indicators of risk reduction in relation to the goals of sustainable development. Albania has made substantial improvement in developing its DRM Strategy. This paper reveals that Albania has made some progress in the area of civil protection as it has developed and prepared a national disaster risk reduction strategy and action plan for 2023-2030. Albania needs to continue working to further improve its civil protection system.

Also, Albania has made improvements to the internal legislation, yet it should accelerate the complete the bylaws of Law 45/2019 and other documents. It is critical the adoption of law on critical infrastructure. As for the disaster data, the only unified database currently used in Albania is DesInventar Sendai. The use of DesInventar, however, is not regulated by Law 45/2019 or related legislation, thus the rules for update and data entries are not defined.

The main findings of this research are also the main conclusions of the paper:

- Incorporation of PDNA into national policy, as this process was institutionalized as part of the recovery and reconstruction plans of earthquake 2019, yet the paper argues for stronger legal mandates to ensure systematic and timely implementation of such assessments in the future.
- More coordination and inter-agency cooperation is needed.
- Legal Gaps and Challenges in Post-Earthquake Recovery, Lack of Specific Legal Provisions for PDNA, as the research identifies a significant gap in the legal framework, as there were no specific legal provisions that required the government to conduct a PDNA immediately after the disaster. This resulted in a more reactive than proactive approach to damage assessment and recovery planning.
- The paper emphasizes that the EU, UN, and World Bank played a significant role in shaping the methodology for PDNA following the 2019 earthquake.
- EU Legislative Alignment: The paper draws attention to the need for Albania to align its disaster recovery laws more closely with EU regulations, especially regarding the Solidarity Fund and other EU financing mechanisms. The research highlights those Albanian legal provisions related to post-disaster financing, such as DCM No. 53, need further updates to incorporate PDNA results as a condition for receiving EU funds.
- Institutional and Legal Recommendations for Improvement: Legal Reform for Systematic PDNA Integration:
    - A major finding of the research is the recommendation for legal reform to mandate the inclusion of PDNA assessments as a compulsory step in disaster recovery procedures. The research suggests that the Civil Protection Law (No. 45/2019) and related regulations should explicitly require the government to conduct a comprehensive PDNA for each major disaster, thus formalizing the process and ensuring consistency in future recovery efforts.
- Strengthening Capacity for Inter-Institutional Coordination:
    - The paper recommends amending laws to give the National Civil Protection Agency more legal authority to coordinate and oversee all PDNA-related activities, including data collection, damage assessment, and recovery planning. This could be achieved by revising DCM No. 923 to clearly define institutional roles and responsibilities.

    - Additionally, the research advocates for the establishment of a dedicated PDNA Task Force under the Civil Protection Committee, which would bring together representatives from relevant ministries (e.g., Ministry of Finance, Ministry of Infrastructure) to ensure smooth coordination.

- Financial and Resource Management Post-PDNA

- Linking PDNA Findings to Budget Allocation:
    - The paper found that the lack of a clear legal requirement for PDNA-based financial planning contributed to inefficiencies in resource allocation after the earthquake. It recommends that future legal frameworks clearly link the results of the PDNA to budgetary allocations for recovery, ensuring that funds are distributed according to the severity of the damage and the sectors most in need of support.

- Improved Legal Mechanisms for Access to International Funds:
    - Another key recommendation is for the Albanian government to update its legal mechanisms to ensure smoother access to international funding sources, such as the EU Solidarity Fund, by making PDNA assessments a formal requirement in the application process.

The research paper concludes that while Albania made significant strides in integrating PDNA into post-disaster recovery efforts following the 2019 earthquake, there remain significant gaps in the legal framework that need to be addressed. Key recommendations include formalizing the PDNA process in national legislation, enhancing inter-institutional coordination, ensuring gender and vulnerability considerations are prioritized, and linking PDNA findings directly to financial and recovery planning processes. These steps are essential for ensuring that future disasters are met with more efficient, transparent, and legally robust recovery mechanisms.

Literature

[1]	Improving Disaster Risk and Loss Information in Albania Summary Report May 2022, p.13 disaster risk in Albania.pdf
[2]	National Disaster Risk Reduction Strategy, approved by Albanian government with Council of Ministers Decision (CMD) No. 94, date 22.03.2023 national_drr_strategy.pdf
[3]	European Commission, Albania Progress report 2023, p. 118 https://neighbourhood-enlargement.ec.europa.eu/document/download/ea0a4b05-683f-4b9c-b7ff4615a5fffd0b_en?filename=SWD_2023_690%20Albania%20report.pdf
[4]	Law 45/2019 "On Civil Protection" https://albcold.gov.al/wp-content/uploads/2021/05/Law-No.-45-On-Civil-Protection.pdf
[5]	Sendai Framework for Disaster Risk Reduction 2015-2030, United Nations Office for Disaster Risk Reduction (UNDRR), 2015, p. 17 Sendai Framework for Disaster Risk Reduction 2015 - 2030
[6]	United Nations Plan of Action on Disaster Risk Reduction for Resilience - Towards a Risk - Informed and Integrated Approach to Sustainable Development, United Nations Office for Disaster Risk Reduction (UNDRR), 2016, p. 1 https://unsceb.org/sites/default/files/2021-01/UN%20PoA%20on%20Disaster%20Risk%20Reduction%20for%20Resilience-ODS.pdf
[7]	A comparative review of country-level and regional disaster loss and damage databases, Bureau for Crisis Prevention and Recovery United Nations Development Programme, 2013, p. 7 Comparative Review of country-level and regional disaster loss and damage databases.pdf
[8]	Disaster Loss Accounting System - Using DesInventar Methodology, p. 3 https://www.desinventar.net/documentation/User-Manual-Analysis-and-Query_EN.pdf
[9]	Estimation of Post-Disaster Needs for Recovery and Reconstruction, Damage, Loss, and Needs Assessment - Guidance Notes, Global Facility for Disaster Reduction and Recovery (GFDR), The International Bank for Reconstruction and Development/The World Bank, Volume 1, 2010, pp. 1-2. https://documents1.worldbank.org/curated/en/617521468335985769/pdf/880860v10WP0Bo0PUBLIC00TTL0Vol10WEB.pdf
[10]	Estimation of Post-Disaster Needs for Recovery and Reconstruction, Damage, Loss, and Needs Assessment - Guidance Notes, Global Facility for Disaster Reduction and Recovery (GFDR), The International Bank for Reconstruction and Development/The World Bank, Volume 2, 2010, p. 3-4. https://documents1.worldbank.org/curated/en/323261468322790996/pdf/880860v20WP0Bo000Damage0Volume20WEB.pdf
[11]	Estimation of Post-Disaster Needs for Recovery and Reconstruction, Damage, Loss, and Needs Assessment - Guidance Notes, Global Facility for Disaster Reduction and Recovery (GFDR), The International Bank for Reconstruction and Development/The World Bank, Volume 3, 2010, p. 1. https://documents1.worldbank.org/curated/en/851971468338516450/pdf/880860v30WP0Bo0timation0Volume30WEB.pdf
[12]	Towards the Inclusive Disaster Risk Management Strategy in Albania albania_drm_system_capacity_assessment_report.pdf
[13]	Commission Staff Working Document, Albania 2023 Report SWD_2023_690 Albania report.pdf

[14]	Albanian National Plan for Civil Emergencies, Tirana, October 2023 PKEC_AL.pdf
[15]	CMD No. 747/2019, "On the Organization and Functioning of the National Civil Protection Agency" (Official Gazette No. 159, Year 2019, Page 12865 https://www.qbz.gov.al/eli/fz/2019/159/e3c16f4c-2af2-47ac-b55b-9073c24561f9
[16]	Decision of the Council of Ministers No. 1020, dated 16.12.2020 "On the Composition, Functioning, and Duties of the Technical Advisory Commission for Disaster Risk Reduction" (Official Gazette No. 223, Year 2020, Page 17507 https://www.qbz.gov.al/eli/fz/2020/223/000aa787-b16c-4e38-b70a-6372c9c36be9
[17]	DCM No. 923, dated 19.11.2020 "On the Functioning and Organization of the Civil Protection Committee and Inter-Institutional Cooperation of Institutions and Structures within the Civil Protection System", (Official Gazette No. 208, Year 2020, Page 14749 https://www.qbz.gov.al/eli/fz/2020/208/bee7e27a-dc54-4747-8bac-dc5ab2e05d2d
[18]	Decision of the Council of Ministers No. 53, dated 01.02.2023 "On Defining the Criteria and Procedures for Allocating Funds for Preventive and Rehabilitative Measures Against Disasters, for Damaged Infrastructure, and Other Activities in the Field of Civil Protection" (Official Gazette No. 18, Year 2023, Page 2077 https://www.qbz.gov.al/eli/fz/2023/18/4416b56f-50c7-4610-bfa7-07aaf49494f4
[19]	Albania, Post Disaster Needs Assessment, Volume A report, Tirana, February 2020
[20]	Albania, Post Disaster Needs Assessment, Volume B report, Tirana, February 2020
[21]	ASIG Geoportal ASIG Geoportal

Management of climate change and environmental risks in securing raw material base and transportation logistics network in the Western Balkans

Amer Smailbegović[1]

Nermin Palić[2]

1 Doc.dr., Technical advisor, DTCare NGO
amer@dtcare.org

2 Doc.dr., Head of the Knowledge Hub for Climate and Sustainability, University College „CEPS-Center for Business Studies" Kiseljak
nermin.palic@ceps.edu.ba

Abstract

Recent climate models indicate that central and western parts of the Balkan Peninsula, particularly Bosnia and Herzegovina (BH), are highly vulnerable to extreme weather events such as heat waves, heavy precipitation, surface runoff, flooding, and mass-wasting episodes. The Dinaric Region remains a critical source of raw materials, including iron, manganese, aluminum, lead, zinc, nickel, magnesium, barite, quartz, and evaporites, along with industrial by-products like tailings and slag, making it strategically important for resource supply and EU CRM/SRM initiatives. BH's long mining history, spanning from Phoenician times through Austro-Hungarian rule and SFR Yugoslavia, has been constrained post-conflict by outdated infrastructure, limited investment, and logistical challenges. Roads in mountainous areas and degraded rail networks hinder bulk transport, while mine tailings and slag repositories remain highly susceptible to mass-wasting, creating environmental and operational hazards. Residual unexploded ordnance further restricts safe exploration and fieldwork, emphasizing the need for advanced risk management and spatial planning. Addressing these challenges requires integrated strategies combining geospatial analysis, predictive modeling, and sustainable planning. Layered geospatial databases incorporating geology, infrastructure, watersheds, climate, land cover, geohazards, UXO/mines, population, and deposits enable better decision-making. Coupled with education in geosciences, civil engineering, and transport, these approaches support workforce development, safe resource exploration, and infrastructure modernization. Aligning with EU directives and the Mineral Resources Initiative, such measures foster sustainable development, resilience, and regional resource security while mitigating social, environmental, and infrastructural risks.

Keywords

Climate change, resource development, critical raw materials, transport, interdisciplinary education

1. Introduction

Bosnia and Herzegovina (BH) has a long-mining history reaching back to the Phoenicians [1] persisting in some form to the present day. Two notable periods of exploration and exploitation in BH are after the Austro-Hungarian annexation in 1878-1914 and during SFR Yugoslavia from 1953-1983. Following the 1991-95 conflict among the Yugoslav states, the exploration and extraction industry in BH has never fully recovered [2]. Many of the mineral deposits were located during the extensive geological mapping that took place between 1962-1979 and the production initiated or expanded in several key areas Buzim (Mn), Ljubija (Fe), Posusje (Al), Citluk (Al), Mostar (Al), Milici (Al), Bratunac (Al), Srebrenica (Pb-Zn-Ag, Al), Olovo (Pb), Vares (Fe, Mn, Pb, Zn), Konjuh (Mg/Ni), as well as considerable interest in the exploitation of non-metals, such asbestos, silica, gypsum, kaolin, salt, etc.[3].

In 2008, the European Commission launched the Mineral Resources Initiative (RMI). This EU policy lays out a diversification strategy to secure non-energy mineral resources for EU industrial value chains and social well-being. A top priority action of RMI was to establish a list of critical raw materials (CRM) and strategic raw materials (SRM) at the EU level. In BH there are currently 17 identified CRM occurrences, which are either present as identified deposits or considerable occurrences. In addition to CRM, principal SRM consist of Fe-reserves, estimated at 653 million metric tons, Mn-reserves, at approximate 180 million tons, Pb-Zn reserves at 56 million tons each and bauxite at 120 million tons [4].

2. Climate change and green transition

Current climate change, reflected in the temperature increase, extreme weather events, changing air circulation patterns etc. is having a pronounced impact across variety of sectors in Bosnia and Herzegovina. The extreme and pronounced heat-waves coupled with heavy and localized precipitation lead to significant potential for surface runoff, flooding and mass wasting episodes [5]. Currently at least 8 major episodes of significant mass-wasting, as a result of heavy precipitation / surface-runoff have occurred in the last decade in Bosnia and Herzegovina [6]. These potentially significant events are presenting considerable technical risks to CRM / SRM exploration and utilization in Bosnia and Herzegovina as well as the entire process of green transition.

Green transition in BH is mainly discussed within the framework of EU initiatives and plans for green transition, but mainly as a passing note or reports on the requirements, mainly in the context of emissions control [7] (OECD 2021) or as country assessment within annual transition reports of the European Bank for Reconstruction and Development (EBRD) or various foundations involved in support of green transition. Given the relative novelty of the subject and the fact that BH is considerably behind in all aspects of green transition, the main themes discussed in the reports by EBRD, Carnegie Foundation, Stockholm Energy Institute, Heinrich Böll Foundation is that BH must improve legislative frameworks and enforcement of environmental policies and energy transition in accordance with the countrywide comprehensive Environmental Strategy [8].

3. Resources and challenges

Bosnia and Herzegovina exhibits several potential source areas for CRM/SRM within EU supply context. The principal commodities are iron, aluminum, manganese, lead-zinc-antimony with some smaller possibilities for magnesium and nickel. In the non-metals category, principal commodities are barite, quartz and evaporites. There are four principal metallogenetic provinces – the karst / paleo-laterite for bauxite concentration (Krajina region, Herzegovina region), metasomatic / sedimentary for large iron and manganese mineralization (Ljubija, Vares and Rudo regions), skarn and replacement deposits in the base of Triassic dolomites (Vares region) and mineralization associated with intrusive bodies (Central Bosnia, Srebrenica). Most of these areas present previous areas of interest, but have not been fully explored using modern methods (geophysics, geochemistry) and hold considerable regional potential. There are also large Miocene basis suitable for concentration of non-metals and evaporites, which can be explored for CRM (Tuzla, Zenica, Banja Luka, Lopare etc); see Figure 1.

There are numerous areas of exploitation in BH, including large concentrations of tailings (Vares, Srebrenica, Gornji Vakuf, Ljubija, Sanski Most), but also concentration basins (Mostar, Posusje, Zvornik) or fly-ash / slag repositories (Zenica, Tuzla, Gacko). Some of the tailings and slag piles hold considerable quantities of CRM, which were not captured during previous exploitation and can be re-processed / re-concentrated. Certain areas would benefit from the reprocessing and removal of tailings / slag piles for it would eliminate the source of potential metallic pollution and/or other hazards (i.e. illegal mining). However, these sites are probably at the greatest threat from mass-wasting events, given their relatively unstable structure and propensity to increase weight by absorbing moisture. Majority of the former mine tailings pile were constructed in an ad-hoc manner and are at risk given the current climate change / surface runoff; See Figure 2.

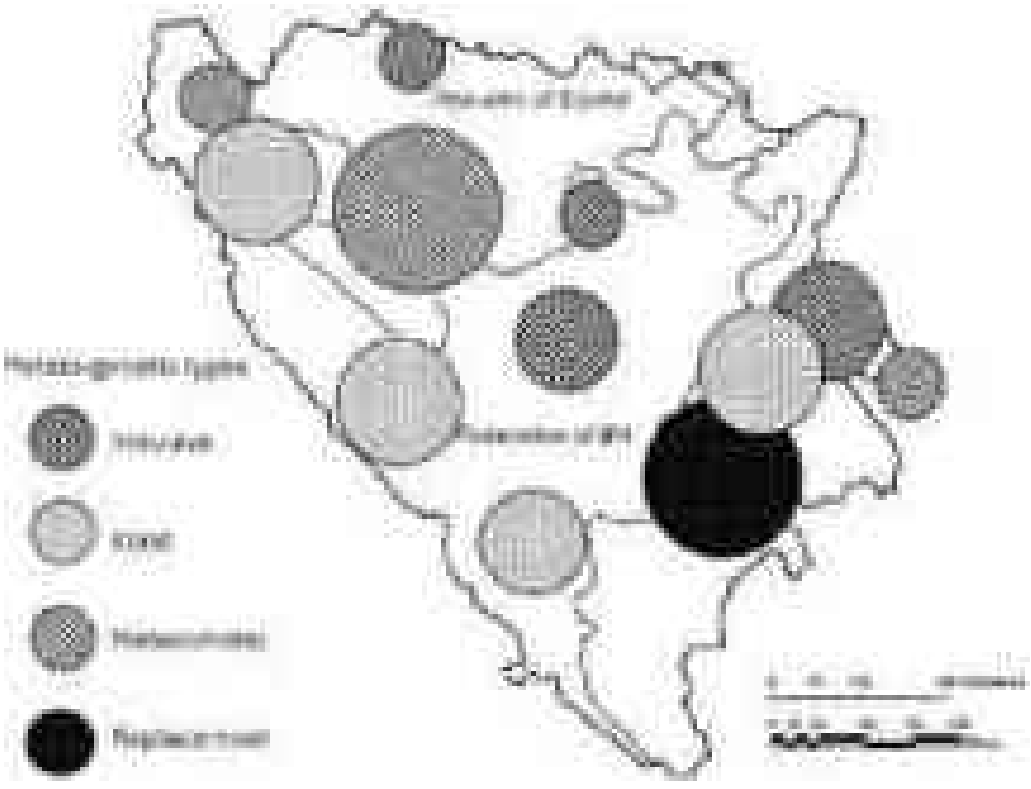


Figure 1 – Metallogenetic provinces of Bosnia and Herzegovina (Authors' work).

Mass-wasting risk is not only affecting the former mine sites and/or potential mineral resource sites, but also the entire infrastructure network. Many of the roads are constructed in a mountainous terrain, along the narrow river valleys and are at risk of rockfall and closure. Most of the road network is inherited from Yugoslav administration and many roads are barely adequate to support heavy traffic (particularly mining traffic). Bosnia and Herzegovina's railway system also suffered due to decentralization and lack of investments in the previous years, but certain efforts have been made to restructure and modernize the railways. Even though, the main arterial rail network was shut down for nearly 7 months during the mass-wasting episode in October of 2024.

From the perspective of critical raw materials logistics, these infrastructure constraints are highly significant. The dominance of road transport for ore and concentrate movement leads to congestion, accelerated road degradation, higher greenhouse gas emissions, and frequent safety risks in urban transit corridors. At the same time, the lack of modernization and electrification of railways limits the capacity to shift heavy bulk cargoes (iron ore, bauxite, coal, slag) from trucks to rail, despite rail being the more sustainable option. Cross-border corridors toward Croatian ports (Ploče, Rijeka) and Serbian/Danube axes remain crucial for export, yet bottlenecks in customs, weak multimodal integration, and limited intermodal terminals (e.g. Tuzla, Zenica) undermine competitiveness in the EU supply context. Developing logistics hubs and transshipment facilities tailored for bulk materials would enhance efficiency, reduce risks, and align BiH transport with EU Green Deal objectives [9].

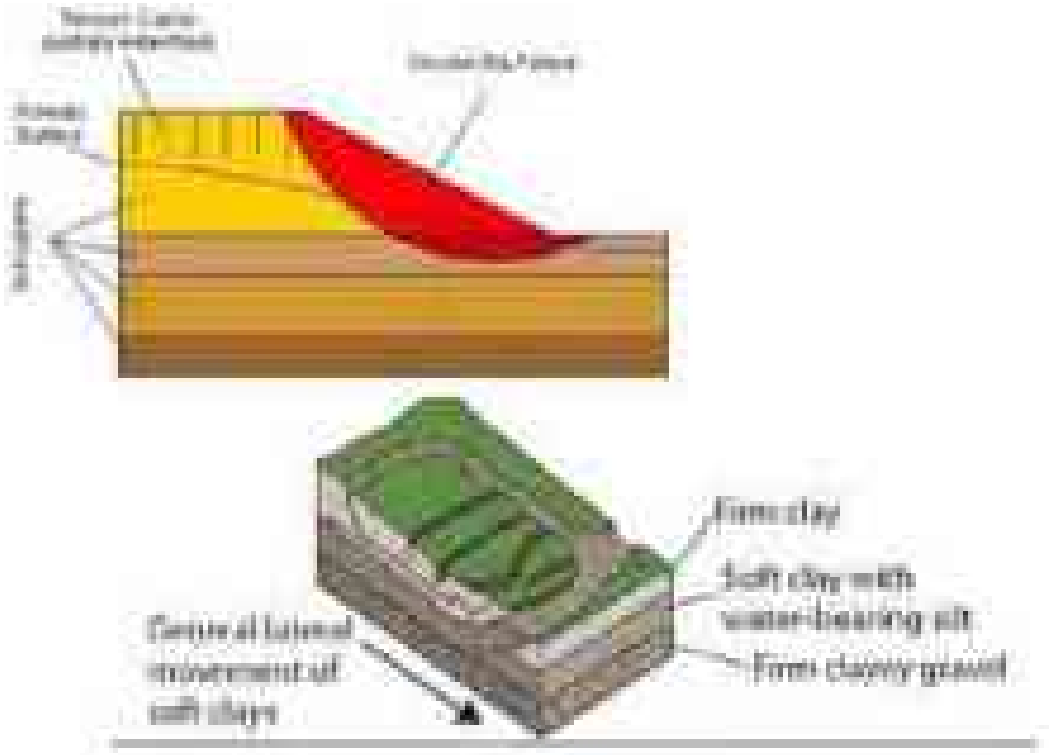


Figure 3 – Modality of mass-wasting (as related to former mine tailings or other unconsolidated areas resulting from poor construction practices or deforestation in Bosnia and Herzegovina (generalized and adapted by authors from [10-11]).

4. Complicating factors

In almost thirty years of its existence as a sovereign state, BH made limited or no progress in most areas of competitiveness and inclusive growth (taxation, digital transformation and media, social policy, employment, enterprise and industrial policy, research-and-development, science education and culture). The country has very limited capacity to cope with a free-market, competitive pressure and market forces in the EU and fails to make significant progress in this area. The quality of education has remained low at all levels while insufficient actions are taken to improve the transport and energy infrastructure. Weaknesses in the transport and logistics sector represent an additional obstacle, as outdated road and rail systems limit the efficient movement of raw materials, while bottlenecks at border crossings, lack of multimodal logistics hubs, and underdeveloped intermodal connections hinder integration with EU supply chains. These shortcomings increase transaction costs, prolong delivery times, and reduce the competitiveness of Bosnia and Herzegovina in regional and international trade. The incoherent, complex and non-viable political apparatus stifles required societal change, while the lack of progress on customs and financial matters with the EU hinders market growth [12].

As a direct consequence from the 1990s conflict, large tracts of lands in BH, particularly along the former conflict-demarcation mines are littered with landmines and unexploded ordnance (UXO). A considerable effort has been made to clear out the urban and near-urban areas. However, considerable portions of rural areas are still deemed unsafe. Given that several large flooding events have occurred, some of the UXO / mines might have shifted posing danger to exploration and fieldwork. The EUFOR mission in Bosnia and Herzegovina maintains an up-to-date coverage and maps of the active de-mining and potentially hazardous areas in BH [13].

Both of these elements illustrate the risk of why, with other potential geospatial layers to consider in this study, one should take account of potential risk – both from technical as well as non-technical risks (NTR) and integrate them into the potential spatial analysis and approach in feasibility planning, developmental studies, education and training.

5. Layering

Novel for Bosnia and Herzegovina, but relatively mature an accepted way of understanding, visualizing, rationalizing and de-risking resource exploration and extraction activities has been the domain of geospatially-driven databases (or in oil and gas sector "data rooms") where all pertinent (and above outlined) elements can be layered, cross-compared and contextually analyzed [14].

Some of the potential geospatial (and open-source) layers that should be implemented within the larger context of understanding and de-risking potential exploration and exploitation activities in Bosnia and Herzegovina are outlined in Table 1, below. The information presented is illustrative at best and it defines only a small segment of all interconnected pieces that may react either as an attenuating or a compounding factor in the new climate reality.

Table 1 – Potential geospatial layers to consider within BH context

Layer	Type	Function	Importance
Geology	Spatial layer	Underlying information	High
Infrastructure	Mesh layer	Connectivity	High
Watershed	Mesh layer	Environmental	High
Land cover	Spatial or Mesh	Environmental	Moderate
Climate map	Spatial	Environmental	Moderate
Geohazards map	Spatial	Risk	Moderate
UXO / Mines map	Spatial	Risk	Moderate
Population	Scale	Logistics	Moderate
Known deposits	Point	Targeting	High
Occurrences	Point	Targeting	High

Additional custom layers are possible and often provided as a starting point, usually by various national or sub-national level governments (i.e. USGS, Mineral Resources of Canada etc.). Whereas some of the information already exists for Bosnia and Herzegovina it is either partial, spatially disorganized or not centralized for the ease of access. Certain spatial layers (i.e. topographic maps) that are generally free (or nominal cost), are generally unavailable or are sold at a premium in Bosnia and Herzegovina. The emergence of open-source geospatial repositories (i.e. Open Street Map, Open Geospatial Consortium, EU Copernicus, NASA EROS Data Center etc.) are presenting a good opportunity to source and implement geospatial data in the cases where the national or subnational governments are unprepared or unwilling to do so.

6. Education and labor

Poor-exposure or complete lack of practical education of geologists and mining engineers, coupled with a considerable digital and geospatial illiteracy, significantly hampers the expectations to roll-out this type of de-risking and predictive analysis, particularly when conducting grassroots exploration. Due to archaic and complex regulations, hiring of foreign professionals or receiving working-permit for staff geologists / exploration personnel is a lengthy and paperwork-intensive process involving variety of governmental agencies in Bosnia and Herzegovina.

Given these challenges and limitations, it is imperative the revise and append the current curriculum in the traffic, civil engineering, geosciences etc. to include more geospatial awareness and use of complementary geospatial layers in the education and

decision-making processes. For example, no exploration permit can be issued unless the certain area is zoned in the current zoning and spatial plan for the municipality and/or canton. Most of the spatial plans are not including the zones of perspective mineralization and are only updated once per decade. This illustrates why it is important to ingrain and maintain certain levels of geospatial literacy from the point of planning, permitting but also operations in the field as well as overall de-risking processes.

7. Concluding remarks

Bosnia and Herzegovina exhibits potential raw material source areas for CRM/SRM. The principal commodities are iron, aluminum, manganese, lead-zinc-antimony with some smaller possibilities for magnesium and nickel. The country currently does not have a sufficient or reliable infrastructure to sustain for the exploration and exploitation of those potential resources. The complicating factors are the changing climate factors that may endanger infrastructure, lead to potential environmental pitfalls or exacerbate other technical or non-technical risks (i.e. unexploded ordnance).

Improvement of the current situation would be best accomplished through the greater emphasis and development of home-grown geospatial capabilities and literacy [15]. Some of the basic geospatial layers could evolve certain sectors by making them more transparent, usable and less prone to risk. To achieve the impetus of geospatial (r)evolution across all levels in BH, it is important to integrate even rudimentary (or entry-level) geospatial elements in the curriculum in the variety of technical disciplines, namely traffic and transportation, geosciences, civil engineering and so on. The investment in the exploration and utilization of resources will not occur until the basic levels of geospatial literacy and awareness have ben reached.

Literature

[1]	Westner, K.J, M Vaxevanopoulos, J. Blichert-Toft, G. Davis, and F. Albarède. 2023. "Isotope and trace element compositions of silver-bearing ores in the Balkans as possible metal sources in antiquity." Journal of Archaeological Science, V.155 https://doi.org/10.1016/j.jas.2023.105791.Dakić D., Perić P.: "Experimental Investigation on Locally Pressed I-beams Subjected to Eccentric Patch Loading", Journal of Constructional Steel Research, 60(3-5), 2004, 525-534, ISSN 0143-974X
[2]	Pašalić, Esad. 1954. „O antičkom rudarstvu u Bosni i Hercegovini". U Glasnik zemaljskog muzeja u Sarajevu. Benac, Alojz. Sarajevo. 47 – 75.
[3]	Geoinzinjering. 1976. Mineral Resources of Bosnia and Herzegovina, Volumes I and II (non-metals, metals and precious metals). Sarajevo, Bosnia and Herzegovina: Geoinzinjering Sarajevo.
[4]	Center for Policy and Governance. 2024. Critical minerals in Bosnia and Herzegovina: perspectives and challenges. Report: https://cpu.org.ba/kriticni-materijali-u-bih-potencijal-perspektive-i-izazovi/
[5]	Trbic, G.; Popov, T.; Djurdjevic, V.; Milunovic, I.; Dejanovic, T.; Gnjato, S.; Ivanisevic, M. Climate Change in Bosnia and Herzegovina According to Climate Scenario RCP8.5 and Possible Impact on Fruit Production. Atmosphere 2022, 11.
[6]	Abolmasov, B. 2016. Landslide risk management in Bosnia and Herzegovina. Report to UNDP BIH and JICA.
[7]	OECD. 2021. "Multi-dimensional analysis of Bosnia and Herzegovina." In Review of the Western Balkans: Assessing Opportunities and Constraints,, by OECD, 246-319. Paris, France: OECD.
[8]	Federal Ministry of Environment and Tourism. 2023. BIH ESAP 2030+ Strategy document-available at: esap.ba
[9]	Palić N.: *"Valorization of Intermodal Logistics Corridor in Bosnia and Herzegovina in Function of Regional Development"*, 8th Carpathian Logistics Congress - CLC 2018: Logistics, Distribution, Transport & Management: Conference Proceedings, Prague, 2018, Vol.1, 34-42, ISBN 978-80-87294-88-8; ISSN 2694-9318
[10]	WISE. 2014. "Slope Stability Calculator - HELP (Draft)", WISE Uranium Project, Online resource available: https://www.wise-uranium.org/csstth.html
[11]	Carter T.G., Lorig L.J., Graaf P.: *"Characterizing Rock Degradability as Basis for Slope Instability Mitigation for Open Pit Closure"*, American Rock Mechanics Association (ARMA), Golden, Colorado, USA, 2024, DOI:10.56952/ARMA-2024-1202
[12]	OECD. 2021. "Multi-dimensional analysis of Bosnia and Herzegovina." In Review of the Western Balkans: Assessing Opportunities and Constraints,, by OECD, 246-319. Paris, France: OECD.
[13]	European Union Force in Bosnia and Herzegovina: Operation Althea. 2025. BIH Minefield Maps. Online resource available: https://www.euforbih.org/index.php/en/bih-minefield-maps
[14]	Putri, R. A., de Santo, J., & Jogo, F. S. (2024). Geospatial analysis applied to mineral exploration: remote sensing, gis, geochemical, and geophysical applications to mineral resources: edited by Amin Beiranvand Pour, Mohammad Parsa, and Ahmed M. Eldosouky, Elsevier Inc, 2023, 326 pp., 141 figures. $165.00 (eBook), ISBN: 9780323956093. International Geology Review, 67(4), 566–568. https://doi.org/10.1080/00206814.2024.2400709
[15]	Smailbegovic, A. & al., e., 2021. Introducing the concept of operations centers, communications nodes and incident command management to Bosnia and Herzegovina with emphasis on natural and environmental disasters.. Velika Gorica, Croatia, Faculty of Applied Sciences Veliga Gorica, Croatia, pp. 41-52.

Rainfall indices as indicators of climatic trends and extremes: A case study of Novi Sad (2014–2023)

Cveta Lazić[1]

Goran Jeftenić[2]

Ljiljana Popović[3]

Slobodan Kolaković[4]

1	Teaching Assistant, Faculty of Technical Sciences, University of Novi Sad *cvetalazic@uns.ac.rs*
2	Assistant Professor, Faculty of Technical Sciences, University of Novi Sad *goran.jeftenic@uns.ac.rs*
3	Associate Professor, Faculty of Technical Sciences, University of Novi Sad *ljiljana.popovic@uns.ac.rs*
4	Associate Professor, Faculty of Technical Sciences, University of Novi Sad *kolakovic.s@uns.ac.rs*

Abstract

This paper presents an overview of relevant rainfall indices used in the analysis of precipitation characteristics, with the aim of improving the understanding of seasonal distribution, the intensity of extremes, and identifying potential climate trends. Such indices enable the recognition of spatial and temporal precipitation patterns and potential indicators of climate change, representing an important tool in contemporary analyses of climatic and precipitation regimes.

The analysis was conducted for the territory of Novi Sad over a ten-year period (2014–2023), based on a time series of daily and monthly precipitation data, which allowed for the calculation of various indices. The Precipitation Concentration Index (PCI) indicates that the distribution of precipitation during the observed period is of moderate character. Through the analysis of the Monthly Rainfall Percentage Index (MRPI), it was observed that the highest monthly precipitation shares were mostly recorded in May and June, indicating a more pronounced seasonal concentration in the late spring and early summer period. Additionally, the wettest days of each year were identified, with their contribution to the total annual precipitation ranging from 5.3% to 17.3%, pointing to the occurrence of pronounced daily extremes in certain years.

The results of the analysis confirm the usefulness of the applied indices for evaluating precipitation distribution and identifying extremes, which is particularly important in the context of ongoing climate change and the increasing frequency of extreme hydrological events. This approach contributes to a better understanding of local precipitation regime characteristics and may serve as a foundation for further climatological, hydrometeorological, and spatial-planning analyses. For future research, it is recommended to extend the temporal scope of the analysis, apply a broader set of indices, and perform more detailed statistical processing to enable a more comprehensive understanding of precipitation trends and variability, as well as to support adaptation efforts in response to potential climate change impacts.

Keywords

Climate change, extreme events, rainfall indices, seasonal distribution

1. Introduction

Analyses indicate that many regions worldwide are experiencing an increase in the frequency and intensity of heavy precipitation, while extreme events are becoming more frequent due to climate change, which increases the risk of natural disasters such as floods and landslides [1].

Considering the growing importance of studying precipitation characteristics in the context of climate change, the aim of this paper was to analyze the distribution and seasonality of precipitation in the area of Novi Sad during the period 2014–2023. The analysis is based on data from the Republic Hydrometeorological Service of Serbia and was carried out using selected rainfall indices, which allow quantification of seasonal patterns, monthly distribution, and the role of extreme daily events in the total annual precipitation. The results of the study contribute to a better understanding of the local precipitation regime and may serve as a basis for further research in the field of climate change and its impacts.

2. Review of Rainfall Indices

This chapter presents the indices commonly used in the literature for analyzing rainfall patterns and assessing the potential impact of climate change on precipitation regimes. According to the recommendations of the Expert Team on Climate Change Detection and Indices (ETCCDI), the core extreme climate indices related to precipitation have been selected, providing insight into seasonal distribution and the occurrence of extremes. In addition to these, the study also considers supplementary indicators such as the Precipitation Concentration Index (PCI), which measures the degree of irregularity in the annual distribution of rainfall; the Daily Rainfall Concentration Index (DRCI), which quantifies the intensity of rainfall concentration in relation to the number of rainy days; and the Monthly Rainfall Percentage Index (MRPI), which represents the monthly share of rainfall in the total annual amount. The application of these indices enables a more detailed understanding of rainfall variability and extremes, thus forming the basis for interpreting local climate trends and the potential consequences of climate change.

2.1. Climate Change Indices

The Expert Team on Climate Change Detection and Indices (ETCCDI) has played a key role in the development of internationally recognized methodologies for detecting and analyzing climate extremes. Its primary objective was to establish standardized climate indices based on daily data, thereby enabling global-scale comparison of analyses and the identification of climate change and variability. Particular attention has been given to extreme events, considering their strong social and economic impacts [2].

As part of its revision efforts, the ETCCDI defined a set of 27 core indices covering both temperature and precipitation, of which 11 belong to the group of precipitation-related indicators. The names and definitions of these indices are presented in Table 1. This framework enables a comprehensive assessment of changes in the intensity, frequency, and distribution of precipitation, and represents a globally acknowledged foundation for climate studies [2].

Table 1 – Rainfall Climate Change Indices [2]

Indices	Name	Description & Formula
Rx1day	Monthly maximum 1- day precipitation	$Rx1day_j = max(RR_{ij})$ - where: *Rx1day*$_j$ - Rxday for period j; *RRij* - daily precipitation amount on day i in period j
Rx5day	Monthly maximum consecutive 5-day precipitation	[illegible] - where: *Rx5day*$_j$ – Rx5day for period j; *RRkj* - precipitation amount for the 5-day interval ending k, period j
SDII	Simple precipitation intensity index	[illegible] - where: *SDII*$_j$ – SDII for period j; *RR*$_{wj}$ - daily precipitation amount on wet days w (RR ≥ 1 mm) in period j; *W* - number of wet days in period *j*
R10mm	Annual count of days when PRCP≥ 10mm	Number of days where: $RR_{ij} \geq 10mm$ - where: *RR*$_{ij}$ - daily precipitation amount on day i in period j
R20mm	Annual count of days when PRCP≥ 20mm	Number of days where: [illegible] - where: *RR*$_{ij}$ - daily precipitation amount on day i in period j
Rnnmm	Annual count of days when PRCP≥ nnmm	Number of days where: $RR_{ij} \geq nnmm$ - where: *nn* - user defined threshold; *RR*$_{ij}$ - daily precipitation amount on day i in period j
CDD	Maximum length of dry spell	Longest sequence of consecutive days where: $RR_{ij} < 1mm$ - where: *RR*$_{ij}$ - daily precipitation amount on day i in period j
CWD	Maximum length of wet spell	Longest sequence of consecutive days where: $RR_{ij} \geq 1mm$ - where: *RR*$_{ij}$ - daily precipitation amount on day i in period j
R95p	Annual total PRCP when RR > 95p	$R95_{p_j} = \sum_{w=1}^{W} RR_{wj}$ - where: *RR*$_{wj}$ - daily precipitation amount on a wet day w (RR ≥ 1.0mm) in period j; *RR*$_{wn}$*95* - 95th percentile of precipitation on wet days in the 1961-1990 period; *W* - number of wet days in the period
R99p	Annual total PRCP when RR > 99p	$R99_{p_j} = \sum_{w=1}^{W} RR_{wj}$ - where: *RRwj* - daily precipitation amount on a wet day w (RR ≥ 1.0mm) in period j; *RRwn99* - 99th percentile of precipitation on wet days in the 1961- 1990 period; *W* - number of wet days in the period
PRCPTOT	Annual total precipitation in wet days	$PRCPTOT_j = \sum_{i=1}^{I} RR_{ij}$ - where: RRij - daily precipitation amount on day i in period j; I - number of days in j

2.2. The Precipitation Concentration Index

The Precipitation Concentration Index (PCI) is a measure that enables the assessment of precipitation distribution throughout the year. Its application provides a clear insight into the spatial variability of monthly precipitation amounts and the manner of their distribution. For this reason, PCI has become a frequently used indicator in numerous climatological and hydrological studies. The calculation is performed using the expression given in Eq. (1):

(1)

where Pi represents the precipitation amount in month i [3].

Based on the calculated PCI value, the uniformity of annual precipitation distribution can be assessed. The obtained values are classified into four categories:

1. PCI ≤ 10 – uniform distribution (low concentration),
2. 10 < PCI ≤ 15 – moderate precipitation concentration,
3. 16 < PCI ≤ 20 – irregular distribution,
4. PCI > 20 – highly irregular distribution (high concentration) [4].

2.3. The Daily Rainfall Concentration Index

The Daily Rainfall Concentration Index (DRCI) was developed to quantify the irregularity of the distribution of rainfall days within a year. Its main purpose is to indicate whether the total annual rainfall originates from a large number of days with smaller amounts or from a small number of days with pronounced extremes. The calculation is performed through the following steps.

1. Classification of all rainy days into predefined intervals.
2. Determination of the number of rainy days (ni) and the total rainfall amount (Pi) in each interval.
3. Calculation of the relative cumulative frequency of rainy days (Xi) and the cumulative percentage of recorded rainfall (Yi), where N is the number of non-zero intervals, according to Eq. (2) and Eq. (3):

(2)

(3)

4. It is assumed that Xi and Yi are related through an exponential relationship Eq. (4):

$$Y = aXexp(bX), \tag{4}$$

where a and b are constants estimated using the least squares method.

5. The area between the exponential curve and the straight line Y = X Eq (5):

$$S = \int_0^{100} [X - aXexp(bX)]dX. \quad (5)$$

6. The DRCI is obtained according to Eq. (6):

$$DRCI = \frac{S}{5000}. \quad (6)$$

The DRCI varies from 0 to 1, where higher values indicate that a smaller number of rainy days accounts for the majority of the total annual precipitation. The results can be interpreted as follows:

1. DRCI > 0.61 - high value (a small number of days contributes most of the annual rainfall),
2. 0.55 < DRCI < 0.61 - moderate,
3. DRCI < 0.55 - low (more uniform distribution across days) [5].

2.4. The Monthly Rainfall Percentage Index

The Monthly Rainfall Percentage Index (MRPI) is used to assess the contribution of each month to the total annual precipitation. It is calculated according to Eq. (6):

$$MRPI_i = \frac{P_i}{P_{tot}} \cdot 100 \quad (6)$$

Where:

- -$MRPI_i$ – share of month i in the annual precipitation total,
- -P_i – precipitation amount in month i (mm),
- P_{tot} – total annual precipitation (mm) [5].

3. Data and methodology

This study used daily precipitation data for the territory of Novi Sad over a ten-year period (2014–2023). The data were obtained from the Yearbooks of the Republic Hydrometeorological Service of Serbia, available on the official website of the Service [6].

Based on these time series, the data were processed using Microsoft Excel, where calculations of selected precipitation climate indices were performed. For each year, the Precipitation Concentration Index (PCI) was calculated to assess the uniformity of rainfall distribution throughout the year, the Monthly Rainfall Percentage Index (MRPI) was determined to evaluate the monthly contribution to the annual precipitation total, as well as the wettest day (Rx1day) in each year and its percentage share in the annual precipitation.

This procedure yielded a set of results that enabled the identification of seasonal patterns, the recognition of dominant months in the precipitation regime, and the assessment of the contribution of extreme daily events to the total annual precipitation. In this way, a foundation is created for analyzing the potential impacts of climate change on the local precipitation regime.

4. Results and discussion

Based on daily precipitation data for Novi Sad for the period 2014–2023, the indices PCI, MRPI, and Rx1day were calculated. The results are presented in the tables below.

The PCI (Table 2) showed values ranging from 10.32 to 15.29. All years fall into the category of moderate precipitation distribution, with the lowest value recorded in 2021 and the highest in 2022. These results indicated a relatively uniform distribution of precipitation throughout the year, without pronounced extreme seasonality. However, values closer to the upper boundary of the moderate interval (2015 and 2022) suggest a higher degree of concentration, although they still remained within the category of moderate distribution.

Table 2 – Precipitation Concentration Index (PCI) for Novi Sad (2014–2023)

Year	PCI (%)	Category
2014	13.52	moderate precipitation distribution
2015	14.16	
2016	10.48	
2017	10.89	
2018	11.65	
2019	12.00	
2020	13.05	
2021	10.32	
2022	15.29	
2023	10.56	

The MRPI (Table 3) highlighted the dominant months in which a larger share of annual precipitation was concentrated. It can be observed that in most years, the highest values were recorded in May and June, indicating pronounced seasonality during late spring and early summer. In 2015, May alone accounted for as much as 27.28% of the annual total, while in 2018 June reached 22.76%. However, certain years deviate from this pattern, such as November 2021 (15.13%) and especially September 2022 (28.2%), when a dominant contribution to the annual total precipitation was recorded. These results suggested that, although seasonality is present, individual extreme events in specific months altered the overall annual precipitation distribution.

Table 3 – Monthly Rainfall Percentage Index (MRPI) for Novi Sad (2014-2023)

	MRPI											
Month Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2014	2.98	1.13	6.07	6.27	24.77	4.68	17.29	9.64	10.33	7.86	0.64	8.35
2015	8.31	9.38	7.81	2.26	27.28	3.80	0.37	14.19	7.49	10.62	7.98	0.51
2016	6.66	6.38	8.50	9.67	11.03	18.58	8.88	5.94	4.37	11.00	8.71	0.29
2017	3.61	3.92	5.94	11.11	16.16	12.80	2.34	3.39	15.88	7.58	7.85	9.41
2018	6.62	11.42	8.45	6.83	8.95	22.76	11.32	7.14	3.78	1.03	3.43	8.26
2019	7.25	2.69	2.52	8.56	23.35	10.08	3.32	12.51	8.40	3.16	8.50	9.67
2020	3.12	6.21	7.34	1.51	6.45	22.08	10.54	18.75	4.28	12.68	1.94	5.09
2021	5.90	7.85	5.65	7.27	8.30	3.15	15.10	6.12	2.16	11.62	15.13	11.73
2022	2.06	4.21	0.20	9.67	3.18	7.74	2.45	18.45	28.21	5.50	10.42	7.93
2023	10.00	8.62	3.81	9.62	18.80	5.33	8.77	6.04	9.56	1.72	12.62	5.11

The analysis of extreme single-day precipitation events (Rx1day) showed significant interannual variability (Table 4). The highest value was recorded in 2015 (121.9 mm), which accounted for as much as 17.3% of the annual total. On the other hand, the lowest maximum was registered in 2023 (35.3 mm), representing only 5.3% of the annual sum. These findings confirmed that, in addition to seasonal concentration of precipitation, individual extreme events strongly influenced the overall precipitation regime, although their contribution varied from year to year.

Table 4 – Wettest day of the year (Rx1day) and its percentage of annual precipitation

Year	Total precipitation (mm)	Rx1day (mm)	Share of Rx1day (%)
2014	816	86.9	10.6
2015	702.7	121.9	17.3
2016	770.7	61.7	8.0
2017	513.1	48.6	9.5
2018	717.1	116.2	16.2
2019	632.1	48.7	7.7
2020	733.2	56.8	7.7
2021	757.6	62	8.2
2022	563.6	68.5	12.2
2023	663.9	35.3	5.3

4.1. Comparative analysis of results with findings from other authors

In one of the studies, extreme precipitation events were analyzed based on daily precipitation values from 14 meteorological stations in Serbia over the period 1961–2020. The research included several indicators, among which was the index of maximum 1-day precipitation (Rx1day). The authors calculated mean values of these indicators for two reference periods (1961–1990 and 1991– 2020) in order to examine possible changes in precipitation distribution due to climate variability and global warming. For the Novi Sad station, the following results were obtained: the average Rx1day value in the first period was 38.2 mm, while in the second period it increased to 52.0 mm, indicating an intensification of extreme daily precipitation in the more recent period [1].

For the purpose of comparison with results from the literature, for the period 2014–2023 the mean value of annual maximum 1-day precipitation (Rx1day) was calculated, amounting to 70.66 mm. This value is higher than the averages reported in the previously described study, where the mean Rx1day was 38.2 mm for the period 1961–1990 and increased to 52.0 mm for 1991–2020. Although this analysis is based on a shorter data series (10 years), the result indicates a possible increase in the intensity of extreme daily precipitation events in Novi Sad in the more recent period. For a more comprehensive and precise assessment of trends, however, comparisons should be made using data series of equal length.

5. Conclusion

The analysis of precipitation indices for the Novi Sad area over the period 2014–2023 enabled the assessment of seasonal distribution, spatial variability, and the occurrence of extremes in the precipitation regime. The results of the Precipitation Concentration Index (PCI) indicated a moderate distribution throughout the entire observed period, confirming the absence of highly irregular patterns. The Monthly Rainfall Percentage Index (MRPI) highlighted May and June as the dominant months in most years, while certain extreme events in other months (e.g., September 2022 and November 2021) disrupted the usual seasonal pattern. The analysis of the wettest days (Rx1day) confirmed that individual extreme events could contribute up to 17.3% of the total annual precipitation, while the lowest contributions were around 5%, underscoring their key role in shaping the annual precipitation regime.

The comparative analysis with literature results showed that Rx1day values in the past decade were higher than the average values recorded in longer reference periods (1961–1990 and 1991– 2020), which may indicate an intensification of daily precipitation extremes in the more recent period. However, due to the limited time series, this conclusion should be interpreted with caution.

The obtained results confirm the usefulness of applying various precipitation climate indices in local analyses, as they allow the recognition of seasonal patterns and the quantification of extreme events. For more comprehensive conclusions and trend identification, future research should extend to longer time series, apply a broader set of indices, and use advanced statistical methods. This would provide a more reliable basis for assessing the impacts of climate change and planning adaptation measures in the local context.

Acknowledgement

The research has been conducted within the project “Introduction of advanced technologies andinnovations into the educational process and research in the fields of civil engineering, geodesy, and disaster risk management and fire safety”, developed at the Department of Civil Engineering and Geodesy, Faculty of Technical Sciences, University of Novi Sad, Serbia.

Literature

[1] Tošić I., da Silva A. S. A., Filipović L., Tošić M., Lazić I., Putniković S., Stosic T., Stosic B., Djurdjević V.: "Trends of Extreme Precipitation Events in Serbia Under the Global Warming", ATMOSPHERE, 16(4), 2025, 436, ISSN 20734433

[2] ETCCDI Climate Change Indices, [Online]. Available: https://etccdi.pacificclimate.org. [Accessed 4 September 2025].

[3] AL-Shamarti H. K. A.: " The Variation of Annual Precipitation and Precipitation Concentration Index of Iraq", IOSR Journal of Applied Physics, 8(4), 2016, 36-44, ISSN 2278-4861

[4] Botai C. M., Botai J.O., Mukhawana M.B., de Wit J., Masilela N.S., Zwane N., Tazvinga H.: "Evaluation of Rainfall Distribution Based on the Precipitation Concentration Index: A Case Study over the Selected Summer Rainfall Regions of South Africa", Hydrology, 12(6), 2025, 136, ISSN 2306-5338

[5] Kaboli S., Hekmatzadeh A. A., Darabi H., Haghighi A.T.: "Variation in physical characteristics of rainfall in Iran, determined using daily rainfall concentration index and monthly rainfall percentage index", Theoretical and Applied Climatology, 144(1/2), 2021, 507-520, ISSN 0177-798X

[6] Republički hidrometeorološki zavod, Meteorološki godišnjaci – klimatski podaci, [Online]. Available: https://www.hidmet.gov.rs/latin/meteorologija/klimatologija_godisnjaci.php. [Accessed 7 July 2025].

Plastic waste reducition in restaurants and hotels along the Shkumbini River

Elona Pojani[1]

Zyra Mahmuti[2]

Perseta Grabova[3]

1	Associate professor, Faculty of Economics, University of Tirana *elona.pojani@unitir.edu.al*
2	Master of Science Risk Management, Faculty of Economics, University of Tirana *zyramahmuti@gmail.com*
3	Associate professor, Faculty of Economics, University of Tirana *perseta.grabova@unitir.edu.al*

Abstract

Plastic pollution in the Shkumbin River Basin is now a major environmental and economic problem for Albania, especially for the hospitality and catering (HoReCa) industry. Field surveys done in 2024–2025 show that single-use plastics (SUPs), mostly PET bottles, LDPE bags, and disposable food service items, make up more than 70% of the visible trash along the river. The HoReCa industry has two roles: it causes a lot of SUP leakage and is also very vulnerable to the reputational and financial losses that come from polluted environments, fewer tourists, and higher operating costs. This study aims to evaluate the viability of transforming the HoReCa sector along the Shkumbin River from reliance on single-use plastics to more sustainable practices, including reusable systems, deposit-return schemes, and compostable alternatives. The analysis was supplemented with interview data from 5 business units operating along the Shkumbini river. The results show that the best way to reduce SUP leakage by 80–90% while still being profitable for businesses is to use reuse systems along with deposit-return schemes for PET and glass. Source separation and material recovery facilities (MRFs) are good for long-term sustainability, but they cost more up front. Although these transitions are expected to yield long-term benefits for the business sector—both in sustainability and economic performance, they necessitate financial commitments that many river-adjacent enterprises cannot readily meet due to constrained resources.

Keywords

Plastic pollution, Shkumbin River, waste management, circular economy, HORECA sector, Albania

1. Introduction

Plastic pollution in Albania, especially in rivers, is a big problem for the environment. Rivers are the main ways that plastic trash gets into the Adriatic Sea. Plastics make up about 9.27% of municipal solid waste, but only 18.8% of it is recycled. More than 76% of it ends up in landfills. About 298,000 people are still outside of formal systems, even though there are services that pick-up trash [1]. The International Union for Conservation of Nature (IUCN) claims that Albania dumps about 8,000 tons of plastic into the Adriatic Sea every year [2]. The Shkumbin River Basin suffers from several pollution hotspots, especially in places like Prrenjas, Librazhd, Elbasan, and Peqin. The HORECA sector is particularly affected by the waste practices, being not only a polluter but also bearing the consequences of the pollution in the business performance.

The goal of this study is to find ways for businesses in the hospitality and catering sector (HoReCa) along the Shkumbin River to cut down on single-use plastic (SUP) waste and to look at the economic benefits of switching to more eco-friendly options. It builds on the "Low Plastic Zone" program, which helped 719 businesses in Albania cut down on SUP waste by 8.2% between 2023 and 2024 [3]. In particular, the paper aims to explore practices of selected business in in using the SUP products and the environmental impacts of such use. In addition, the study will assess the economic implications of replacing single-use items (e.g., plastic bottles and cutlery) with reusable or compostable alternatives using data from the literature, evaluating the environmental benefits in terms of reducing plastic waste generation and minimizing leakage.

The paper is organized as follows. In the first part, a literature review, focusing on the concepts of plastic waste impacts and environmental cost benefit analysis is presented. Then, the second part of the paper describes the methodology applied, and the results of both qualitative analysis and quantitative data used for this research. The paper concludes in recommendations applicable to the HORECA sector.

2. Literature review

Plastic waste is considered the plastic that has been thrown away after it is no longer useful, either through formal waste management systems or informally in the environment. The European Environment Agency [4] considers plastic waste both durable and single-use plastics, like packaging, construction materials, and textiles. Globally, post-consumer plastics like packaging and bottles make up the most plastic demand, with packaging making up almost 40% of the total [5]. From a typological standpoint, plastic waste can be classified based on its origin and polymer composition. There are different kinds of polymers, such as PET, HDPE, LDPE, PP, PS, and PVC, each posing a different impact on the environment. Recycling technology also differs based on the type of plastic [2].

Marine ecosystems are particularly impacted by plastic waste. Through rivers, every year, about 11 million metric tons of plastic end up in the oceans, where it breaks down into microplastics that stay there for hundreds of years [6]. Microplastics are present in isolated ecosystems, including Arctic ice and deep-sea sediments, indicating their widespread distribution and durability [7]. Plastic pollution harms not only marine

habitats but also soils, agricultural productivity, and terrestrial environments by releasing toxic chemicals [8]. These materials can become part of everyday impacting human health life through food, air, or direct skin contact [9] [10]. The chemicals present in plastics like BPA and phthalates, can cause severe health effects [11].

Besides the environmental impacts, plastic pollution causes billions of dollars of loss every year, especially in tourism, fisheries, and the marine industry. "Ghost nets" or abandoned fishing gear, get caught in marine life and lower fish yields [12]. The tourism sector must pay fees for cleaning up beaches and coastal areas [13], and waste management systems have to deal with high costs because recycling and inefficient landfilling [14].

A key focus of contemporary research on plastic waste management is the evolution of consumption and waste systems via the incremental substitution of single-use plastics (SUPs) with reusable or compostable alternatives. This systemic change goes beyond just replacing individual products. It needs supporting infrastructure like deposit-return schemes, washing and refilling logistics, and material recovery facilities [15]. This transition has many benefits. For the environment, it stops plastic from leaking into rivers and landfills, reduces greenhouse gas emissions, and stops long-term microplastic contamination [16]. For businesses, it reduces repeated purchases and waste-management costs—particularly in the HoReCa sector, while also creating new jobs in the recycling and reuse industries [17]. For consumers, it builds trust and strengthens the image of businesses and municipalities as environmentally responsible actors [18].

Plastic waste management has become a central policy priority across Europe, given its environmental externalities and economic implications. In Albania, the issue is framed within an EU-aligned legal context, with particular emphasis on single-use items that dominate urban waste streams. As Albania aligns with the EU Single-Use Plastics Directive (EU) 2019/904, bans on items such as plastic cutlery, plates, straws, and expanded-polystyrene packaging induce operational change while enhancing investment in reusables, eco-certifications, and alternative packaging that can strengthen tourism competitiveness.The legal framework in Albania (Law No. 10463/2011, "On Integrated Waste Management") is in line with EU definitions. It prioritises plastic waste because of its size and the risks it poses for the environment [19]. About 9.2% of urban waste in Albania is plastic, and a major part of it comes from single-use packaging [1]. Phasing out single-use plastics in Albania is not only environmentally beneficial; it also advances circular-economy practices aligned with EU policy objectives. The planned introduction of extended producer responsibility (EPR) will further reallocate waste-management costs from municipalities to producers and importers, indirectly easing burdens on businesses and consumers and accelerating the transition to a circular economy. The next section will investigate this issue further, focusing on a particular context in Albania, the HoReCa sector along the Shkumbini River.

3. Study methodology

The study area in this research is the Shkumbin River basin, a crucial hydrological system in Albania, spanning roughly 181 kilometres from its origin in the Valamara Mountains to its discharge into the Adriatic Sea near Divjaka. The river flows through a variety of landscapes, such as mountains, farmland, and cities. This means that it crosses many different human activities that create and change the flow of plastic waste. There are

more than 250,000 people living in the basin area, which is about 2,445 km^2. Some of the cities and towns in the area are Prrenjas, Librazhd, Elbasan, Peqin, Rrogozhina, and Divjaka, each carrying different waste management issues.

There were several reasons why the Shkumbini Basin was chosen as the study area. First, it represents a hotspot for pollution traveling to the Adriatic Sea, with rivers acting as pipes for plastic to flow from land to the sea. Second, the basin is home to cities and administrative units that have different abilities to collect, transport, and recycle waste. This makes it possible to study how social, financial, and institutional factors affect plastic waste outcomes. Elbasan is an urban municipality with a larger population and more industrial activity than rural municipalities like Prrenjas and Librazhd, where service coverage is often incomplete. This variety gives us a chance to look at different ways that plastic waste is made and moves. Third, the Shkumbini is a very diverse ecosystem that supports fish, plants along the riverbanks, and irrigation systems for farming. Plastic pollution threatens these functions by making the water less clean, blocking irrigation channels, and breaking up habitats. The river is important to society because many settlements have relied on it for water, farming, and transportation for a long time. Plastic waste not only damages the environment, but it also lowers the cultural and aesthetic value of the river, making it less appealing to tourists in places like Librazhd and Elbasan.

In terms of plastics, the Shkumbin River is one of the most polluted river basins in Albania. ETMI (2025) baseline studies show that plastics make up more than 70% of all riverbank litter. BeMed+ (May 2024) monitoring recorded 1,185 litter reports over four days, including 558 unitary items (PET bottles, LDPE bags, cups, food packaging), 31 bulky items (furniture, tires, construction plastics), and 596 accumulation zones where waste was uncountable. Observed spatial patterns show everyday consumption: PET bottles and LDPE bags dominate overall volumes; single-use food-service items (cups, plates, straws) cluster near city centers; and hygienic plastics (wet wipes, diapers, masks) point to improper disposal in household and healthcare settings. ETMI found that the plastic densities of hundreds of items per 100 meters were like those of rivers in Southeast Asia that are very polluted. These plastics are carried downstream to the Adriatic Sea, where Albania sends up to 8,000 tonnes of them each year [2].

Table 1 – Plastic Waste in the Shkumbin River (ETMI 2025 & BeMed+ 2024)

Category	Description	Observations/Reports
Unit waste	PET bottles, plastic bags, cups, packaging	558 cases (May 2024)
Bulky waste	Plastic furniture, tires, construction parts	31 cases (May 2024)
Accumulation area	Large, uncountable volumes	596 zones (May 2024)
Composition	Plastic share in river waste	>70% (June 2025)
Most common types	PET, LDPE, PP, hygienic-sanitary	Present in all segments

Source: (ETMI 2025 & BeMed+ 2024)

4. Method and data

This study utilizes a mixed-methods approach, predominantly focusing on quantitative data from the HoReCa sector, supplemented by qualitative insights derived from interviews with business owners and managers. The main goal is to look at the costs and benefits of cutting down on single-use plastics (SUPs) and switching to more eco-friendly options. In summary, the methodology includes:

a. Qualitative survey and data collection: Primary data were collected through semi-structured questionnaires distributed to five representative HoReCa businesses in Elbasan and Librazhd. They were used to collect data on the number of customers, SUP items usage, and monthly costs. This information was used to figure out the economic baselines for the current use of plastic and to test out different scenarios using compostable or reusable materials. This information was supplemented with qualitative interviews. Managers and staff from five representative HoReCa businesses took part in interviews sections. The interviews gave us information on behavioral factors, perceived obstacles to sustainable alternatives, and Albania's SUP regulations. These interviews also highlighted seasonal plastic usage variance, logistical issues (e.g., storage, disposal), and fine concerns, providing valuable qualitative insights to supplement quantitative data. Table 2 presents the basic profile of surveyed units, showing diversity in size, location, and seasonality.

b. Comparative cost analysis: The study looked further at how much the selected companies spent on SUPs and alternatives each month and each season. To give a more accurate picture of the finances, hidden costs like waste transport, storage space, and possible legal liabilities were also included. To achieve this analysis adaptation from international studies (e.g., BeMed projects, Mediterranean tourism sector) were modified for the Albanian context to emphasize best practices and viable policy options.

Table 2 – General Data of Surveyed HoReCa Units

Unit	Typology	Location	Employees	Clients/Day	Seasonality
Sopoti Caffe	Café	City center	5	100	All year
Imperial Hotel	Hotel	Rural/touristic area	20	200	All year
Bar Restorant Moglica	Restaurant	Rural/touristic area	10	120	All year
Balkan Hotel	Hotel	Rural/touristic area	18	180	Mainly tourist season
Vila Zeneli	Restaurant	Rural/touristic area	8	90	All year

Source: Authors' field survey and interviews (March–May 2025).

This design keeps the focus of the analysis on the HoReCa sector's practices and economic effects, rather than on the costs of the municipal system.

5. Results of the questionnaires and interviews

Interviews conducted with managers and employees from five HoReCa businesses (two hotels, two restaurants and one café) in Elbasan and Librazhd confirmed that single-use plastics (SUP) are used in the daily operations of the sector. All interviewees reported regular use of plastic bottles, cups, straws, plates and bags, with monthly expenses ranging from 40,000 to 120,000 ALL (400-1200 EUR), depending on the size of the business and the number of customers. Seasonal differences were also evident: urban hotels and cafés reported relatively constant use throughout the year, while rural and tourism-oriented restaurants recorded a significant increase in consumption during the tourist season. Managers emphasized that the main reason for the continued use of plastic is its low cost, wide availability and convenience. However, they expressed concern about the difficulties associated with storing and disposing of large quantities of plastic waste, noting that the lack of storage space and the need for frequent disposal make operations less efficient.

Regarding alternatives, most interviewees expressed a preference for biodegradable and compostable products (such as paper cups, wooden cutlery, and cardboard bags), which are perceived as better for the environment and more acceptable to consumers. However, their higher price—40–70% above plastic alternatives—was seen as a heavy financial burden, especially for small enterprises with limited profit margins. Managers emphasized that consumers expect prices to remain stable, which limits the ability to pass on these additional costs to them, necessitating state intervention through subsidies or fiscal incentives.

A recurring theme during the interviews was the awareness of the hidden costs associated with the use of plastic: costs for waste collection and transportation, the need for additional storage space for bulk packaging, and the fear of potential fines due to the increasingly rigorous enforcement of national legislation restricting SUPs. Despite the challenges, all businesses expressed interest in adopting more environmentally sustainable practices, provided that systemic mitigating measures are implemented. These include deposit-based return programs for bottles (DRS), municipal investments in recycling infrastructure, and consumer awareness campaigns to drive behavioral change. These findings highlight that the HoReCa sector has a high level of awareness of the environmental impacts of plastics and shows a willingness to transition, but the main obstacles remain the nature of economic costs and infrastructural deficiencies that limit the implementation of changes. Table 3 summarizes by theme the results of the process.

Table 3 – Thematic matrix of interview results

Theme	Key Insights	Implications
Current Use of SUPs	All five businesses (2 hotels, 2 restaurants, 1 café) rely daily on plastic bottles, cups, straws, plates, and bags. Monthly spending ranges from 40,000–120,000 ALL, with seasonal peaks in tourist-oriented establishments.	Plastic use is structural to operations; any intervention must account for seasonality and demand patterns.
Barriers to Change	Plastics are cheap, convenient, and widely available, but storage and disposal create logistical burdens. Biodegradable alternatives cost 40–70% more, making them unaffordable for small businesses. Customers resist price increases.	Economic constraints are the primary obstacle; businesses need cost-sharing mechanisms (e.g., subsidies, pooled procurement) to adopt alternatives.

Theme	Key Insights	Implications
Hidden Costs Awareness	Businesses recognize indirect costs: waste collection/transport, extra storage space, and risk of fines under stricter SUP regulations.	Indicates growing pressure to transition and readiness to adopt change if systemic solutions are provided.
Willingness to Transition	All businesses expressed interest in environmentally friendly practices but stressed the need for enabling measures such as deposit–return schemes (DRS), municipal recycling investments, and consumer awareness campaigns.	Policy action should focus on infrastructure investment, financial incentives, and behavior change campaigns to enable a sector-wide shift.

Source: The Authors

6. Insights from a cost–benefit analysis and HoReCa sector case studies

Literature shows through a cost–benefit analysis (CBA) that preventing one ton of plastic leakage is estimated to generate €70 in benefits [20], including avoided collection, transport, and landfill costs, fewer riverbank clean-up operations, potential revenues from recyclables (PET, aluminum, glass), and improved tourism aesthetics. Among the strategies considered to achieve this, reusable systems combined with deposit–return schemes (DRS) provided the strongest performance, with program costs of €35 per ton and realized benefits of €49 per ton, resulting in a net positive balance of +€14 per ton. This option offers multiple co-benefits: it reduces SUP leakage by up to 80–90%, achieves high return rates for PET and glass containers, and is broadly supported by HoReCa businesses and urban consumers provided that adequate infrastructure is in place. Source separation with material recovery facilities (MRFs) ranked second-best, achieving near break-even performance (–€1.5 per ton) but representing a critical long-term investment for Albania's recycling capacity and alignment with EU circular economy targets. Other measures—biodegradable products, single-use glass recycling, and awareness campaigns—were found to be important but insufficient on their own, with negative net balances ranging from –€32 to –€0.5 per ton. Table 4 summarizes the finding from selected literature sources.

Table 4 – Cost–Benefit Summary of Plastic Reduction Options for the HoReCa Sector

Option	Program Cost (€ / ton)	Capture Rate (%)	Realized Benefit (€ / ton)	Net Balance (€ / ton)	Remarks
Reuse + DRS (PET/Glass)	35	70	49	+14	Strong financial case; reduces SUP leakage by 70–90%
Source Separation + MRF	40	55	38.5	–1.5	Near break-even; builds long-term infrastructure
Biodegradables + Composting	60	40	28	–32	Requires composting facilities; expensive for SMEs
Single-Use Glass (Recycling)	45	50	35	–10	Viable only when integrated into reuse systems
Awareness Campaigns	10	15	10.5	–0.5	Low-cost but supportive measure, not sufficient alone

Source: Adapted from World Bank (2018), UNEP (2021), BeMed (2022), ETMI Baseline Study (2025)

These data were further contextualized using field survey data from five HoReCa units in Elbasan and Librazhd (two hotels, two restaurants, one café). The surveyed establishments serve 80–150 customers per day (cafés/restaurants) and 200–250 customers per day (hotels) during the tourist season, with a marked rise in SUP use during peak summer months (Table 2). Monthly plastic-related expenditures ranged from 40,000 to 120,000 ALL (400-1200 EUR) per business, depending on size and location (Table 5).

When compared to "green" alternatives—glass bottles, cardboard cups/plates, and wooden cutlery—the cost difference was significant: switching would increase monthly expenses by 40–70%, raising average monthly costs from about 66,500 ALL to nearly 158,000 ALL (665 EUR-1580 EUR) (Table 6). However, plastics also carry hidden costs, including 5,000–10,000 ALL (50-100 EUR) for transport, 3,000 ALL (30 EUR) for storage, and potential future fines. When these externalities are accounted for, the effective cost of plastic use rises to approximately 74,500 ALL (745 EUR) per month, narrowing the cost gap and strengthening the case for transition (Table 7).

Beyond the economic analysis, interviews revealed that managers acknowledge the logistical challenges of storing and disposing of large amounts of SUP waste and express growing concern about regulatory pressure. Most respondents favoured systemic solutions—such as DRS programs, municipal investments in recycling infrastructure, and consumer awareness campaigns—that would enable them to adopt reusable and recyclable alternatives without jeopardizing profitability.

Table 5 – Monthly Plastic Consumption and Costs in ALL

Unit	Plastic Bottles (20 ALL)	Plastic Cups (2 ALL)	Plastic Plates (4 ALL)	Fork/Knife (3 ALL)	Plastic Bags (5 ALL)	Straws (1 ALL)	Total Monthly Cost ALL)
Sopoti Caffe	30,000	6,000	0	0	1,500	2,400	39,900
Imperial Hotel	72,000	9,000	12,000	9,000	3,000	3,000	108,000
Bar Rest. Moglica	36,000	4,800	7,200	4,500	2,250	1,800	56,550
Balkan Hotel	60,000	7,200	9,600	7,200	3,000	2,400	89,400
Vila Zeneli	24,000	3,600	4,800	3,600	1,500	1,200	38,700

Source: Authors' calculations based on interview data (2025)

Table 6 – Monthly Costs for Green Alternatives

Unit	Glass Bottles (50 ALL)	Cardboard Cups (5 ALL)	Cardboard Plates (7 ALL)	Wooden Forks (6 ALL)	Cardboard Bags (10 ALL)	Paper Straws (3 ALL)	Total Monthly Cost (ALL)
Sopoti Caffe	75,000	15,000	0	0	3,000	7,200	**100,200**
Imperial Hotel	180,000	22,500	21,000	18,000	6,000	9,000	**256,500**
Bar Rest. Moglica	90,000	12,000	12,600	9,000	4,500	5,400	**133,500**
Balkan Hotel	150,000	18,000	16,800	14,400	6,000	7,200	**212,400**
Vila Zeneli	60,000	9,000	8,400	7,200	3,000	3,600	**91,200**

Source: Authors' calculations based on market prices and interview data (2025)

Table 7 – Financial Comparison: Plastics vs. Green Alternatives

Material	Average Monthly Cost (ALL)	Hidden Costs (ALL)	Total Effective Cost (ALL)
Plastic	66,510	+8,000 (transport + storage)	**≈ 74,500**
Green Alternative	158,760	0 (no waste transport)	**≈ 158,760**

Source: Authors' calculations based on field data and cost estimates (2025).

Note: Calculations assume 30 days of operation per month.

Overall, these results confirm that no single measure is sufficient to tackle SUP leakage. The most effective pathway is a hybrid approach that places reuse systems and DRS at the center, reinforces them with MRF-based recycling infrastructure, and complements them with HoReCa-specific interventions (eco-certifications, refill systems) and public awareness campaigns to build consumer trust. This integrated model not only reduces SUP leakage immediately but also positions the HoReCa sector as a leader in Albania's circular economy transition, improving its competitiveness in tourism markets and aligning with EU SUP and extended producer responsibility directives.

7. Conclusions

This study has demonstrated that plastic pollution in the Shkumbin River basin constitutes both an environmental and economic challenge, with the HoReCa sector situated at the core of the issue and its resolution. Businesses in Elbasan and Librazhd provide evidence that using single-use plastics (SUPs) like bottles, cups, plates, and straws every day costs a lot of money each month, has hidden waste management costs, and can hurt a company's reputation. Plastics may seem like a good deal in the short term, but they create long-term problems for cities, local ecosystems, and the tourism economy.

The comparison of alternatives shows that no one option is enough on its own. Biodegradable products are still expensive and useless without composting infrastructure. Single-use glass only becomes competitive if there are deposit-return schemes (DRS) in place. Awareness campaigns are cheap and well-received by the public, but they don't do much good unless they are backed up by changes to the system. The best results come from a strategy that includes reusable systems, better recycling infrastructure, and targeted actions in specific areas, like banning single-use plastics and setting up refill stations. These steps can cut SUP leakage by 80 to 90%, bring Albania in line with EU rules, and make HoReCa businesses leaders in eco-friendly tourism.

A gradual and integrated transition is needed. Reuse and recycling should be the main parts of the system, with incentives, education, and legal compliance with EU policies as support. This change not only helps HoReCa businesses have a smaller impact on the environment, but it also makes them more competitive, builds customer trust, and gets the industry ready for the stricter rules that will come from the EU and national governments. So, dealing with plastic pollution in the Shkumbin River basin is not only good for the environment, but it is also a good chance for long-term economic growth.

Literature

[1] Eurostat. (2022). Recycling rates in the European Union. Retrieved from https://ec.europa.eu/eurostat

[2] IUCN. (2020). National guidance for plastic pollution hotspotting and shaping action. Gland, Switzerland: International Union for Conservation of Nature.

[3] Milieukontakt Albania. (2024). Final evaluation of the Low Plastic Zone initiative. Tirana: Milieukontakt Albania.

[4] European Environment Agency (EEA). (2021). Plastics, the circular economy and Europe's environment. Luxembourg: Publications Office. https://doi.org/10.2800/473368

[5] OECD, 2022 OECD. (2022). Global Plastics Outlook: Economic drivers, environmental impacts and policy options. Paris: OECD Publishing. https://doi.org/10.1787/de747aef-en

[6] Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768–771. https://doi.org/10.1126/science.1260352

[7] Tekman, M. B., Wekerle, C., Lorenz, C., Primpke, S., Hasemann, C., Gerdts, G., & Bergmann, M. (2020). Tying up loose ends of microplastic pollution in the Arctic: Distribution from the sea surface, through the water column to deep-sea sediments at the HAUSGARTEN observatory. Environmental Science & Technology, 54(7), 4079–4090. https://doi.org/10.1021/acs.est.9b06981

[8] Rillig, M. C. (2012). Microplastic in terrestrial ecosystems and the soil? Environmental Science & Technology, 46(12), 6453–6454. https://doi.org/10.1021/es302011r

[9] Wright, S. L., & Kelly, F. J. (2017). Plastic and human health: A micro issue? Environmental Science & Technology, 51(12), 6634–6647. https://doi.org/10.1021/acs.est.7b00423

[10] Leslie et al., 2022

[11] Talsness, C. E., Andrade, A. J. M., Kuriyama, S. N., Taylor, J. A., & vom Saal, F. S. (2009). Components of plastic: Experimental studies in animals and relevance for human health. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2079–2096. https://doi.org/10.1098/rstb.2008.0281

[12] Richardson, K., Hardesty, B. D., & Wilcox, C. (2019). Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis. Fish and Fisheries, 20(6), 1218–1231. https://doi.org/10.1111/faf.12407

[13] Newman, S., Watkins, E., Farmer, A., Ten Brink, P., & Schweitzer, J. P. (2015). The economics of marine litter. In M. Bergmann, L. Gutow, & M. Klages (Eds.), Marine Anthropogenic Litter (pp. 367–394). Springer. https://doi.org/10.1007/978-3-319-16510-3_14

[14] Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768–771. https://doi.org/10.1126/science.1260352

[15] Geueke, B., Groh, K., & Muncke, J. (2018). Food packaging in the circular economy: Overview of chemical safety aspects. Food Packaging and Shelf Life, 18, 100–111. https://doi.org/10.1016/j.fpsl.2018.06.001

[16] Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., ... & Giorgini, E. (2021). Plasticenta: First evidence of microplastics in human placenta. Environment International, 146, 106274. https://doi.org/10.1016/j.envint.2020.106274

[17] Rochat, D., Binder, C. R., Diaz, J., & Jolliet, O. (2013). Combining life cycle assessment and risk assessment to screen and compare potential impacts of products. Environmental Impact Assessment Review, 43, 1–8. https://doi.org/10.1016/j.eiar.2013.05.001

[18] BeMed. (2021). Beyond Plastic Med: Commit to a plastic-free Mediterranean Sea. Monaco: Beyond Plastic Med.

[19] Adhami, E. (2022). Position paper on the single-use plastic ban in Albania: Policy framework and challenges. INCA Albania / BeMed Program.

[20] ETMI 2020.[Deliverable 1: Baseline assessment of plastic pollution along the Shkumbin River. Environmental and Territorial Management Institute, Tirana.

Management of geothermal waters after their use for balneological purposes: Environmental impacts and the importance of sustainable practices.
Case study: Llixha of Elbasan-Albania

Joana Gjipalaj[1]

Oltion Marko[2]

Denisa Selimi[3]

Xhuana Xhika[4]

1 Prof. Asoc. Joana Gjipalaj, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania,
joana.gjipalaj@fin.edu.al

2 Prof. Dr.Oltion Marko, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania
oltion.marko@fin.edu.al

3 BSc. Denisa Selimi, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania
denisa.selimi@fin.edu.al

4 BSc. Xhuana Xhika, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania
xhuana.xhika@fin.edu.al

Abstract

The use of geothermal waters for balneological purposes offers significant health benefits due to their unique chemical and thermal properties. However, the management of these waters after therapeutic use presents important environmental challenges. These used geothermal waters often contain high concentrations of dissolved minerals, organic matter and microbial contaminants, which can adversely affect soil, surface water, and groundwater ecosystems if not properly treated. This study examines the environmental impacts associated with post-balneological geothermal water discharge and explores potential treatment and sustainable management methods, including physical, chemical, and biological approaches, as well as reinjection strategies. This study focuses specifically on the Llixhat of Elbasan in Albania, a prominent geothermal spa facility where geothermal waters are extensively used for therapeutic treatments but are not subjected to any form of preliminary or post-use treatment. The direct discharge of untreated geothermal effluents into the surrounding environment raises serious concerns regarding soil salinization, microbial proliferation and deterioration of water quality in nearby ecosystems. The implementation of these approaches could significantly mitigate environmental impacts and contribute to the long- term sustainability of geothermal resources. By addressing both the local situations at the Llixha of Elbasan and broader implications for geothermal water management, this study emphasizes the urgent need for environmentally sustainable practices in balneological operations. Additionally, continuous monitoring of water quality parameters is essential to safeguard both human health and ecosystems. The integration of sustainable technologies and regulatory frameworks will ensure the long-term viability of balneological resources and ecosystems.

Keywords

Geothermal waters, Environmental impacts, Wastewater management, Sustainable practices

1. Introduction

Geothermal waters are natural groundwater heated within the Earth by magma or hot rocks, rising to the surface through fissures and cracks. They are stored within deep geological formations and often contain a high concentration of dissolved minerals due to prolonged interaction with surrounding rocks. These waters can reach the surface through natural springs or can be extracted by drilling wells [1]. Their temperature can range from mildly warm to very high, depending on the depth and geothermal gradient of region. Geothermal waters represent a valuable natural resource with environmental, therapeutic, and economic importance, as they combine both thermal energy and mineral composition beneficial for multiple applications [2-4]. They are classified into: Low-temperature - Geothermal waters-typically below 90ºC, suitable for direct use such as balneology, heating, aquaculture and agriculture; and High-temperature - Geothermal waters-above 150ºC, primarily used for electricity generation and industrial processes [2]. In Albania, geothermal waters represent an important natural resource, strongly connected to the country tectonic activity and complex geological structure. Albania lies in a favourable geothermal zone, where carbonate and sedimentary rock formations create underground reservoirs that supply thermal springs with temperature ranging from approximately 29ºC to over 65ºC. Albania has considerable potential for renewable energy generation from geothermal waters, but this sector is still unexplored. The main use of geothermal waters in Albania is for balneology purposes, as thermal baths of Llixha Elbasan, and other areas are well-known for therapeutic treatments and relaxation [5-8]. The aim of this study is to identify the environmental impacts associated with post-balneological geothermal water discharge and explores potential treatment and sustainable management methods for the study area Llixha Elbasan.

2. Theoritical background of the study area

The Llixha region, situated southeast of Elbasan city within the Shkumbini river valley at an elevation of 300-500 meters, is characterized by its thermal springs, which have been renowned since antiquity for their therapeutic qualities. The genesis of these springs is governed by a specific geological and hydrological framework. Structurally, the area lies within the Kruja tectonic zone, defined by the Llixha syncline, which is bounded by the Elbasan-Valeshit and Papër anticlines. The aquifer itself consists of a deep-seated, karstified, and highly permeable anticlinal structure composed of Cretaceous to Paleogene carbonate formations, hydraulically connected to the Tervol anticline recharge zone approximately 17 km to the southeast. Within the syncline, these formations are interspersed as calcareous olistoliths within Upper Oligocene flysch and conglomerate-sandstones, creating the pathways through which the thermal waters of the Kruja geothermal zone are channeled [9]. This deep-circulation system results in 20 springs with stable discharge rates and high temperatures of 55–65 °C. Hydrochemically, the waters are classified as chloride-sulfate-sodium-calcium type and are characterized by substantial hydrogen sulfide (H_2S) content, designating them as sulfhydryl or 'strong sulfide' waters [10].

Figure 1 – Geological map of the studied area Llixha-Elbasan region [9]

3. Environmental impacts after balneological use

The utilization of geothermal waters for balneological purposes, such as thermal baths and health resorts, brings significant social and economic benefits. However, their discharge into the environment after use can create a series of environmental impacts if not properly managed. These impacts are primarly related to the chemical composition, high temperature, and mineral load of the waters.

Figure 1 – Geological map of the studied area Llixha-Elbasan region [9]

3.1. Thermal pollution

Discharged spa effluent often remains substantially warmer than ambient waters; continuous warm effluent can alter river temperatures, affecting dissolved oxygen levels and aquatic biota. Thermal plumes may favour invasive species or disrupt spawing cycles in sensitive reaches.

3.2. Chemical pollution and salinity

Geothermal waters are commonly enriched with minerals and trace elements (e.g., chloride, sulfate, sodium, silica, arsenic in certain settings). Direct discharge without treatment can increase salinity and introduce undesirable constituents to soils and groundwater, leading to vegetation stream and groundwater quality degradation.

3.3. Scaling, clogging and soil alteration

Mineral precipitate (calcite, silica, sulfates) can accumulate in channels and soils where brine or thermal waters are discharged, reducing infiltration, changing soil structure, and damaging infrastructure.

3.4. Microbiological and public health issues

Balneological facilities must maintain hygiene standards; poorly managed effluent can disseminate pathogens or create vector habitats. Although the thermal environment often suppresses some pathogens, a monitoring program is needed to reduce health risks.

4. Sustainable post-use management options

Sustainable post-use management of geothermal waters is essential to balance the benefits of balneological activities with the protection of natural ecosystems. Once the therapeutic and recreational functions of these waters are fulfilled, they must be managed in a way that minimizes pollution, conserves resources, and supports long-term ecological integrity. Traditional practices of direct discharge into rivers or soils are increasingly seen as unsustainable due to their environmental impacts. Instead, modern approaches such as reinjection, controlled cooling, water treatment, and cascade use provide more environmentally responsible solutions. These options ensure that geothermal resources continue to serve human needs without compromising water quality, biodiversity, or the sustainability of the geothermal reservoir itself.

4.1. Reinjection

Reinjection of used geothermal water into the producing reservoir or nearby aquifer mitigates surfaces discharge impacts, preserves the hydrostatic balance, and can help maintain reservoir pressure and lifetime. Reinjection requires temperature and chemistry matching, suitable well design an d monitoring programs to avoid scaling or clogging in injection wells.

4.2. Cascade utilization

Cascade use applies geothermal water sequentially across multiple applications for example, first for balneology, then for space heating, greenhouse irrigation, or district heating via heat exchangers. Cascade use maximizes energy extraction and reduces overall discharge volumes and temperatures.

4.3. Treatment and dilution

When reinjection is impractical, targeted treatment (precipitation, neutralization, filtration) followed by controlled discharge or constructed wetlands can reduce concentrations of problematic constituents. Controlled dilution with low-salinity water may be necessary where treatment is limited.

4.4. Monitoring and adaptive management

A monitoring program should track temperature, major ions, trace elements of concern, total dissolved solids (TDS), and biological indicators upstream and downstream of discharge points. Monitoring allows early detection of impacts and informs adaptive management (e.g. changing discharge locations, adjusting reinjection protocols).

5. Conclusions and recommendations

This study concludes that the Llixha geothermal area in Elbasan represents a significant balneological resource of considerable value. The current post-utilization discharge of thermal waters presents a critical challenge, risking thermal pollution, chemical contamination of local ecosystems, and a potential decline in the resource's therapeutic quality. To address this, a series of prioritized interventions is essential. An immediate priority is a technical feasibility study to evaluate the viability of reinjecting spent geothermal fluids and establishing cascade systems for sequential energy and

agricultural use. Concurrently, the establishment of a robust baseline monitoring program—tracking physicochemical parameters like temperature, major ions, and Total Dissolved Solids (TDS), alongside key ecological indicators—is imperative to detect changes in the aquifer and surrounding environment. Furthermore, upgrading the existing discharge infrastructure to incorporate heat exchangers and sedimentation basins would mitigate environmental impacts and improve efficiency. Finally, the development of formal local permitting procedures and proactive stakeholder engagement frameworks is crucial to ensure regulatory compliance and community support. The synergistic implementation of these actions will not only mitigate environmental degradation and protect public health but also significantly enhance the socio-economic resilience and long-term value of the Llixha spa complex.

Literature

[1]	Lund, J.W., Freeston, D.H., & Boyd, T.L. (2010). Direct Utilization of Geothermal Energy 2010 Worldwide Review. Geothermics, 39(3), 159-180.
[2]	DiPippo, R. (2015). Geothermal Power Generation: Developments and Innovation. Woodhead Publishing.
[3]	Ayling, B., & Minissale, A. (2013). Sustainable Use of Geothermal Energy. Geothermics, 45, 9-17.
[4]	Arnórsson, S. (2000). Environmental Effects of Geothermal Power Production. Geothermics, 29(4-5), 453-461.
[5]	Jaka, B., & Islami,M. (2015). Geothermal Energy in Albania: Current Status and Perspectives. Renewable and Sustainable Energy Reviews, 41, 360-367.
[6]	Muka, M., & Gjika, D. (2013). Geothermal Fields of Albania and Their Potential Uses. Energy Procedia, 36, 635-644.
[7]	Aliaj, S., & Karaj, A. (2008). Hydrogeological Features of the Thermal Springs in Albania. Journal of Balkan Geophysical Society, 11(2), 95-105.
[8]	Gjika, D., & Cukali, M. (2016). Therapeutic Properties of Albanian Thermal Waters and Their Balneological Use. Albanian Journal of Medicine and Science, 8(1), 45-52.
[9]	Kodhelaj, N. (2007). The Llixha-Elbasan Hot Springs in Albania: Study of Temperature Conditions and Utilization Calculations. UNU-GTP Report.
[10]	Çomo, E., Hasimi, A., Kiri, E., Tako, E., & Shatro, A. (2023). Hydrochemical Assessment of the Aquifer of Thermal Waters in Llixha, Elbasan, Using Stiff Diagrams. Environmental Sciences Proceedings, 26(1), 167.

On the use of standards in risk management regulations

Johan Ingvarson[1]

1 Lecturer, Division of Risk Management and Societal Safety, Faculty of Engineering, Lund University
johan.ingvarson@risk.lth.se

Abstract

Standards are extensively used in risk management regulations. Aiming to contribute to an improved knowledge base on how to utilise standards in risk management regulations, this paper discusses the strengths, weaknesses, and effects of using prescriptive or standardised approaches (so-called hard regulations) and non-prescriptive (soft) approaches to risk management regulations. The discussion in this paper is based on a PhD thesis that explores the benefits and deficiencies of hard and soft regulatory approaches to risk management regulations. When evaluating the arguments presented in the discussion of hard vs. soft regulations, it cannot be concluded that one side of the discussion has stronger arguments than the other. Since arguments are highly contextual, each argument must be scrutinised in the specific application area or risk management domain. Similarly, the effects of hard or soft regulations are contextual, and the balance between the benefits and disadvantages must be explored in each situation.

Since using standards in regulations relies on the standard reflecting the best available knowledge, the process of producing the standard is essential. Consequently, the PhD thesis also examines the dynamic nature of risk management standardisation processes using a participant observation approach through which obstacles and pitfalls to successful standardisation associated with power relations are revealed by examining who is most active and influential in the development of standards.

Building on the research findings, it is suggested that a hard regulatory approach is beneficial for non-complex decision-making situations with high strength of knowledge. For decision-making situations characterised by increasing complexity, uncertainty, and ambiguity, softer approaches are more suitable. To ensure relevant standards are used in regulation, regardless of whether a hard or soft regulatory approach is chosen, the standardisation process (i.e. the production of the standard) should involve adequate participation and balanced representation from all relevant stakeholders (including risk practitioners and risk scientists). Every voice should be heard, and standardizers must remain vigilant to prevent power imbalances or misuse of power.

Keywords

Standardisation, risk management, risk assessment, regulations, hard law, soft law

1. Introduction

Managing and governing risk is a key component in regulatory regimes covering a wide range of technical disciplines. The way in which risk management is implemented into regulations varies significantly across countries [1], with two main strands of regulatory design: hard regulations contain detailed prescriptive requirements for how something should be achieved or performed, whereas soft regulations define functional requirements that focus on what is to be achieved or describe the required performance rather than outlining the required solution. If the level of detail prescribed in risk regulations is viewed as representing the level of standardisation, "hard" regulatory regimes represent a high level of standardisation, whereas "softer" regulations with lesser prescriptive requirements represent low levels of standardisation. In practice, however, even softer regulations may refer to prescriptive standards through guidelines or recommendations, retaining a praxis of high level of standardisation.

A development towards increased standardisation is observed in diverse risk domains such as terrorism and security risk management, cybersecurity, disaster risk management, and land-use planning [2], [3]. Even if prescriptive regulations are implemented in several countries and seem preferable among many stakeholders, there is no consensus on using standards and standardised approaches in risk management regulations as the most appropriate approach. Various contributors have added to the discussion with intellectual reasoning that problematises the use of standards related to risk management, e.g., [4], [2]. This paper is based on the findings of a research project related to the standardisation of risk and the risk of standardisation, conducted at Lund University from 2020 to 2025, culminating in a PhD thesis [5]. With the PhD thesis specifically discussing how standards should be used in a land-use planning risk management context, the ambition of this paper is to broaden the discussion by providing a perspective that is not risk domain-specific. The aim of this paper is to discuss how standards should be designed if used in risk management regulations.

2. Theoretical and Empirical background

2.1. Standards and standardization

In modern societies, standards are ubiquitous. Without diving into the "world of standards" [6], with its plentiful definitions of what standards are and numerous ways to categorise various types of standards, for the sake of discussion in this paper, standards describe something that should be followed to achieve an expected outcome. A standard represents a set of best-practice rules established through a standardisation process involving best available knowledge and expertise. This paper discuss the type of standards referred to as "process standards" [7] or "procedural standards" [8] that outline the expectations on which critical risk management activities (risk identification, risk analysis,

risk characterisation, risk evaluation, risk communication, etc.) should be performed to adequately manage risks, with or without specifying how they should be executed in practice. For example, ISO 31000 provides guidelines on managing risk using a set of principles, a framework, and a process. It does not define the expected output from applying these guidelines or directly measure the quality of risk management efforts.

2.2. Strengths and weaknesses of standardisation

Exploring the debate on soft versus hard regimes or low versus high levels of standardisation, it is evident that both approaches have strengths and weaknesses. In [9], an overview of the pro and con arguments found in scientific literature is provided, using a set of categories that tie together the commonalities of the comprehensive flora of claims and counterclaims used in the debate. Firstly, highly standardised approaches are assumed to provide *uniformity* through a prescribed, harmonised, and uniform "recipe" for how to assess, manage and/or govern risk. Simply put, prescriptive regulations are straightforward to follow, easy for interested stakeholders to check and easy for regulators to enforce. Secondly, standardisation brings *efficiency* in terms of the effective use of available resources, as everyone knows what is expected. Moreover, standards are more than just directions to follow; they are *elucidative*, pointing out what is relevant, valued, and important. Last but not least, standards are intended to represent *"best available knowledge"*, and if continuously revised, they are intended to represent flexible norms and provide the most up-to-date information on technology developments.

The weaknesses of hard regulations or high levels of standardisation are linked to criticism directed towards *conceptual deficiencies*, targeting the very fundamentals of risk and standardisation as phenomena and concepts. Managing risk is about managing uncertainties. Since standardisation encompasses elements of harmonisation and streamlining, standardising risk management could easily lead to simplifications that overlook uncertainties instead of addressing them. Secondly, prescriptive approaches are criticised for serving as a *barrier to innovation*, as standards are often developed based on past experiences, for which there are no precedents for novel technologies or solutions. Furthermore, a prescribed solution means that stakeholders may be locked into compliance with a set of *"one-size-fits-all"* type requirements, whereby flexibility is limited and the ability to address unique conditions on a case-by-case basis is restricted, thereby hampering the ability to adapt to specific needs. With standards specifying minimum solutions, the described requirements are in focus, not the optimal balance between risk and other aspects. This *compliance-driven* approach to managing risk may lead to loss of ownership, decreased ambition levels, and reduced motivation to conduct adequate and accurate risk assessments. A high level of standardisation is also criticised for *"over-managing"* risk, referring to the increased bureaucracy and resources allocated to administration rather than more rewarding risk management activities, as well as actors potentially implementing more extensive measures to ensure compliance with the standard. The last category of weaknesses discussed in [9] is that of *legitimacy* since standards and standardisation processes are associated with legitimacy challenges related to aspects of transparency (despite being open to all actors and resulting in an openly available end-result, the development of standards occurs in non-public proceedings with limited transparency of the work in process), accountability (e.g., who is to blame if things go wrong even if a standard is complied with – the issuer of the standard or the actor com-

plying with the inadequate standard?), and participation (specific groups such as unions, workers, smaller actors, vulnerable groups of the public, scientists and scholars, and even government regulators are under-represented in standardisation work).

Also included in the Lund University research project was an argument analysis that dissected the complete set of pro and con arguments, adding a perspective on the strength of each argument. The argument analysis in [10] indicates that many arguments are assessed as weak, interconnected, and potentially even contradictory. Arguments that favour standardisation are generally neither stronger nor weaker than the arguments that oppose standardisation. Instead, the benefits and disadvantages of hard versus soft risk management regulations are highly contextual and linked to value preferences. Consequently, it is not possible to suggest whether the strengths of standardisation generally outweigh the weaknesses.

2.3. Effects of standardisation

As a response to the findings in [5] and [9] that the arguments used to discuss soft versus hard risk management regulations lack empirical evidence, an additional activity in the research project was directed towards exploring the effects of high versus low levels of standardisation among practitioners in countries with different types of regulations for land-use planning. The study [11] concludes that standardisation does not come with only positive or negative effects, and specific effects are not exclusively the result of a high or low level of standardisation. Rather, the effects of different levels of standardisation of risk management regulations are highly contextual, and the balance of benefits and shortcomings of specific regulatory regimes must be explored in each situation. The most frequently discussed themes of the effects of standardised risk management regulations for land-use planning are briefly described below (from [5]):

Harmonisation: A high degree of standardisation brings increased harmonisation of outputs, resulting in a decision basis that can be understood, interpreted, compared, and used similarly regardless of who produces the decision basis and who receives it. Generally, respondents perceive harmonisation as primarily a positive effect. The opposite of non-detailed functional regulatory requirements will bring the opposite, and hence negative, effects, such as diverse decision bases using different calculation methods and a limited ability to compare different situations.

Predictability: A positive effect of highly standardised requirements is that risk management activities (e.g., risk assessments) are performed as expected using a predefined and agreed-upon approach and format. Supervisory activities (e.g., regulators verifying or validating risk assessments) are also made easier.

Competence: On the one hand, a high level of standardisation may result in a reduced need for specialist risk management competence, as a defined "recipe" should be followed. On the other hand, the use of standards with detailed requirements may reduce the potential for risk assessments to be performed as a "tick the box" activity if adequate competence is not available.

Flexibility: The ability to apply requirements to different types of risk and various contexts is significantly influenced by the level of standardisation. For example, detailed regulations can lead to reduced flexibility when risk assessments are less tailored to specific circumstances, making the decision-making basis misleading if the standard does not align with the situation. However, reduced flexibility may be compensated by improved comparability with similar situations (the result of "harmonisation" discussed above). Another negative aspect of limited flexibility is that risk assessments may be too detailed or not detailed enough.

Compliance: A highly standardised approach may result in a focus on compliance where different parties act or perform according to what is required by the regulation rather than what is most suitable in the specific situation. Alternatively, it may generate a perspective of "tell me what to do, and I do it" rather than trying to actually understand the risk situation.

Efficiency/effectiveness: Streamlining the risk management process will improve the utilisation of resources (time, money, etc.) when performing risk management activities (e.g., producing and reviewing risk assessments) while maintaining or even enhancing quality. A uniform approach also improves the dialogue between parties and facilitates knowledge sharing and experience transfer.

2.4. Influencing the development of standards

Using standards in risk management regulations, the content and quality of the standard are naturally the main contributors to its potential success. Very simply, standards are developed by bringing a group of experts together to discuss, deliberate, and reach a consensus. Consequently, this process of developing the standard is crucial for standardisation output. Therefore, one of the research activities aimed to examine the dynamic nature of risk management standardisation processes, with a focus on the influence of individual participants and their roles in the workgroups involved in producing the standards. By investigating power relations and the group dynamics of standardisation groups, [12] reveals obstacles and pitfalls to successful standardisation associated with power relations by examining who is most active and influential in the development of standards. The paper is underpinned by empirical data from the hundreds of hours spent with various workgroups related to risk management standardisation.

The study's main conclusion is that there are ample opportunities for individuals to influence standardisation processes, and all participants need to be attentive to the use of power to prevent undue impact. To address this, it is suggested that power theory fundamentals should be included in the introduction to standardisation for all standardisers, particularly the induction of chairs and convenors. Since any participant can significantly impact the process and output by understanding the rules of the game and playing it, there is a need for an improved vetting process for participating in the work. Specifically, the chair or convenor of a group has a highly influential role, requiring a particularly high level of competence to be sustained and monitored. In addition, the toolkit available for standardisation leaders should be expanded to include practical methods and techniques to ensure the inclusion of participants and promote interaction. These practical tools would support transparent and fair risk management standardisation processes.

In the study, it is also concluded that people with high proficiency in English interact more in standardisation activities than participants with a lower command of English. This is challenging since study observations indicate that someone using advanced language decorated with abbreviations and standardisation jargon is likely to be more influential than the less conversant participant, even if there is no actual, objective "technical" superiority between the two. To balance potential influence and ensure that valuable input from non-English-speaking experts is captured, it is suggested that standardisation activities and a diverse flora for deliberation with minimal language barriers are developed and promoted. Activities should also be designed so that actual presence is not a requirement to be heard.

3. Using standards in risk management regulations

At the core of the PhD thesis, which synthesises the knowledge generated by the research project [5], is a set of key aspects that should be considered when assessing the use and design of standards in risk management regulations. The aspects are developed from the set of categories that tie together the commonalities of strengths and weaknesses used in the debate on hard versus soft regulations (discussed in chapter 2.2. in this paper), the most frequently discussed themes of effects of standardised risk management regulations for land-use planning (chapter 2.3.), and the standardisation process characteristics (chapter 2.3.). The discussion of each of the aspects is briefly introduced below (for the comprehensive discussion including references, see [5]):

1. Uniformity, conformity, and predictability: With a standard specifying what to do (which risk management activities to perform, i.e. risk identification, risk analysis, risk characterisation, risk evaluation, risk communication, etc.), and how to do it (selection of risks, choice of risk analysis methods, calculation tools, input parameter values, risk acceptance criteria, etc.), the intended result will be achieved. However, performing the activities may vary significantly despite using the same standard. The competence of the people involved, the availability and quality of information and data, how precisely the standard is complied with, and the assumptions and simplifications in the system model of what is being assessed are just a few factors that cause variations in the final delivery. Ideally, a standardised approach will result in a predictable result. Considering the complexity, uncertainty, and ambiguity of risk [13], it may seem naïve to expect that a hard regulatory approach would produce adequately predictable results in accurately representing the "truth" about risk. However, by nature, they would probably be more predictable than the results of a soft approach. Using standards to increase uniformity and conformity is understandably desirable from a practitioner's perspective, as it simplifies their work (and potentially reduces job opportunities). For regulators, they would receive information in a familiar and approved format, which would facilitate review. However, from a risk theory and philosophical perspective, producing conformity and homogeneity is counterproductive since risk management and governance require diversity and heterogeneity.

2. Risk identification: The first step in any risk management approach is to identify relevant risks. Building on adequate knowledge of the system and past experiences, relevant risks are identified and subsequently characterised, presented, evaluated, etc. Therefore, using a standard that outlines the relevant risks or defines how to identify them may be attractive. The standard could (or, ideally, would) include non-typical and less familiar risks and those not of particular interest to the party performing the assessment to support the identification and inclusion of all relevant risks. This approach is beneficial for systems that are well-known and non-complex. An inherent challenge of standards, however, is that they are built on past experiences. A characteristic of complex risks is that they are associated with significant uncertainties (i.e. limited historical data), which is typically required for successful standardisation. Consequently, hard regulations are less suitable for unfamiliar and complex risks, as standards may reduce the capacity to discover new risks.

3. Efficiency and effectiveness: Standardisation is intended to lead to efficiency (doing things right) and effectiveness (doing the right things). Being explicit about what is required allows actors to streamline their internal work processes, and experiences are easily shared between actors. There is also less need for "reinventing the wheel," since recognised solutions can be reused, eliminating the need to explore alternative solutions. Hence, standardisation is beneficial from the perspective of producing the decision basis for managing risk. A potential disadvantage is that some actors or situations may be subject to increased administrative requirements if the standard includes higher ambition levels than current practice.

4. Best available knowledge: Standards are intended to represent the best available knowledge. This is, however, contested, as standardisation processes sometimes suffer from inadequate representation of risk scientists, resulting in the best available knowledge not being utilised. Since standards are regularly reviewed and updated, there are opportunities to incorporate recent developments as they emerge and are implemented. However, standards are criticised for often failing to keep pace with changes, so they become outdated due to the emergence of new knowledge or alternative solutions.

5. Compliance: A strength of the hard law approach with detailed prescriptions is that the standard then represents defendable, auditable processes and a way to demonstrate and verify compliance. The downside of being explicit about what exactly is expected is that the standard then specifies minimum solutions and does not encourage higher ambition levels. A strong compliance-driven focus could also potentially lead to a loss of ownership and reduced motivation to perform risk management activities, thereby reducing the quality of these activities. In practice, focusing on compliance with prescriptive requirements for risk management should result in improved performance and an enhanced decision-making basis. At the same time, there are limited incentives to perform better than the standard, which would contradict the continuous improvement ambition of many actors' risk management policies. This indicates that standardising risk management regulations for non-complex risk situations characterised by a high degree of agreement among actors would help raise the bar for most decision-making situations. Resources can then

be routed to the more complex and controversial situations where non-standardised approaches can stimulate "out of the box" thinking and novel solutions, unrestrained by detailed requirements for performing risk management activities.

6. Flexibility: Hard regulations using prescriptive requirements intend to limit flexibility by prescribing a one-size-fits-all type of solution that is not tailored to the specific situation. There are several negative effects of this, including standards acting as a barrier to innovation and novel solutions, and characterised risk levels relating less accurately to the actual risk if the standard does not correctly reflect the situation studied in a particular case.

7. Competence: Managing risk involves managing uncertainties, which requires specific skills and competencies to produce risk assessments and interpret their results. Reliance on standards may lead to a deterioration in technical competence, potentially impacting the quality of the decision-making basis. In the long term, it may also lead to lower quality in standards if deteriorating competence results in less expertise to update them. If there is a "recipe" to follow, there may be less need for specialist risk management competence. If less risk competence is available to decision-makers, the risk may be misinterpreted or downplayed. On the one hand, an increased level of standardisation may require less specialist risk competence, but on the other hand, more risk competence is required to manage the risk adequately. In this paradox, the disadvantages of a prescriptive approach outweigh the benefits if managing risk is reduced to a "tick the box" activity and adequate competence is not available. Risk management is more than just ensuring that the decision basis is provided; adequately managing risk requires experienced specialists who are up to speed on the most recent advances in risk science to help inform decisions.

8. Facilitate risk governance: Increasing the level of standardisation for governing risk may help facilitate the integration of several sources of information in multi-actor risk assessment processes. However, if one type of risk is standardised, other risks may be neglected or receive inadequate attention. It is, therefore, challenging from a risk governance perspective if one aspect underpinning decision-making on land-use planning is highly standardised, while other aspects (costs, impacts on the economy, environmental concerns, aesthetics, cultural environment aspects, socioeconomic factors, etc.) are not.

9. Legitimacy: Regardless of whether a hard or soft approach is chosen for managing risk in land-use planning, strong buy-in from actors is required. If standards are used, participation and influence from a wide range of actors in the production of the standards will increase legitimacy. Standards and standardisation are criticised for inadequate transparency (i.e., public access to information and decision-making procedures) and inadequate or imbalanced stakeholder representation (e.g., involvement of participants and representation from academia, the public, etc.), which generates legitimacy concerns. Any standard used in risk management regulations must be developed as a joint, transparent effort with all relevant actors, who must be attentive to the use of power to prevent undue impact on the production of standards. Utilising new practical methods and techniques, this effort should ensure the inclusion of participants and promote interaction.

4. Conclusions

Building on the research findings in [5], it is concluded that for "simple" risk problems [14] with high strength of knowledge, a hard regulatory approach using process-type standards should be employed in risk management regulations. "Simple" risk problems refer to non-complex decision situations where it is possible to quite accurately predict relevant risk scenarios, their likelihood of occurrence and the severity of their consequences. Using a hard approach in these situations will reinforce the benefits of using a prescribed, harmonised and uniform "recipe" for how to identify and characterise risk. In non-complex situations, there is limited ambiguity in interpreting risk, making it fairly straightforward to utilise recognised tools for risk management and governance (e.g., conventional risk assessment methods, risk calculation tools, and risk criteria). In situations where past experiences are available and relevant, the criticism directed towards a hard approach being a barrier to innovation is avoided.

However, for decision situations with increasing complexity and unfamiliarity, past experiences are no longer available, and best practices are not yet established. Consequently, the balance between the advantages and disadvantages of using a prescribed "recipe" will change. The higher the complexity (i.e. the difficulty of identifying and quantifying risk scenarios), uncertainty (i.e. difficulty in accurately predicting the likelihood of events and/or their consequences), and ambiguity (i.e. different views on how to interpret risk and risk assessment results and the priorities to be made when balancing risks and benefits), softer approaches are more suitable. A standard defining the adequate and necessary steps of the risk management and governance process, without prescribing how the steps should be executed in detail, would allow flexibility and improvisation in the specific approaches applied in each decision-making situation. A soft process type-standard for complex, uncertain, ambiguous risk problems would allow resources to embrace the multifaceted risk domain and holistically manage and govern risk - rather than reducing risk management to a "tick the box" activity.

Literature

[1]	Hood, C., Rothstein, H., Baldwin, R.: "The government of risk: understanding risk regulation regimes", Oxford University Press, 2001, 217p.
[2]	Olsen, O. E., Juhl, K., Lindøe, P. H., Engen, O. A.: "Standardization and Risk Governance A Multi-Disciplinary Approach", Routledge, 2020, 290p.
[3]	Ingvarson, J.: "The Basis for Debating Standardization of Risk for Land-use Planning is Incomplete", Proceedings of ESREL / PSAM 2020, pp. 3981-3988.
[4]	Aven, T., Ylönen, M.: "The strong power of standards in the safety and risk fields: A threat to proper developments of these fields?", Reliability Engineering & System Safety, 189, 2019, pp. 279–286.
[5]	Ingvarson, J.: "Standardisation of Risk and the Risk of Standardisation - Using standards in risk management regulations for land-use planning", PhD Thesis, Lund University, Lund, 2025, 105p.
[6]	Brunsson, N., Jacobsson, B.: "A World of Standards", Oxford University Press, 2000, 188p.
[7]	Brunsson, N., Rasche, A., Seidl, D.: "The Dynamics of Standardization: Three Perspectives on Standards in Organization Studies", Organization Studies, 33(5/6), 2012, pp. 613–632.
[8]	Timmermans, S., Berg, M.: "The Gold Standard: The Challenge of Evidence-Based Medicine and Standardization in Health Care", Temple University Press, 2003, 269p.
[9]	Ingvarson, J.: "Standardization in Risk Management Regulations: What Can We Learn From Scientific Literature?" Proceedings of ESREL 2021, pp. 1245-1252.
[10]	Ingvarson, J., Hassel, H.: "On the strength of arguments related to standardization in risk management regulations", Safety Science, 158, 2023.
[11]	Ingvarson, J.: "Effects of standardization in risk management regulations for land-use planning related to process industries and transportation of dangerous goods", Journal of Loss Prevention in the Process Industries, 91, 2024.
[12]	Ingvarson, J.: "Who influences standardisation processes? The example of risk management standards", Journal of Standardisation, Vol. 4, 2025.
[13]	van Asselt, M. A., Renn, O.: "Risk governance", Journal of Risk Research, 14(4), 2011, pp. 431–449.
[14]	Aven, T., Renn, O.: "Some foundational issues related to risk governance and different types of risks", Journal of Risk Research, 2019, pp. 1–14.

Energy efficiency in buildings as a source of carbon credits: a case study of Prrenjas, Albania

Kristjana Omeri[1]

Teida Shehi[2]

1 MSc, Faculty of Civil Engineering, Polytechnic University of Tirana, Str. Muhamet Gjollesha nr. 54, Tirana, Albania
kristjanaomeri@gmail.com

2 PhD, Faculty of Civil Engineering, Polytechnic University of Tirana, Str. Muhamet Gjollesha nr. 54, Tirana, Albania
teida_shehi@hotmail.com

Abstract

This article examines the relationship between energy efficiency in the building sector and carbon credit trading mechanisms, highlighting their potential for reducing greenhouse gas emissions and creating economic benefits. The article analyzes the Albanian legal framework on energy efficiency and climate policy and connects it with international practices and regulations governing carbon markets, both compliance and voluntary. The empirical part of the research focuses on a case study conducted in the city of Prrenjas, Albania. In this study, 75 residential buildings were surveyed to collect data on energy consumption and the presence or absence of thermal insulation. Results show that buildings equipped with thermal insulation consume, on average, about 20% less energy than those without insulation, leading to significant reductions in CO_2 emissions. Using standard emission factors, the analysis estimates the potential for these energy savings to translate into carbon credits if integrated into carbon markets, suggesting a possible financial incentive for future investments in energy efficiency measures. Although further steps would be needed to develop detailed methodologies and procedures for certifying such projects, the findings indicate that energy efficiency in buildings could contribute meaningfully to Albania's climate goals while simultaneously offering economic advantages. The article concludes by emphasizing the need for national and local policies to support the broader adoption of energy efficiency measures and facilitate access to carbon markets, viewing this as a sustainable pathway toward urban development, improved living conditions, and climate change mitigation. The article also briefly reflects on possible barriers, such as the need for greater awareness of carbon market opportunities and for improved capacity to quantify and verify energy savings. While not extensively analyzed, the study acknowledges that energy efficiency measures may contribute to improved indoor conditions and offer indirect social benefits. Aligning national legislation with international standards is also recognized as an important step for enabling access to future carbon finance mechanisms.

Keywords

Energy efficiency, Carbon credits, Carbon markets, Buildings, Prrenjas, CO_2 emissions

1. Introduction and objectives of the study

Global climate change presents one of the most significant challenges of the 21st century. The building sector accounts for nearly 37% of global CO_2 emissions, making it a crucial target for decarbonization policies. Improving energy efficiency in buildings reduces primary energy demand, enhances energy security, and lowers operational costs, while also generating measurable emission reductions. These reductions can be transformed into carbon credits, representing an opportunity to link local mitigation efforts with international carbon markets.

In the European Union (EU), energy efficiency is considered a cornerstone of climate policies, complementing renewable energy expansion and the implementation of emission trading systems. For Albania, an aspiring EU member, integrating these mechanisms represents both an obligation and an opportunity to align domestic policies with EU standards.

The objectives of this study are:

1. To examine the link between energy efficiency in residential buildings and carbon credit opportunities.
2. To review the enabling policy and legal frameworks.
3. To analyze a case study in Prrenjas to quantify energy savings and potential CO_2 reductions.

2. Methodology

The methodology consists of three stages:

1. Survey Design and Data Collection
2. Energy Consumption Analysis
3. CO_2 Emission Calculations

The household survey was conducted in June 2025.
This approach ensures replicability and provides a realistic assessment of the potential role of small municipalities in contributing to national and international carbon reduction targets.

3. Legal and policy framework

Albania has adopted several legislative measures to align with EU energy and climate policies. The Law on Energy Efficiency (No.124/2015, amended 2019) and the Law on the Energy Performance of Buildings (No.116/2016) transpose the EU directives 2010/31/EU (EPBD) and 2012/27/EU on energy efficiency. Albania's Nationally Determined Contribution (NDC) under the Paris Agreement commits to reducing GHG emissions by 20.9% by 2030 compared to baseline scenarios.

The National Energy Strategy 2024–2030 and the Energy Efficiency Strategy 2018–2030 further outline objectives for building retrofits, renewable energy integration, and the reduction of fossil fuel dependency. While Albania is not yet part of the EU Emissions Trading System (ETS), voluntary carbon markets remain accessible pathways for monetizing building retrofits. Strengthening institutional capacity for Monitoring, Reporting and Verification (MRV) will be a prerequisite for Albania's participation in carbon credit trading.

3.1. International experiences in building energy efficiency

International experiences provide valuable lessons. In the European Union, the Renovation Wave initiative aims to retrofit 35 million buildings by 2030, with an expected 60% reduction in CO_2 emissions from the residential sector. In Central and Eastern Europe, countries such as Poland and Bulgaria have successfully implemented targeted subsidies and low-interest loans to accelerate retrofitting. In Germany, the state-owned KfW Development Bank (*Kreditanstalt für Wiederaufbau*) has financed building retrofits since the 1990s, leading to billions of euros in energy savings and millions of tonnes of avoided emissions.

Beyond Europe, China's Green Building Action Plan and India's Energy Conservation Building Code integrate energy efficiency with carbon finance. These international cases demonstrate the feasibility of combining national policies with carbon markets—an approach Albania can replicate in cities like Prrenjas.

4. Climate challenges and the building sector

Globally, the building sector is recognized as one of the most energy-intensive and carbon-intensive sectors, responsible for approximately 30–40% of total final energy consumption and nearly 37% of global CO_2 emissions. A large share of this demand is associated with heating, cooling, and electricity for lighting and appliances. Without transformative measures, global building-related emissions are projected to continue rising due to urbanization, population growth, and increased comfort expectations.

In Albania, the challenges are particularly acute. The majority of the building stock was constructed before the introduction of modern energy efficiency standards, with limited insulation, outdated construction materials, and inefficient heating technologies. Heating demand dominates energy use, especially during the long and cold winters in inland areas such as Prrenjas. Reliance on electricity and firewood for heating further contributes to high energy intensity, air pollution, and greenhouse gas emissions. These conditions not only hinder Albania's climate mitigation goals but also exacerbate social issues such as energy poverty, where households spend a disproportionate share of their income on basic energy needs.

Energy-efficient retrofits offer a pathway to simultaneously address these environmental and socio-economic challenges. Interventions such as external wall insulation, roof and floor insulation, replacement of single-pane windows with double

or triple glazing, and installation of efficient heating systems can reduce energy demand in buildings by 30–50%. Moreover, integrating renewable energy sources, such as rooftop solar panels and heat pumps, can further decarbonize the sector.

Beyond emission reductions, energy-efficient housing delivers multiple co-benefits: improved indoor air quality, enhanced thermal comfort, reduced household expenditures on energy, and increased property values. These measures are especially relevant in small municipalities like Prrenjas, where low-income households face both economic and health vulnerabilities. By prioritizing building retrofits, municipalities can not only contribute to national climate commitments but also improve the well-being of their residents, demonstrating the dual environmental and social dividends of energy efficiency.

5. Carbon markets and credits from energy efficiency

5.1. What are carbon markets?

Carbon markets are economic systems that allow the trading of *carbon credits*, each typically representing one ton of CO_2 (or equivalent GHGs (Greenhouse Gases)) reduced, avoided, or removed from the atmosphere. They function under the principle of *cap-and-trade*, where a maximum emission cap is set, and allowances can be bought or sold depending on whether entities exceed or stay below their limits.

By putting a price on emissions, carbon markets create financial incentives for industries and governments to adopt cost-effective mitigation measures. Without such mechanisms, emission reductions would often rely on more expensive and less efficient policies.

Carbon markets cover the six major GHGs (Greenhouse Gases) identified in international agreements (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) and operate either as **compliance markets** (legally binding) or **voluntary markets**.

5.2. Compliance vs. voluntary markets

Compliance Carbon Markets are established by governments through legislation (e.g., EU ETS (Emission Trading Schemes), California Cap-and-Trade). They set legally binding emission caps, issue allowances, and penalize non-compliance. These markets directly contribute to achieving Nationally Determined Contributions (NDCs) under the Paris Agreement.

Voluntary Carbon Markets (VCMs) operate outside legal obligations, allowing companies or individuals to purchase credits to offset emissions. Typical projects include reforestation, renewable energy, and methane recovery. Standards such as *Verra* and *Gold Standard* certify the credibility of these offsets.

Figure 2 – Comparison of Compliance and Voluntary Carbon Markets

Feature	Compliance Market	Voluntary Market
Legal basis	Mandated by law	Voluntary, no legal obligation
Objective	Meet binding GHG (Greenhouse Gases) targets	Offset emissions, CSR (Corporate Social Responsibility) , branding
Participants	Companies, NGOs (Non-Governmental Organizations), individuals	Regulated industries
Products	Allowances, CERs (Certified Emission Reductions)	Voluntary credits
Oversight	Government, regulated exchanges	Independent standards

6. Case studies of Prrnejas

The empirical analysis was conducted in the municipality of Prrenjas, a small urban center in southeastern Albania characterized by cold winters, relatively low household incomes, and a building stock dominated by structures constructed during the socialist period (1970s–1980s). These conditions make it an appropriate case study for exploring the nexus between energy efficiency, carbon reduction, and socio-economic co-benefits.

The household survey covered 75 residential buildings, including both detached houses and multi-family apartment blocks. Results indicated that 40% of buildings were partially or fully insulated, while 60% had no insulation at all. The absence of insulation was particularly evident in older apartment blocks, where residents reported high energy bills and poor indoor comfort. Detached houses demonstrated more variability in performance, depending on construction quality, retrofitting interventions by individual households, and heating system type.

Energy consumption patterns revealed a clear difference between insulated and non-insulated buildings. Apartment blocks constructed in the 1970s–1980s recorded the highest annual energy use, reflecting their poor envelope design and reliance on inefficient heating systems, often electricity-based or wood-burning stoves. In contrast, buildings that had undergone partial retrofits (such as window replacement or roof insulation) demonstrated significant reductions in energy demand, confirming the cost-effectiveness of even incremental improvements.

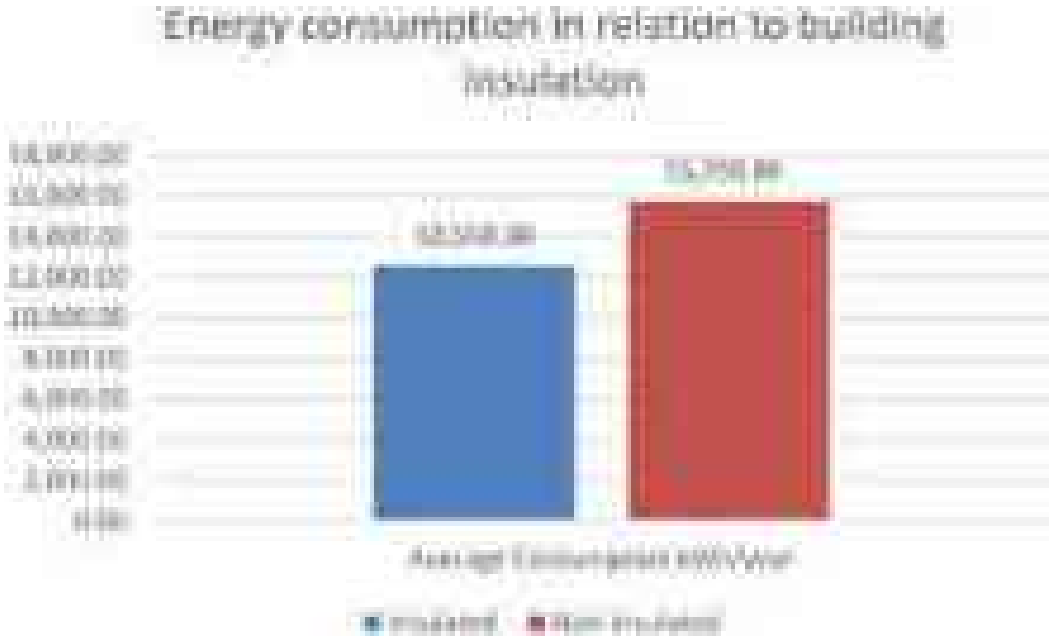
Table 2 – Energy consumption and emissions by building insulation status

Building Category	Average Energy Consumption (kWh/year)	Estimated CO_2 Emissions (tCO_2/year)
Insulated	12,550.38	3.14
Non-Insulated	15,758.86	3.94

The comparison shows that non-insulated buildings consume, on average, 25% more energy than insulated ones, leading to approximately 1.1 tCO_2 higher annual emissions per building. When aggregated, the retrofit of all 45 non-insulated buildings included in the survey could reduce emissions by about 50 tCO_2 annually.

Translating these reductions into financial value through carbon markets, the study estimated potential revenues of USD 8–12 per tCO_2. This would correspond to USD 400–600 annually per cluster of buildings if credits were sold in voluntary markets. While this figure may appear modest in absolute terms, it could represent an important co-financing mechanism when combined with government subsidies, donor-funded programs, or municipal support schemes. Moreover, the potential will grow over time as carbon credit prices are expected to rise in line with global decarbonization commitments.

Beyond financial gains, these findings carry important implications for household well-being and urban sustainability in Prrenjas. Retrofitting efforts would reduce energy bills, alleviate energy poverty, and improve indoor comfort levels. Additionally, lower firewood consumption could contribute to better local air quality, with associated health benefits.



Graphic 1 – Energy consumption in relation to building insulation

Insulated buildings consume on average ~3,200 kWh/year less energy than non-insulated ones, which represents a reduction of around 20% in consumption. The analysis showed that there is a significant difference between the two groups in terms of total annual energy use. Specifically, insulated buildings, which represent about 43% of the studied sample, record an average consumption of 12,550 kWh/year, whereas non-insulated buildings, representing 57% of the sample, have an average consumption of 15,758 kWh/year. This difference of 3,208 kWh/year is a clear indicator of the impact of thermal insulation in reducing energy losses and, consequently, in improving the energy efficiency of buildings.

7. Conclusions and recommendations

This research concludes that energy efficiency in buildings reduces emissions while unlocking carbon finance opportunities. The case of Prrenjas shows that even small municipalities can benefit from integrating building retrofits with carbon markets.

Key Recommendations:

1. Strengthen national building codes on energy performance.
2. Develop pilot carbon-financed retrofit projects.
3. Establish national MRV systems for carbon credit generation.
4. Encourage public-private partnerships for building retrofits.
5. Promote regional cooperation on carbon market readiness.

By aligning national strategies with carbon finance mechanisms, Albania can transform energy efficiency into a driver of sustainable, low-carbon development.

Literature

[1]	Ürge-Vorsatz, D., et al. (2012). Energy end-use: Buildings. In Global Energy Assessment – Toward a Sustainable Future (pp. 649–760). Cambridge University Press, Cambridge, UK.
[2]	Sovacool, B. K., & Griffiths, S. (2020). The cultural barriers to a low-carbon future: A review of energy efficiency studies in buildings. Renewable and Sustainable Energy Reviews, 119, 109567.
[3]	European Commission (2010). Directive 2010/31/EU on the energy performance of buildings (EPBD).
[4]	European Commission (2012). Directive 2012/27/EU on energy efficiency.
[5]	European Commission (2018). Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions.
[6]	UNFCCC (2015). Paris Agreement.
[7]	IPCC (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of WG III to AR6.
[8]	Albanian Parliament (2015). Law No. 124/2015 on Energy Efficiency.
[9]	Albanian Parliament (2016). Law No. 116/2016 on the Energy Performance of Buildings.
[10]	Boston Consulting Group & World Economic Forum (2021). Net Zero Carbon Cities.
[11]	IEA (2021). Net Zero by 2050: A Roadmap for the Global Energy Sector.
[12]	UNDP (2020). Unlocking the Potential of Energy Efficiency in the Western Balkans.
[13]	World Bank (2022). Western Balkans Green Transition: Opportunities and Challenges.
[14]	Gold Standard (2021). Methodologies for Energy Efficiency Projects in VCM.

Societal impact of cars with reference to Sarajevo Canton

Leonardo Pavičić[1]

Nermin Palić[2]

1 MBA, Mozzart BH Play d.o.o.
leonardo.pavicic@stu.ibu.edu.ba

2 Doc.dr., Head of the Traffic and Transport Engineering Study Program, University College „CEPS-Center for Business Studies" Kiseljak
nermin.palic@ceps.edu.ba.

Abstract

This research investigates the societal impact of cars in Sarajevo Canton, aiming to provide a comprehensive understanding of how motorization affects urban life. The study reviews existing literature, highlighting historical patterns of car dependency, urban planning, and transportation development, while outlining expectations for future mobility trends. This establishes the theoretical foundation for analyzing society's reliance on private vehicles and frames the context for the research hypotheses. The study confirms three main hypotheses: society's dependency on cars for daily mobility, Sarajevo's evolution into an "automotive city," and the societal costs of the automotive revolution, including rising traffic accident rates, congestion, environmental impacts, and implications for public safety. Data analysis examines global motorization trends, local growth in registered passenger cars, motorization rates, active driver licenses, and historical trends from 1955 to 1989, providing a longitudinal perspective on urban mobility behavior. Traffic accident data across Sarajevo Canton and the Federation of Bosnia and Herzegovina illustrate the social and safety consequences of increasing car reliance. The research further identifies potential strategies to reduce car dependency, including re-evaluating existing transport solutions, promoting sustainable mobility alternatives, and enhancing public awareness. By combining empirical analysis with urban planning insights, the study highlights opportunities for improving transport infrastructure, reducing environmental and social costs, and fostering safer, more sustainable urban mobility. Finally, the research introduces a new thesis for future studies aimed at mitigating the societal costs of car dependency. It provides a foundation for exploring alternative mobility strategies, including public transport enhancement, pedestrianization, cycling infrastructure, and traffic management measures. Overall, this study underscores the need for informed urban planning and policy interventions to create a socially responsible and resilient mobility framework in Sarajevo and comparable urban contexts.

Keywords

Societal impact, car dependency, automotive city, Sarajevo Canton, motorization rate

1. Introduction

Around the world, the societal impact of cars has become a central issue in debates on sustainable mobility, climate change, and urban development. Automobility is not only a technical matter of transport efficiency, but also a profound social, economic, and environmental challenge. Globally, cars dominate urban mobility, accounting for more than 70% of passenger transport, yet this dominance comes with rising congestion, air pollution, greenhouse gas emissions, and public health risks. European policy frameworks, such as the EU Green Deal and the Sustainable Urban Mobility Plan (SUMP) initiative, explicitly aim to reduce car dependency, promote alternative transport modes, and align with the Sustainable Development Goal 11 on sustainable cities and communities. The scholarly literature emphasizes that car dependency is deeply embedded in urban planning, historical transport policies, and societal norms, and that its consequences are multifaceted, affecting traffic safety, public health, environmental sustainability, and social equity.

In Bosnia and Herzegovina, these global challenges are amplified by structural factors, including the absence of a domestic automotive industry, heavy reliance on imported and older vehicles, and limited investment in sustainable transport infrastructure. Sarajevo Canton, the country's largest urban and economic hub, reflects these dynamics most acutely. Despite the adoption of a Sustainable Urban Mobility Plan in 2020, car dependency continues to rise, prompting concerns that Sarajevo may be evolving into an "automotive city." This research investigates the societal impact of cars in Sarajevo Canton, analyzing historical patterns of motorization, urban planning, and transportation development. The study examines longitudinal data on registered vehicles, driver licenses, and traffic accidents, providing insights into trends in private vehicle reliance, the social costs of congestion, traffic safety, and environmental impacts. By situating Sarajevo within both national and global contexts, the research clarifies the starting point for exploring interventions aimed at sustainable urban mobility.

The study further identifies potential strategies for mitigating car dependency, including the re-evaluation of existing transport solutions, promotion of public transport, cycling, and pedestrian infrastructure, and the adoption of traffic management measures. By combining empirical analysis with urban planning insights, this research establishes a theoretical and practical framework for understanding the societal, environmental, and infrastructural challenges of motorization. It also introduces a foundation for future studies focused on enhancing sustainable mobility, reducing environmental and social costs, and creating safer, more resilient urban transport systems in Sarajevo and comparable urban contexts. In doing so, the study bridges the gap between policy objectives, academic research, and local urban realities, providing a clear context for the subsequent analysis of mobility patterns and interventions.

2. Review on literature

The history of cars is complex and dates back to the 15th century with DaVinci's early prototypes. The internal combustion engine, considered the heart of modern cars, marked a revolutionary moment in 1886 in Germany. [1] Subsequent innovations such as

the tire, carburetor, differential, crank-starter, steering wheel, and pedal-brake control established the basic structure of the car. [2] At the end of the 19th century, Ford's mass production further shaped global automotive history. [3]

Despite their technological achievements, cars faced early criticism. Scholars and critics noted traffic fatalities, street rearrangements, and societal conflicts between users and non-users of streets [4-5]. Norton, D.P. introduced the concept of the "automotive city," describing urban adaptation to private vehicles as a Darwinian-like selection process. By the mid-1920s, organized automotive interest groups, "motordom," began influencing urban transportation policies.

Today, cars remain central to daily mobility, with an estimated 1.47 billion vehicles worldwide, up from 1.18 billion in 2020. [6-7] They dominate urban and rural transport, representing 70% of passenger-km in cities and 90% in rural areas, while public transport and active mobility modes remain under 10% globally. Cars' social, health, and environmental impacts are widely recognized. [8-9]

To address these issues, Sarajevo Canton adopted the "Sustainable Urban Mobility Plan" in 2020 to promote low-emission transport and reduce motorization growth (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2020). Local authors highlight the inadequacy of current urban mobility planning, partly due to rising motorization. [10] The concept of "de-transition" toward a low-car city guides future strategies, aiming to introduce new mobility elements and reduce dependency on private vehicles. [11] The plan targets a reduction in the average annual motorization growth rate from 2.88% (2013–2018) to 2.60% (2019–2025). [12]

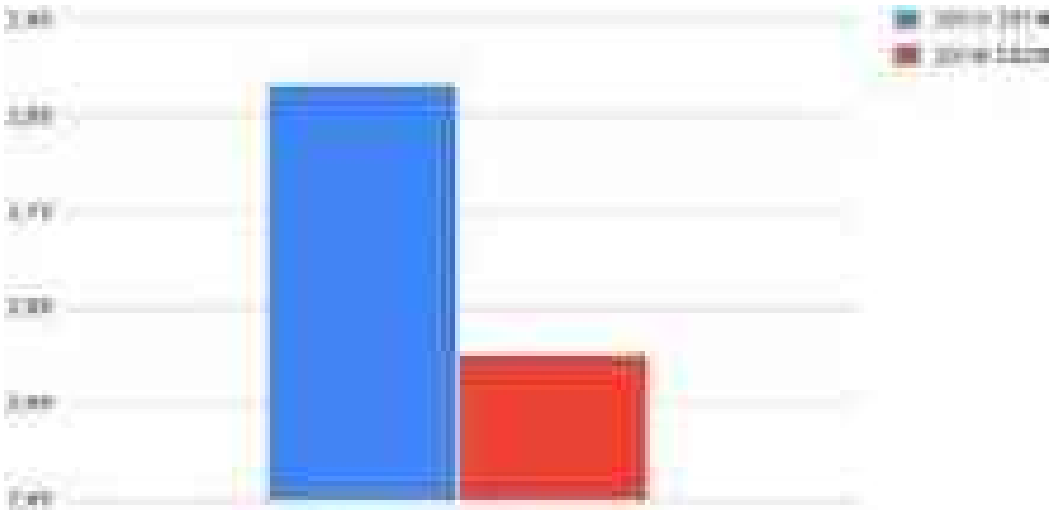


Figure 1 – Average Annual Growth Rate of Motorization in the Sarajevo Canton [12]

3. Hypotheses

This research is guided by three main hypotheses that frame the analysis of urban mobility in Sarajevo Canton. First, it is hypothesized that the society under study exhibits a high degree of car dependency, with private vehicles dominating daily transportation and shaping patterns of social mobility. Second, Sarajevo, as the central city

of the Canton, is hypothesized to have developed—and continues to develop—characteristics typical of an "automotive city," where urban form, transport infrastructure, and daily life are increasingly organized around car use. Third, the study posits that the ongoing automotive revolution imposes significant social, environmental, and safety costs, figuratively "devouring its children," through rising traffic accidents, congestion, pollution, and related public health risks.

By exploring these hypotheses, the research aims to answer two overarching questions: To what extent is our society—and Sarajevo Canton in particular—car-dependent? And, to what degree do our cities reflect the features of automotive cities, specifically in the ways Sarajevo has evolved in response to motorization trends? Together, these hypotheses provide a conceptual framework for examining the historical and contemporary impacts of car dependency on urban life, infrastructure, and sustainability.

4. Data analysis

As it has been noticed the general rapid increase in automobile ownership has transformed urban areas all over the world. Despite that this topic opened ongoing public discussion it is noticed that there is almost no research that has been conducted to show how the phenomenon of rapid increase in automobile ownership affects society.

The primary objective of this data analysis is to assess the effect of car ownership on traffic congestion, evaluate environmental implications, and analyze social accessibility within the region of Sarajevo Canton. To achieve this objective the next secondary data collected by using quantitative method:

1. Worldwide motorization rate;
2. The number of cars registered in Canton Sarajevo;
3. Historical data on car ownership in Sarajevo during the period of former Yugoslavia;
4. Data collected by a survey on public transportation in Sarajevo Canton;
5. Population data regarding potential drivers in the area of Sarajevo Canton.

Data that is analyzed through this research is collected from sources: Organisation Internationale des Constructeurs d'Automobiles OICA (2020) [7]; Bosnian Automobile and Motorcycle Club BIHAMK (2015-2024) [13]; Statistical Yearbook of Yugoslavia (1990) [14]; Japan International Cooperation Agency (2020); Japan International Cooperation Agency (2020) [15]; Population estimates from 2014 to 2023, Agency for statistics of Bosnia and Herzegovina, Demographic Yearbooks, Bosnia and Herzegovina Population census results from 2013.

This framework should enhance understanding of the complex dynamics between general automobile usage and general societal impacts as well as automobile usage and societal impacts in Canton Sarajevo. This framework will set clear boundaries for the discussion.

4.1. Worldwide motorization rate data analysis

The first point of data analysis is examination of world motorization rate through reviewing the number of passenger cars in use all over the world. Data that is shown in the figure below is data about number of passenger cars in the world (by regions) in year 2015 and year 2020, with average annual growth rate data, data about population at observed region, and data about the number of passenger cars in use per 1000 inhabitants.

Table 1 – Passenger cars in use in the world [7]

Observed region	2015	2020	Difference 2015-2020	Average Annual Growth Rate 2015-2020	Population	Approximate number of passenger cars in use per 1,000 inhabitants
Europe	338,848,000	373,038,000	34,190,000	2%	744,849,811	477,87
America	235,192,000	244,862,000	9,670,000	1%	592,296,233	405,25
Asia/Oceania/ Middle East	344,000,000	524,691,000	180,691,000	9%	5,177,263,280	83,89
Africa	31,174,000	38,087,000	6,913,000	4%	1,526,805,617	22,68
All regions	949,214,000	1,180,678,000	231,464,000	4%	8,041,214,941	132,44

The data that has been analyzed shows a global increase in the number of passenger cars from 949 million in 2015 to 1.18 billion in 2020, a growth of about 231 million cars worldwide, representing an average annual growth rate of 4%. [7] Between 2015 and 2020, the global growth of passenger vehicles was highest in Asia/Oceania/Middle East (+180.7 million, 9% annual), followed by Europe (+34.19 million, 2%), America (+9.67 million, 1%), and Africa (+6.91 million, 4%). In terms of passenger cars per 1,000 inhabitants, Europe leads with 477.87, followed by America (405.25), Asia (83.89), and Africa (22.68). These trends highlight rapid vehicle growth in emerging regions and high vehicle density in Europe and America.

4.2. Bosnia and Herzegovina motorization rate data analysis

Analysis of Bosnia and Herzegovina's motorization rate shows a consistent increase in registered passenger cars from 801,387 in 2014 to 1,108,711 in 2023, indicating rising car dependency among citizens. [13] District Brčko experienced growth from 23,418 to 36,191 cars, reflecting high motorization levels relative to its smaller population. The Federation of Bosnia and Herzegovina consistently leads in total car numbers, increasing from 499,577 to 671,108, likely due to population concentration and urbanization, while the Republic of Srpska grew from 278,392 to 401,412, showing similar trends in

reliance on personal vehicles. National motorization rates rose from 227.28 to 324 cars per 1,000 inhabitants, with District Brčko reaching 447.1, the Republic of Srpska 360.07, and the Federation 312.14, highlighting growing car ownership across all regions.

4.3. Federation of Bosnia and Herzegovina motorization and driving licenses analysis

Within the Federation, all 10 cantons show growth in car ownership. Sarajevo Canton has the highest registrations, from 117,116 in 2014 to 152,445 in 2023, reflecting its urban hub status. [13] Tuzla and Zenica-Doboj Cantons also show steady increases, while smaller cantons maintain lower numbers. Motorization rates per 1,000 inhabitants mirror these trends, with Sarajevo increasing from 282.40 to 362.72 and Tuzla from 223.50 to 300.05, indicating rising dependency on private vehicles. Driving license data from 2014 to 2023 shows Sarajevo Canton with the highest growth, from 158,664 to 209,568 licenses, corresponding to 382.58 to 498.63 per 1,000 inhabitants, reflecting urban mobility and economic growth. Other cantons show steady but slower increases in licenses, confirming the link between car ownership and licensing trends. Historical data from 1955 to 1989 for Sarajevo indicates gradual growth in motorization, from 0.76 cars per 1,000 inhabitants in 1955 to 139.66 in 1989, paralleling broader Yugoslav trends.

4.4. Federation of Bosnia and Herzegovina traffic accidents analysis

Traffic accident trends in Bosnia and Herzegovina increased with vehicle ownership, peaking around 48,000 incidents in 2016 and then declining to approximately 34,500 by 2019 before gradually rising to 35,148 in 2023. [13] Fatalities decreased nationally from 297 in 2014 to 222 in 2022, with a slight increase to 255 in 2023. Within the Federation, fatalities fell from 161 to 116 before rising slightly to 135, while Sarajevo and Tuzla Cantons consistently recorded the highest accident numbers due to heavy traffic and urban density. Sarajevo Canton peaked in total accidents in 2015 with 11,475 incidents and decreased to 7,061 in 2021, later rising to 10,161 by 2023. Smaller cantons show far fewer incidents, indicating lower traffic volumes and motorization levels. These trends support the hypothesis that higher car ownership and urbanization correlate with increased traffic accidents and highlight the importance of targeted road safety measures.

5. Discussion

All of the three stated hypotheses are supported through the analyzed data. Hypothesis number one is supported by:

- The general growth of the number of passenger cars in the world that has been analyzed for the period from 2015 to 2020: The general rise in the number of passenger cars in the world for the period from 2015 to 2020 indicates that passenger cars remain a globally dominant mode of daily transportation. The assumed reason for this growth is the fact that cars are not used just to facilitate traveling but also to provide people with access to employment, education, and social engagements. The general opinion is that this is a characteristic of suburban and rural areas but it is clear that the general growth of the number of passenger cars in the world also happens in urban areas, especially in regions of Europe and Asia ;
- The growth of motorization rate in the Bosnia and Herzegovina and Federation of Bosnia and Herzegovina across 10 cantons from 2014 to 2023: The general growth of the motorization rate in the Federation of Bosnia and Herzegovina across 10 cantons from 2014 to 2023 indicates that personal vehicles became an essential component of daily life in the observed area. The growth of the motorization rate in urban areas, especially in Sarajevo Canton, indicates that public transportation options are still inadequate for a large number of citizens. This growth also implies that there is an active societal trend of owning a car as a status symbol, and this reflects globally recognized trends ;
- The growth of the number of driver licenses in the Federation of Bosnia and Herzegovina across 10 cantons: The general growth of the number of driver's licenses in the Federation of Bosnia and Herzegovina across 10 cantons indicates a rising demand for personal mobility and individual vehicle use. The trend of growth implies that citizens view the possession of driving skills as a necessity. Possession of a driver's license there is a desire of a large number of citizens to own a car ;
- The general growth of passenger car ownership rate in Sarajevo in the period from 1955 to 1989 compared to today: During the observed period of time, the growth in car ownership in Sarajevo reflected rising improved accessibility to vehicles, and changing social norms, with cars increasingly symbolizing freedom, progress, and, probably, social status. As Sarajevo grew and modernized through this period, cars became an attractive and affordable traveling solution.

Hypothesis number two is supported by:

- The growth of motorization rate in the Federation of Bosnia and Herzegovina across 10 cantons: The general growth of motorization rate in the Federation of Bosnia and Herzegovina across 10 cantons, especially highlighted in Sarajevo Canton, supportss and accelerates the development of Sarajevo as an automotive city ;

- The growth of driver licenses in the Federation of Bosnia and Herzegovina across 10 cantons: A driver's license is a key component that enables people to become car addicted and car addiction is the basic assumption of an automotive city.
- The general growth of passenger car ownership rate in Sarajevo in the period from 1955 to 1989: This marked the beginning of Sarajevo's transformation into an automotive city, where the automobile was no longer just a luxury but an integral part of daily life.

Hypothesis number three is supported by:

- The general growth of traffic accident rates in the Federation of Bosnia and Herzegovina: The growing number of traffic accidents serves as one reminder of the negative consequences of car usage. The number of traffic accidents fluctuates, but it still indicates a general trend of high accident rates. Rising fatalities, injuries, and long-term health consequences resulting from traffic incidents are the consequences that *"devouring its children."* The "automotive revolution" brought significant benefits to society, but it also contributed to it in a bad way.

To contribute discussion the positive and negative societal impacts of cars, and their usage, are presented as follows.

The assumed positive societal impact of cars, based on and derived from the analyzed data and literature, is shown through:

1. Enhanced mobility indicated through the rising number of registered cars. This indicator is especially highlighted in the Sarajevo Canton ;
2. Improved accessibility is an indicator that follows enhanced mobility and leads to better access to specific spots when public transport is limited. This indicator is especially highlighted in the Sarajevo Canton ;
3. Higher passenger vehicle ownership stimulates consumer spending and boosting economies. It is clear that Sarajevo Canton is in the category of most profitable regions observed by this characteristic.

The assumed negative societal impact of cars, based on and derived from the analyzed data and literature, is shown through:

1. Strained existing infrastructure that leads to traffic congestion, increased demand for parking, and higher maintenance costs for roads ;
2. Challenging environment for policymakers that are facing challenges in urban planning in an effort to manage the impacts of increased vehicle use ;
3. Contribution to air pollution and greenhouse gas emissions, impacting public health and affecting climate change ;
4. Significantly warmer and louder urban areas, especially when it comes to comparison with rural surroundings, created by the increased number of vehicles.
5. Social inequality for those without access to vehicles and disparities in access to mobility ;

6. Contributing to the increased number of traffic accidents impacting public health.

Are we car-dependent society ?

The data that has been analyzed and presented fully supports the claim that our society is cars dependent society, and giving us a clear answer to this question.

Are our cities automotive cities ? If they are in what way Sarajevo evolved into an automotive city ?

The data that has been analyzed and presented fully support the claim that our cities are automotive cities. Sarajevo evolved into an automotive city and the basic characteristics that indicates accuracy of this statement are: almost constant growth of the number of registered passenger cars in Sarajevo Canton and almost constant growth of the motorization rate in Sarajevo Canton.

6. Conclusion

It is clear that our society is car-dependent, as evidenced by the global rise in passenger cars, which remain central to societal concerns and will continue to be so for the foreseeable future. De-transitioning to a low-car city will not simply reverse historical trends but will require new strategies, as noted by Taillandier et al. (2023). In Sarajevo Canton, the Sustainable Urban Mobility Plan aims to reduce motorization growth, but events like the 2020 decline in registered vehicles—a "black swan"—could create a misleading sense of progress, obscuring the systemic changes needed to genuinely reduce car dependence.

Despite policy efforts, motorization is likely to continue rising, and it remains uncertain when or if these measures will translate into social change. Reducing car dependence must focus on maintaining overall mobility while promoting alternative, sustainable transport. The increasing number of cars, both globally and in Sarajevo, demonstrates that car dependency has evolved into a social structure, creating a stable "social addiction" rooted in the long history of automobile use.

This research supports the thesis that individual car dependence accumulates into societal car dependence, highlighting the need for further studies on how cars shape everyday life. Understanding this dynamic can inform the development of new sustainable solutions aimed at mitigating this entrenched car-dependency while improving mobility.

Literature

[1] Bellis, M.: *"The History of Cars"*, ThoughtCo, 2025, Retrieved from: https://www.thoughtco.com/who-invented-the-car-4059932

[2] Mokyr, J.: *"The Second Industrial Revolution 1870-1914"*, Northwestern University, 1998, 7p.

[3] Eli, S., Hausman, J.K., Rhode, P.: *"The Model T"*, Working paper 31454, National Bureau of Economic Research, 2023

[4] Miner, P., Smith M, B., Jani, A., McNeill, G., Gathorne-Hardy, A.: *"Car harm: A global review of automobility's harm to people and the environment"*, Journal of Transport Geography, Elsevier, 2024

[5] Norton, D.P.: *"Fighting Traffic: The Dawn of the Motor age in the American City"*, Massachusetts Institute of Technology, 2008

[6] Stumpf, R.: *"Here's About How Many Cars Are There in The World in 2023"*, The Drive, 2023

[7] OICA (Organisation Internationale des Constructeurs d'Automobiles): *"Motorization Rate 2020-Worldwide*, 2020, Retrieved from: https://www.oica.net/category/vehicles-in-use/

[8] Van Audenhove et al.: *"The Future of Mobility 5.0"*, Arthur D.Little&Polis, 2024

[9] Gössling, S.: *"Why cities need to take road space from cars - and how this could be done"*, Journal of Urban Design 2020, vol. 25, no. 4, p.443–448.

[10] Lindov, O., Omerhodžić, A., Bušić, D.: *"Challenges of implementation of the sustainable urban mobility plan for Sarajevo 2020-2025"*, Proceedings, 2nd Conference on Urban Planning and Regional Development_sustainable urban development, 2020

[11] Taillandier, C., Dijk, M., & Vialleix, M.: *"Back to the future: "De-Transition" to Low-Car cities"*, Future Transportation, 2023 vol. 3, no 2., p.808–839.

[12] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: *"Sarajevo Canton and City of Sarajevo Sustainable Urban Mobility Plan (SUMP)"*, 2020

[13] BIHAMK: "*Information on Registered Road Vehicles in Bosnia and Herzegovina in the Period January–December 2015-2024"*

[14] Statistical Yearbook of Yugoslavia (SZZS), 1990.

[15] Japan International Cooperation Agency, *"Data Collection Survey on Public Transportation in Sarajevo Canton"*, Bosnia and Herzegovina Final Report, 2020

Sustainability and recycling of composite materials

Marina Rakočević[1]

Vasilije Bojović[2]

Svetislav Popović[3]

1 Prof. dr, Faculty of Civil Engineering, University of Montenegro
marinarakocevic2013@gmail.com

2 MSc in civ. eng, Teaching assistant, Faculty of Civil Engineering, University of Montenegro
vasilije.b@ucg.ac.me

3 MSc in civ. eng, Ingenieurbüro Stengel, Munich, Germany
svetislav.popovic@rcstengel.com

Abstract

Composite materials are formed by combining two or more materials with different properties on a macroscopic scale. Typically, composite materials consist of fibers embedded within a matrix, resulting in a new material with enhanced characteristics that cannot be achieved by the individual components of these materials. This approach provides designers with a broad selection of material options tailored to the specific requirements of each project.

Due to their advanced properties, composite materials are increasingly utilized across various industries, including aviation, military, automotive, space technology, and civil engineering. The development of composite materials is driven by technological advancements and the evolving needs of modern society.

In the realm of sustainability, composite materials serve a dual purpose. On one hand, they help reduce energy consumption and emissions of harmful gases by creating lighter and more durable structures. On the other hand, they present challenges related to recycling and their environmental impact. Addressing these issues requires a range of recycling technologies, each with varying degrees of success depending on the material type. Although there is no perfect solution for recycling, the combination of mechanical, chemical, and thermal recycling methods, along with innovative reuse in construction and energy applications, is becoming increasingly important.

The paper provides a brief overview of the historical development of composite materials, their classification, and applications in various industrial sectors. It examines the sustainability aspects by outlining both the advantages and disadvantages of these materials. Additionally, the paper presents the methods of recycling applied so far, and comments on the application of the considered materials from the perspective of the service lifecycle. At the end of the paper, conclusions and recommendations for the future development of sustainable composite materials, based on the principles of the circular economy, are given.

Keywords

Composite materials, fiber, matrix, development, sustainability, recycling

1. About composite materials

1.1. Development of composite materials

Composite materials are formed by combining at least two consituents with different material properties: a matrix and reinforcing fibers. This results in a material with significantly improved physical-mechanical, chemical, and functional characteristics [1].

Historically, the development of composites has been closely linked to societal growth and technological progress. The first application of composite materials dates back to the period of ancient civilizations, where a combination of straw and clay was used for construction purposes. In Mesopotamia and China, wood and bamboo were combined, while in Greece and Rome, mortars with volcanic ash were used, resulting in a material that is the forerunner of modern concrete. In the Middle Ages, wood reinforced with resins was used in shipbuilding, and layered laminated wood was used in the production of weapons. The Industrial Revolution (18th -19th century) marked a turning point with the emergence of reinforced concrete, which was created by embedding reinforcing steel bars in concrete.The introduction of new synthetic resins and polymers (at the end of the 19th century) paved the way for the development of polymer composites. In the 20th century, composite materials, which are obtained by combining glass fibers with a polymer-based matrix, were developed. This was followed by the development of composites with carbon and aramid fibers (Kevlar), which found wide application in the military and aviation industries. Due to their low specific mass, high resistance, and load-bearing capacity, these modern composites have found applications in various industries, including construction, the automotive industry, and beyond.

In recent decades, research has increasingly focused on advancing the development of nanocomposites incorporating nanoparticles or nanotubes, which exhibit significantly improved properties. Additionally, bio-composites containing natural fibers (such as flax, hemp, and bamboo) integrated in a biodegradable matrix have been developed as a sustainable solution. Another notable development is the advent of smart composites capable of adapting to external stimuli and changing conditions. Today, modern composite materials are widely used in the aviation and space industry, medicine, dentistry, construction, energy industry, and sports.

1.2. Composite materials classification

Four commonly accepted types of composite materials are, Figures 1-4:

a) Fibrous composite materials,
b) Particulate composite materials,
c) Laminated composite materials,
d) Combination of the previous composite materials types.

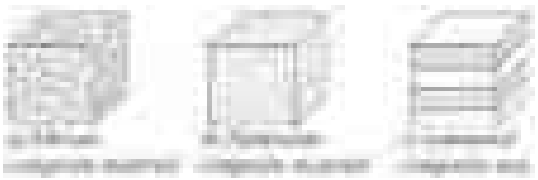


Figure 1 – Composite materials types [1]

Figure 2 – Composite material [2]

Fibrous composite materials are produced by embedding rigid and brittle fibers in a matrix. These composites exhibit high load-bearing capacity and mechanical strength. The arrangement of fibers in the matrix has a significant impact on the material properties.

Particulate composite materials consist of a large number of particles combined with a matrix. These particles are preferably approximately the same size in all directions. The size of particles has a great influence on the properties of the composite material. When particles are added to the matrix, stiffness and resistance to temperature effects increase, while shrinkage decreases. An example of a particle-reinforced composite is concrete, a mixture of cement and aggregate.

Figure 3 – Composite material products, left [3], right [4]

Laminated composite materials are obtained by bonding layers made of different materials to achieve improved physical-mechanical properties. These materials exhibit a higher load-bearing capacity, stiffness, and resistance compared to the individual materials from which they are made. The properties of laminated composites depend on the characteristics of the individual materials, as well as on the arrangement and the orientation of the fibers in the layer. With the proper arrangement of layers, the disadvantages of laminated composites can be significantly mitigated.

According to *Jones* [5], materials used for laminated composites are: Bimetals, Clad Metals, Laminated Glass, Plastic-Based Laminates, and Laminated Fibrous Composite Materials.

Bimetals are laminates consisting of two metals, usually with different thermal expansion coefficients. They are used in electronics (e.g., thermostats, switches) and civil engineering, in special constructions where large temperature fluctuations occur (e.g., nuclear reactors). Clad Metals are produced by combining corrosion-resistant aluminum with high-strength aluminum alloys, resulting in a material that combines the advantages of building materials. These materials are extensively used in the aviation industry, construction, and shipbuilding.

Laminated Glass is widely used in construction and in the automotive industry. Plastic Laminates are formed in different ways to obtain material with the best possible properties. Plastic laminates include plastic-glass and nylon fibers connected by resins.

Laminated Fibrous Composite Materials are composed of multiple layers (plies), each containing fibers embedded in a matrix. These layers are bonded together to form a laminate. The fibers in each layer may be continuous, discontinuous, or woven. Continuous fibers can be oriented in a single direction, in two directions, or arranged arbitrarily. The mechanical properties of the laminate are significantly influenced by fiber orientation. The most commonly used fibers include glass, carbon, polymer, and boron. Glass fibers are widely used due to their balance of low cost and high strength, although they exhibit relatively low stiffness. These fibers are produced from silicon dioxide, with E-glass being the most prevalent type due to its high resistance to moisture and chemical exposure. Carbon fibers are manufactured through the chemical carbonization of various resins or by the thermal decomposition of polyacrylonitrile (PAN) fibers at elevated temperatures. They are characterized by high tensile strength, a high modulus of elasticity, and resistance to temperature fluctuations. Aramid fibers, such as Kevlar and other aromatic polyamides, demonstrate high strength and stiffness along the fiber axis but possess significantly reduced properties perpendicular to the fibers. While aramid fibers are generally resistant to fatigue compared to other fibers, their mechanical properties deteriorate at elevated temperatures. For all laminated composites, fatigue analysis is associated with many uncertainties, particularly because standardized S–N fatigue curves are not provided in the existing standards, which necessitates an experimental approach or the use of empirical data to obtain reliable design parameters. Boron fibers are inherently composite, consisting of boron deposited onto a carbon or tungsten core using specialized technological processes. These fibers are primarily applied in the aviation and construction industries to reinforce metals and ceramics, although their widespread use is limited by high production costs. In addition to these fibers, short, high-strength fibers – whiskers are used as well. Despite their high strength, whiskers are not widely adopted due to their high production costs and are primarily used in military and aerospace applications. Furthermore, specialized PREPREG (PREimPREGnated) fibers are used in the automotive industry. These fibers are manufactured by impregnating fabric with a polymer matrix.

Laminated composite matrices are classified as metal, polymer, or ceramic, with polymers most commonly used. Matrix polymers are categorized as thermoset resins (epoxy resins, polyester resins, vinyl esters, bismaleimides (BMI), phenolic, polyamide, and cyanate resins), and thermoplastic matrices (crystalline thermoplatic, polyphenylsulfide (PPS), polymers based on sulfone derivatives - polysulfone (PSU), polyether sulfone (PES), polyaryl sulfone (PAS), polyetheramide (PED)). Thermosets' advantages are low production temperatures and effective fiber coating. However, when reheated, they retain their shape, which means they cannot be reprocessed. That presents an environmental challenge. On the other hand, thermoplastic matrices can be softened and reshaped when reheated, which enables partial recycling or rehabilitation of the material. Additionally, thermoplastics exhibit greater resistance to impact loads and have a lower tendency to absorb moisture. Thermosets are more widely used due to their lower price. Metals (Metal Matrix Composites-MMC) are also used as matrix materials. Composites with this type of matrix exhibit excellent mechanical properties, including high strength, stiffness, and thermal conductivity. Materials used in metal matrices include aluminum and its alloys, titanium alloys, magnesium alloys, copper, and others. The primary

disadvantages of these matrices are their high cost and limited recyclability. Furthermore, the production technology of metal matrices is sometimes highly demanding. Composites with a ceramic matrix (CMC) have lower mechanical properties. While cost-effective manufacturing is possible using conventional methods, enhanced mechanical performance requires more complex and expensive production techniques. Ceramic matrices are characterized by brittle failure.

2. Use of composite materials and the green agenda

Modern composite materials are primarily used in energy and transportation due to their significant contributions to reducing energy consumption and emissions. Additional applications include construction, sports, and medicine.

In energy, modern composite materials are used for:

- Wind turbines – blades of wind generators are made of composites, mainly composites based on glass and carbon fibers.
- Solar energy – solar power plant substructures often use composites due to their durability and weathering.

In transportation, composite materials are used in:

- Aerospace industry – to reduce mass (thereby fuel consumption) and increase load-bearing capacity, composites (especially composites with carbon fibers) are used in airplanes and spacecraft. Some aircraft manufacturers use composites in percentages higher than 50%.
- Automotive industry – to reduce vehicle weight, which directly affects lower fuel consumption and reduced CO_2 emissions.
- Shipbuilding and railways – due to corrosion resistance, durability, and weight reduction of the structure.

There is a wide range of applications for composite materials in civil engineering and architecture, particularly in the production of structural elements, facade panels, roof and insulation systems, etc. The advantages of applying these materials include long service life, low specific mass, and excellent thermal insulation properties. Due to their high strength-to-weight ratio, composite materials are used in the construction of roller-coaster trains and similar attractions.

In the field of sports and recreation, the application of composite materials is evident in the manufacture of bicycles, tennis rackets, hockey sticks, skis, and other sports equipment, where carbon and polymer composites are used to achieve an optimal balance of strength and low mass.

In medicine, these materials are used in orthopedics and dentistry for the production of orthopedic aids, implants, prostheses, and fillings, primarily due to their strength, durability, and biocompatibility.

In recent decades, the use of composites in the military and defense industry has increased. Armor, helmets, weapons, and elements of combat vehicles are often made of composites due to their high thermal and mechanical resistance, as well as low specific mass.

From the above, it can be concluded that composite materials are occupying an increasingly important place in modern industry and engineering, thanks to their specific properties that allow the combination of advantages of different materials in one structure. Examples of composites in everyday use range from fiberglass and carbon fibers to laminates and polymer composites, all the way to advanced bio-composites.

The European Green Deal, especially the Circular Economy Action Plan (CEAP) and related regulations, explicitly address materials like composites through several mechanisms: Circular Economy Action Plan, European Circular Composites Alliance (ECCA), EU-funded demonstration projects, End-of-Life Vehicle Regulation (ELV), Ecodesign for Sustainable Products Regulation (ESPR), and Plastics Strategy and links to composites.

Composite materials and their recycling connect with several Sustainable Development Goals (SDGs) of the UN, like SDG 12 – Responsible Consumption and Production; SDG 9 – Industry, Innovation, and Infrastructure; SDG 13 – Climate Action; SDG 11 – Sustainable Cities and Communities; and SDG 7 – Affordable and Clean Energy.

From the green agenda perspective, i.e., the global strategy for sustainable development, pollution reduction, and the transition to a circular economy, composite materials play a dual role. On the one hand, they offer opportunities for improving energy efficiency and reducing harmful gas emissions. On the other hand, raise issues related to recycling and environmental impact.

The advantages of composite materials in the green transition refer to:

- Weight reduction and energy savings – composites, especially those based on carbon fibers and polymers, are significantly lighter than metals. Their application in the automotive, aircraft, and marine industries results in lower fuel consumption and, consequently, a reduction in CO_2 emissions. Additionally, due to their high strength-to-weight ratio, the use of composites yields lighter and more environmentally friendly products.

- High durability and long service life – higher resistance to corrosion and wear prolongs the life cycle of the product, which contributes to lower resource consumption and waste reduction.

- Application in renewable energy sources – wind turbines, solar power plants, and many other elements of green technology rely on composite materials due to their high strength and resistance to environmental influences.

- Insulation properties – composites often possess excellent thermal and acoustic insulation properties that contribute to energy efficiency in construction and architecture.

However, although composite materials have many advantages, they also present a challenge within the green agenda. Apart from the high cost, one of the key problems is recycling. Due to the heterogeneity of materials (matrix materials and fibers), their separation and reuse are complex and energy-demanding technological processes, especially in the case of thermosensitive polymers and carbon fibers. In addition, the

manufacturing of composites sometimes requires the application of chemicals with a negative environmental impact, which limits the areas available for recycling plants. Therefore, bio-composites are being developed. These composites are based on natural fibers (flax, hemp, bamboo, etc.) and biodegradable matrices, offering more environmentally friendly solutions.

The global strategy of sustainable development implies the reduction of the carbon footprint, the transition to renewable energy sources, the improvement of energy efficiency, and the development of new technologies that minimize negative environmental impact. In this context, advanced materials play a key role, and composite materials stand out as a particularly significant group. The application of "green" composites in transportation, construction, energy, and the production of various products, including those for sports and medical use, can significantly contribute to achieving the green transition objectives.

Considering the above, in the future, a significant focus will be on developing circular composite materials that can easily be recycled or reused. At the same time, innovations in nanotechnology and biomimetic materials open possibilities for creating new generations of composites with low environmental impact. Therefore, composite materials will become an indispensable tool in achieving the green agenda goals, especially in areas such as clean energy, sustainable mobility, smart construction, and waste reduction.

3. Sustainability and recycling of composite materials

3.1. Sustainability

From the sustainability aspect, the use of composite materials has both advantages and disadvantages [6-10]. The application of these materials brings significant benefits in terms of energy savings, emission reduction, and life extension, but also presents challenges in the production process and at the end of the life cycle. The disadvantages are related to recycling and environmental impact. The characteristics of composite materials from the aspect of sustainability are given in Table 1.

To eliminate the disadvantages of these materials, the development of bio-composites is a solution that can facilitate easier recycling and promote the transition to a circular economy in the composite materials industry. Bio-composites, composed of natural fibers and biodegradable polymers, offer a sustainable alternative to synthetic materials. These composites are used for car interior components and as structural elements. Natural fibers have lower density, low cost, good sound and thermal insulation properties, as well as a lower environmental impact [9].

Table 1 – Advantages and disadvantages of composite materials from the sustainability aspect

	Advantages	**Disadvantages**
Energy efficiency	Lower mass, resulting in lower fuel consumption and reduced CO_2 emissions	Fiber production is energy demanding
Life cycle	Corrosion and wear resistance, long service life, resulting in less wast	Recycling problem due to difficult separation of matrix and fibers
Ecology	The possibility of using composites from natural fibers and biodegradable matrices – bio-composites	Landfilling is not sustainable, while incineration releases toxic gases
Application in green technologies	Useful for manufacturing wind turbines, solar power plants, electric vehicles, etc.	Polymer matrices depend onfossil raw materials
Civil and mechanical engineering	Significantly better thermal and sound insulation, resulting in energy savings. Simpler procedures for repairs and reconstruction of buildings. Reduction of the effective forces of machine elements results in a lighter structure and a more favorable CO^2 footprint.	Environmental impact from the use of chemicals and additives

3.2. Recycling and the end-of-life cycle

Recycling of composites is one of the biggest challenges [6-10] regarding their sustainability. Mechanical, thermal, and chemical recycling, as well as energy use through incineration, are commonly used recycling methods.

In mechanical recycling, the composite material is pressed, ground, or cut and used as an additive in new composites or concrete. This method is cost-effective, but results in materials with lower mechanical properties compared to the original ones.

Thermal recycling is carried out by pyrolysis. By heating the composite in the absence of oxygen, the polymer matrix is removed, allowing the glass and carbon fibers to be partially preserved. However, although thermal recycling enables the reuse of fibers, this process requires a lot of energy and carries the risk of damaging the fibers.

Solvolysis is chemical recycling carried out using a solvent to break down the matrix and release the fibers. The solvent can be water, alcohol, acids, etc. Through this recycling process, highquality fibers with approximately the same properties as the original are obtained. However, solvolysis is still under development and is accompanied by expensive and complex technology.

Through incineration in cement manufacturing plants or power plants, the polymer matrix can serve as fuel, while the fibers can be used as an additive to cement. The recycling of composite materials is represented in various industries, including aviation, automotive, cement, and energy (such as wind turbine blades). Development in the recycling field is led by large companies. Airbus and Boeing are developing and using systems for recycling carbon fibers from old aircraft parts. BMW and Mercedes use recycled carbon fibers for interior panels and non-load-bearing vehicle components. Old wind turbine blades can be mechanically recycled and used as building material for bridges, footpaths, or furniture. Recycled fiberglass from shipbuilding and old turbines can be used as fuel and as an additive to clinker, an intermediate product in cement production technology.

There is no perfect solution for the recycling of composite materials, but the combination of mechanical, chemical, and thermal recycling, as well as innovative reuse in construction and energy, is gaining importance. The advantages and disadvantages of composite recycling methods are presented in Table 2.

Table 2 – Composite materials recycling methods

	Advantages	**Disadvantages**
Mechanical recycling	Simple, cheap, fast	The recycled material has lower mechanical properties
Thermal recycling	Possible to reuse some of the fibers	High energy required, fiber degradation
Chemical recycling	Recycled fiber is almost of the same quality as the orginal one	Expensive, complex, still under development
Energy use	The polymer matrix serves as fuel, the fibers as a mineral supplement	The fibers cannot be reused in a composite form

"Green" composites, i.e., those with natural fibers and biomatrix, such as bio-composites, can be recycled within the limits of 20% to 100% of cases, depending on the recycling method. In contrast, classical (non-"green") composites, such as epoxy-glass or epoxy-carbon, can be recycled up to 20%, also depending on the recycling method. Most often, at the end of their life cycle, if the refurbishment or structural improvements are deemed impossible or economically unviable, they are stored in landfills or burned in energy plants (incinerators). The recycling process of classical composites is complex, expensive, and does not completely return the materials to their original state. The reason for the above lies in the fact that the fibers (glass, carbon, aramid) are permanently connected to the polymer matrix (epoxy, polyester), and it is almost impossible to completely separate them using the aforementioned methods. Therefore, it is necessary to improve existing recycling methods and develop new, significantly more efficient methods. The tendency to increase the degradability of composites by a large percentage would make these materials more sustainable. This requires new technologies and sustainable solutions that will provide alternatives to existing approaches in modern industry.

4. Conclusion

Composite materials play a significant role in advancing new technologies and promoting sustainable solutions. Their application in the transportation, construction, and energy sectors directly contributes to lowering the carbon footprint and improving energy efficiency. However, unresolved challenges related to recycling and environmental impact persist, necessitating ongoing research into bio-composites and sustainable manufacturing processes.

Although composite materials are sustainable in many aspects, for their broader adoption, energy consumption during production (especially for carbon fibers), the complexity of the recycling process, economic profitability, and the feasibility of replacing conventional materials have to be taken into account.

The development of composite materials is closely linked to the progress in recycling technologies, regulatory frameworks, and circular economy initiatives. Modern composites serve as a powerful instrument in achieving sustainable development objectives. Their properties enable resource optimization, energy efficiency, pollution reduction, and an extended product life cycle when proper analysis and design procedures are implemented. However, further improvements in production and recycling processes are necessary for their contribution to sustainability to become even more significant.

Integrating the development of composite materials with the green agenda objectives represents a key step towards a sustainable future.

Literature

[1]	Kollar P. L., Springer S. G.: *"Mechanics of composite structures"*, Cambridge University Press, Cambridge, 2003.
[2]	Pešić I.: "Konačnoelementni model za analizu izvijanja kompozitnih grednih konstrukcija", doktorska disertacija, Sveučilište u Rijeci, Rijeka, 2012.
[3]	https://www.chemo-commerce.com/kompozitni.html, 22.09.2025, 3:03PM
[4]	https://www.teamrapidtooling.com/hr/blog/koje-vrste-kompozitnih-materijalakoristi/, 22.09.2025,3:05PM
[5]	Jones M. R.: *"Mechanics of composite material"*, second edition, Taylor & Francis Inc., Philadelphia, USA, 1999.
[6]	Pickering, S.J.:*"Recycling technologies for thermoset composite materials—current status"*, Composites Part A: Applied Science and Manufacturing, 37(8), 2006, 1206–1215.
[7]	Oliveux G., Dandy, L. O., Leeke G. A.: *"Current status of recycling of fibre reinforced polymers: Review of technologies, reuse and resulting properties"*, Progress in Materials Science, 72, 2015, 61–99.
[8]	Ragaert K., Delva L., Van Geem, K.: *"Mechanical and chemical recycling of solid plastic waste"*, Waste Management, 69, 2017, 24–58.
[9]	Koronis G., Silva, A., Fontul, M.: *"Green composites: A review of adequate materials for automotive applications"*, Composites Part B: Engineering, 44(1), 2013, 120–127.
[10]	Lin H., Dong K., Luan J., Li C., Zhao D., Zhao C., Li X.: *"Repairable, Degradable and Recyclable Carbon Fiber-Reinforced Bio-Based Epoxy Vitrimer Composites Enabled by Facile Transesterification"*, Polymers 2025, 17(17), 2025, 2387.

Fire safety of energy-efficient buildings: The role of combustible and circular materials

Meri Cvetkovska[1]

Milica Jovanoska-Mitrevska[2]

Ana Trombeva Gavriloska[3]

1	Prof., Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, Skopje, North Macedonia *cvetkovska@gf.ukim.edu.mk*
2	Asist. prof., Ss. Cyril and Methodius University in Skopje, Faculty of Civil engineering, Skopje, North Macedonia *m.jovanoska@gf.ukim.edu.mk*
3	Prof., Ss. Cyril and Methodius University in Skopje, Faculty of Architecture, Skopje, North Macedonia *agavriloska@arh.ukim.edu.mk*

Abstract

The global shift towards sustainable construction and energy-efficient building design has brought forward new challenges in fire safety. Modern energy-efficient buildings frequently incorporate advanced insulation systems, airtight envelopes and renewable or recycled construction materials, many of which are combustible. This paper examines the fire safety implications of integrating such materials, particularly those used to enhance thermal performance or those selected to support circular economy principles, such as reused wood, biocomposites and plastic-based insulation. While these materials offer environmental benefits, they may significantly increase the fire load, release toxic smoke and accelerate flame spread, especially in highly insulated and airtight buildings.

The paper reviews current trends in material use, evaluates relevant fire performance standards (e.g., Euroclass system) and analyzes fire behavior of key materials such as expanded polystyrene (EPS), polyurethane (PU), wood fiber boards and recycled plastics. A specific emphasis is placed on the balance between sustainability and safety, highlighting the need for integrated design approaches that consider fire risk from the earliest stages of planning.

The study also reviews best practices in fire prevention strategies, such as compartmentation, fire-resistant cladding systems and the use of intumescent coatings. The paper calls for updated regulatory frameworks and testing protocols that address the evolving risks in energy-efficient and circular construction, ensuring that green building efforts do not compromise occupant safety. Case studies of recent fire incidents are discussed to illustrate the complex interactions between energy efficiency measures, material combustibility and fire performance. Ultimately, the research underscores the importance of harmonizing energy efficiency, material circularity and fire safety in future building design.

Keywords

Fire safety, energy-efficient buildings, combustible materials, circular economy, insulation, wood, recycled materials, sustainable construction, fire-resistant design

1. Introduction

The contemporary built environment is undergoing a rapid transformation driven by the urgent need to reduce greenhouse gas emissions and minimize the environmental footprint of construction. Energy-efficient building design, supported by global initiatives such as the European Green Deal and the Paris Climate Agreement, [1-2], has placed sustainability at the forefront of architectural and engineering practice. The adoption of advanced thermal insulation, airtight building envelopes and the integration of renewable or recycled construction materials has become increasingly common. These measures undoubtedly contribute to energy savings and align with principles of the circular economy.

However, the use of new materials and design strategies has introduced unforeseen challenges in terms of fire safety. Many energy-efficient materials, particularly plastic foams, woodbased composites and recycled plastics, exhibit high combustibility and can release large quantities of toxic gases under fire exposure.

Due to limited ventilation pathways, in case of airtight buildings fire development is not faster but more severe than in buildings without thermal insulation and energy efficient windows. In the "unsealed" buildings, the availability of oxygen enables sustained combustion and repetition of temperature peaks, with maximum temperatures near the fire source. This led to higher thermal radiation and longer exposure to elevated temperatures. Such conditions create an immediate and severe thermal threat to occupants, while the higher smoke layer position allows for somewhat better visibility and escape possibilities. By contrast, in the "sealed", or airtight buildings, the limited oxygen supply reduces the overall intensity and duration of open flames but creates a hazardous environment dominated by toxic smoke, low oxygen levels and severely reduced visibility. Moreover, the accumulation of unburned gases significantly increases the risk of backdraft if ventilation is suddenly introduced. Thus, while unsealed buildings present greater danger from intense heat and prolonged fire duration, airtight buildings pose a more insidious risk through toxic atmosphere, oxygen depletion and explosive fire behavior.

This duality of sustainability and safety presents a central dilemma: while environmentally friendly, certain construction choices may inadvertently increase the vulnerability of buildings to fire.

This paper critically examines the implications of material choices in sustainable construction for fire safety. It provides an overview of key combustible materials used in energy-efficient and circular buildings, evaluates their fire behavior and reviews relevant regulatory frameworks such as the Euroclass classification system. It also highlights fire safety design strategies, including compartmentation, protective coatings and advanced façade systems, while underscoring the need for updated standards and integrated design approaches.

2. Materials in energy-efficient and circular construction

Fire safety considerations in energy-efficient and circular construction are essential to achieving both sustainability and resilience. The thermal, environmental and fire characteristics of insulation materials, wood-based and bio-composites and recycled polymers collectively influence energy performance, carbon footprint and overall safety. Table 1 summarizes these material classes by energy efficiency, circularity and fire performance.

2.1. Plastic-based insulation

Expanded polystyrene (EPS) and polyurethane (PU) foams are among the most widely used materials for improving thermal performance. Their low thermal conductivity enables significant reductions in heating and cooling energy demand. However, materials such as expanded polystyrene (EPS) and polyurethane (PU) foams, while highly effective in improving energy efficiency, are problematic from both a circularity and fire safety perspective.

Expanded Polystyrene (EPS) comes from fossil-based feedstocks and is hard to recycle. Mechanical and chemical recycling methods exist, but large-scale recovery is rare due to contamination during demolition, transport challenges and the low value of recycled EPS. Polyurethane (PU) foams face even bigger end-of-life issues. As thermoset plastics, they cannot be remelted or turned into high-value products. Some downcycling and experimental chemical recycling processes exist, but industrial use is still very limited.

EPS and PU are highly combustible, characterized by low ignition temperatures and rapid flame spread once ignited and the release of dense, toxic smoke containing carbon monoxide and hydrogen cyanide and melts and drips under heat exposure. Past fire incidents in insulated façades have demonstrated that these materials can facilitate vertical fire spread if not adequately protected.

2.2. Wood and biocomposites

Wood fiber insulation boards, laminated timber elements and bio-composites, often formulated with agricultural residues or natural fibers bound with biobased or synthetic resins, are increasingly preferred for their renewable origins, carbon sequestration potential and comparatively low embodied energy.

Beyond their environmental benefits, these materials can be engineered to achieve meaningful levels of fire resistance through treatments, charring behavior optimization and protective encapsulation. Nevertheless, their organic content inherently contributes to the overall fire load, which requires careful consideration in performance-based fire design.

From an energy efficiency perspective, wood fiber boards provide moderate thermal performance and some heat storage capacity, so they can contribute to seasonal comfort and to reduced heating and cooling demands. However, their performance depends strongly on board density, moisture content and climate.

2.3. Recycled plastics and circular materials

The transition toward a circular economy has accelerated the reuse of plastics, rubber and other polymers in building products such as insulation boards, façade cladding and interior finishes. These materials offer clear environmental advantages by diverting waste from landfills and reducing demand for virgin feedstocks.

However, the heterogeneity of recycled polymer streams introduces significant challenges in fire safety assessment. Variations in polymer type, filler content and the presence of additives or contaminants can lead to unpredictable ignition characteristics, inconsistent flame spread rates and variable smoke toxicity. Such variability complicates classification under standardized fire testing protocols and hinders reliable performance prediction.

Table 1 – Comparison of Considered Materials by Energy Efficiency, Circularity and Fire Safety

3. Regulatory frameworks and standards

3.1. Euroclass system

The Euroclass system (EN 13501-1), [3], is the prevailing European standard for reaction-tofire classification. It assesses ignitability, flame spread, heat release, smoke production and flaming droplets, providing a harmonized approach across EU member states. Materials are classified from A1 (non-combustible) to F (no performance determined). Table 2 presents the Euroclass ratings of selected materials, together with their key fire behavior characteristics and relevant design considerations.

Table 2 – Euroclass Classification of Selected Materials

Material	Euroclass Rating	Key Fire Behavior Characteristics	Notes
Expanded Polystyrene (EPS)	E–F	Easily ignitable, melts and drips, rapid flame spread	Needs protective cladding
Polyurethane (PU)	C–E	High heat release, toxic smoke (HCN, CO)	Fire retardants improve performance but limited effectiveness
Wood Fiber Board	C–D	Burns steadily, contributes to fire load, produces smoke	Performance varies withdensity and fire-retardant additives
Recycled Plastic Insulation	Variable (D–F)	Unpredictable fire behavior, inconsistent composition	Lack of standardized testing protocols

3.2. Euroclass system

While the Euroclass system provides a structured approach, critics argue that small-scale tests do not always capture real-world fire dynamics, particularly for complex assemblies such as insulated façades. Standardized tests often focus on isolated materials rather than entire building systems. For example, EPS insulation may achieve a Euroclass E rating, but when combined with protective cladding, adhesives and air cavities, fire performance can vary significantly. Real fire scenarios also involve multiple materials interacting, which cannot be fully represented in laboratory conditions. This discrepancy highlights the need for updated testing protocols that better reflect contemporary energy-efficient building designs.

3. Case studies of fire incidents

4.1. Dijon fire, (Dijon, 2010)

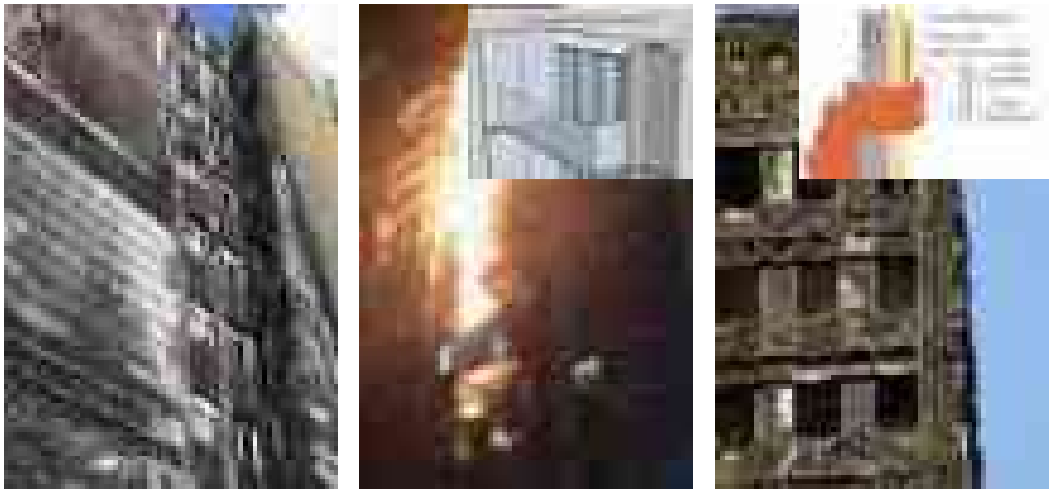
The fire started from an external rubbish container resulting in vertical spread on the façade system. The façade is an ETICS system with polystyrene insulation, [4-5], Figure 1.

4.2. Lacrosse Apartment fire, (Melbourne, 2014)

The 2014 Lacrosse Apartment fire in Melbourne exposed the extreme risk of combustible façades. Polyethylene-core aluminum composite panels enabled flames to race from an eighth-floor balcony to the roof within minutes. Subsequent investigations revealed failures in product certification, regulatory oversight and compliance enforcement, [6-5], Figure 1.

4.3. Grenfell Tower, (London, 2017)

The Grenfell Tower tragedy underscored the dangers of combustible insulation and cladding systems. Polyisocyanurate (PIR) and aluminium composite panels contributed to rapid vertical fire spread, leading to huge consequences. While the building complied with certain regulatory requirements, the fire revealed deficiencies in both product testing and risk evaluation frameworks, [8-9], Figure 1.



Dijon, France 2010 Façade Fire, [4-5]

Lacrosse Apartment Fire (Melbourne, 2014), [6-7]

Grenfell Tower Fire (London, 2017), [8-9]

Figure 1 – Case Studies of Fire Incidents

4.4. Other notable incidents

Several façade fires across Europe, the Middle East and Asia have involved EPS and PU insulation boards or other plastic-based insulation, often in combination with combustible cladding. These cases demonstrate that even materials deemed "acceptable" in isolated testing can fail under realworld conditions, particularly when used in airtight, highly insulated structures.

5. Fire safety design strategies

Effective fire safety in modern circular buildings requires a multi-layered approach that combines prevention, containment and system-level resilience. The following strategies highlight key measures:

- **Compartmentation:** One of the most effective methods of containing fire is compartmentation, which involves subdividing a building into fire-resistant sections, Figure 2. This strategy prevents flame and smoke spread, buying critical time for evacuation and firefighting.

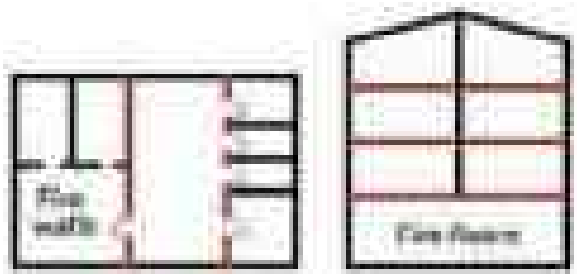


Figure 2 – Compartmentation of Building

Figure 3 – Intumescent Coatings

- **Protective Cladding and Intumescent Coatings:** The application of non-combustible cladding or intumescent coatings can significantly improve the fire resistance of combustible materials. Intumescent paints, for instance, swell when exposed to heat, forming a protective char layer that insulates the underlying substrate.
- **Ventilation and Smoke Control:** Given the airtight nature of modern energy efficient buildings, controlled ventilation and smoke extraction systems are essential. Mechanical smoke control systems can prevent toxic gas accumulation, which is often the primary cause of fatalities in residential fires.
- **Fire-Safe Material Innovation:** Ongoing research into bio-based composites with embedded fire retardants, or hybrid insulation materials that combine organic and inorganic components, shows promise. Such innovations aim to merge sustainability with acceptable fire performance.
- **Balancing Sustainability and Safety:** The integration of circular and energy efficient principles in construction cannot be pursued in isolation from safety concerns. A holistic approach is required, Figure 4, where energy performance,

carbon reduction and fire safety are addressed simultaneously from the early design stages. This entails collaboration between architects, engineers, material scientists and fire safety professionals. Furthermore, regulatory frameworks must evolve to account for new risks associated with combustible sustainable materials. Performance-based design, rather than prescriptive rules, offers a pathway forward by evaluating how entire building systems behave under realistic fire scenarios.

Table 3 summarizes key fire mitigation strategies for energy-efficient, circular buildings, outlining their primary function and providing example applications. Together, these measures show how thoughtful design choices, material selection, and performance-based approaches can enhance fire safety while supporting sustainability objectives.

Table 3 – Fire Mitigation Strategies in Energy-Efficient Buildings

Strategy	Function	Example Application
Compartmentation	Limits fire spread between zones	Fire-rated walls and floors
Fire-resistant cladding	Protects combustible insulation in façades	Non-combustible mineral-based panels
Intumescent coatings	Expands under heat to insulate combustible core	Timber beams, steel structures
Mechanical smoke control	Prevents toxic gas buildup	Pressurized stairwells, exhaust fans
Material innovation	Combines sustainability with fire safety	Bio-based composites with embedded retardants

Figure 4 – Integrated Design Approach for Safe and Sustainable Buildings

6. Conclusion

The global push for sustainable and circular construction has introduced a new generation of building materials that, while environmentally beneficial, often present elevated fire risks. Plasticbased insulation, wood composites and recycled polymers enhance energy performance but can accelerate fire growth, produce toxic smoke and challenge existing safety frameworks. Current testing methods, though useful, fail to fully capture the complexities of modern assemblies and building envelopes.

Best practices such as compartmentation, protective coatings and smoke control systems can mitigate some of these risks, but they must be paired with more rigorous standards and updated regulations. Lessons from recent fire incidents, most notably Grenfell Tower, emphasize the critical importance of harmonizing sustainability with safety.

Ultimately, future building design must embrace integrated strategies where energy efficiency, material circularity and fire resilience are not competing objectives but interdependent aspects of sustainable construction. Only through such holistic approaches can the built environment achieve its dual goals of environmental responsibility and occupant protection.

Literature

[1]	European Commission. (2019). The European Green Deal https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019DC0640
[2]	United Nations. (2015). Paris Agreement. United Nations Treaty Collection. https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[3]	European Committee for Standardization (CEN). EN 13501-1:2018
[4]	https://www.bienpublic.com/faits-divers-justice/2020/11/20/dix-ans-apres-l-incendie-d-adoma-uneplaie-toujours-a-vif
[5]	Ministry of Housing, Communities and Local Government. (2019, December 9). *Fire performance of cladding materials research – Appendix A: Literature review*
[6]	https://www.theguardian.com/uk-news/2017/jun/15/cladding-in-2014-melbourne-high-rise-blazealso-used-in-grenfell-tower
[7]	Badrock, G. (2016). Post incident analysis report: Lacrosse Docklands, 25 November 2014 [Conference paper]. MATEC Web of Conferences, 46, 06002. https://doi.org/10.1051/matecconf/20164606002
[8]	https://cfpa-e.eu/final-report-everyone-failed-when-grenfell-tower-burned/
[9]	Mitchener, G. (2018). Impact of Grenfell Tower fire disaster on polyisocyanurate industry. Polimery, 63(10), 716–722. https://doi.org/10.14314/polimery.2018.10.8

Pathways for circular economy implementation in construction

Meri Cvetkovska[1]

Milica Jovanoska Mitrevska[2]

Todorka Samardzioska[3]

Ognen Marina[4]

Liljana Dimevska Sofronievska[5]

1	Professor, Faculty of Civil Engineering, University "Ss. Cyril and Methodius", Skopje *cvetkovska@gf.ukim.edu.mk*
2	Assistant Professor, Faculty of Civil Engineering, University "Ss. Cyril and Methodius", Skopje *m.jovanoska@gf.ukim.edu.mk*
3	Professor, Faculty of Civil Engineering, University "Ss. Cyril and Methodius", Skopje *samardzioska@gf.ukim.edu.mk*
4	Professor, Faculty of Architecture, University "Ss. Cyril and Methodius", Skopje *ognen.marina@arh.ukim.edu.mk*
5	Assistant Professor, Faculty of Architecture, University "Ss. Cyril and Methodius", Skopje *ldimevska@ukim.edu.mk*

Abstract

The construction sector exerts immense pressure on natural resources and is a major contributor to global waste and CO_2 emissions. Construction and demolition activities generate substantial waste, particularly in developed regions, underscoring the urgent need for more sustainable practices. This paper examines how the 10R framework, Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover, can guide the construction sector toward a circular, regenerative model. By prioritizing waste prevention and extending the lifecycle of materials and components through design and reuse strategies (R0–R7) before considering recycling or recovery (R8–R9), the framework offers a practical roadmap for minimizing environmental impact while maximizing resource efficiency.

The paper highlights effective circular construction practices, including design for disassembly, modularity and prefabrication, multi-functionality, the use of bio-based and recyclable materials and material tracking through digital passports. Case studies such as, the Circular Building in London, the Super Circular Estate in the Netherlands and Pikku-Finlandia in Finland, illustrate successful implementation across steel, concrete and timber structures, revealing both opportunities and challenges.

Achieving sector-wide circularity also demands systemic support, including stakeholder collaboration, standardized protocols and policy incentives. Collectively, these approaches position the 10R framework as a practical, actionable pathway for transforming the construction sector toward a regenerative, low-carbon and resilient future.

Keywords

Circular economy, 10R strategies, sustainable construction, resource efficiency, regenerative buildings.

1. Introduction

The construction industry is among the most resource-intensive and carbon-intensive sectors globally, driving significant consumption of raw materials, high energy use and substantial waste generation.As a result, it plays a pivotal role in achieving global net-zero carbon goals. In 2023, buildings were responsible for 32% of global energy demand and 34% of CO_2 emissions, with operational emissions reaching a record 9.8 gigatonnes and embodied carbon contributing around 2.9 gigatonnes [1]. Despite modest progress, the sector remains far from on track to meet net-zero carbon and climate resilience targets by 2050. CO_2 emissions have risen by 5% since 2015, falling short of the 28% reduction required by 2030 to align with the Paris Agreement [2]. This gap underscores the urgent need to accelerate decarbonization and resource efficiency through emerging strategies.

For decades, the construction industry has followed a linear "take-make-dispose" model, in which materials, components and buildings are produced, used once and subsequently discarded, generating substantial waste and depleting finite resources. Implementing a circular economy (CE) in construction requires a comprehensive re-evaluation of the entire value chain. In a circular framework, waste is minimized at the source and all stages of the conventional linear system are restructured, encompassing resource extraction, material processing, design, construction, use, maintenance and end-of-life recovery, thereby closing the loop, Figure 1.

Figure 1 – Transition from Linear to Circular economy [3]

The shift toward circularity necessitates a fundamental redesign of how products and buildings are envisioned, used and managed. Key principles include designing for disassembly, modularity, multifunctionality and extended product lifecycles. Digital tools such as Building Information Modeling (BIM) and material passports support the tracking of components, enabling their reuse, refurbishment, or recycling while maintaining material quality and transparency.

This paper explores pathways for implementing circular economy principles in construction, highlighting opportunities, challenges and practical strategies. Several exemplary case studies are evaluated, demonstrating that integrating circular principles into the built environment is not only technically feasible but also yields significant environmental, economic and social benefits. It gives us the power to grow prosperity, jobs and resilience while cutting greenhouse gas emissions, waste and pollution.

2. The 10R Framework of the circular economy

The 10R framework is a structured hierarchy of strategies that operationalize circular economy principles by minimizing waste and maximizing resource efficiency, [4-5]. It consists of ten approaches: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover, Figure 2. These strategies are ranked according to their capacity to retain value and reduce environmental impact, with Refuse and Rethink being the most desirable. Although originally developed as a general framework, the 10R hierarchy is highly applicable to construction sector. The built environment is characterized by high material intensity, long asset lifespans and substantial construction and demolition waste streams, making it a critical sector for circular intervention. Applying the 10R hierarchy to construction enables stakeholders to prioritize upstream strategies such as refusing unnecessary new builds, rethinking design for multifunctionality and reducing resource demand through lean construction before resorting to lower-order strategies such as recycling or energy recovery.

Figure 2 – 10R Strategy [4]

3. Building for circularity

In order to implement circular economy principles in construction, several interconnected strategies can be applied to optimize resource use, reduce waste and improve sustainability outcomes throughout a building's life cycle:

- Recycled and Renewable Materials: Incorporating recycled concrete, reclaimed wood, recycled steel and bio-based alternatives such as hempcrete reduces reliance on virgin resources, conserves energy and lowers carbon emissions associated with material production.
- Design for Disassembly (DfD) and Reuse: Buildings are planned for easy dismantling, allowing components like steel beams, façade panels and flooring to be recovered and reused in future projects, minimizing demolition waste and preserving material value.
- Modular Construction: Prefabricated, modular designs enable flexible building configurations, easy relocation and component reuse, which extend the functional lifespan of materials and reduce construction time and costs.
- Material Passports: Digital tracking of building materials ensures transparency, supports reuse and recycling and enables efficient end-of-life management.
- Adaptive Reuse: Repurposing existing structures preserves embodied energy, extends the life of both materials and structures and reduces the environmental impacts of new construction.
- On-Site Waste Minimization: Lean construction practices, accurate material planning and efficient logistics reduce excess material use, cut costs and limit waste generation.

Applying circular economy principles in construction delivers long-term environmental, economic and social benefits by fostering innovation, reducing dependence on raw materials and aligning the built environment with broader sustainability goals. Central to this vision are modular and prefabricated components, which simplify construction, enable future dismantling and allow buildings to be expanded, reconfigured, or relocated with minimal disruption, extending the life of materials and reducing resource demand. Design for disassembly (DfD) ensures that building components can be efficiently separated and recovered at the end of their lifecycle, supporting high-quality reuse and minimizing construction and demolition waste. Material selection is equally critical, prioritizing sustainable, recyclable and bio-based materials such as recycled steel, reclaimed wood, biodegradable insulation and natural fiber composites to reduce environmental impact and conserve embodied energy. Salvaging materials from demolition sites and practicing urban mining further decreases waste, lowers carbon emissions and promotes healthier indoor environments. Advanced technologies like Building Information Modelling (BIM), alongside policy frameworks, green procurement standards and certification systems such as LEED and BREEAM, enable better planning and facilitate the adoption of circular practices. Despite challenges like regulatory barriers, market demand and logistical complexity, coordinated efforts from policymakers, designers and industry stakeholders are driving the construction sector toward a more sustainable, circular and resource-efficient future.

4. Circular construction strategies for Steel, Concrete and Timber structures

Common construction materials, such as steel, concrete and glass, are energy-intensive and resource-depleting, making it crucial to understand their material-specific challenges and opportunities when integrating circular economy principles in the construction sector.

4.1. Steel Structures

Steel is one of the most recyclable construction materials. The opportunities that make it highly suitable for circular applications are:

- Design for Disassembly (DfD): Steel structures can be designed with demountable connections. The components can be bolted rather than welded, allowing for easy disassembly and reuse in future projects.
- Standardization and Modularity: Standardized steel elements enable easy replacement, reuse and integration into new structures.
- Recycling: Steel retains its properties after recycling, making it ideal for closed-loop recycling systems.
- Urban Mining: Decommissioned steel structures can be systematically dismantled and components can be reused or recycled.
- Parallel to opportunities there are few challenges, as:
- Ensuring structural integrity and meeting modern codes for reused elements.
- Tracking material history and quality, which can be addressed using digital tools like BIM and material passports.

Figure 3 – Circular building, London, erection of steel frame and structural connection detail, [6]

The Circular Building, developed for the 2016 London Design Festival by Arup, The Built Environment Trust, Frener & Reifer and BAM, demonstrates circular construction through modular steel framing, reclaimed materials and design for complete disassembly, Figure 3. Modular components, dry assembly techniques and QR-coded BIM tracking enabled efficient construction, easy deconstruction and high-quality material recovery. Serving as a temporary exhibition, the building educated visitors on circular practices while all components were systematically dismantled and stored for future reuse. By repurposing reclaimed materials in new projects, the initiative reduced environmental impact and set a precedent for integrating circular economy principles into construction.

4.2. Concrete structures

Concrete poses more challenges in circular applications due to its monolithic nature and lower recyclability compared to steel or timber. The opportunities for concrete are:

- Concrete Recycling: Crushed concrete can be used as aggregate for new concrete or road sub-base material.
- Precast Modular Elements: Prefabricated concrete components can be designed for disassembly and reuse.
- Carbon Capture in Concrete: Emerging technologies allow for CO_2 to be captured and stored in concrete during production.
- Adaptive Reuse: Instead of demolition, concrete buildings can be refurbished or repurposed, preserving embodied energy.

The challenges for the concrete reuse are:

- Dismantling reinforced concrete is labor- and energy-intensive.
- Quality control of recycled aggregate can be variable.
- Cement production remains highly carbon-intensive, requiring innovation in low-carbon binders (e.g., geopolymer concrete).

Figure 4 – Hoisting of elements and two 3D units for the construction of two circular houses (Type A left and Type B middle). The structure for the third house (Type C) has been made of recycled concrete, [7]

The Super Circular Estate (SCE) project in Kerkrade, represents circular concrete construction by deconstructing a 10-story apartment building and reusing its materials to build three new houses, achieving at least 95% reuse of components, Figure 4. Foundation has been made out of circular concreate (aggregate for the concrete have been acquired by crushing the existing concreate structure and only 7% of new cement has been added during production of concrete for the foundation).

Main loadbearing structure of the two houses has been directly reused from the existing building by cutting 3D concrete modules from the existing structure, while the main loadbearing structure of third house has been made of circular concreate (aggregate and cement for the concrete, only 5% of new cement has been added during production of concrete for the structural walls).

Partitioning walls have been directly reused from the existing building as well as wooden frames for doors and kitchen cabinets have been directly reused and finally, façade has been constructed out of parts using crushed concrete pieces from the existing building brick, cut off elements and recycled concrete

Selective deconstruction, material processing and integration into new structures ensured structural safety and compliance, while the project incorporated design-for-future-disassembly principles and detailed material documentation. By reducing construction waste, carbon emissions and reliance on virgin materials, the SCE project provides a replicable model for circular construction and sustainable urban development.

4.3. Timber structures

Timber is a renewable material with strong potential in circular construction, especially with the rise of engineered wood products like cross-laminated timber (CLT).

The opportunities for implementing the circular economy in construction of timber buildings:

- Reusability and Bio-based Design: Timber elements can be easily dismantled and reused with minimal processing.
- Carbon Storage: Wood stores carbon throughout its lifecycle, contributing to carbon neutrality.
- Design for Flexibility: Timber lends itself well to modular design, allowing for future modifications or reuse of components.
- Biodegradability: End-of-life timber products can be composted or used in bioenergy systems (with care to avoid treated wood).

The challenges for circular timber structures are:

- Durability and fire resistance must be managed carefully in reused timber.
- Preservatives and adhesives may affect recyclability or biodegradability.
- Market demand and regulations for reused wood may be limited in some regions.

Figure 5 – Circular building Pikku-Finlandia (Little Finlandia) in Helsinki, Finland, [8]

Pikku-Finlandia was designed as a temporary venue to replace Finlandia Hall during its three-year renovation, Figure 5. The project was organised by Aalto University, the City of Helsinki and Finlandia Hall in the autumn of 2019. The design used whole untrimmed tree trunks as load-bearing columns, thus minimising processing costs and impacts. Its modular and multifunctional design allows for easy disassembly, relocation and adaptation to new uses, such as a school or daycare, extending the building's lifecycle. Prefabricated timber components facilitated efficient construction, reduced waste and enabled the building to function as a temporary public venue while raising awareness of sustainable practices. Planned disassembly and material reuse demonstrate how circular timber construction can combine functionality, adaptability and environmental responsibility.

5. Conclusions

The environmental footprint of buildings and infrastructure is immense, yet it can be dramatically reduced through sustainable design, construction and management practices. Transitioning toward circular, low-impact urban development is essential to meeting global climate, biodiversity and sustainability targets. By embedding circular economy principles, the construction sector can minimize waste, conserve finite resources and create significant economic and social value, ranging from new employment opportunities to strengthened community resilience. Real-world case studies across steel,

concrete, and timber construction demonstrate that circular strategies are not only feasible but also highly effective. Techniques such as modular design, design for disassembly, material recovery and adaptive reuse allow the built environment to satisfy current functional needs while lowering environmental impact. When fully embraced, these approaches can transform construction into a regenerative system, preserving natural resources, enhancing ecosystem health, and ensuring long-term environmental sustainability for generations to come.

Literature

[1]	Hamilton, I., & Hsu, S.-C. (Eds.). (2025). Global Status Report for Buildings and Construction 2024/2025. Global Alliance for Buildings and Construction (GlobalABC). https://globalabc.org/sites/default/files/2025-03/Global-Status-Report-2024_2025.pdf.
[2]	Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104.
[3]	https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy
[4]	Potting, J., Hekkert, M., Worrell, E., Hanemaaijer, A. (2017) CIRCULAR ECONOMY: MEASURING INNOVATION IN THE PRODUCT CHAIN.
[5]	Tleuken, A., Karaca, F., Askar, R., Leindecker, G., Kahraman, İ., Giarma, C., Cervantes Puma, G. C., Pineda-Martos, R., Bolatkhanov, I., Palermo, M., Arrè, L., Syed, A. A. S., Ahad, I. U., Sofronievska, L. D., Cvetkovska, M., Tavares, V., & Bragança, L. (2024). Circularity criteria and indicators at the building component and system level. In Circular Economy Design and Management in the Built Environment (pp. 335–370). Springer. https://doi.org/10.1007/978-3-031-73490-8_13
[6]	https://www.steelconstruction.info/Circular_building
[7]	https://www.uia-initiative.eu/en/news/super-circular-estate-project-journal-no-5-municipality-kerkrade
[8]	https://pub.norden.org/nord2023-031/6-circular-construction-projects-support-platforms-and-tools

Waste management sector: Evaluating the municipal waste system in Elbasan and opportunities for improvement

Perseta Grabova[1]

Julia Dado[2]

Elona Pojani[3]

1 Perseta Grabova, University of Tirana
perseta.grabova@unitir.edu.al

2 Julia Dado, Master Student in Risk Management
julia.dad09@gmail.com

3 Elona Pojani, University of Tirana
elona.pojani@unitir.edu.al

Abstract

This paper examines the potential for economic and environmental improvements in the waste management sector of Elbasan Municipality, with a specific aim on plastic waste. It evaluates how improved waste sorting at the source within households, institutions, and businesses could reduce municipal disposal costs while generating revenue from recyclable materials. The article seeks to describe the present condition of waste management and identify essential stakeholders engaged in collecting, sorting, and recycling via the examination of waste management plans from Elbasan. This study analyses the types of waste collected, the role of public and private actors, and current recycling rates. Part of the work is to assess the economic benefits that can be achieved through more efficient waste separation practices: including savings from reduced landfill and clean-up costs, as well as potential revenues from selling sorted plastic to local recycling companies instead of incinerating it. Through interviews with representatives of recycling companies and municipal waste managers, the study also examines the dynamics of the market for recyclable plastics.

A cost-benefit analysis is utilized to assess the financial benefits, savings, and broader impacts of moving towards a more sustainable and circular model of plastic waste management. The main goal is to propose realistic and cost-effective solutions, adapted to the reality of Elbasan, to make the city's waste management plan more efficient and environmentally friendly. The results of the study aim to help policymakers make informed decisions and promote cooperation with other stakeholders, so that the waste management system functions better at the regional level.

Keywords

Plastic Waste; Municipal Waste Management System; Circular Economy; Elbasan Municipality, Albania

1. Introduction

Municipal waste management remains one of the most demanding environmental and governance challenges across Albanian cities, particularly in Elbasan. This municipality faces increasing waste volumes, limited landfill capacity, outdated infrastructure, and minimal public engagement in recycling. Among the most problematic waste streams is plastic waste, which continues to accumulate in landfills and open spaces due to inefficient collection, lack of source separation, and underdeveloped recycling systems.

This paper aims to evaluate, the current waste management practices within the Municipality of Elbasan, particularly in relation to recyclable waste, and explores the possibility of shifting to a recyclable waste management system as a more circular and economically efficient model. It analyses the potential for cost savings and environmental benefits through better source separation, stakeholder coordination, and recycling infrastructure.

In general, waste management involves the collection, transportation, processing, recycling, or disposal of waste materials, aiming to reduce their environmental and health impacts. Plastic waste poses unique challenges due to its volume, durability, and low degradation rate, making recycling an essential strategy for managing this growing issue.

This research combines quantitative and qualitative methods, including a cost-benefit analysis (CBA), stakeholder interviews, and policy reviews, to evaluate whether transitioning from a landfill-based system to a two-bin recyclable waste management system is a viable solution for Elbasan. The study also outlines systemic challenges such as governance fragmentation, low public awareness, and infrastructure gaps and concludes with practical, financially viable recommendations to improve municipal waste performance and support a more sustainable future.

The paper is organized as follows. First a literature review, focusing on the concepts of waste management, circular economy and environmental cost benefit analysis is offered. Then, the second part of the paper describes the methodology applied, and the results of both qualitative and quantitative methods used for this research. The paper concludes in recommendations relating to the waste management system in Elbasan.

2. Literature review - Waste management, circular economy and economic benefits

Waste management includes organized processes for collecting, transporting, treating, and disposing of waste to minimize environmental impact and protect public health [1]. Traditionally, it has relied on linear systems like landfilling and incineration, which offer short-term relief but cause long-term problems such as resource depletion and environmental degradation [1]. The circular economy, on the other hand, supports a long-term strategy that moves away from the "take, make, dispose" paradigm and towards decreasing waste at the source and getting value back via reuse, recycling, and recovery [2]. This methodology lengthens the life of products, makes better use of resources, and lowers the need for new materials [2].

Plastic pollution is a major challenge, within the waste management issues, due to plastics' durability and slow decomposition. This means they may stay around for decades and hurt ecosystems, animals, and human health by contaminating them and leaking chemicals [3]. To solve this issue, it is needed to use integrated waste management and the concepts of a circular economy across the plastic value chain [3]. Challenging this issue requires integrated waste management and broad adoption of circular economy principles across the plastic value chain. The implementation of an efficient waste management system also supports key UN Sustainable Development Goals, such as reducing urban environmental impact (SDG 11.6), minimizing waste generation (SDG 12.5), and preventing marine pollution (SDG 14.1) [4]. Implementing circular economy practices at the municipal level is crucial to prevent plastic pollution and reduce environmental harm [4].

Waste management has evolved from basic disposal methods to integrated, sustainability-driven systems [5]. Initially centered on the linear model, reliance on landfilling and incineration has gradually shifted toward sustainable practices. The 1992 UN Rio Conference formalized this transition, emphasizing resource efficiency and pollution prevention [6]. European legislation reflects this progression, starting with waste reduction focus in the 1970s-80s, recycling targets in the 1990s, and a comprehensive embrace of circular economy principles by the 2010s [7]. Recent policies like the EU Plastics Strategy and Packaging and Packaging Waste Regulation stress maintaining material use through sharing, reducing, reusing, repairing, renewing, and recycling [7]. Better waste sorting delivers significant economic benefits by lowering landfill volumes and generating revenue from selling recyclables [8]. This reduces disposal costs and provides income from materials like plastics, which can command prices between 300 and 700 EUR per ton depending on quality and type [8]. Beyond direct financial returns, sound waste management reduces indirect costs linked to environmental harm, such as greenhouse gas emissions and pollution-related health issues [9]. Recycling also yields consumer benefits, as many are willing to pay for sustainable waste services. Studies consistently report net positive financial outcomes for recycling across various waste streams, proving economic advantages over disposal methods [10].

Albania, as a lower-middle-income country, faces major waste management challenges like poor collection infrastructure, limited source separation, and low recycling rates [12]. Despite aiming to meet EU standards, systemic gaps persist, causing environmental problems such as marine pollution from waste in waterways [11]. Public awareness about proper disposal remains low [11]. However, opportunities to boost recycling exist through investments in valuable waste streams, better infrastructure, and policy integration of environmental values [5].

The transition toward sustainable waste management grounded in circular economy principles and improved recyclable waste systems offers major environmental and economic benefits. While challenges persist, especially in developing contexts like Albania, progress is achievable through technological innovation, public involvement, and strategic investment. For long-term sustainability, less harm to the environment, and economic prosperity, it is important to put recycling, resource recovery, and waste reduction first.

3. Methodology, data and analysis

This research paper uses a mixed-methods approach to investigate the use of a recycle waste management system and its economic implications in the municipalities of Elbasan, integrating both qualitative and quantitative data to provide inclusive understandings. In summary, the methodology combined rigorous quantitative analysis with in-depth qualitative exploration to provide a holistic view of waste management, despite inherent research limitations.

3.1. Quantitative research approach

This component focused on evaluating the technical efficiency of a two waste stream management system in Elbasan. It involved collecting and analysing numerical data to measure performance, identify challenges, and track expenses. The deep analysis was conducted using a simple CBA analysis and the same method and tool employed by the municipalities, which was developed by expert Eduard Canaj as part of a project by the Regional Environmental Center (REC) in 2013, with support from the Swiss Agency for Development and Cooperation (SDC) – Decentralisation and local development programme (DLDP model). This method includes a model and manual excel data entry for calculating total waste management costs and benefits. These measurements provided insights into recycle waste management system quality and potential improvements.

The CBA of Elbasan's urban waste management plan follows the DLDP model (2013) [13] for cost calculation and the Zaman model (2016) [11] for estimating benefits. The main costs include capital investments, operating expenses, disposal fees, depreciation, and administrative costs, with operating costs accounting for the largest share of total expenditures. In contrast, the main benefits are derived from material substitution through recycling, energy savings, avoided environmental costs, and overall economic gains. These estimates provide a comprehensive financial overview, allowing for an informed evaluation of the plan's economic feasibility and long-term sustainability.

3.2. Qualitative research approach

This section analyzed public perception and policy compliance related to plastic waste management in the Elbasan municipality. The aim was to provide a detailed overview of the behaviors, attitudes and level of community engagement with existing waste management initiatives. The interviews served as a key element for verifying the study findings and filling contextual gaps, providing valuable insights into how waste management policies are interpreted and implemented at different administrative levels. The interviews also helped to understand the impact of political, financial and infrastructural constraints on the results achieved. For this purpose, two key representatives from Elbasan Municipality and four large businesses operating in the area were interviewed. The discussions were based on 12 focused questions, which addressed current

waste management practices, their knowledge of existing policies and suggestions for improvements. The perspectives gathered were important in identifying intervention points for optimizing the system, including strengthening coordination mechanisms, improving waste flows, and providing personalized support to local actors.

Some limitations of this research apply, including potential respondent bias in interviews and surveys, which could affect the objectivity of qualitative data and potential of human error while concluding the analysis. The scope was also constrained by resource availability, limiting the number of municipalities and stakeholders involved.

4. Survey and interview findings on plastic waste management in Elbasan

The survey and interview data collected from representatives of the Elbasan Municipality reveal several systemic issues affecting the effectiveness of recyclable or plastic waste management system at the local level. The results are grouped into four key thematic areas: public awareness, policy and institutional alignment, stakeholder roles, and system infrastructure and are summarized in thematic matrix (Figure 1) with priority levels assigned based on urgency and potential impact.

Survey responses and interviews consistently highlighted low public awareness as a major barrier to effective plastic waste management. Despite some localized efforts, such as school-based reuse initiatives and youth programs, these activities remain limited in scope and do not significantly influence broader public behavior. The continued widespread use of plastic bags reflects limited behavioral change. Moreover, the lack of large-scale public education campaigns and unreliable environmental content in school curricula were identified as major flaws. Overall, awareness initiatives are fragmented and under-resourced, with no sustained strategy for public engagement in waste separation or reduction.

Although Albania possesses a legal framework for waste management, enforcement at the municipal level in Elbasan is weak. Responsibilities are spread across multiple municipal departments, with no centralized authority to ensure coordination or accountability. This institutional fragmentation has resulted in overlapping mandates, inefficient implementation, and an inability to align with national waste management objectives. A newly adopted five-year municipal plan aims to reduce the volume of recyclable waste sent to landfills by 50%. However, interviews indicate that the plan faces serious implementation challenges, including budget constraints, a lack of internal recycling capacity, and unreliable data on waste generation and flows.

Plastic waste management efforts involve collaboration between public authorities, informal actors, and private collectors. However, each group operates under significant constraints. Municipal authorities, while responsible for oversight and planning, suffer from continuing underfunding, which has led to support on informal and private waste collectors. These private actors face legal doubts, limited policy support, and insufficient financial incentives, reducing their ability to operate sustainably. Interview participants stressed the need for clearer policies, fiscal incentives, and institutional support to strengthen stakeholder engagement across the sector.

Survey data suggest that formal waste collection services cover approximately 51–75% of Elbasan's urban area.[1] However, there is no system for source separation; recyclable materials are informally extracted from mixed waste by informal collectors and then sold to intermediary centers. Recycling activities are inconsistent, with limited tracking of volumes processed or their final destination. Many recyclables still end up in landfills or poorly equipped sorting centers. There are infrastructural gaps, including inadequate facilities, insufficient human resources, and the lack of an official recycling framework weaken efforts to scale plastic waste management. Additionally, the absence of reliable data obstructs effective planning and evaluation.

Overall, the findings indicate that while Elbasan Municipality has articulated ambitious goals for plastic waste reduction, its ability to implement them is constrained by low public engagement, fragmented governance, insufficient stakeholder incentives, and critical infrastructure and data gaps. These systemic deficiencies pose significant challenges to achieving measurable progress in plastic waste management and recycling outcomes.

Figure 1 – Thematic matrix – This matrix was developed by the authors as part of this study, using primary data from surveys and interviews conducted

Thematic Area	Key Findings (Survey + Interview Data)	Main Gaps / Challenges	Implications for Policy & Practice	Priority
Public Awareness & Participation	Low public awareness and engagement. School/youth programs too limited in scope. High use of single-use plastics persists.	No large-scale education campaigns. Inconsistent environmental curricula. Fragmented, underfunded awareness efforts.	Launch city-wide awareness campaigns. Integrate waste management topics into school curricula. Partner with media and influencers for outreach.	High
Policy Enforcement & Institutional Coordination	Legal framework exists but is weakly enforced. Responsibilities are scattered across departments. New municipal plan faces implementation barriers.	Overlapping mandates. Budget and capacity constraints. Inadequate data on waste flows.	Create a central coordinating body. Secure dedicated recycling budget. Strengthen data collection and monitoring.	High
Stakeholder Engagement & Incentives	Dependence on informal and private collectors. Private actors face legal and financial barriers. Weak collaboration across stakeholders.	Lack of incentives. Informal sector not integrated. Limited institutional support.	Introduce fiscal incentives and subsidies. Formalize role of informal collectors. Establish regular stakeholder forums.	Medium
System Coverage & Infrastructure	Only 51–75% of urban area has formal collection. No source-separation system. Recycling data not tracked.	Infrastructure gaps. Insufficient human resources. Lack of recycling framework.	Expand collection coverage. Build infrastructure for source separation. Implement tracking and reporting systems.	High

[1] Interview conducted with Elbasan municipal representatives and data collection from waste management municipal 5 year plan.

5. Cost-benefit analysis findings for Elbasan Municipality

The cost-benefit analysis (CBA) was conducted over a five-year period to evaluate the financial and environmental viability of investing in a recyclable waste management system. This timeframe was chosen to capture both the short-term implementation costs and the medium-term returns from interventions such as plastic sorting, recycling programs, and awareness campaigns. It compared current waste management expenses with projected costs under a recycling-focused model, while evaluating benefits such as revenue from recyclables, lower landfill fees, and environmental savings. A five-year horizon allowed for a realistic assessment of system maturation, stakeholder adaptation, and the gradual accumulation of economic and ecological benefits.

This section aims to provide the key considerations necessary to carry out the cost-benefit analysis (CBA) of climate change adaptation measures in Albania. Among these, the discount rate is a critical parameter, as it significantly influences the estimation of the present value of adaptation costs and benefits. As noted by Valverde et al. (2022), higher discount rates diminish the present value of future benefits, potentially undermining the economic justification for long-term adaptation investments. Conversely, lower discount rates emphasize the importance of building long-term resilience. Since many adaptation efforts involve significant upfront costs while delivering sustained benefits over time, the selection of an appropriate discount rate is essential. This section presents the discount and sensitivity rates applied, along with their respective sources (EC, 2025; UNDP, 2015), as core inputs to the CBA.

Costs include five main categories. Capital costs (1) are one-time investment in vehicles and bins and infrastructure for waste collection. Operating costs (2), the largest component as ongoing expenses, include transport, container washing, and handling of recyclable and inert waste. Disposal costs (3) are fees for sending waste and entry to the landfill. Depreciation (4), assumed over five years at a 20% annual rate, for the next 5 years, while administration costs (5) contribute to management and overhead expenses at a 0.09% of total previous costs. Based on the calculations, annual costs have increased by approximately 2.5%, reflecting adjustments for economic fluctuations over the 5-year period.

Table 1 – Cost Calculations

Source: Elbasan waste management municipal plan[1]

[1] Bashkia Elbasan. (2025). Draft Plani Lokal i Menaxhimit të Integruar të Mbetjeve të Ngurta Urbane 2025–2030 [PDF]. Elbasani.gov.al. https://elbasoni.gov.al/wp-content/uploads/2025/02/Draft-Plani-Lokal-i-Menaxhimit-te-Integruar-te-mbetjeve-te-ngurta-urbane-2025-2030-Bashkia-Elbasan-1.pdf

Benefits were measured across four areas. Material substitution (1) from selling recycled plastic and paper at market price. Energy savings (2), reduced energy use by recycling materials. Avoided costs (3) including reduced landfill use and pollution, and overall economic benefits (4) from recycling activities. The financial projections were derived using the Zaman model (2016) or benefit transfer model, calibrated with parameters appropriate for a lower-middle-income country such as Albania. Benefits were calculated based on the number of residents and other factors such as recycling and collection rate stated in the Elbasan's current municipal plan but revised on the Zaman model (2016). Together, these figures provide a balanced view of both the financial demands and gains of the waste management plan.

Table 2 – Benefits Calculations

Notes on the calculation: Annual benefits were adjusted to reflect a 2.5% increase, accounting for anticipated economic changes over the analysis period. The numbers in all the calculation in table 1 and 2 are in ALL (Leke) currency.

5.1. Net cost Present Value (NPV) and Benefit-Cost Ratio (BCR) calculations

By following the steps outlined above, the annual costs and benefits have been calculated for each year of the analysis period. The next step involves determining the total financial performance over time by computing the Net Present Value (NPV) and the Benefit-Cost Ratio (BCR) using the following formulas:

(1)

(2)

(3)

Where: C0 = Initial investment (cost at time 0), Ct = Cost incurred in year t, r = Discount rate (3%)[2], t = Year (from 2025 to 2030), n = Total number of years (5)

The base discount rate (r) used in this paper is taken from the European Commission (2025) reference for Croatia in the Eurozone as the closest reference to Albania. [15]

[2] European Commission. (2025, April). Reference and base rates – April 2025: Croatia (Eurozone). Directorate-General for Competition. https://competition-policy.ec.europa.eu/document/download/846ab160-b622-4771-98fe-b751c0b48949_en?filename=reference_rates_base_rates2025_04_croatia_eurozone.pdf

In this research, preliminary analyses involved checking data for completeness and quality to ensure it's suitable for analysis.

The NPV net reflects the difference between discounted benefits and costs over the evaluation period. Based on the calculations NPV>0 or 191,615,059.78 ALL or 1,955,255.71 EUR. A positive NPV indicates that the project generates more economic value than it costs, confirming its financial

(4)

On the other hand, the BCR compares the present value of benefits to the present value of costs. After calculations the BCR is 1.2076 or BCR>1. A BCR greater than 1 means that the benefits outweigh the costs, indicating a financially sound investment.

6. Conclusions and recommendations

The results of this study demonstrate that transitioning to a two-bin recyclable waste management system in Elbasan Municipality is significantly more sustainable and cost-effective than the traditional landfill-based model. Based on a cost-benefit analysis, the recycling system produced a positive Net Present Value (NPV) of 1.95 million EUR and a Benefit-Cost Ratio (BCR) of 1.20 over a five-year period, confirming its financial viability. Although initial investments in infrastructure and operations result in short-term costs, the system generates increasing long-term benefits through material recovery, energy savings, reduced landfill fees, and broader environmental gains.

Complementary survey and interview findings highlight systemic issues within the current waste management structure such as low public engagement, fragmented institutional coordination, and limited infrastructure which further support the need for change. Therefore, it is recommended that the municipality adopt a two-bin system for basic waste separation, invest in recycling facilities and vehicles, implement sustained public education campaigns, establish stronger institutional oversight, and introduce financial incentives for formal and informal waste actors. Together, these measures would enable Elbasan to reduce landfill dependency, improve resource efficiency, and achieve a more resilient, economically viable waste management system.

Acknowledgment

This research was conducted within the framework of the BeMed+ Project (Beyond Plastic Med – Commit for a Mediterranean Sea Without Plastic), a regional initiative dedicated to reducing plastic pollution across the Mediterranean basin. The project is financed by the Fonds Français pour l'Environnement Mondial (FFEM) and led by BeMed, in collaboration with the International Union for Conservation of Nature

(IUCN) and the Surfrider Foundation Europe (SEF). In Albania, the project is coordinated by the Institute for Nature Conservation in Albania (INCA), which leads efforts to reduce plastic leakage and promote sustainable practices, particularly within the Shkumbin River watershed. The project supports fieldwork, stakeholder engagement, and policy development, emphasizing the empowerment of municipalities, businesses, and civil society to co-create lasting solutions for a plastic-free Mediterranean.

Disclaimer

The views and interpretations expressed in this paper are those of the authors and do not necessarily reflect the positions of BeMed, FFEM, IUCN, Surfrider Foundation Europe, INCA, or any other implementing partner. Responsibility for the content rests entirely with the authors.

Literature

[1] Aiguobarueghian, I., Adanma, U. M., Ogunbiyi, E. O., & Solomon, N. O. (2024a). Reviewing the effectiveness of plastic waste management in the USA. World Journal of Advanced Research and Reviews., 22(2), 1720. doi:https://doi.org/10.30574/wjarr.2024.22.2.1518

[2] Sharma, H. B. (2021). Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery. The Science of the Total Environment, 800. doi:https://doi.org/10.1016/j.scitotenv.2021.149605

[3] Pilapitiya, P. G. (2024). The world of plastic waste: A review. Elsevier BV, 11. doi:https://doi.org/10.1016/j.clema.2024.100220

[4] Mihai, F.-C. G.-B.-M.-S. (2021). Plastic pollution, waste management issues, and circular economy opportunities in rural communities. Sustainability, 20. doi:https://doi.org/10.3390/su14010020

[5] Anwar, M. A. (2024). Challenges and prospects of multilayer plastic waste management in several countries: A systematic literature review. Case Studies in Chemical and Environmental Engineering, 10, 100911. doi:https://doi.org/10.1016/j.cscee.2024.100911

[6] Moruf, A. A. (2020). Public-Private Partnership (PPP) in residential solid waste management in Ibadan: Challenges and opportunities. Journal of Geography and Regional Planning, 13(1), 30. doi:https://doi.org/10.5897/jgrp2019.0721

[7] Caceres-Mendoza, C. S. (2023). Life cycle assessment of filament production in distributed plastic recycling via additive manufacturing. Cleaner Waste Systems, Volume 5,100100. doi:https://doi.org/10.1016/j.clwas.2023.100100

[8] Denne, T., Irvine, R., Atreya, N., Robinson, M. (2007). Recycling: Cost benefit analysis (Final report). Wellington, New Zealand: Ministry for the Environment. Retrieved from https://environment.govt.nz/publications/recycling-cost-benefit-analysis/

[9] Aiguobarueghian, I. A. (2024b). Waste management and circular economy: A review of sustainable practices and economic benefits. World Journal of Advanced Research and Reviews, 22(2), 1708. doi:https://doi.org/10.30574/wjarr.2024.22.2.1517

[10] Torkayesh, A. E. (2022). Integrating life cycle assessment and multi criteria decision making for sustainable waste management: Key issues and recommendations for future studies. Renewable and Sustainable Energy Reviews, 168, 112819. doi:https://doi.org/10.1016/j.rser.2022.112819

[11] Zaman, A. (2016). A comprehensive study of the environmental and economic benefits of resource recovery from global waste management systems. ournal of Cleaner Production, 1-10. doi:http://dx.doi.org/10.1016/j.jclepro.2016.02.086

[12] Municipality, B. (2024, 12 20). Berati Riciklon. Retrieved from Facebook: https://www.facebook.com/people/Berati-Riciklon/61560920889960/

[13] DLDP. (2013). Metodat e llogaritjes së kostos dhe tarifës në menaxhimin e mbetjeve të ngurta në nivel Njësie të Qeverisjes Vendore në Shqipëri. DECENTRALIZATION AND LOCAL DEVELOPMENT PROGRAM. Tirana: Decentralisation and local development programme (dldp).

[14] Bashkia Elbasan. (2025). Draft Plani Lokal i Menaxhimit të Integruar të Mbetjeve të Ngurta Urbane 2025–2030 [PDF]. Elbasani.gov.al. https://elbasoni.gov.al/wp-content/uploads/2025/02/Draft-Plani-Lokal-i-Menaxhimit-te-Integruar-te-mbetjeve-te-ngurta-urbane-2025-2030-Bashkia-Elbasan-1.pdf

[15] European Commission. (2025, April). Reference and base rates – April 2025: Croatia (Eurozone). Directorate-General for Competition. https://competitionpolicy.ec.europa.eu/document/download/846ab160-b622-4771-98fe-b751c0b48949_en?filename=reference_rates_base_rates2025_04_croatia_eurozone.pdf

Forests and climate change

Peter Spathelf[1]

Marcus Lindner[2]

Frits Mohren[3]

1 Professor for Applied Silviculture, Department of Forestry, Timber and Environment, University for Sustainable Development Eberswalde (HNEE)
peter.spathelf@hnee.de

2 Head of Resilience Programme, European Forest Institute, Resilience and Governance Programmes

3 Professor of Forest Ecology and Forest Management, Wageningen University & Research

Abstract

Climate change has become a main driver of environmental change due to a significant rise of global mean surface temperatures and extreme weather events. Globally, the mean annual surface temperature has risen by more than 1.3°C in 2011-2024 compared to pre-industrial conditions (1850-1900), and has been proven to be human-caused to a high degree. In Europe, temperature rise is higher than the global average, and within Europe south-western, central and north-eastern Europe as well as the alpine regions experienced the highest increase. When considering extreme weather events, the frequency and magnitude of warm extremes has increased whereas cold extremes have become less common. Climate change magnifies the impacts of disturbance events, and a higher frequency and intensity of disturbances are very likely and have to be taken into account in forest management. Central European forests have been a carbon sink for decades. The future of carbon sequestration and storage in European forests will be influenced by the intensity of forest management and harvesting, as well as climate change and the severity of disturbances.

Keywords

Climate change, Disturbances, Carbon sequestration and storage, Forest management, Central Europe

1. Introduction

Climate change has become a main driver of environmental change due to a significant rise of global mean surface temperatures and extreme weather events. Future warming depends on future GHG emissions, with cumulative net CO2 dominating. The assessed best estimates and very likely ranges of warming for 2081-2100 with respect to 1850–1900 vary from 1.4 [1.0 to 1.8]°C in the very low GHG emissions scenario (SSP1-1.9) to 2.7 [2.1 to 3.5]°C in the intermediate GHG emissions scenario (SSP2-4.5) and 4.4 [3.3 to 5.7]°C in the very high GHG emissions scenario (SSP5-8.5). Projected global GHG emissions from NDCs (Nationally Determined Contributions) announced prior to COP26 would make it likely that warming will exceed 1.5°C and also make it harder after 2030 to limit warming to below 2°C [1]. Continued GHG emissions will further affect all major climate system components, and many changes will be irreversible on centennial to millennial time scales. Many changes in the climate system become larger in direct relation to increasing global warming. Continued global warming is projected to further intensify the global water cycle, and very wet and very dry weather and climate events and seasons [e.g.; 2-4]. So which type of climate will we get in the future in Central Europe? Probably not just a shift to a warmer climate such as from temperate oceanic or subcontinental to subtropical Mediterranean, but a climate where still severe (late) frosts are occurring but with higher mean and extreme temperatures, therefore causing a higher demand for evapotranspiration. The climatic water balance, especially in the vegetation period, will fall below zero in many regions in Europe. Days with extreme temperatures (e.g., 30° C) will rise in number.

Due to climate change and forest damages in many parts of Europe [e. g. 5-7] there are current debates on forest crises, 'disaster forest', or the need for a paradigm shift in forestry [8]. There are doubts as to whether the path that European forestry has taken for many decades is the right one ['Der Holzweg', 9], the forestry sector and forest ownership as a whole are accused of serious mistakes, indeed they are considered to be part of the problem [10]. In the meantime, since some decades close(r)-to-nature forest management as a sustainable and ecosystem-based form of forest management has become an attractive and promising model for many forest owners to stabilize their forests and provide diverse ecosystem services [11-13].

2. Carbon budgets – European forests as sink or source[1]

2.1. Carbon storage and sink

Forests can contribute significantly to the global carbon cycle and climate change mitigation by sequestering carbon from the atmosphere and storing it in forests (forest biomass and soil) and in wood-based products (with long life-cycles), and also through the use of forest biomass to substitute for fossil-fuel-intensive materials, products and fossil energy [14;15]. This is also the case in Europe, where the majority of forests are managed. Forest management has largely influenced the present tree species composition [16] and wood production potential [17;18] of forests, and will continue to do so for the coming decades (e.g.; 19;20].

In Europe, the forest area and carbon storage have both increased since the 1950s for several reasons. The forest area has increased by about 30% between 1950 and 2000, and by 9% since 1990 up to the present [21]. This has occurred through natural forest expansion and the afforestation of low-productivity agricultural lands [22]. The ratio of annual harvested timber to the total annual increment of forests for a long time was below 80% across Europe, remaining relatively stable for most countries until around 2015; recent studies reveal that tree harvest in Europe's forests increased since then (23-25; 7]. Additionally, improved forest management practices and changing environmental conditions (e.g., nitrogen deposition, climate warming and the elevation of atmospheric CO2 concentrations) have increased the carbon sequestration and storage in European forests [e.g., 26]. The growing (carbon) stock of European forests has clearly increased more rapidly over the last few decades than the forest area (e.g., 17.5 million ha between 1990 and 2015), as the average volume per hectare has been increasing. It should be noted, however, that the recent increase in forest disturbances has regionally reversed this trend [7] and some countries like Czech Republic have lost substantial shares of their growing stock volume [5; 27].

There are significant distinctions among the forest carbon sinks in different parts of Europe due to large differences in the forest area and structure (age and tree species composition). These are related to differences in the prevailing climatic and site conditions, the intensity of past and current forest management activities, and the level of socioeconomic development [28]. In Northern Europe, where the share of forest area is higher than in other parts of Europe, the forest landscapes are dominated by mainly coniferous and even-aged forests. In Central and Southern Europe, broadleaved deciduous and mixed evergreen forests are more common [21]. Overall, the forests are more productive and have higher volumes of growing stock in Central and Western Europe than in other parts of Europe. In Western Europe, plantations of fast-growing, often exotic tree species show very high growth rates. Forest productivity is, nowadays, limited by the length of the growing season and the relatively low summer temperatures in Northern Europe, whereas in Southern Europe, it is limited by water availability, with many forests also being located on sites with low potential for wood production.

[1] *Chapter from Kilpeläinen & Peltola (2022)*

The prevailing environmental conditions, current forest structure, management traditions and different socioeconomic factors have also affected the intensity of forest management. Management intensity varies from fully protective for biodiversity conservation, to uneven and even-aged rotation forestry, which affects forest carbon sequestration and storage. Forest ownership structures, and targets set for forest management and its possible constraints, have also, together, affected the intensity of forest management and harvesting and thus the development of carbon sinks and storage and the wood production potential of European forests [17;18]. Currently, ca. 50% of forests in the EU are privately owned, with about 16 million private forest owners [29]. In forest management, different ecosystem services may also be emphasised to a greater degree, depending on set targets and constraints in different regions [30; 28].

The growing (carbon) stock of European forests (see Figure 1) is currently double what it was in the 1990s. The carbon-stock increases in forests and wood products, and the average annual sequestration of carbon in the forest biomass, was 155 million t in 2020. Currently, EU forests sequester ca. 10% of Europe's greenhouse gas (GHG) emissions [21]. When considering the carbon storage in wood products (an additional ca. 12 Tg C year-1) and the substitution effects of the forest sector, additional 3% of the total GHG emissions in the EU28 are avoided [29; 31].

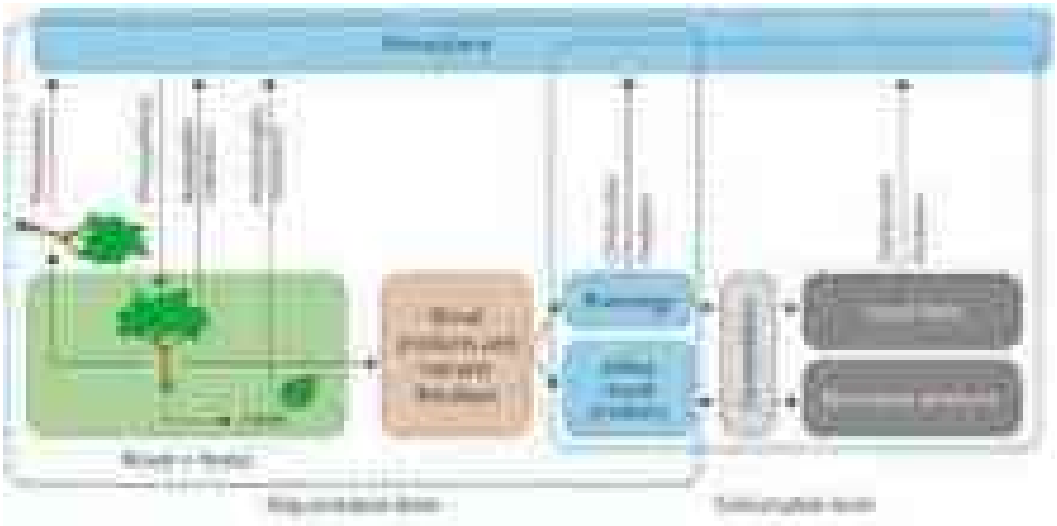


Figure 1 – Carbon sequestration in the forest system (forest pool, products and substitution) [according to 29].

Furthermore, woody biomass provides ca. 6% of the energy consumed in the EU [32]. On the other hand, the first signs of saturation in the European forest carbon sink were recognised in the 2010s [33]. Today, after several severe disturbance years in Europe's forests and e.g., the loss of 5 % of the Norway spruce volume, it is far more uncertain, whether the carbon sink contained in European forests (and the broader forest sector) will remain at the same level as before [34].

2.2. Carbon dynamics in a forest ecosystem

The carbon dynamics in a forest ecosystem comprise the carbon uptake by trees (and ground vegetation) in the above- and belowground forest biomass, and carbon release through the autotrophic (metabolism of organic matter by plants) and heterotrophic

(metabolism of organic matter by bacteria, fungi and animals) respiration. The forest ecosystem is a carbon sink if it absorbs more carbon from the atmosphere than it emits, resulting in an increase in the carbon storage of the forest (forest biomass and soil). Moreover, the forest store can be expanded by utilising wood in durable products. The carbon dynamics of a forest ecosystem are controlled by environmental (climate, site) conditions, and the structure (age, stocking, tree species composition, etc.) and functioning of the forest ecosystem.

The carbon sequestration and stock of forest biomass may vary greatly in a forest ecosystem over time, these are controlled by the initial stand characteristics, the type and intensity of management (e.g., forest reproductive material, thinning and fertilisation) [35] and the length of the rotation period [36]. Whereas around 45 % of the forest carbon is stored in the aboveground biomass, 55 % are part of the soil (organic layer and mineral soil until 90 cm depth) [37-39]. The carbon stock in soil is generally relatively stable, although it is affected by carbon inputs from litter fall and carbon outputs from the decay of litter and humus, the latter representing earlier litter input of unrecognisable origin [40]. The decomposition of humus and litter contributes significantly to soil carbon emissions at the beginning of the rotation period, but in the later stages of stand development, carbon input is prevailing [e.g., 41]. Generally, for most of the duration of stand development, the stands act as carbon sinks.

Management intensity affects the carbon sequestration and stocks in forests through changing the structure and functioning of an ecosystem. A managed forest ecosystem sequesters carbon as trees grow, but loses carbon in harvesting. By comparison, in unmanaged forest ecosystems (e.g., old-growth forests), the carbon dynamics are affected by the age structure, the mortality of trees, natural regeneration and the ingrowth of seedlings in canopy gaps [42]. The annual growth rate of trees can be higher in managed than in unmanaged (intact) forest landscapes [43; 44]. Older forest stands can store more carbon, but the rate at which they remove additional carbon from the atmosphere is substantially lower, and can even become negative as the mortality increases and exceeds the regrowth [45]. On the other hand, devastating abiotic (e.g., wind storms and forest fires) and biotic (e.g., insect outbreaks) disturbances may cause a sudden decrease in carbon sequestration and storage in forest ecosystems. The extent and speed of change depends on post-disturbance management (whether damaged wood is salvaged or left in the forest to decay).

The use of appropriate, site-specific regeneration methods and materials (e.g. improved reproductive materials with better growth rates and survival), the proper timing and intensity of precommercial and commercial thinnings, and forest fertilisation on sites with limited nutrient availability, have been proposed as ways of increasing carbon sequestration (and timber production) over one rotation in e.g. France and boreal forests [46-48]. According to Olsson et al. [49], nitrogen fertilisation may also increase the sink and storage of carbon in upland (mineral) soils in Norway spruce stands due to the simultaneous increase in litter production and decrease in the decomposition of soil organic matter and heterotrophic respiration in the soil. However, there have been contradictory findings on the effects of nitrogen fertilisation on the decomposition of soil organic matter and soil respiration [e. g., 50]. The maintenance of higher stocking in thinnings, together with longer rotations, may also increase the carbon stock in forest ecosystems over a rotation period [51; 35]. Overall, carbon sequestration and storage may be increased in forests in different ways by modifying current forest management practices. However, the same measures may affect forests differently.

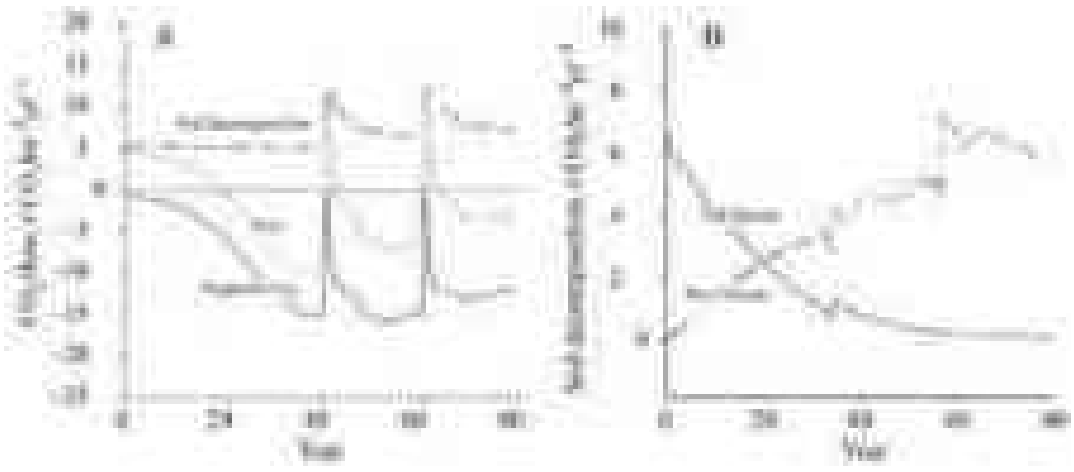


Figure 2 – Development of annual carbon flows of net ecosystem CO2 exchange (NEE: carbon sequestration + soil decomposition) [according to 52].

Figure 2 provides an example of the development of the net ecosystem CO2 exchange (NEE) of a boreal, even- aged Norway spruce stand on a medium-fertility upland site over an 80-year rotation period, based on the gap-type forest-ecosystem model SIMA [40] simulations [41]. Seedling stands (2000 seedlings per ha) act as a carbon source over the first 20 years after a clear-cut because the carbon sequestration is lower in young seedling stands than the carbon emissions from decaying humus and litter in the soil. As carbon sequestration increases, a stand becomes a carbon sink. The thinnings at ages 40 and 60 years produce peaks in the carbon emissions due to harvesting and the decay of logging residuals.

3. Synthesis

The World will face continuous climate change with still uncertain magnitude, but with high likelihood, the change of disturbance regimes will be an even more crucial factor shaping our forest landscapes in the future. Climate change magnifies the impacts of disturbance events, and a higher frequency and intensity of disturbances are very likely and have to be taken into account in forest management. Extreme climate events with unprecedented duration of drought and changing seasonal distribution of precipitation – shifting towards more winter precipitation and less in summer. Moreover, the number of days in the growing season with precipitation is also projected to decrease, with more heavy rainfall events. Consequently, availability of soil moisture, which is crucial for ecosystem productivity, will be limited more often, with drastic impacts on forest ecosystems. Hence, we might see increased year-to-year variation, and chances are that normal/good years may be overcompensated by disturbance pulse releases [c.f. 53].

Due to an increasingly saturated forest sink and a higher vulnerability to climate change of many forests, climate change mitigation through long-lived harvested wood products with potential to substitute fossil fuels and energy intensive materials become more and more relevant during the transition period to carbon neutrality. Nevertheless, Sustainable Forest Management will become more volatile and difficult because planned harvests may no longer be always feasible, if fellings are increasingly dominated by salvage cutting. This is a major threat for the development of resilient mixed species stands.

Literature

[1] IPCC (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press.

[2] Mann, M.E., Rahmstorf, S., Kornhuber, K., Steinman, B.A., Miller, S.K., Coumou, D. (2017) Influence of Anthropogenic Climate Change on Planetary Wave Resonance and Extreme Weather Events. Scientific Reports 7, 45242.

[3] Lorenz, R., Stalhandske, Z., Fischer, E.M. (2019) Detection of a Climate Change Signal in Extreme Heat, Heat Stress, and Cold in Europe From Observations. Geophysical Research Letters 46, 8363- 8374.

[4] Felsche, E., Böhnisch, A., Poschlod, B., Ludwig, R. (2024) European hot and dry summers are projected to become more frequent and expand northwards. Communications Earth & Environment 5, 410.

[5] Hlásny, T., Zimová, S., Merganičová, K., Štěpánek, P., Modlinger, R., Turčáni, M. (2021) Devastating outbreak of bark beetles in the Czech Republic: Drivers, impacts, and management implications. Forest Ecology and Management 490, 119075.

[6] Patacca, M., Lindner, M., Lucas-Borja, M.E., Cordonnier, T., Fidej, G., Gardiner, B., Hauf, Y., Jasinevičius, G., Labonne, S., Linkevičius, E., Mahnken, M., Milanovic, S., Nabuurs, G.-J., Nagel, T.A., Nikinmaa, L., Panyatov, M., Bercak, R., Seidl, R., Sever, M.Z.O., Socha, J., Thom, D., Vuletic, D., Zudin, S., Schelhaas, M.-J. (2023) Significant increase in natural disturbance impacts on European forests since 1950. Global Change Biology 29, 1359-1376.

[7] Seidl, R., Senf, C. (2024) Changes in planned and unplanned canopy openings are linked in Europe's forests. Nature Communications 15, 4741.

[8] Spathelf, P. (2021) Mischen possible. Contribution for 'DIE WELT', 06.03.2021, S. 20.

[9] Knapp, H. D., Klaus, S. & Fähser, L. (2021) Der Holzweg. Wald im Widerstreit der Interessen. Oekom-Verlag. 477 S.

[10] Bode, W. (2019) Systemische Waldwirtschaft. Zum Paradigmenwechsel in der Forstwissenschaft. Naturschutz und Landschaftsplanung 51(05). 226-234.

[11] Stiers, M., Annighöfer, P., Seidel, D. et al. (2020) Quantifying the target state of forest stands managed with the continuous cover approach – revisiting Möller's "Dauerwald" concept after 100 years. Trees, Forests and People 1. https://doi.org/10.1016/j.tfp.2020.100004. Letzter Zugriff 15.01.2022.

[12] Brang, P., P. Spathelf, J.B. Larsen et al. (2014) Suitability of close-to-nature silviculture for adapting temperate European forests to climate change. Forestry 87. 492-503.

[13] Larsen, JB, Angelstam, P, Bauhus, J et al. (2022) Closer-To-Nature Forest Management. From Science to Policy 12. European Forest Institute. https://doi.org/10.36333/fs12.

[14] Nabuurs G-J, Delacote P, Ellison D, Hanewinkel M, Hetemäki L, Lindner M (2017) By 2050 the mitigation effects of EU forests could nearly double through climate smart forestry. Forests 8:484. https://doi.org/10.3390/f8120484

[15] Leskinen P, Cardellini G, González-Garcia S, Hurmekoski E, Sathre R, Seppälä J, Smyth C, Stern T, Verkerk PJ (2018) Substitution effects of wood-based products in climate change mitigation. From science to policy 7. European Forest Institute, Joensuu

[16] Spiecker, H. (2003) Silvicultural management in maintaining biodiversity and resistance of forests in Europe—temperate zone. J Environ Manag 67(1):55–65. https://doi.org/10.1016/S0301-4797(02)00188-3

[17] Rytter L, Ingerslev M, Kilpeläinen A, Torssonen P, Lazdina D, Löf M, Madsen P, Muiste P, Stener LG (2016) Increased forest biomass production in the Nordic and Baltic countries – a review on current and future opportunities. Silva Fenn 50(5):1660

[18] Verkerk P-J, Fitzgerald JB, Datta P, Dees M, Hengeveld GM, Lindner M, Zudin S (2019) Spatial distribution of the potential forest biomass availability in Europe. For Ecosyst 6:5. https://doi.org/10.1186/s40663-019-0163-5

[19] Koehl M, Hildebrandt R, Olschofsky K, Köhler R, Rötzer T, Mette T, Pretzsch H, Köthke M, Dieter M, Abiy M, Makeschin F, Kenter B (2010) Combating the effects of climatic change on forests by mitigation strategies. Carbon Balance Manag 5:8

[20] Lindner M, Fitzgerald JB, Zimmermann NE, Reyer C, Delzon S, van der Maaten E, Schelhaas M-J, Lasch P, Eggers J, van der Maaten-Theunissen M, Suckow F, Psomas A, Poulter B, Hanewinkel M (2014) Climate change and European forests: what do we know, what are the uncertainties, and what are the implications for forest management? J Environ Manag 146:69– 83. https://doi.org/10.1016/j.jenvman.2014.07.030

[21] Forest Europe (2020) State of Europe's forests 2020. Forest Europe, Bratislava

[22] Palmero-Iniesta, M., Pino, J., Pesquer, L., Espelta, J.M. (2021) Recent forest area increase in Europe: expanding and regenerating forests differ in their regional patterns, drivers and productivity trends. European Journal of Forest Research 140, 793-805. https://doi.org/10.1007/s10342-021-01366-z

[23] Ceccherini, G., Duveiller, G., Grassi, G., Lemoine, G., Avitabile, V., Pilli, R., Cescatti, A. (2020) Abrupt increase in harvested forest area over Europe after 2015. Nature 583, 72-77.

[24] Hyyrynen, M., Ollikainen, M., Seppälä, J. (2023) European forest sinks and climate targets: past trends, main drivers, and future forecasts. European Journal of Forest Research 142, 1207-1224.

[25] Lerink, B.J.W., Schelhaas, M.J., Schreiber, R., Aurenhammer, P., Kies, U., Vuillermoz, M., Ruch, P., Pupin, C., Kitching, A., Kerr, G., Sing, L., Calvert, A., Dhubháin, Á.N., Nieuwenhuis, M., Vayreda, J., Reumerman, P., Gustavsonn, G., Jakobsson, R., Little, D., Thivolle-Cazat, A., Orazio, C., Nabuurs, G.J. (2023) How much wood can we expect from European forests in the near future? Forestry 96, 434-447.

[26] Pretzsch, H., Bieber, P., Schütze, G. et al. (2014) Changes of forest stand dynamics in Europe. Facts from long-term observational plots and their relevance for forest ecology and management. Forest Ecology and Management 316. 65-77.

[27] Washaya, P., Modlinger, R., Tyšer, D., Hlásny, T. (2024) Patterns and impacts of an unprecedented outbreak of bark beetles in Central Europe: A glimpse into the future? Forest Ecosystems 11, 100243.

[28] European Environmental Agency (EEA) (2008) Global and European temperature (CSI 012), Assessment April 2008. Copenhagen. Retrieved February 10, 2009 from http://themes.eea.europa.eu/IMS/IMS/ISpecs/ISpecification20041006175027/IAssessment1202733436537/view_content

[29] Nabuurs, G.J., Delacote, P., Ellison, D., Hanewinkel, M., Lindner, M., Nesbit, M., Ollikainen, M., Savaresi, A. (2015) A new role for the forests and the forest sector in the EU post-2020 climate targets, From Science to Policy 2. European Forest Institute, Joensuu, p. 30.

[30] Hengeveld GM, Nabuurs G-J, Didion M, van den Wyngaert I, Clerkx APPM, Schelhaas M-J (2012) A forest management map of European forests. Ecol Soc 17(4). https://doi.org/10.2307/26269226

[31] Korosuo, A., Pilli, R., Abad Viñas, R., Blujdea, V.N.B., Colditz, R.R., Fiorese, G., Rossi, S., Vizzarri, M., Grassi, G. (2023) The role of forests in the EU climate policy: are we on the right track? Carbon Balance and Management 18.

[32] Eurostat (2020) Agriculture, forestry and fishery statistics – 2019th edn. https://doi.org/10.2785/798761

[33] Nabuurs, G.-J., Lindner, M., Verkerk, P. J. et al. (2013) First signs of carbon sink saturation in European forest biomass. Nature climate change. UBLISHED ONLINE: 18 AUGUST 2013 | DOI: 10.1038/NCLIMATE1853.

[34] McDowell, N.G., Allen, C.D., Anderson-Teixeira, K., Aukema, B.H., Bond-Lamberty, B., Chini, L., Clark, J.S., Dietze, M., Grossiord, C., Hanbury-Brown, A., Hurtt, G.C., Jackson, R.B., Johnson, D.J., Kueppers, L., Lichstein, J.W., Ogle, K., Poulter, B., Pugh, T.A.M., Seidl, R., Turner, M.G., Uriarte, M., Walker, A.P., Xu, C. (2020) Pervasive shifts in forest dynamics in a changing world. Science 368, eaaz9463.

[35] Routa J, Kilpeläinen A, Ikonen V-P, Asikainen A, Venäläinen A, Peltola H (2019) Effects of intensified silviculture on timber production and its economic profitability in boreal Norway spruce and Scots pine stands under changing climatic conditions. Forestry 92(3):1–11. https://doi.org/10.1093/forestry/cpz043

[36] Lundmark T, Poudel BC, Stål G, Nordin A, Sonesson J (2018) Carbon balance in production forestry in relation to rotation length. Can J For Res 48(6):672–678

[37] Luyssaert, S., Ciais, P., Piao, S.L., Schulze, E.-D., Jung, M., Zaehle, S., Schelhaas, M.J., Reichstein, M., Churkina, G., Papale, D., Abril, G., Beer, C., Grace, J., Loustau, D., Matteucci, G., Magnani, F., Nabuurs, G.J., Verbeeck, H., Sulkava, M., WERF, G.R.v.d., Janssens, I.A. (2010) The European carbon balance: part 3: Forests. Global Change Biology 16, 1429-1450.

[38] De Vos, B., Cools, N., Ilvesniemi, H., Vesterdal, L., Vanguelova, E., Carnicelli, S. (2015) Benchmark values for forest soil carbon stocks in Europe: Results from a large scale forest soil survey. Geoderma 251-252, 33-46.

[39] Wellbrock, N., Bolte, A. & Flessa, H. (2016) Dynamik und räumliche Muster forstlicher Standorte in Deutschland.: Ergebnisse der Bodenzustandserhebung im Wald 2006-2008. Thünen Report 43. 342 S.

[40] Kellomäki S, Peltola H, Nuutinen T, Korhonen KT, Strandman H (2008) Sensitivity of managed boreal forests in Finland to climate change, with implications for adaptive management. Phil Trans R Soc B 363:2339–2349. https://doi.org/10.1098/rstb.2007.2204

[41] Kilpeläinen A, Strandman H, Alam A, Kellomäki S (2011) Life cycle assessment tool for estimating net CO2 exchange of forest production. Glob Change Biol Bioenergy 3(6):461–471

[42] Luyssaert S, Schulze E-D, Börner A, Knohl A, Hessenmöller D, Law BE, Ciais P, Grace J (2008) Oldgrowth forests as global carbon sinks. Nature 455:213–215

[43] Kellomäki S (2017) Managing boreal forests in the context of climate change. In: Impacts, adaptation and climate change mitigation. CRC Press, Boca Raton

[44] Moomaw WR, Law BE, Goetz SJ (2020) Focus on the role of forests and soils in meeting climate change mitigation goals: summary. Environ Res Lett 15(4):045009. https://doi org/10.1088/1748-9326/ab6b38

[45] Gundersen P, Thybring EE, Nord-Larsen T, Vesterdal L, Nadelhoffer KJ, Johannsen VK (2021) Oldgrowth forest carbon sinks overestimated. Nature 591:E21–E23. https://doi.org/10.1038/s41586-021-03266-z

[46] Serrano-León, H., Ahtikoski, A., Sonesson, J., Fady, B., Lindner, M., Meredieu, C., Raffin, A., Perret, S., Perot, T., Orazio, C. (2021) From genetic gain to economic gain: simulated growth and financial performance of genetically improved Pinus sylvestris and Pinus pinaster planted stands in France, Finland and Sweden. Forestry: An International Journal of Forest Research 94, 512–525.

[47] Haapanen M, Janson G, Nielsen UB, Steffenrem A, Stener LG (2015) The status of tree breeding and its potential for improving biomass production – a review of breeding activities and genetic gains in Scandinavia and Finland. Skogsforsk, Uppsala

[48] Hynynen J, Salminen H, Ahtikoski A, Huuskonen S, Ojansuu R, Siipilehto J, Lehtonen M, Eerikäinen K (2015) Long-term impacts of forest management on biomass supply and forest resource development: a scenario analysis for Finland. Eur J For Res 134:415–431

[49] Olsson P, Linder S, Giesler R, Högberg P (2005) Fertilization of boreal forest reduces both autotrophic and heterotrophic soil respiration. Glob Change Biol 11(10):1745–1753. https://doi.org/10.1111/j.1365-2486.2005.001033.x

[50] Högberg, P., Näsholm, T., Franklin, O., and Högberg, M. N. (2017) Tamm review: on the nature of the nitrogen limitation to plant growth in Fennoscandian boreal forests. For. Ecol. Manag. 403, 161–185. doi: 10.1016/j.foreco.2017.04.045

[51] Liski J, Pussinen A, Pingoud K, Mäkipää R, Karjalainen T (2001) Which rotation length is favourable to carbon sequestration? Can J For Res 31:2004–2013. https://doi.org/10.1139/x01-140

[52] Kilpeläinen, A., Peltola, H. (2022) Carbon Sequestration and Storage in European Forests. In: Hetemäki, L., Kangas, J., Peltola, H. (eds) Forest Bioeconomy and Climate Change. Managing Forest Ecosystems, vol 42. Springer, Cham. https://doi.org/10.1007/978-3-030-99206-4_6.

[53] Reyer, C.P.O., Bathgate, S., Blennow, K., Borges, J.G., Bugmann, H., Delzon, S., Faias, S.P., Garcia-Gonzalo, J., Gardiner, B., Gonzalez-Olabarria, J.R., Gracia, C., Hernández, J.G., Kellomäki, S., Kramer, K., Lexer, M.J., Lindner, M., van der Maaten, E., Maroschek, M., Muys, B., Nicoll, B., Palahi, M., Palma, J.H.N., Paulo, J.A., Peltola, H., Pukkala, T., Rammer, W., Ray, D., Sabaté, S., Schelhaas, M.-J., Seidl, R., Temperli, C., Tomé, M., Yousefpour, R., Zimmermann, N.E., Hanewinkel, M. (2017) Are forest disturbances amplifying or canceling out climate change-induced productivity changes in European forests? Environmental Research Letters 12, 034027.

Ergonomic risks management in the textile industry

Silvana Mekić[1]

Sanjin Adam Mujagić[2]

1 Msc, Assistant Professor, University of Tuzla, Faculty of Mining, Geology and Civil Engineering
silvana.mekic@untz.ba

2 Student, University of Tuzla, Faculty of Mining, Geology and Civil Engineering
sanjinadammujagic02@gmail.com

Abstract

This paper outlines main ergonomic risks that threaten the health of workers in the textile industry, more precisely at the sewing workstation, emphasizing the importance of conducting specific measurements of working conditions and observing workers while performing their tasks to identify critical body postures. For such assessments, specialized measuring instruments are used to evaluate microclimate parameters, while methods such as the Rapid Upper Limb Assessment (RULA) are applied to assess risks related to body posture and exposure to factors that may cause musculoskeletal disorders. In a case study of a workplace in the textile industry, instruments were used to measure temperature and noise, while workplace observation revealed additional risks such as inadequate height of work surfaces, poorly designed chairs, repetitive movements, and poor arrangement of tools and equipment, all of which force workers into unnatural postures for long periods and create unnecessary body movements. Furthermore, the very method of performing tasks can increase strain on workers, but with proper improvements to work organization and reduction of repetitive movements, while maintaining productivity, the risk of musculoskeletal disorders can be significantly lowered. This paper highlights the need for implementing ergonomic solutions that improve workplace conditions, providing employees with healthier, safer, and more comfortable environments, which in turn enhances motivation, safety, and overall company productivity. The application of the RULA method in this research constitutes a significant scientific contribution, as it systematically assesses the risks of awkward body postures and provides a basis for recommendations to improve ergonomic working conditions.

Keywords

Occupational health, ergonomics, working position, productivity, textile industry, RULA

Introduction

In recent times, increasing efforts and financial resources have been invested in finding solutions to the problems and consequences arising from work-related activities that have caused musculoskeletal disorders. It is a widely held belief among many experts that the frequency of musculoskeletal disorders, as the leading work-related illness, is a direct result of disregarding ergonomic principles when designing workplaces.

Ergonomics is the field of study that examines human behavioural, psychological, and physiological capabilities and limitations. By understanding these capabilities and limitations, professionals in the field of Ergonomics can then design new work environments, or modify established work environments, to maximize productivity, worker comfort, and overall efficiency. [1]

Ergonomic risk refers to physical stress-related factors and workplace conditions that carry the risk of injury or disorders of the operator's musculoskeletal system. In general, ergonomic risk is present whenever job demands exceed the operator's ability to perform the work task. [2]

In the textile industry, the entire technological process is structured around workplaces starting with fabric cutting, then proceed on to sewing, and finally end with finishing operations and quality control. At all of these workplaces, most activities are carried out either standing or sitting, with active use of the hands and visual focus on the task, often involving prolonged awkward body postures and frequent repetitive movements. All of these activities, if not accompanied by adequate rest and change of posture, can over time lead to musculoskeletal disorders.

According to research conducted by the Dutch on the Belgian working population, it was found that occupational groups with most common complaints of the neck and upper extremities were seamstresses and tailors (65,0%), bricklayers, carpenters and other construction workers (54,0%), and secretaries (44,9%). [3] This research is precisely the motivation for carrying out an ergonomic risk assessment of the sewing workstation using an appropriate method.

Globally, there are many tools and methods available for assessing ergonomic risks, and each method provides better indicators for a specific type of work. For our purpose, we selected the RULA (Rapid Upper Limb Assessment) method as the most appropriate, since it evaluates the postures and loads of the upper limbs and the upper part of the body-areas that are the most active in the sewing workstation.

In addition to minimizing ergonomic risks of musculoskeletal disorders, full comfort in the work environment also requires providing the worker with appropriate microclimatic conditions and monitoring the threshold values of all harmful factors that can affect workers' health at the workplace. This is achieved through continuous measurement and control of microclimatic conditions to keep them within the limits prescribed by standards, and ideally within optimal ranges. In this specific case, we measured temperature and noise levels, while also recording the values of other microclimatic parameters and physical hazards present at the workplace.

1. RULA (Rapid Upper Limb Assessment) method

If we directly translate the name of the method, RULA would mean "Rapid Upper Limb Assessment," This method provides a quick and easy way to evaluate musculoskeletal load in work tasks where there is a risk of strain on the neck and upper limbs.

This method uses very simple tools and was developed with the aim of providing screening working population to assess exposure to the risk of upper limb work-related disorders, to identify muscle efforts associated with work posture and excessive force during static and repetitive work, and finally produce a score that indicate the urgency for taking preventive measures to avoid illnesses and injuries.

Advantages of the RULA method include the fact that no investments are required for materials, equipment, or worker training. The method is very simple, easy to implement, and cost-effective. It allows us to analyze and evaluate the current situation, compare it with changes or potential modifications, and better assess the effectiveness of those changes. The main limitation of this method is that it is only evaluates the upper part of the body and does not assess other body parts, including the fingers.

1.1. Areas of application

The RULA method has four main applications:

1. To calculate musculoskeletal risk, usually as part of a broader ergonomic investigation.

2. To compare musculoskeletal loads between current and modified workstation designs.

3. To evaluate outcomes such as productivity or equipment suitability.

4. To educate workers about musculoskeletal risks created by different working postures.[4]

1.2. Method application procedure

The RULA method is applied by determining the posture and position of a specific body part according to prescribed rules and tables, where each posture is illustrated and assigned a specific score on worksheets. The worksheet consists of Part A and Part B.

- Part A includes the positions of the upper arms, lower arms and wrist.
- Part B includes the posture of the neck, trunk, and legs.

Both parts include ratings for muscle use and force/load levels, which are scored separately and added to the initial posture scores. The final score from tables A and B are then cross-referenced in table C, which provides the overall assessment level or final risk score.

Based on the values obtained from table C, in a specific table (Table 2.) we determine the level of urgency for carrying out ergonomic analyses and implementing workplace changes.

The procedure for conducting the RULA method is carried out in three main steps:

1. Selection of the body posture to be assessed.
2. Scoring of the posture using scoring sheets, body part diagrams, and tables.
3. Converting the results into one of four action levels. (Showed in Table 2.)

By analyzing working posture using the RULA method, it is possible to gain insight into body load and enable the redesign of the workplace, which results in working in a more favourable posture with reduced fatigue and strain. [5]

2. Ergonomic risk analysis of the sewing workstation

At first glance, work in the textile industry may not appear to be physically demanding, and associated strain may seem minimal. However, static load during prolonged sitting, repetitive movements, and awkward body postures involved in sewing work indicate a high risk of developing musculoskeletal disorders (MSD). This disorders are currently among the leading occupational diseases in the workplace.

The sewing operation itself is performed in short intervals (20–60 seconds) and is repeated continuously throughout the work shift, depending on the size of the production batch. Given the work demands, this process can be characterized as highly repetitive. [6]

For the ergonomic analysis of the workplace, we selected an example from a company specializing in the production of high-quality men's and women's shirts. The company operates in the textile industry and applies modern technological processes in garment manufacturing. Its headquarters is located in Bosnia and Herzegovina, and its products are intended for both domestic and international markets. The production facility is organized into several functional units, including the cutting room, sewing room, finishing department, and quality control. In the apparel manufacturing process, sewing accounts for approximately 70% of the total production time of a garment [7], which is why this study focuses on the sewing workstation.

As part of their internship, a student observed the workflow and working conditions at this company and recorded the following findings related to the sewing workstation:

The sewing operator's workday lasts eight hours and takes place in a closed production hall, where each worker has their own workstation equipped with a sewing machine. Throughout the entire day, operators perform a series of repetitive movements with their hands and feet, hands continuously guide and join pieces of fabric, while the foot controls the machine by pressing the pedal. These movements require a high level of precision, as each stitch must be accurate, and even minor mistakes may result in the rejection of the product. The work is organized so that each worker often sews only one part of the garment.

Since lighting is extremely important for sewing tasks, it was noted that each workstation is equipped with its own light source, providing sufficient illumination for the fine and precise work required. This observation was confirmed by previously recorded measurements of brightness levels, which ranged from 470 to 550lux.

Table 1 – Results of measured noise on workplace whit ARW-95 instrument

Time	Measurement place	Acceptable	Measured	Results
10:30	manufacturing facility	< 85 dB	68 dB	Acceptable
12:30	manufacturing facility	< 85 dB	74 dB	Acceptable
14:30	manufacturing facility	< 85 dB	78 dB	Acceptable
15:30	manufacturing facility	< 85 dB	70 dB	Acceptable

3. Application of the RULA method – case study of sewing workstation

Figure 1 – Body posture of a female sewing machine operator

By observing sewing machine operators in this company, we selected an image showing the working posture in which the workers spend most of their time during work, clearly demonstrating improper posture and forced positioning of the upper body parts. Using a protractor in the picture , we determined the angle of the upper body positions, specifically The torso and the neck of the sewing operator while performing the work. (Figure 1.)

From the selected worker's posture, we assessed the positions of specific body parts as treated by the RULA method.

For the sewing operator's workplace, the score for the upper arm position was 2 points, while the forearm position is rated with 1 point, plus 1 additional point for moving left or right outside the body's symmetry. The wrist position is rated with 2

+ 1 points, whit an additional point for wrist rotation (left-right movement around the wrist) during work. The image shows the selected positions of the upper arm, forearm, and wrist corresponding to the sewing operator's workplace.

Figure 2 – Selected images of the upper arm, forearm, and wrist positions corresponding to the sewing machine operator according to the RULA method [8]

Furthermore, the neck posture of the sewing operator was rated with 3 points, due to the assessment that the neck bends more than 20°. Similarly, the trunk posture was also rated with 3 points, as it leans forward between 20°–60° during work.

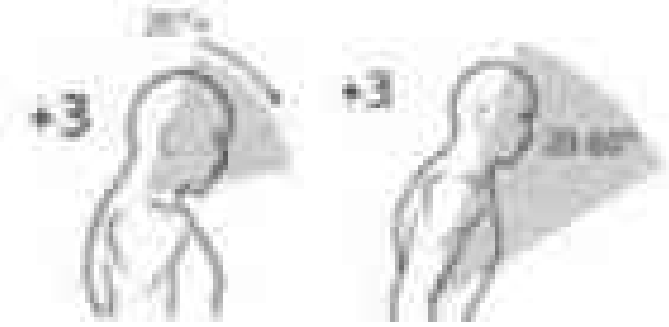


Figure 3 – Selected images of the neck and trunk of the sewing machine operator according to the RULA method [8]

The scores obtained for the upper arm, forearm, and wrist are entered into Table A, where the intersecting value is read. In this case, the value is 3.

From Table A for the sewing operator's workplace, we can read the value 3, but when we add 1 point due to the repetitive work at the sewing station (repeating 4 times per minute) and static muscle load lasting more than 10 minutes, the final result for Table A is 4. For this workplace, we did not consider load weight scoring because the worker does not lift weights exceeding 2 kg.

The scores obtained for the neck and trunk postures are entered into Table B, where, based on the intersection of these two values and the leg position, we obtain a result of 4.

From Table B we read the value 4, to which we add 1 point due to repetitive movements and static loading lasting longer than 10 minutes, resulting in a final score of 5. The total scores from Table A and Table B, including the additional points, are then entered into Table C, where the intersection gives the final overall score.

The final score is 5, it indicates a medium level of risk, further investigation and change soon. (Table 2.)

Table 2 – Levels of MDS risk by RULA method [9]

Score	Level of MSD Risk
1-2	negligible risk, no action required
3-4	Change may be needed
5-6	Medium risk, further investigation, change soon
6+	Very high risk, implement change now

4. Results and recommendations

The results of the ergonomic risk assessment for musculoskeletal disorders using the RULA method for the sewing operator's workplace showed that ergonomic analysis and change to the workplace need to be carried out soon (within a reasonable timeframe). This would involve redesigning the workstation, establishing appropriate microclimatic parameters for the working environment, controlling noise levels, providing adequate lighting, and ensuring proper workplace organization, all within defined deadlines and according to priorities. If fully implemented, these measures will protect workers' health and extend their working life, ultimately resulting in better productivity for the company. Where there are no absences due to illness leave or production defects caused by poor working conditions, business performance improves, leading to higher satisfaction among both workers and employers.

In the specific case of sewing operators, redesign is proposed by providing workers with ergonomically acceptable chair with adjustable height, so that chair height can be adapted according to the worker's stature, thus preventing improper posture during work. When designing the workplace, it is necessary to set correct angles of the kinematic system. The appropriate position at the foot pedal of the sewing machine is at angle of 90–100°, and the optimal angles for joint systems are: lower leg to thigh at 90–100°, and thigh to trunk at 90–95°. Such positioning reduces tension in the lower leg muscles, thereby increasing the motor efficiency of movements when operating the sewing machine and sewing products. In addition, it provides good foot mobility when pressing the heel to lift the presser foot or activate the thread-cutting mechanism [10].

Proper body posture during work can also be supported by ergonomic training, which would make workers more aware of the consequences of improper posture and demonstrate correct body positioning, as shown in the illustration.

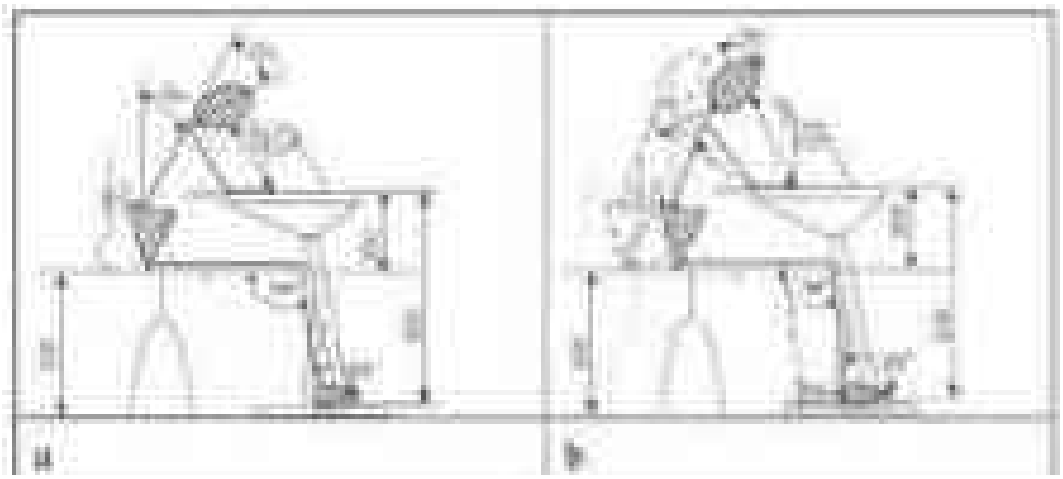


Figure 4 – Presentation of workplace: a) unfavourably design, b) favourably shaped [11]

Since certain measurements of temperature, noise, and other microclimatic factors were conducted, we can conclude that the temperatures and measured noise levels do not exceed the values defined by standards. However, due to the presence of a considerable noise level during most of the working time, communication may be hindered and concentration affected. Therefore, shorter breaks are recommended, as well as, in the foreseeable future, modernization of sewing machines with technology that produces less noise.

In the subject company in, short breaks are already defined even 2 hours of work followed by 15 minute break. These breaks can be used for stretching and walking, as well as for mental relaxation through conversation with colleagues. We consider this a good preventive measure both for the risk of musculoskeletal disorders and for breaking the monotony of work, which affects mental health.

Another challenging aspect of the sewing operator's workplace is the established work quota – the defined number of shirts that mast be sewn in one working day. However, quota do not always have to be negative; they guide the worker and defined the clear goal within the job. At the same time, it is important to consider the worker's capabilities, so that these demands are not too high and do not overload the worker beyond their capacity. Proper assessment of the daily quota helps in this regard, where ergonomic experts can provide precise guidance to the employer.

Through collaboration between the employer and experts in occupational safety and ergonomics, a realistic quota can be set, and with improved ergonomic conditions, this quota can be more easily achieved without negative consequences for workers and with positive effects on productivity.

Conclusion

Managing ergonomic risks in the textile industry requires expert analysis of the technological process, primarily through real-time observation, the use of specific risk assessment methods, and the measurement of factors affecting comfort in the working environment.

Through observing the sewing operator's workplace and the applying the RULA method for ergonomic risk assessment, we have gained insight into the extent to which this workplace is exposed to musculoskeletal disorders and how urgently preventive measures need to be taken. Additionally, we identified factors that further burden the worker during the eight-hour workday.

The RULA method is a very simple tool for assessing ergonomic risks related to musculoskeletal disorders and is easily applicable, especially for tasks that involve loading of the upper extremities or upper body. However, this method provides guidelines on which body part is under strain and how urgently measuring need to be taken, but without an expert it is difficult to know exactly what action to implement.

The shortcomings of the RULA method lie in the subjectivity of the assessment and the lack of detailed biomechanical analysis, that is, its inability to provide an in-depth quantitative evaluation of the musculoskeletal system. Therefore, RULA can primarily be used as a guideline or a rapid tool to identify the most strained parts of the upper body and the urgency of the intervention, while for a more detailed analysis and precise risk assessment it is recommended to combine it with other methods and rely on the expertise of the evaluator.

This method can always be supplemented with other ergonomic risk assessment tools to obtain more comprehensive data on the entire body, such as the REBA method for whole-body ergonomic assessment, since RULA is limited to evaluating only the upper extremities.

The existence of software solutions, such as the ErgoPlus Industrial application, further facilitates and accelerates the application of the RULA method, thereby increasing its practical value in industrial settings.

Literature

[1]	J.P. Kohn: "Ergonomic process management", CRC Press, 1997
[2]	Pavlović-Veselinović S.: "Ergonomic risk", University of Niš, 2013
[3]	Blatter B.M and Bongers P.M.: "Work related neck and upper limb symptoms (RSI): high risk occupations and risk factors in the Belgian working populations, rapport, Hoofddorp, 1999
[4]	Štajcer D.: "Workload analysis in production process using RULA methods", Karlovac University of Applied Science, Safety and Protection Department, Undergraduate thesis, 2022
[5]	Kirin S.: "Introduction to Ergonomics", Karlovac University of Applied Science, Safety and Protection Department, book, 2019
[6]	Kirin S.: "ERGONOMIC STUDIES OF THE STRAIN IN PERSONS WORKING IN THE GARMENT SEWING INDUSTRY", Journal Sigurnost 62 (3) 239-249, 2020
[7]	Kirin S. et al. :"Workload and Fatigue in the Technological Sewing process", Journal Tekstil 53 (5) 226 – 244, 2004
[8]	Klarić L.:"RULA Method for Ergonomic Risk Assessment of Work Tasks", University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Master's thesis, 2021
[9]	A-Step-By-Step Guide:" Rapid Upper Limb Assessment (RULA)", www.ergo-plus.com
[10]	Sušnik J. : " Ergonomic Physiology", Didaktika 1992, ISBN 86-7707-019-2
[11]	Kirin S., Hursa Šajatović A.: " The characteristics of the work and work load in the garment industry", Journal Sigurnost 65 (3) 269-282, 2023

Application of wood biomass ash as a partial replacement of cement in sustainable concrete

Todorka Samardzioska[1]

Meri Cvetkovska[2]

Milica Jovanoska Mitrevska[3]

Maja Putic[4]

Marija Menchevska[4]

1	Full Professor, Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, Skopje, Macedonia *samardzioska@gf.ukim.edu.mk*
2	Full Professor, Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, Skopje, Macedonia *cvetkovska@gf.ukim.edu.mk*
3	Assistant Professor, Ss. Cyril and Methodius University in Skopje, Faculty of Civil engineering, Skopje, Macedonia *m.jovanoska@gf.ukim.edu.mk*
4	MSc student, Ss. Cyril and Methodius University in Skopje, Faculty of Civil engineering, Skopje, Macedonia

Abstract

The increasing demand for sustainable construction materials and the urgent need to reduce the environmental impact of cement production have prompted researchers and engineers to explore alternative binders. Although the concrete is indisputable today, there is always possibility for improvement, as an ideal building material does not exist, especially in terms of safety, durability and sustainability. The concrete industry has great potential for a positive shift towards sustainable production and reducing the negative impact on the environment. One promising approach is the utilization of wood biomass ash, generated from the ovens in bakeries, as a partial replacement for cement in concrete.

This paper investigates the use of wood biomass ash as a substitute for cement in cementitious composites. Five different formulations were made for concrete mixtures with 0%, 5%, 10%, 15% and 20% wood biomass ash as a substitute for cement. The concrete samples were prepared and tested at 28 days according to the procedures and requirements specified in the national Macedonian standards (MKS EN). The study explores the physical and chemical characteristics of the wood ash, including its particle fineness, and comparison to ordinary cement. It also evaluates the impact of ash substitution on key concrete properties such as consistency, workability, compressive strength, flexural strength and tensile splitting strength. The use of biomass ash not only contributes to the reduction of carbon dioxide emissions from cement manufacturing but also supports waste valorisation and circular economy principles.

The findings indicate that, with proper processing and quality control, biomass ash can serve as an effective and environmentally beneficial substitute for cement in various concrete applications. This approach offers a dual benefit: mitigating the environmental footprint of the construction sector and providing a sustainable solution for biomass waste management.

Keywords

Wood biomass ash, sustainable concrete, circular economy, carbon reduction, green construction, waste valorization

1. Introduction

The exceptional rate of population growth and urbanization has driven a large increase in the demand for cement in the past few decades. With a consumption of one ton per inhabitant of the planet per year, concrete is the second most used material on the planet after water. The significant increase in cement production has resulted in alarming levels of CO^2 emissions into the atmosphere. According to the World Cement Association, global cement production is expected to reach 8.2 billion tonnes by 2030 [1]. China, as the largest cement producer, leads with 853 million tons of CO_2 emitted due to cement production, followed by India with 149 million tons, the United States with 41 million tons etc. For comparison, cement production in Macedonia releases 352.744 t CO_2, which actually represents 0.17 t/capita in Macedonia.

The advancement of scientific achievements in the last few decades with the rapid change in technologies and innovations has initiated a global emphasis on cleaner and environmentally friendly techniques in all fields. Although concrete is indisputable today, there is always room for improvement, as an ideal building material does not exist, especially in terms of safety, durability and sustainability. The concrete industry has great potential for a positive shift towards sustainable production and reducing the negative impact on the environment. The constant search for ways to preserve natural resources should result in replacing the use of natural raw materials with alternative ones. One way to address this issue and reduce CO_2 emissions from the cement production process is by replacing cement with locally available by-products that are pozzolanic in nature: waste materials and by-products from other industries, waste from agricultural plants, construction waste, etc. Their disposal represents a major environmental problem.

Wood waste is considered a carbon-neutral fuel because wood absorbs the same amount of carbon dioxide when it grows as it releases through combustion. This gives the wood an advantage over other types of biomass, as it produces less waste [2]. In 2010, wood and wood waste accounted for a total of 49% of the total energy consumed from renewable sources in the European Union [3]. Macedonia has significant biomass potential as a fuel: 39% of the Macedonian territory is covered by forest [4]. Therefore, it is necessary to ensure sustainable and efficient ash management. One of the possibilities for sustainable ash management is its application in construction and industry. Wood ash management refers to its storage, disposal, and potential use or reuse. Increasing ash volume leads to reduced space for its disposal, i.e. increased handling and transportation, which leads to increased waste management costs [5]. The costs of managing biomass waste ash are between 200 and 500 euros per tonne, and in the future, increasing landfill costs can be expected in the form of taxes or landfill fees, as well as difficulties in finding new landfills and stricter EU directives related to ash disposal [6]. Data available from the literature indicate that 70% of wood biomass ash is disposed of, 20% is processed and applied as a soil additive in agriculture, and 10% is used for other purposes [2, 7]. The eventual disposal of ash without any form of control can cause air pollution with small particles carried by the wind [8], groundwater pollution due to leaching of heavy metals from the ash, and the entry of heavy metals into the food chain. Previous scientific research has shown that fly ash can be used in the construction industry [9].

The composition of ash depends on the type of wood (biomass) from which it is obtained, the temperature at which the wood is burned, and the location in the plant from which the ash is collected. Ash produced from wood in bread bakeries is a potential source for the production of mineral additives, which could be used as a partial replacement of the cement in cement composites.

Some of the actual standards provide a set of requirements for fly ash obtained by 50% co-combustion of coal and 50% of pure wood biomass. However, they do not provide conditions for use of pure wood biomass. Therefore, additional research is necessary into the possibility of using wood biomass ash in the construction industry, which, on the other hand, would result in reduced negative impacts of the construction industry on the environment. The large amount of waste ash produced in the process of using wood as a fuel source for baking bread in bakeries across the country provides a challenge for finding possibilities of using wood waste as a building material.

This paper examines the use of wood biomass ash generated in bakery ovens as a substitute for cement in cementitious composites. The main mechanical properties of the resulting cement composites were analysed. Based on the own experimental studies, the potential for using ash in structures as a substitute for cement has been determined. The paper should bring the problem of managing wood biomass ash closer to civil engineers and help them make decisions about material selection.

2. Materials and methods

2.1. Properties of the wood ash

Ash is a powdery residue after the combustion of woody biomass, which contains compounds of both organic and inorganic origin. Pure wood, wood residues such as bark, sawdust, or products such as pellets, briquettes, chips, which are obtained by processing waste wood from the wood industry, can be used as wood biomass. The type of wood, its storage time and conditions affect the calorific value, thus the energy efficiency of combustion and the chemical composition of the ash produced. The chemical composition of biomass ash is characterized by a high content of alkaline compounds that affect its solubility. Hardwood (deciduous trees such as oak, beech, walnut) or softwood (evergreen trees such as pine, spruce, fir) can be used for combustion, producing 6-10% ash. The hardwood is generally denser and therefore produces more ash when burned.

Typically, wood ash contains carbon in the range of 5-30%. The main elements of wood ash include calcium (7-33%), potassium (3-4%), magnesium (1-2%), manganese (0.3-1.3%), phosphorus (0.3-1.4%) and sodium (0.2-0.5%). The density of wood ash varies depending on the type of biomass and the technology. The density of cement is usually in the range of 2.08 to 2.6 g/cm3, [10, 9, 11-12]. It is evident that the density of ash is less than the density of cement. The sample of the used ash is presented in Figure 1. The experimental investigation of the chemical composition of the ash was carried out in accordance with MKS EN 196-2, [13]. The results are presented in Table 1 and compared to the composition of ordinary cement.

Figure 1 – Wood Ash

Table 1 – Wood Ash Comparison of the composition of wood ash and ordinary Portland cement (OPC)

Oxides	Wood ash (% of weight)	OPC (% of weight)
SiO_2	13.21	17–25
Al_2O_3	0.86	3–8
Fe_2O_3	1.93	0.5–6
CaO	40.61	60–67
MgO	3.90	0.1–4
Alkali (Na^2O and K^2O)	/	0.5–1.3
SO^3	0.42	1–3
Heat losses	31.45	/
Insoluble residue	1.94	/
Total	100	100

Chemical composition of the wood ash showed that the presence of CaO, SiO2 and Al2O3 is lower than the usual content of these compounds in cement. The Table 1 shows that the presence of calcium oxide in the ash is between 61% and 68% of the usual presence in cement, and the presence of SiO2 is between 53% and 78% of the usual presence in cement. The presence of Al2O3 is between 11% and 43% of the usual presence in cement. This deficiency may further contribute to the reduction of strength characteristics. Namely, Al2O3 has an indirect role in formation of C3S and C2S - blocks of the main minerals of the cement clinker, mainly through promoting the liquid phase during clinker burning.

2.2. Recipies for concrete mixtures

Five different formulations were made for concrete samples with 0%, 5%, 10%, 15% and 20% wood biomass ash as a substitute for cement. The concrete samples were prepared and tested at 3, 7 and 28 days according to the procedures and requirements specified in the current national MKS standards: the compression strength, the flexural tensile strength and splitting tensile strength of the samples.

Cement type CEM I 52.5 R was used for preparation of the concrete mixtures. It is pure Portland cement with a small addition of gypsum and up to 5% other mineral admixtures. The aggregate used for this research is limestone from the Govrlevo quarry in Skopje, in three fractions. The drinking water from the city water supply of Skopje was used in the mixtures. The admixture Superfluid 21M1M Eco from the manufacturer Ading - Skopje was used. It is a superplasticizer that allows significant reduction in the amount of water in the concrete mix without affecting the consistency or significantly increase workability without changing the amount of water. The admixture is a light yellow liquid with density of (1.05±0.02) g/cm3 and pH value from 4-6. The composition of all five mixtures is presented in Table 2.

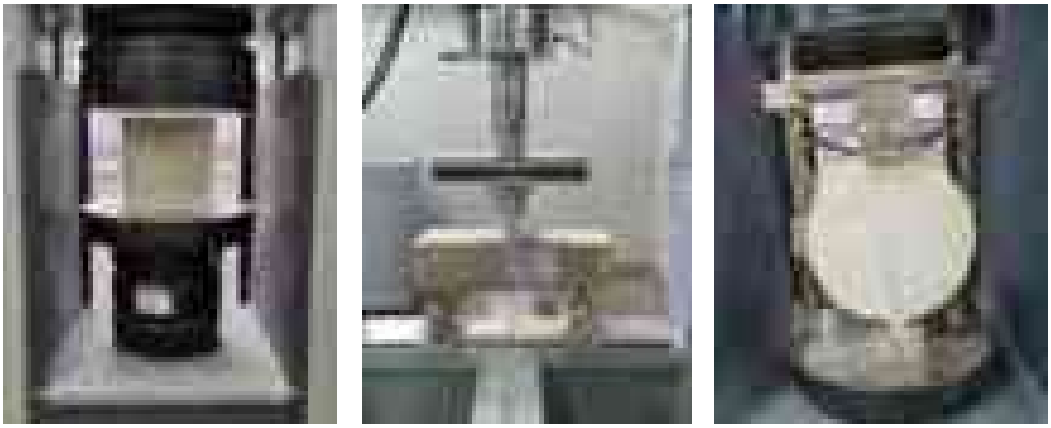
Table 2 – Composition of concrete mixtures

Components	**Participation in the mixture [kg/m³]**				
Mixture	1. reference	2. ash 5%	3. ash 10%	4. ash 15%	5. ash 20%
I fraction (0-4 mm)	886,9	886,9	886,9	886,9	886,9
II fraction (4-8 mm)	362	362	362	362	362
III fraction (8-16 mm)	561,1	561,1	561,1	561,1	561,1
Type CEM I 52,5 R	370	351,5	333	314,5	296
Water	229,40	237	244,2	237	252
Ash	0	18,5	37	55,5	74
Superfluid 21M1M Eco	1,85	1,85	1,85	1,85	1,85

Furthermore, the fresh mixture properties were tested: porosity, density and consistency according [14]. The necessary samples (concrete cubes, prisms and cylinders) in hardened condition were prepared and tested according to the actual standards [15-17], presented in Figures 2 and 3.

a) b)

Figure 2 – Concrete samples: a) cubes for compressive strength; b) prisms and cylinders



a) b) c)

Figure 3 – Testing samples: a) compressive strength; b) flexural strength; c) tensile strength

3. Results and discussion

3.1. Fresh concrete

Density and consistency of the fresh concrete mixtures were tested. Measured density of the five mixtures varied from 2326 to 2409 kg/m^3. However, density variations range within a small range (up to 3.2% difference), meaning that all types of concrete have normal density. This leads to the conclusion that the porosity of all mixtures is similar, as well.

The results of the slump test for the consistency of the concrete are shown in Table 3. The ratio of water to binder ranges between 0.62 and 0.68. In general, in order to maintain the same consistency or the same class of consistency, an increase in the ash content requires increase in the water content. However, the fourth sample has a lower slump test value because it contains a smaller amount of water. This suggests that the target consistency was not achieved for this mixture. This deviation was due to experimental error and further affects the mechanical properties results.

Table 2 – Composition of concrete mixtures

mixture	water [kg]	binder [kg]		water/binder	consistency [mm]
		cement	ash		
1. reference 0%	229,4	370	0	0,62	185
2. ash 5%	237	351,5	18,5	0,64	190
3. ash 10%	244,2	333	37	0,66	215
4. ash 15%	237	314,5	55,5	0,64	140
5. ash 20%	252	296	74	0,68	215

3.2. Hardened concrete

Testing the mechanical properties of hardened concrete is imperative for ensuring that the finalized concrete product meets the material requirements and ensures the safety of the structure. The compressive strength at 3, 7 and 28 days, flexural strength and tensile strength were tested according to the actual national standards [15-17].

The compressive strength of the samples at 3, 7 and 28 days is presented in Figure 4.

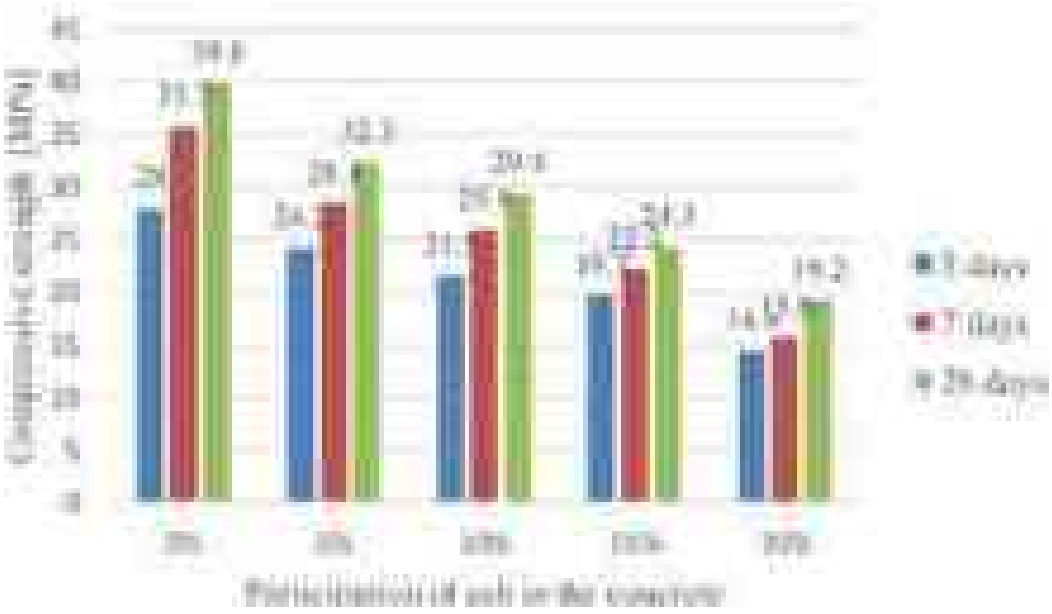


Figure 4 – Compressive strength of cubes with various percentage of ash at 3, 7 and 28 days

Figure 4 shows that the compressive strength decreases with increasing percentage of fly ash in the concrete mix. The samples with 20% replacement of the cement with ash show nearly twice lower compressive strength after 3, 7 and 28 days, respectively. The compressive strength at the third day reached about 75% of the total strength for the samples with presence of ash, being 81% for the mixture number 4 with 15% of ash, in comparison with the 70% of the total strength for the reference samples with 0% ash.

Flexural strength was tested for 3 sample prisms per each mixture and the average values are presented in Figure 5. Increasing the wood biomass ash content in all concrete mixtures results in a decrease in the 28-day flexural tensile strength of the concrete, Figure 5. The trend line in Figure 5 shows a constant decrease. An ash content of 5% results in a 14.7% decrease in flexural strength compared to the reference. The recipe with 10% ash has a reduced strength compared to the reference mixture by as much as 37.4%, while recipe no. 4 with 15% ash shows a reduction in flexural strength by 29.3% compared to the etalon. The fifth recipe with 20% ash shows the lowest flexural strength, which is 40% of the reference one. The third formulation with 10% ash is below the trend line, deviating more than expected, while the formulation with 20% ash shows satisfactory flexural strength. It should be emphasized that due to the combined effects of varying w/b and ash content, reductions in compressive, flexural, and tensile strength cannot be attributed solely to the ash.

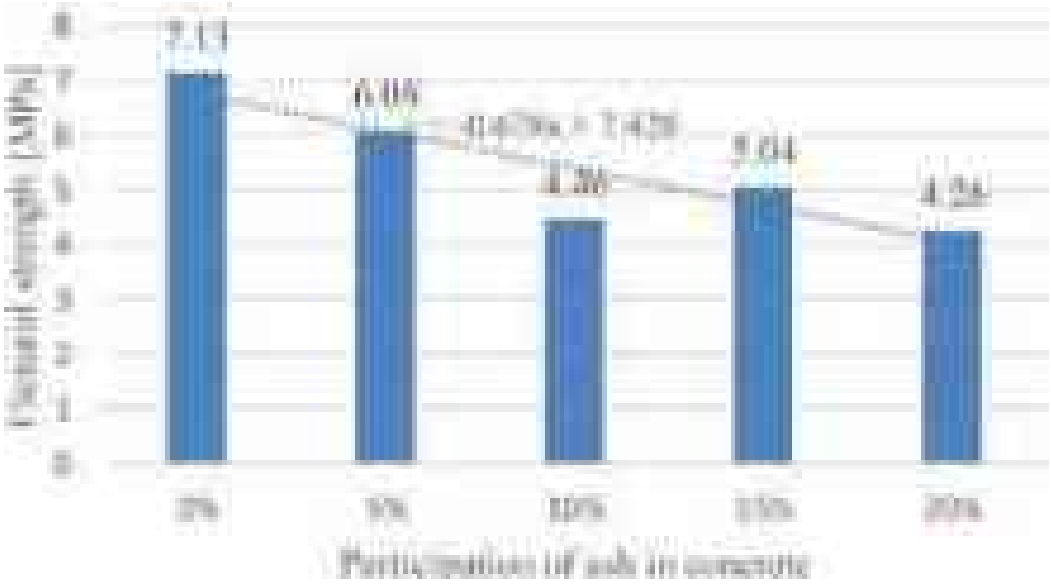


Figure 5 – Flexural strength of the concrete prisms with different percentage of ash

Tensile strength was tested performing tensile-split test on 3 cylinder samples per each mixture and the results are presented in Figure 6.

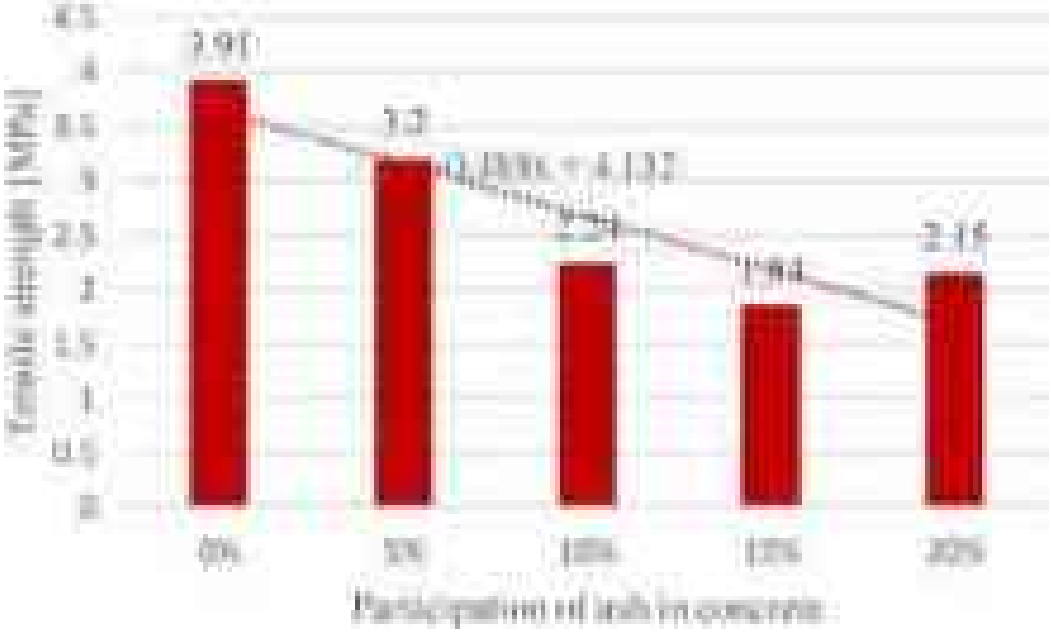


Figure 6 – Tensile strength of the concrete cylinders with different percentage of ash

The results in Figure 6 show that the reference mix no. 1 has the highest tensile splitting strength at 28 days (3.91 MPa). Increasing the content of wood biomass ash in all concrete mixtures results in a reduced tensile splitting strength of the concrete. The 5% ash content gives a tensile splitting strength 3.20 MPa, or a reduction of 18% compared to the standard. The formulation with 10% ash has a reduced strength compared to the standard by 42.7%, while formulation no. 4 with 15% ash shows a reduction in flexural strength by 52.9% compared to the standard. The fifth formulation with 20% ash shows a slightly higher tensile splitting strength of 2.15 MPa, which is 45% lower than the standard.

4. Conclusion

The research conducted in this paper concerns the impact of including ash from woody biomass as a substitute for cement in concrete. Testing of fresh and hardened concrete was performed by partially replacing the cement with 5, 10, 15 and 20% wood ash. The results point to general trends and conclusions from concrete testing when replacing part of the cement with ash:

- Increasing the amount of ash reduces the consistency and workability of the concrete. Due to the rapid reaction of water with the concrete mix, it is necessary to add the water quickly.
- The density of the concrete does not undergo large relative changes and all types of samples represent normal concretes with a density of 2326 - 2409 kg/m^3.
- Compressive strength decreases with increasing ash content. The degree of reduction depends on the amount of water added. Practically, ash replacement of up to 10% could be used without compromising performance.
- Increasing the wood biomass ash content in all concrete mixtures results in a reduced flexural strength of the concrete, from 14.7% to 40% relative to the reference mixture. Similar effects were observed in the tensile splitting strength of the concrete; it was reduced from 18% to 52.9% compared to the reference mixture.

The results indicate the possible recovery and reuse of biomass ash in environmentally friendly cement composites, which contributes to reducing the use of natural raw materials, reducing pollution from cement production. However, usability should be confirmed only after proper processing and validation. The potential reuse of wood ash can reduce landfill waste disposal, while at the same time improving the sustainable perspective of cement production, reducing the energy required for cement production. At the same time, CO_2 emissions can be reduced and natural resources can be conserved, without worrying about reducing the supply of ash from wood biomass from bakeries. However, the results are partially limited due to the changes in the w/b ratio. Furthermore, the effect of the ash should be confirmed in future through additional tests (pozzolanic reactivity, XRD/XRF, particle fineness).

Literature

[1] Andrew, R. M: *"Global CO_2 emissions from cement production"*. Earth Syst. Sci. Data 10, 195–217, https://doi.org/10.5194/essd-10-195-2018 (2018).

[2] Chowdhury S., Mishra M., Suganya O.: *"The incorporation of wood waste ash as a partial cement replacement material for making structural grade concrete: An overview"*, Ain Shams Engineering Journal, 6 (2015) 2, pp. 429–437.

[3] Eurostat (2012), *"Statistics in focus, renewable energy"* (available at http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-12-044/EN/KS-SF-12-044-EN.PDF).

[4] Nikchevic S., Ed. (2018): *"JP Makedonski shumi: 1998-2018"*. Skopje. ISBN 978-608-4571-38-4., p. 18.

[5] Štirmer N., Carević I. (2022): *"Utilization of Wood Biomass Ash in Concrete Industry"*, in book "Biomass", February 2022, InterTech Open.

[6] Adrian K., James A.K, Thring, R.W., Helle S., Ghuman H.S.: "*Ash Management Review— Applications of Biomass Bottom Ash"*, Energies 2012, 5 (2012), pp. 3856-3873.

[7] Alghurair M. S.: *"Evaluation of Using Wood Waste Ash in Concrete"*, Arab Journal for Scientific Publishing (AJSP) (2020). ISSN: 2663-5798.

[8] Garcia M.L., Sousa-Coutinhob J. (2013): *"Strength and durability of cement with forest waste bottom ash"*, Construction and Building Materials, 41 (2013), pp. 897–910.

[9] James A.K., Thring R.W., Helle S., Ghuman H.S.: *"Ash Management Review—Applications of Biomass Bottom Ash"*, Energies 2012, 5 (2012), pp. 3856-3873.

[10] Fořt J., Šál J., Žák J., Černý R. (2020): *"Assessment of Wood-Based Fly Ash as Alternative Cement Replacement"*, Sustainability, Vol. 12, No. 22, 17 November 2020, MDPI.

[11] Netinger Grubeša I., Barišić I., Dokšanović T., Šandrk Nukić I., Kralik D., Glavaš H., Ivanović M (2021): *"Različiti aspekti primjene pepela biomase"*, pp.44-53.

[12] https://inundatii.ro/en/floods-directive-implementation-1st-cycle/ (last accessed on 13th September 2025)

[13] MKS EN 196-2:2024 Method of testing cement - Part 2: Chemical analysis of cement, ISRSM.

[14] MKS EN 12350-2:2019 Testing fresh concrete - Part 2: Slump test, ISRSM.

[15] MKS EN 12390-4:2025 Testing hardened concrete - Part 4: Compressive strength, ISRSM.

[16] MKS EN 12390-5:2019 Testing hardened concrete - Part 5: Flexural strength of test specimens, ISRSM.

[17] MKS EN 12390-6:2024 Testing hardened concrete - Part 6: Tensile splitting strength of test specimens, ISRSM.

Remediation method for mercury polluted site selected using analytical hyerarchy process

Zvjezdan Karadžin[1]

Jasmin Isabegović[2]

Miralem Sejdinović[3]

Edisa Nukić[4]

1	Associate prof., Faculty of Mining, Geology and Civil Engineering, University of Tuzla *zvjezdan.karadzin@untz.ba*
2	Ph.D, IGMG Institute, Tuzla *jasmin.isabegović@yahoo.com*
3	Chemical Engineer, TQM Institute, Tuzla *miralemsejdinović@gmail.com*
4	Associate prof., Faculty of Mining, Geology and Civil Engineering, University of Tuzla *edisa.nukic@untz.ba*

Abstract

Mercury is one of the most problematic toxic substances that may be found at contaminated sites. The special physical and chemical characteristics of mercury make the management of mercury contaminated sites a challenge, especially when it comes to remediating large industrial sites and mercury mining sites.

One of the sites contaminated with mercury is former Chlorine – Alkali complex (HAK1), situated in the industrial zone of Tuzla town, Bosnia and Herzegovina

Content of mercury in soil, ground waters and construction materials of the Electrolysis plant within the HAK 1 was determined in the frame of the UNEP/MAP programme and GEF MedProgramme entitle: Reducing Pollution from Harmfull Chemicals and wastes in Mediterranean HO Spots.

Numerous techniques can be used to treat mercury contaminated soils and effluents. Some processes are merely physical (sedimentation), others are physicochemical (coagulation, flocculation, adsorption, etc) yet others are chemical (oxidation, precipitation, etc.) The appropriate choice depends on various factors, mainly the speciation of the element and present of other agents,

This paper deals with analysis into potential methods of mercury remediation primarily based on Analytical Hierarchy Process (AHP).

The basic criteria for each of the remediation methods were separated into technical, economic, reliability and prevention criteria, which are further divided into several sub-criteria, a process aimed at determining the most suitable remediation methods for the study case.

Keywords

Mercury pollution, Industrial Hotspots, remediation methods, AHP

1. Introduction

In general, a contaminated site is a place where there is an accumulation of toxic substances or residues which may affect the soil, groundwater, sediments and even air, and in the case of mercury to levels that pose a risk to the environment or human health or be above the safe limits recommended for a specific use. Metallic mercury is a liquid at room temperature, the only metal with this property, and also evaporates at room temperature.

Mercury is one of the most problematic toxic substances that may be found at contaminated sites: the special physical and chemical characteristics of mercury make the management of mercury contaminated sites a challenge, especially when it comes to remediating large industrial sites and mercury mining sites.

Due to its properties, once mercury has entered the environment, it remains there adopting different physical and chemical forms reaching all of the environmental media to a greater or lesser extent: air, soil, water, sediments and even the building.

One of potential contaminated sites was found to be area of HAK 1 – Electrolysis plant in Tuzla, Bosnia and Herzegovina, and it was investigated through Small Scale Funding Agreement (SSFA).

The objective of the Small Scale Funding Agreement (SSFA) was to contribute to the implementation of the UNEP/MAP Programme of Work (POW) and Budget for the biennial 2022/2023 and the GEF MedProgramme-Child Project 1.1 entitled Reducing Pollution from Harmful Chemicals and Wastes in Mediterranean Hot Spots and Measuring Progress to Impacts (hereinafter referred to as Child project 1.1 or CP 1.1). The MedProgramme is being implemented in several GEF eligible countries, including Bosnia and Herzegovina. [1]

2. The location of the research polygon

The considered site of the Chlor alkali Complex (HAK) is located in the central part of the Industrial Zone Tuzla, Bosnia and Herzegovina, in the immediate vicinity of the existing facilities of Tuzla Thermal Power Plant, Dita Tuzla, Xela BH-YTONG, C.I.B.O.S. Sarajevo, Kemokop d.o.o. Tuzla and others.

Access to the location is possible from the internal road that connects to the main road M4 Doboj – Tuzla, which is approx. 230 m away.

The river Jala flows to the northwest of the site at a distance of approx. 200 m. [2]

In geological terms, the location of HAK is in the central part of the "Kreka Coal Basin", as a very complex geological coal-bearing structure in which a number of units for the exploitation of coal, surface and pit mines, have been operating, of which surface mine "Šikulje" and "Dubrave", and "Mramor" underground mine are currently active. Many other coal units have stopped with exploitation, with minor or major consequences for the environment, during more than 125 years of coal exploitation in the Kreka lignite Basin. [3]

The immediate and broader environment of HAK is densely populated and urbanized, with numerous settlements and associated infrastructure.

In the immediate surroundings are: Tuzla with suburb settlements Bukinje, Šićki Brod, Plane, Husino, Miladije, Mihatovići, Mramor, Lipnica etc.; town of Lukavac and town of Živinice.

Figure 1 – Location of pollution with mercury – HAK 1 factory – research polygon (Source – Google Earth)

The company was organized as a complex of several factories within one compound whose main goal was the production of "polyols".

Chlorine, lime, propylene were used for the production of propylene oxide as basic raw materials. The production of chlorine was carried out at the Electrolysis plant and by-product of this plant was HCl acid and NaOH alkali. Electrolysis process included usage of mercury cells

A large amount of salt water and electricity was necessary for the operation of electrolysis, along with good communication connections, and that was probably the main reason for the construction of HAK 1 in the area of Tuzla town. [4,5]

Figure 2 – View of the Electrolysis building from the northeast side-current state

3. Remediation of mercury contaminated site

A method often used when making decisions about various benefits is the "Analytical Hierarchy Process" (AHP) i.e. the analytical hierarchical evaluation procedure. AHP is a comprehensive, logical and structured thinking process, and very useful in solving problems, which have multiple aspects or criteria to consider. Multi Criteria Decision Making (MCDM) can be performed using the AHP method. During the process of evaluating the method of remediation of the site from mercury pollution, 4 criteria were used which were further divided into several sub-criteria.

When using the AHP, it is necessary to know the technological procedure in order to identify the criteria and sub-criteria, which must be evaluated.

3.1. The pollution – Point source

Giving the components of the environment (air, water and soil) into which mercury was released, two periods were considered, the operational period of Electrolysis plant and the period of its disassembly when, without an appropriate plan and monitoring, mercury also got into the components of the environment through spills on flour and into the drainage system.

It is assumed that removal of mercury cells from Electrolysis plant, along with other pipes and equipment from the plant resulted in accidental spillage of mercury which end up in drainage channels and then further into soil, and ground water presenting a threat to the environment.

Primary source of pollution is mercury present Electrolysis plant foundations and walls. Secondary source is soil, around and underneath the plant, and ground water around the plant.

Soil contamination around the plant is determined and highest values of contaminations are within surface layers while contamination of deeper layers is lower.

According to the laboratory analysis obtained from the samples of soil, building materials and water from piezometers drilled recently, it could be seen that five samples of soil are above maximum contamination level (intervention level according to Dutch Target and Intervention Values, Soil Protection Act (Stb, 2005a), all 18 samples from building materials are above the intervention level and none of the samples from piezometers are above the intervention level. It should be stressed that piezometers were drilled recently, and the leaching effect should be monitored in the following period of time. [1,6]

3.2. AHP Methodology

The basic criteria for each of the remediation methods are divided into technical, economic, reliability and prevention criteria, which are further divided into several sub-criteria as presented in the following table.[7]

Table 1 – AHP criteria for the study case

CRITERIA			
Technical	**Economical**	**Reliability**	**Location**
Permanent remediation of mercury pollution in soil, water and buildings	A method whose application costs less than 100,000 KM	The method applied in Bosnia and Herzegovina	Permanently prevents the possibility of spreading pollution from the site
Remediation of mercury pollution in one medium	A method whose application costs between 100,000 KM and 1,000,000 KM	The method applied in the region	It prevents the possibility of spreading pollution through one of the media
Partial remediation of mercury pollution in one of the media (soil, water, building)	A method whose application costs between 1,000,000 KM and 10,000,000 KM	The method used in the world	It partially prevents the possibility of spreading pollution through one of the media
It does not solve the pollution	A method whose application costs between 10,000,000 KM i 100,000,000 KM	Method proven in experimental - laboratory conditions	It does not address the possibility of spreading pollution
	A method whose implementation costs more than 100,000,000 KM or the price cannot be determined	The method is based on theoretical and scientific research	

The value of each of the sub criterion for the individual deposit is obtained on the basis of the assessment of the fulfilment of the set boundary conditions as given in Table 2.

Table 2 – Evaluation of criteria

Compliance with the condition W (n)	Definition
0	Elimination criterion not met
1	The criterion is met
2	The criterion is met with considerable certainty
3	The criterion is met multiple

A weight factor was added to each of the sub-criteria and thus a final assessment of the potential method was obtained.

Table 3 – Weight factor sub-criteria and elimination criteria [7]

Sub criterion	Weight factor	Elimination criterion
T1	0.25	NO
T2	0.12	NO
T3	0.05	NO
T4	0	YES
E1	0.25	NO
E2	0.2	NO
E3	0.1	NO
E4	0.05	NO
E5	0.01	NO
R1	0.25	NO
R2	0.2	NO
R3	0.15	NO
R4	0.1	NO
R5	0.05	NO
L1	0.25	NO
L2	0.15	NO
L3	0.1	NO
L4	0	YES

The sub-criterion and the associated weight factor are broken down into all the elements that make up the considered sub-criterion.

If any of the eliminatory sub-criterion is graded zero (0), the final result of the analysis is automatically displayed as zero (0).

The final assessment of the rehabilitation method was obtained by applying the formula:

$$Stot = \Sigma Sk \cdot Zk$$

where:

Stot – total assessment of the rehabilitation method

Sk – assessment of the rehabilitation method according to criterion k

Zk – weight factor of criterion k

At the end of the evaluation process, the remediation methods were sorted with regard to the final evaluation.

3.3. Assessment of remediation metohds

Table 4 – Summary of various in situ soil mercury remediation technologies [7]

Technology	In situ thermal desorption
Description	Mercury is converted to gaseous or vapor phase from the contaminated sites by heat treatment and then collected and treated
Positives	No depth treatment limitation; less sensitive to subsurface heterogeneities
Negatives	High cost; potential risks from release of mercury vapor; negative impacts on the ecological health at the treated site
Applicability	Sandy soil; mobile mercury species (e.g., after soluble, exchangeable, and elemental mercury)
Costs*	$50 to $250/ton of soil
Availability and applicability in BiH	Non existing technology in BiH
Evaluation according to the criteria (AHP)	0,97
Technology	Electrokinetics
Description	A low intensity direct current is passed between a cathode and an anode imbedded in the contaminated soil so that mercury ions move toward the oppositely charged electrodes
Positives	No excavation required; little disturbance to contaminated site; simultaneous removal of other contaminants; relatively lower cost
Negatives	May need complexing agents to mobilize mercury; concerns associated with release of mercury vapor, disposal of mercury waste, and mobilization of insoluble and nontoxic mercury compounds
Applicability	All soil types, especially clay soil; inorganic mercury species
Costs*	$26–$296/m^3
Availability and applicability in BiH	Non existing technology in BiH
Evaluation according to the criteria (AHP)	0,50
Technology	In situ soil flushing
Description	An appropriate washing solution is injected into or sprayed onto the contaminated soil so that the contaminants become mobilized and can be later extracted

Positives	Efficient in removing Hg from subsurface soil; does not require excavation, treatment, and disposal of soil wastes; treatment equipment is easy to construct and operate; can be coupled with other in situ technologies for better Hg removal
Negatives	Requires chemical additives; solubilizing contaminants poses risks and is unacceptable to regulators and public; intrusive to the treated area
Applicability	Homogeneous, permeable soils with permeability greater than 1×10−3 cm/s; mobile mercury species
Costs*	$79–171/m^3
Availability and applicability in BiH	Non existing technology in BiH
Evaluation according to the criteria (AHP)	1,15
Technology	Containment
Description	Contaminated soils are isolated and contained by low permeability physical barriers to prevent or reduce the migration of mercury in the soil
Positives	Low cost; does not require excavation and disposal of hazardous waste; can be applied together with other technologies to enhance Hg remediation effectiveness; protects groundwater from being contaminated
Negatives	Leaves the contaminants on site; requires long-term sampling and monitoring of the treated sites and underlying groundwater
Applicability	Contaminated soils of low hazard and mobility; not applicable if there exists a more permanent and cost effective remedy, implementation is difficult, or there is potentially high risk
Costs*	$166–500/m^3 (vertical barriers)
Availability and applicability in BiH	Exists in BiH. Applicable in BiH
Evaluation according to the criteria (AHP)	2,10
Technology	Solidification / stabilization
Description	Contaminated soils are mixed with treatment reagents to reduce the mobility and/or permeability of contaminants by physical encapsulation and/or chemical stabilization
Positives	Mature and commercially available; receptible to US and EU regulatory agencies; effective in immobilizing contaminants and meeting regulatory cleanup levels
Negatives	Can increase the volume of the contaminated area; may pose risks in a longer term; introduces chemical agents that may cause problems themselves
Applicability	The applicability depends on the mobility of mercury

Costs*	Averaging ~$255/m^3
Availability and applicability in BiH	Exists in BiH. Applicable in BiH
Evaluation according to the criteria (AHP)	1,44
Technology	Vitrification
Description	Contaminated soils are heated and molten by high temperature treatment and cooled to form a solidified, chemically inert, vitreous mass wherein the contaminants are immobilized
Positives	Minimizes the disturbance of the soil and surrounding environment; multiple contaminants can be remediated simultaneously; environmental-friendly; cost effective; can be applied to a large area; high esthetic value and public acceptance
Negatives	This technology is still immature; requires lengthy remediation duration; vulnerable to environmental conditions;
Applicability	Sites with shallow contamination; sites with low contaminant concentrations
Costs*	$49–$204/m^3
Availability and applicability in BiH	Non existing technology in BiH
Evaluation according to the criteria (AHP)	0,35
Technology	Vitrification
Description	Contaminated soils are heated and molten by high temperature treatment and cooled to form a solidified, chemically inert, vitreous mass wherein the contaminants are immobilized
Positives	Minimizes the disturbance of the soil and surrounding environment; multiple contaminants can be remediated simultaneously; environmental-friendly; cost effective; can be applied to a large area; high esthetic value and public acceptance
Negatives	This technology is still immature; requires lengthy remediation duration; vulnerable to environmental conditions;
Applicability	Sites with shallow contamination; sites with low contaminant concentrations
Costs*	$49–$204/m^3
Availability and applicability in BiH	Non existing technology in BiH
Evaluation according to the criteria (AHP)	0,35

Technology	Nanotechnology
Description	Stabilized iron sulfide nanoparticles are injected into the contaminated soil to immobilize mercury by ion exchange or adsorption
Positives	Does not use any toxic reagents; preparation can be conducted on site; low cost and energy requirements
Negatives	Immature technology; health and safety concerns about the use of nanoparticles
Applicability	Both surface and subsurface soil, elemental and methylated mercury
Costs*	$1.47/m^3 (chemical cost only)
Availability and applicability in BiH	Non existing technology in BiH
Evaluation according to the criteria (AHP)	0,64
Technology	Phytoremediation
Description	Green plant is used to clean up mercury-contaminated site through phytoextraction phytostabilization, or phytovolatilization
Positives	Minimizes the disturbance of the soil and surrounding environment; multiple contaminants can be remediated simultaneously; environmental-friendly; cost effective; can be applied to a large area; high esthetic value and public acceptance
Negatives	This technology is still immature; requires lengthy remediation duration; vulnerable to environmental conditions; harvested plant biomass needs offsite treatment; consumption of contaminated plants by wildlife; introduction of invasive and nonnative premeditative plants; phytovolatilization does not remove or immobilize mercury permanently; genetically engineered plants with both merA and merB genes are not permitted for use; release of mercury vapor from phytovolatilization process
Applicability	Sites with shallow contamination; sites with low contaminant concentrations
Costs*	$49–$204/m^3
Availability and applicability in BiH	Might be applicable in BiH (it can be used in conjunction with other technologies)
Evaluation according to the criteria (AHP)	1,40

4. Conclussions

The results of mercury presence in the former HAK1 factory compound show that all of construction material samples exceed mercury intervention values; all soil samples (except for the B20 borehole sample) also exceed intervention values, while water samples taken from piezometers do not exceed intervention values. Since these are newly excavated piezometers and having in mind the meteorological conditions in the past period

with low percentage of rainfall, it is assumed that there has not yet been a leakage of mercury into groundwater, which is not a sign that it will not occur in the future. Furthermore, it is concluded that the main and only source of contamination of groundwater and soil is actually the building in which the electrolysis plant is located and that the remediation of the building and the surrounding soil would lead to reduced, if not completely prevented, intermediate cross-contamination of the environment.[1]

Conducted research and obtained laboratory results served as crucial inputs in Analytical Hierarchy Process (AHP) that was used to determine the most appropriate method for remediation of mercury contaminated site. AHP analysis included several criteria such as site specificity, experience in such operations in our country, availability, efficiency and applicability of remediation technologies in the area contaminated with mercury, as well as economic assessment of the costs of remediation works.

Based on that two technologies or combination of technologies were selected, namely - Containment and Solidification/Stabilization technologies, which showed the greatest potential as the most appropriate and effective in this case and treatment can be performed both in situ and ex situ.

Literature

[1]	Karadžin Z., Isabegović J., Sejdinović M.: „Project: Mercury (Hg) soil and groundwater assessment at HAK 1, Chemical industrial complex", Faculty of Mining, Geology and Civil Engineering Tuzla, funded by GEF Med Programme and UNEP, Tuzla, 2023
[2]	Bosna S company: „Environmental impact study upon closure of former Chemical complex - HAK 1", company Bosna S , Sarajevo, 2013
[3]	Karadžin Z.: *„A new approach to monitoring environmental hazards related to lignite mining in Kreka lignite mines"*, International scientific conference "Geotechnics in Function of Environmental Protection" "Mining" magazine, No 39-40, page 13-24, Tuzla, 2005
[4]	Andrejaš F. et al: „Report on status of hazardous waste materials in the compound of former HAK 1 Chemical factory", Tuzla, 2021
[5]	Japanese agency JICA in cooperation with Ministry of Foreign Trade and Economic Affairs of Bosnia and Herzegovina: „Project for master plan for remediation of hotspots in Bosnia and Herzegovina", Sarajevo, 2014
[6]	Karadžin Z., Isabegović J., Marković J., Nukić E.: „Assessment on the contamination of soil and groundwater with mercury at the chemical industrial complex, HAK 1, Tuzla", Engineering Conference, page 39-43, Bečići, Monte Negro, 2023
[7]	Karadžin Z., Isabegović J., Sejdinović M.: „Project: Environmental sound management (ESM) plan towards mercury disposal/remediation at HAK 1", Faculty of Mining, Geology and Civil Engineering Tuzla, funded by GEF Med Programme and UNEP, Tuzla, 2024

Sustainable water management under limited resources through artificial neural networks

Željka Beljkaš[1]

Snežana Rutešić[2]

Miloš Knežević[3]

Ivona Krulanović[4]

1	Assistant Professor, University of Montenegro *zeljkab@ucg.ac.me*
2	Associate Professor, University of Montenegro *snezanar@ucg.ac.me*
3	Full Professor, University of Montenegro *knezevicmilos@hotmail.com*
4	MSc Civil Engineering, Agency for Design and Planning Ltd. Nikšić *ivona.krulanovic.15@gmail.com*

Abstract

The escalating impacts of global climate change, coupled with rapid urbanization and population growth, are placing unprecedented stress on water resources, transforming water scarcity into a critical issue even in regions traditionally unaffected. Under such constraints, the accurate forecasting of water demand emerges as an essential pillar for sustainable water resource management and the resilience of supply systems. This study investigates the determinants of average daily per capita water consumption, encompassing economic, socio-demographic, cultural, climatic, and infrastructural factors, with a particular emphasis on the transformative influence of climate change on consumption patterns.

To advance the precision of water demand forecasts, artificial neural networks (ANNs) were employed, incorporating two climatic, one socio-economic, and one demographic factor as primary input variables. Multiple ANN architectures were systematically evaluated, with the optimal configuration—featuring three input neurons, nine hidden neurons, and one output neuron—achieving a mean absolute percentage error (MAPE) of just 6.51%. This result underscores the capacity of ANNs to capture complex, nonlinear interdependencies governing water use, significantly outperforming conventional estimation approaches.

The results of this research highlight the crucial role of data-driven forecasting models in supporting adaptive water management strategies, particularly in scenarios of heightened climatic variability and resource scarcity. By enabling utilities and policymakers to anticipate demand fluctuations with greater confidence, such models facilitate proactive infrastructure planning, optimized distribution, and targeted conservation measures. Ultimately, this study contributes to strengthening the long-term sustainability and operational reliability of water supply systems in Montenegro and offers insights applicable to other regions facing similar environmental and demographic pressures.

Keywords

Water demand forecasting, climate change impacts, water resource management, artificial neural networks, urban water supply, sustainable infrastructure planning

1. Introduction

Global climate change, urbanization, and population growth are increasingly burdening available water resources worldwide. Water scarcity is no longer an issue only for arid regions but has become a reality even in areas traditionally not facing such challenges. Under these circumstances, efficient water consumption management becomes crucial for preserving water resources and ensuring the stability of water supply systems.

When designing water supply systems, it is crucial to select accurate and sufficient input data. One of the main parameters is the average daily water demand per capita. In the current practice of system design in Montenegro, this value is usually adopted based on literature recommendations. Given that this parameter is critical for system sizing, more attention must be paid to its precise determination, especially in modern conditions where water resources are increasingly limited.

2. The average daily water demand per person

The average daily water demand per person encompasses consumption for various needs and varies depending on the level of sanitary and technical equipment in households, living standards, water prices, settlement layout, type of settlement, presence of sewerage, climatic conditions, and other factors [1]. This parameter forms the basis for the functional sizing of water supply systems and is regulated by relevant legislation in most countries.

In Montenegro, the method for determining this value is not precisely defined. According to available literature and strategic documents [2][3], significant differences in the methodology of determining the required amount of water have been observed. Differences also exist among individual settlements, where per capita water consumption values range from 250 l/day/person to over 2000 l/day/person.

2.1. Factors that influence the value of the average daily water demand per person

Water consumption depends on numerous factors —economic, socio-demographic, cultural, climatic, and infrastructural [4]. It is important to emphasize that environmental awareness and public policies aimed at rational water use can significantly contribute to reducing consumption. Moreover, the quality and maintenance of the water supply network, i.e., reducing losses through leaks and technical defects, directly impact the total system demand.

2.1.1. Impact of climate change on water consumption patterns

Climate change has a profound impact on water consumption patterns by altering key meteorological and hydrological parameters. Rising average temperatures generally increase the demand for water for drinking, personal hygiene, and especially for cooling and irrigation purposes. Longer dry periods coupled with intense, short rainfall events disrupt the natural replenishment of groundwater and reservoirs, leading to more pronounced seasonal water shortages.

Moreover, climate-induced shifts in precipitation regimes can change the reliance on different water sources, pushing communities to draw more from centralized water supply systems.

The increasing frequency of heatwaves and other extreme weather events often results in sudden spikes in water demand, challenging the capacity of existing infrastructure.

These dynamics highlight the necessity of incorporating climate data into consumption forecasting models. By accounting for projected temperature and rainfall changes, water utilities can better anticipate demand fluctuations and implement adaptive management strategies, which are crucial under conditions of limited and increasingly variable water resources.

2.2. Determination of the average daily water demand per person

The estimation of per capita water demand within a water supply system can be approached through various methodologies. One widely used method involves applying an aggregated formula that accounts for different categories of water use:

$$np = (C_1 \cdot Q_1 + C_2 \cdot Q_2 + C_3 \cdot Q_3 \cdot e + C_4 \cdot Q_4) \cdot m \cdot o \cdot f \quad [5]$$

where:

- Q_1 represents household water consumption,
- Q_2 denotes water use for irrigation and gardening,
- Q_3 corresponds to communal and public service needs,
- Q_4 covers consumption by small businesses and public facilities,
- C_1, C_2, C_3, and C_4 are adjustment coefficients reflecting the characteristics of various urban zones (central, suburban, etc.),
- e is a coefficient accounting for the extent of green spaces,
- m captures variations in consumer structure,
- o adjusts for the level of household amenities,
- f represents the influence of climatic conditions.

The most commonly used method of estimating future water demand per person is based on already-built water supply systems with similar characteristics [6]. Methods for determining the average daily water demand include analyses of historical data on delivered and billed water, taking into account the number of inhabitants and seasonal variations. More precise estimates are obtained through long-term monitoring and analysis of actual consumption [7]. However, traditional forecasting methods, such as linear

regression models or seasonal statistical approaches (ARIMA, SARIMA), often fail to adequately capture the nonlinear patterns of water consumption, which depend on a variety of factors, including demographic, climatic, socio-economic, and seasonal influences.

2.3. Water demand management and the importance of forecasting

Water demand management is one of the key tools for ensuring the sustainable use of water resources, particularly under the combined pressures of climate change, rapid urbanization, and increasing demands from both the population and industry. As water availability becomes more variable and uncertain, utilities and policymakers are required to adopt integrated approaches that balance supply and demand while maintaining service reliability and resource sustainability.

Effective water demand management enables several critical functions:

- Optimization of available water distribution, ensuring equitable allocation across residential, commercial, industrial, and agricultural users, even during peak demand periods or drought conditions.
- Reduction of physical and commercial losses through improved leakage detection, pressure management, and identification of unauthorized or illegal connections, thereby enhancing overall system efficiency.
- Implementation of demand-side policies, including dynamic pricing strategies and public awareness campaigns, which promote conservation behaviors and reduce unnecessary consumption.
- Evidence-based infrastructure planning, where investment decisions for expanding or upgrading water supply networks, storage facilities, and treatment plants are aligned with long-term demand projections and resilience objectives.
- Integration with climate adaptation strategies, by incorporating hydrological and meteorological data into planning processes to anticipate future stress on water resources.

In this context, accurate and reliable water consumption forecasts serve as the foundation for both strategic and operational management of water supply systems. They enable utilities to:

- Perform timely capacity planning, avoiding over-dimensioning or under-utilization of infrastructure.
- Implement proactive interventions, such as seasonal demand management measures, drought response actions, or temporary supply reallocations.
- Enhance resilience and reduce the risk of shortages, particularly during extreme weather events, by ensuring that supply systems can respond flexibly to sudden fluctuations in demand.
- Support decision-making under uncertainty by simulating multiple scenarios of population growth, climate variability, and socio-economic development.

Consequently, improving the accuracy of demand forecasting models—especially by integrating climate projections, demographic trends, and behavioral data—is essential for achieving sustainable, adaptive, and cost-effective water resource management.

3. Artificial neural networks

Artificial neural networks (ANNs) are a powerful tool for modeling complex nonlinear relationships. Their application in the field of hydrotechnics is increasingly common, as they allow for high prediction accuracy even when classical mathematical methods face limitations [8].

The process of forming ANNs includes selecting the network architecture, defining weight coefficients, and a training phase. The most commonly used structures for predictions are multilayer perceptrons (MLP), where the number of layers and neurons depends on the problem complexity and available data.

The architecture of an artificial neural network (ANN) (Figure 1) consists of neurons systematically arranged into connected layers. Each layer has a specific function, with neurons within that layer performing particular computational tasks. Usually, the output of one layer becomes the input for the next, allowing data to be gradually transformed as it moves through the network.

A standard ANN consists of an input layer, one or more hidden layers, and an output layer. The complexity of the modeling task determines the number and size of hidden layers. Establishing the architecture involves selecting the number of layers, defining the number of neurons in each hidden layer, and specifying the interconnections among them, which are critical decisions in the network design process [8].

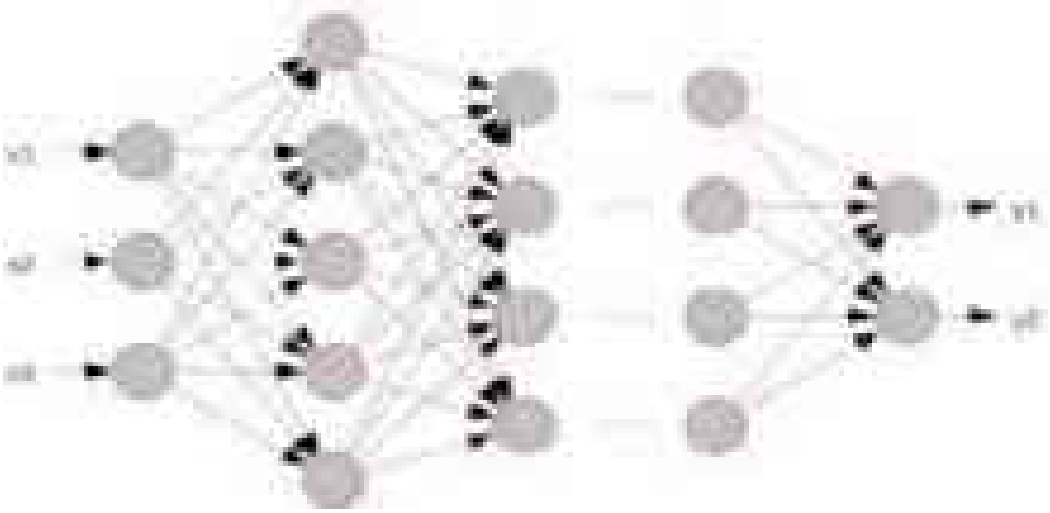


Figure 3 – Representative ANN architecture [6]

Activation functions (also called transfer functions) determine how inputs are processed within neurons to produce outputs. Common types include the step function, threshold logic, sigmoid, and ReLU, each affecting the network's nonlinearity and learning ability differently.

The training phase adjusts the synaptic weights through iterative optimization to minimize the error between the network's output and the target values. This process incrementally refines the model, enhancing its predictive accuracy over successive iterations.

4. Case study: prediction of water consumption

In this paper, ANNs were used to predict the average daily water consumption per capita, taking as input variables the mean daily air temperature, precipitation amount, average salary, an the number of registered tourists. The number of permanent residents was not used as an input since it did not change during the analyzed period.

The analysis is based on official and authoritative data sources, including annual water supply reports, hydrometeorological datasets [9], and national demographic statistics for a five-year period [10].

Initially, the dataset was standardized employing the Standard Scaler method. Following this preprocessing step, the data was partitioned into separate subsets for training and testing purposes, with 80% allocated to model training and the remaining 20% reserved for performance evaluation.

Subsequently, the neural network architecture was specified by determining both the total number of layers and the number of neurons within each layer. In the configurations explored for this study, the number of neurons in the hidden layer was systematically varied between 3 and 18, enabling the assessment of different complexities to identify the most effective model structure.

A series of neural network architectures was systematically explored in order to identify the configuration that would yield the lowest prediction error for average daily per capita water consumption. Various combinations of input, hidden, and output neurons were evaluated, allowing for a comparative assessment of model performance. Through this iterative experimentation, the architecture that demonstrated superior predictive capability comprised three input neurons, a hidden layer containing nine neurons, and a single output neuron. This optimized network achieved a mean absolute percentage error (MAPE) of 6.51%, underscoring its effectiveness in capturing the complex relationships between climatic and demographic variables and water demand.

Such a low prediction error is particularly significant in the context of contemporary water resource management, where precise demand forecasting is essential for informed decision-making. Accurate models enable water utilities and planners to proactively adjust operational strategies, optimize infrastructure investments, and mitigate the risks associated with resource scarcity and fluctuating consumption patterns, thereby contributing to the long-term sustainability of water supply systems. These results confirm that by integrating climatic, economic, and demographic variables, the ANN model successfully captures the nonlinear dependencies that govern water demand. Also, the findings of this case study demonstrate that artificial neural networks (ANNs) provide a robust and sophisticated approach for predicting average daily water consumption, which is particularly relevant in light of the growing frequency of climatic extremes and the associated unpredictability in water use.

5. Conclusion

This study emphasizes the importance of accurate water demand forecasting and proactive resource management, particularly in the context of increasing scarcity and uncertainty of water availability. Global challenges such as climate change, rapid urbanization, and ongoing population growth are putting unprecedented strain on water supply systems worldwide, requiring a fundamental change in how water resources are planned, monitored, and managed.

By analyzing the diverse set of factors that influence per capita water demand—including economic conditions, demographic dynamics, infrastructure development, and climatic variability—this research highlights the inherent complexity of accurately estimating water requirements.

These results indicate the necessity of adopting localized, data-driven approaches that integrate real-time monitoring, historical consumption analysis, and predictive modeling tailored to the specific socio-economic and environmental conditions of each service area. Such adaptive methodologies not only improve the reliability of demand projections but also provide a more robust foundation for sustainable water supply planning, infrastructure optimization, and climate resilience.

The implications for water resource management are profound. Accurate demand forecasts are fundamental to ensuring the operational reliability and sustainability of water supply systems. They enable utilities and governing bodies to:

- Optimize the allocation and distribution of scarce water resources, ensuring that supply meets location-specific and time-dependent demand variations while maintaining system reliability and minimizing operational costs.
- implement targeted, data-driven strategies to minimize physical and commercial losses, improve leakage detection, and identify unauthorized or illegal consumption;
- devise pricing and regulatory policies that promote conservation and efficiency,
- plan, prioritize, and phase infrastructure investments—such as network expansion, storage facilities, and treatment capacities—so they are appropriately scaled, timed, and aligned with projected demand scenarios under varying socio-economic and climatic conditions.

Moreover, due to decreasing water availability and more irregular supply patterns, integrated and flexible water management is essential. This requires incorporating climate forecasts and socio-economic changes into predictive models to better anticipate sudden increases in demand and reduce the risk of supply failures or interruptions.

Future research directions should prioritize the inclusion of broader socio-economic indicators, infrastructure characteristics, and real-time monitoring data, which would further refine prediction models and support dynamic management strategies. These advancements are critical for shifting water governance from a reactive approach to a proactive and predictive management framework. This transition enables stakeholders to enhance the resilience, reliability, and long-term sustainability of water supply systems, particularly under challenging environmental and operational conditions.

In conclusion, this study highlights that in an era marked by constrained water resources, the implementation of advanced analytical tools—such as artificial neural networks—paired with comprehensive water demand management practices, is not merely advantageous but indispensable. These approaches provide the foundation for informed decision-making and strategic planning, thereby safeguarding water security and ensuring the continued provision of this vital resource for both current and future generations.

Literature

[1]	Cominola, A., Preiss, L., Thyer, M. et al. "The determinants of household water consumption: A review and assessment framework for research and practice" Clean Water 6, 11, 2023. https://doi.org/10.1038/s41545-022-00208-8
[2]	The Water Management Base of the Montenegro, Government of Montenegro, Podgorica
[3]	"Water Management Strategy of Montenegro." Ministry of Agriculture and Rural Development, Government of Montenegro, Podgorica, June 2017.
[4]	Aleksić, N., Šuteršić, V. "Uticajni faktori i određivanje stvarne potrošnje vode u domaćinstvima u Republici Srbiji." The Faculty of Engineering Sciences, University of Kragujevac, 2021.
[5]	Sekulić, G., Ćipranić, I. "Komunalna hidrotehnika – teorijske osnove i rješeni primjeri." The Faculty of Civil Engineering, University of Montenegro, Podgorica, 2015.
[6]	Krulanovic, I., Cipranic, I., Beljkas, Z. "Prediction of water demand in water supply systems using artificial neural networks." The 9th International Conference Civil Engineering-Science and Practice, 9(5), 477–488, March 2024.
[7]	Edwards, K., Martin, L. "A Methodology for Surveying Domestic Water Consumption." Water and Environment Journal, 9(5), 477–488, October 1995.
[8]	Simonović, M. B. "Primjena veštačkih neuronskih mreža za kratkoročno predviđanje i analizu sistema daljinskog grejanja." The Faculty of Mechanical Engineering, University of Niš, Niš, 2016.
[9]	http://meteo.co.me/
[10]	https://monstat.org/cg/

T5

Sustainable urban and rural development

Towards the AI city: Artificial intelligence technologies development and application

Anđela Knežević[1]

Dušan Ignjatović[2]

1 MSc of Engineering in Architecture and Urbanism, Teaching Assistant, University of Belgrade - Faculty of Civil Engineering, Bulevar kralja Aleksandra 73, Belgrade, Serbia
aknezevic@grf.bg.ac.rs.

2 Full Professor, University of Belgrade - Faculty of Architecture, Bulevar kralja Aleksandra 73/II Belgrade, Serbia.

Abstract

Artificial Intelligence (AI) is emerging as an enabler of urban transformation, offering tools for energy optimization, transport automation, healthcare, and planning. This paper explores the shift from Smart Cities, where AI functions as a supportive tool, to AI Cities, where AI systems operate as autonomous agents in governance and service delivery. The research reviews contemporary examples of AI integration within urban structures, providing insights into current practice. The study aims to offer a theoretical framework for AI city development, evaluate existing implementations, and propose recommendations for future planning, emphasizing ethical, technological, and social considerations. Drawing on the 2022 UN-Habitat AI and Cities report, the paper reviews risks and opportunities across key sectors and highlights the potential of AI to support the United Nations Sustainable Development Goals (SDGs). A case study of Saudi Arabia's NEOM project, The Line, illustrates both the ambition and uncertainty of building an AI-driven city. The findings suggest that AI Cities are becoming increasingly plausible, but their success must be measured not only by technological sophistication, but by inclusivity, sustainability, and improved quality of urban life. Ultimately, the paper argues that ethical frameworks and localized adaptation are essential to prevent misuse. Equally, planners and policymakers must collaborate with technologists to ensure AI strengthens urban identity rather than erasing it.

Keywords

AI City, Smart City, Urban Sustainability, Urban Governance, Sustainable Development Goals (SDGs), NEOM/ The Line, Autonomous Systems

1. Introduction

By 2050, nearly 70% of the global population is expected to live in cities. Urban areas serve as centres of activity, offering citizens diverse opportunities and services, including enhanced education, advanced healthcare, broader employment prospects, varied housing, efficient transport networks, inter-city connectivity, and rich cultural experiences. To manage these increasingly complex urban environments, local, regional, and national administrations are turning to advanced technologies to improve operational efficiency and service delivery.

Figure 1 – Vision of the city of the future based on the Sustainable Development Goals (image generated by DALL-E), source: author, 2024.

Rising population density, the demand for faster urban problem-solving, and the development of sustainable urban strategies underscore the need to leverage all available tools, including contemporary technological innovations, to achieve the United Nations Sustainable Development Goals [1]. Science fiction and visionary concepts of future cities have long imagined urban environments shaped by the potential of AI (Figure 1). Advances in technology highlight the feasibility of integrating AI systems into urban processes, creating intelligent infrastructures that optimize services, mobility, and resource management. In today's cities, such integration is increasingly necessary, facilitating governance and operational efficiency. Future technological developments may allow urban planners to design cities that function as interconnected systems, partially or fully managed by AI, while remaining human-centred in scale and experience. This study examines the concept of AI cities (Artificially Intelligent cities), focusing on the distinction between smart cities and AI-driven urban environments. It investigates the potential for AI autonomy, associated risks, and practical applications. Based on literature and secondary sources, including UN-Habitat reports and scholarly works on AI in urbanism, this research combines theoretical analysis with practical case study. While the AI city concept remains largely speculative, this study provides exploratory guidance for its development, acknowledging that practical applications are still in an early, formative stage.

2. Artificial intelligence in the city

The concept of the smart city emerged alongside technological development. In the 1990s, technology companies began exploring ways to improve urban life through digital innovations. By the 2000s, the term smart city gained popularity and began to appear more realistic with advances in technology. Smart cities are based on the use of technological achievements to facilitate urban governance and to improve various aspects of life, such as mobility, healthcare, education, and process management within the city. These systems rely on digital technologies, often employing methods of machine learning and deep learning, though not at the full capacities of AI. They function as tools that process large volumes of data with speed and precision beyond human ability. The key distinction between smart cities and AI cities lies in the role of AI. In smart cities [4], AI is merely a technological tool that supports decision-making, while humans remain the final authority. In contrast, in an AI city, AI plays a more advanced role: through the analysis of collected data, it autonomously generates solutions and management proposals.

An AI city represents the integration of an entire AI system into the urban structure. The application of AI enhances the smart city model [5]. AI applied at the urban level can be described as urban AI. Urban AI collects data, processes it, and objectively identifies shortcomings and potential solutions to urban problems. This development leads to the notion of AI urbanism [6], understood as a reconfiguration of urban systems, built space, and lived experience into something new and distinct from previous iterations, a process that remains only partially explored and still poorly defined. An AI city should be able to autonomously gather and process massive volumes of data [5], in other words, all data available to it in order to propose solutions and actions for urban development. The full integration of AI into daily life creates a largely uncharted concept of the city, inferred from current understanding of technology and urban systems across spatial, political, socio-economic, and cultural dimensions. While cities have historically evolved based on functional needs or prevailing ideologies, the uncertain capacities of AI make the necessity and ideology of an AI city difficult to define. AI urbanism and spatial planning are neither linear nor ahistorical but are complex, context-dependent processes shaped by past planning decisions. As such, it destabilizes both the material and immaterial urban fabric [6]. Figure 2 illustrates the differences between smart and AI urbanism in terms of their functions, the role of technology, and its degree of integration. The smart city embodies an ideology of functional improvement in service of residents and administration, echoing modernist principles. By contrast, the AI city reflects a postmodern discourse, questioning AI's capacity for autonomy, embracing plurality and inclusivity, deconstructing power dynamics, and aspiring toward transformative change. Within the AI city, AI operates as a governance system that generates solutions based on contextual data and specific challenges, within boundaries designed to channel its actions toward fairness and ethical responsibility. AI must be responsible, transparent, and autonomous. The outcomes of AI integration will inevitably vary depending on the urban structures to which it is applied, as well as cultural contexts. Since urban development cultures differ across the globe, AI integration will be conditioned by cultural heritage. The use of digital twin technologies is expected to enable AI to evaluate urban environments more effectively. For example, European cities, carrying both the weight of history and a drive for innovation, are likely to preserve their existing

structures as a marker of urban identity while still pursuing transformation into AI cities to enhance the quality of life for their residents. What remains uncertain, however, is whether physical space and the traditional focus of urban planning will diminish in importance, as attention shifts toward optimizing the quality of everyday urban experiences through increasingly sophisticated algorithms and technological solutions.

However, the development of AI is inextricably linked to the urban environment. Transport automation addresses mobility challenges within urban structures, service robots operate in public spaces, social activities are closely tied to urban areas, and even predictive algorithms often determine the locations of criminal activities or market events. AI acts as an agent, an actor or executor [7], which becomes evident through its operations within a web of circumstances and activities, all situated in urban contexts. The development of the urban environment, in turn, depends on these activities, as does the development of AI in relation to the city. Technology does not advance independently of human needs. As Greenfield [7] explains, the purpose of a system is what it does, meaning that a system cannot perform tasks for which it was not designed. A technological system can only function within the scope of its design, so if its output deviates from the intended goal, an error has occurred.

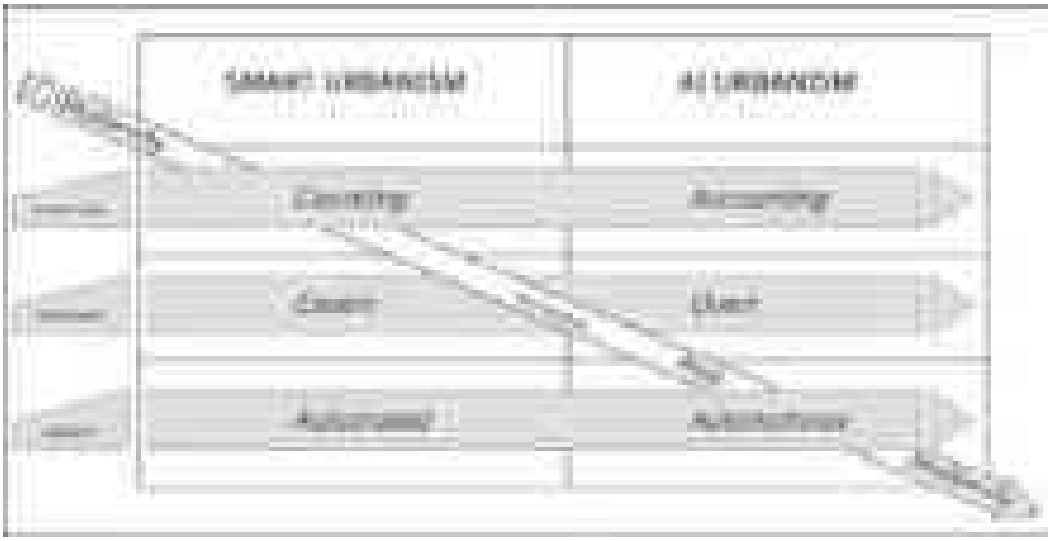


Figure 2 – Comparison of smart urbanism and AI urbanism, source: [6].

Specifically, for AI to govern a city, detailed human programming of the system is required, along with monitoring to minimize errors. Currently, technology cannot create solutions independently, and whether an autonomous system could govern a city remains undefined. To operate effectively within the environment in which humans live and function daily, AI must develop alongside that environment. Its development depends on being fed data from which it can generate solutions. Familiarity with a sector cannot be achieved merely by providing AI with regulations or laws; it must be shown how humans operate within that sector, including common mistakes or biases, and be informed about social actions addressing those issues, such as the work of relevant organizations. Only then can AI establish a reliable database from which it can generate informed solutions or decisions.

3. Theoretical frameworks and recommendations for implementing an Artificially Intelligent city

In 2022, the United Nations Human Settlements Programme—UN-Habitat—published a report titled *Artificial Intelligence and Cities: Risks, Applications, and Governance* [8] (hereinafter referred to as the Report), which serves as a key reference for this topic. UN-Habitat monitors and encourages the development of cities worldwide, aiming to safeguard human rights within the context of emerging technologies that have yet to fully demonstrate their potential. By balancing technological advancement with ethical considerations, the Report provides a foundation for guiding urban progress and achieving inclusive and responsible integration of AI systems into urban environments. The Report is structured as a set of recommendations grounded in human rights principles, the Sustainable Development Goals (SDG) [1], the *New Urban Agenda* [9], *Guiding principles for artificial intelligence in cities* [10] and UNESCO's *Recommendations on the Ethics of Artificial Intelligence* [11]. All of these frameworks are globally recognized documents that uphold human rights and collectively aim to serve the public good. Their recommendations provide guidance for sustainable urban development, particularly in contexts where AI becomes an integral part of the city. Past experiences with AI integration into urban systems offer insights into both positive outcomes and potential unintended consequences. Importantly, AI systems optimized for one local context may not be suitable for another. In other words, unifying AI systems across culturally and value-diverse urban environments may not produce equally effective results if integration depends on factors that differ across regions. Consequently, each local administration should develop its own algorithms, trained on the specific values, social norms, and operational practices of that context. Table 1 presents the contents of the Report. The Sustainable Development Goals associated with each sector illustrate the potential impact of AI on urban life. These objectives indicate that AI's influence on urban life encompasses the development of sustainable intelligent cities, more efficient urban planning and spatial strategies, improved allocation and optimization of resources, and the promotion of inclusive development and equality on a global scale.

Table 1 – Key urban sectors and potential factors across development aspects in achieving the AI city concept, based on UN-Habitat recommendations for AI implementation (sectors 1–7) and additional sectors (a, b), source: author, 2024.

Achieving the SDGs would improve quality of life in cities and provide clear guidelines for AI integration. However, these goals also reveal risks that require careful management. The most pressing concern is data security: while personal data is essential for effective planning, risks of misuse and cyberattacks limit its collection. Reliable, error-free systems are crucial, as is transparency to ensure residents understand AI-driven decisions. Because AI systems are human-made and evolving, errors are inevitable but must be identified and corrected. Uncertainty about AI's full capacities also creates risks of mismanagement, with system failure posing the most serious threat, which is akin to infrastructural collapse. Additional sectors further illustrate AI's potential. Environmental monitoring could enable real-time pollution control, while education could benefit from personalized learning, improved access, and flexible spaces. Together, these applications show AI's promise, but also underline the need for secure, reliable, and ethically guided development.

The integration of AI into a city, and the AI city itself, follows a continuous life cycle with five phases: design, creation, integration, usage, and maintenance (Figure 3). Each phase feeds back into design, shaping the AI system's operational ideology and in-

fluencing the city's evolving functions. An AI city is defined not just by function but by how its systems meet contemporary urban needs, creating new demands for planners' skills. Mapping these phases also clarifies planning fields and key intervention points.

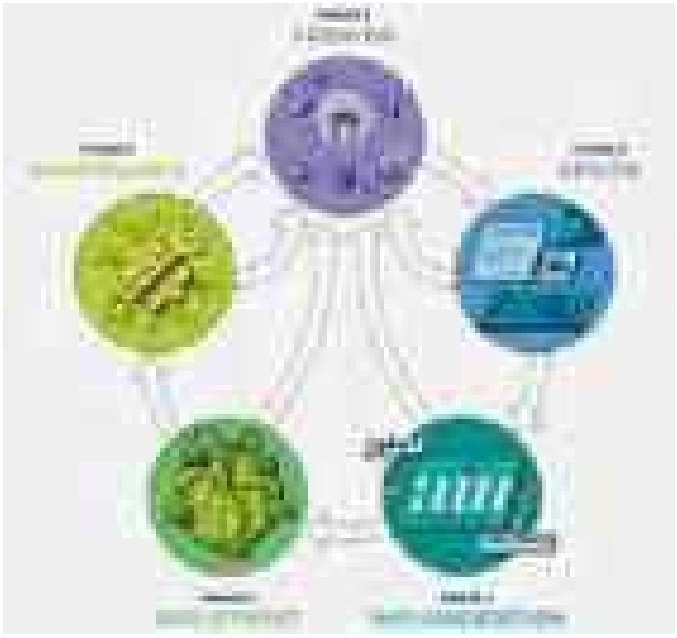


Figure 3 – Artificial Intelligence Lifecycle, source: [8].

Strategies for urban development with AI implementation include recommendations [8] that provide an effective framework for leveraging AI in ways that align with human needs and lifestyles. From the perspective of urban planning and studies, they raise questions about necessary changes and improvements in professional skills. Planning is already extensive in scope, and some recommendations support existing objectives pursued by planners. Implementing AI systems and integrating them into administrative bodies is more complex than simply spatially positioning the necessary technological capacities. Planners' roles also intersect with political and developmental dimensions; they must participate in the implementation of AI within local and national institutions. Conversely, the events, data collection, and processed information generated by AI will provide planners with valuable inputs for designing higher-quality urban environments in the future.

3. Practical applications of Artificial Intelligence in the city

The theoretical framework described in the previous section emerges from the need to establish recommendations for further development. These recommendations are grounded in research on existing phenomena of AI system implementation and integration. Such systems have been present in urban structures for years as isolated experimental interventions, essential for understanding how structured technological apparatuses function within human environments. The presence of similar AI systems

in different contexts indicates the possibility of studying system behaviour depending on the application context. Currently, a large number of households use robots to assist with daily tasks, and AI system implementation in homes has even become a trend, e.g. robotic cleaners, household drones. At first glance, they appear to be simple household devices, yet they are a direct result of AI systems and technological advancement. Urban robots also include delivery robots, which gained popularity during the COVID-19 pandemic in Milton Keynes, UK [6]. Today, the same city employs robotic waiters in restaurants. Interaction with robots in public urban spaces is both engaging and enjoyable for people, while simultaneously allowing robotic algorithms to gather data to improve future performance. Beyond small robots, urban life increasingly relies on software designed for city-specific needs (urban software). These are algorithms that create platforms filled with information through smartphone applications, such as those related to commerce, transport, and social networks. Applications for shopping, ranging from groceries to real estate, or for booking accommodations define urban demand patterns [12]. Transport-focused applications collect and process data from all users, build databases, identify behavioural patterns, and generate predictive models, e.g. Uber [13]. Autonomous transport is emerging as a major objective for urban development as autonomous electric vehicles have already been implemented in various cities. For instance, London Airport has a public transport system to the train station operating as autonomous pods, currently monitored by humans but forming an integrated platform for further advancement. Additionally, Rimac has launched a robot-taxi project set to integrate into the urban fabric of Zagreb. AI-driven vehicles must respond to citizens' needs while simultaneously learning about behaviour within urban structures. In city management, AI is increasingly used as a tool for designing and planning higher-quality public spaces. AI collects vast amounts of data useful for decision-making and establishing guidelines for planners. Such technologies are found in smart urban furniture, which often performs additional functions. For example, street lighting with integrated AI technology and brightness sensors can optimize energy consumption and enhance public safety. Planners can also benefit from data collected through AI personal assistants such as Alexa [14] and Siri [15]. Combining data from both public and private sectors provides a comprehensive platform for informed urban planning. Some cities in China have integrated AI into municipal governance. This required the adoption of legal and planning documents to guide decision-making and future development. Cities have created digital replicas of existing urban structures, so all actions in the digital space have parallel effects in the physical environment. Planned construction is oriented toward creating systems optimized for AI operation. The presence of the aforementioned AI systems and others, along with research on them, shows that future urban development depends not only on humans but also on AI technology and the data it can provide. The accumulation and synthesis of this knowledge with planning expertise will enable the creation of AI cities, with initial examples already emerging.

One prominent example is Neom, a new urban development in Saudi Arabia [16]. Launched in 2017 and financed by the Saudi Public Investment Fund, the name Neom is a portmanteau meaning new future, encompassing multiple interconnected projects forming a cohesive whole. Neom is envisioned as a transformative urban space designed to integrate state-of-the-art technology while promoting sustainability and development. Its components include The Line, Oxagon, Trojena, Sindalah, and Magda, all planned as sustainable projects with minimal environmental impact. Conceptually, Neom sits on the fine line between utopia and dystopia. Its ultimate outcome will only become clear over time through implementation. Currently, Neom represents a collection of architectural dreams and ideologies, as well as an urban planning challenge due to the incompletely defined master plan and the rapid pace of project development (Figure 4).

Figure 4 – Timeline of the Neom Project Development, source: [18].

The central focus of the Neom project is the region of the linear intelligent city, The Line. It has been presented to the public as already planned and designed, accompanied by visual materials depicting its envisioned future. Further development of the idea highlighted the need for additional regions to support the main linear axis. The Line, a linear city 170 km long, 500 m high, and 200 m wide, stretches across three regions of Saudi Arabia: the coastal desert, the mountains, and the high valley, creating an impression of the scale of the space it intersects. Construction conditions and the project's ideology ensure that 95% of the natural environment surrounding the city will remain preserved. Additionally, the project is founded on five pillars of contemporary urban development ideology: technology, community, quality of life, nature, and sustainability [16]. The planned spatial interventions have sparked a cascade of theoretical and practical interpretations regarding the project, as well as future architectural and urban planning initiatives. Since the concept of a linear city is not new, this spatial model has historical precedents (Industrial City of the 1900s, Stalingrad in the 1930s, London in the 1940s, Exodus in the 1970s [17]) and can therefore be compared and interpreted in that context. However, the key difference between The Line and all previous projects lies in the level at which technology and systems are integrated. The Line is an intelligent city governed and maintained by AI, algorithms, software, hardware, and other technological tools. It is on the path to becoming the first fully AI-driven city in the world.

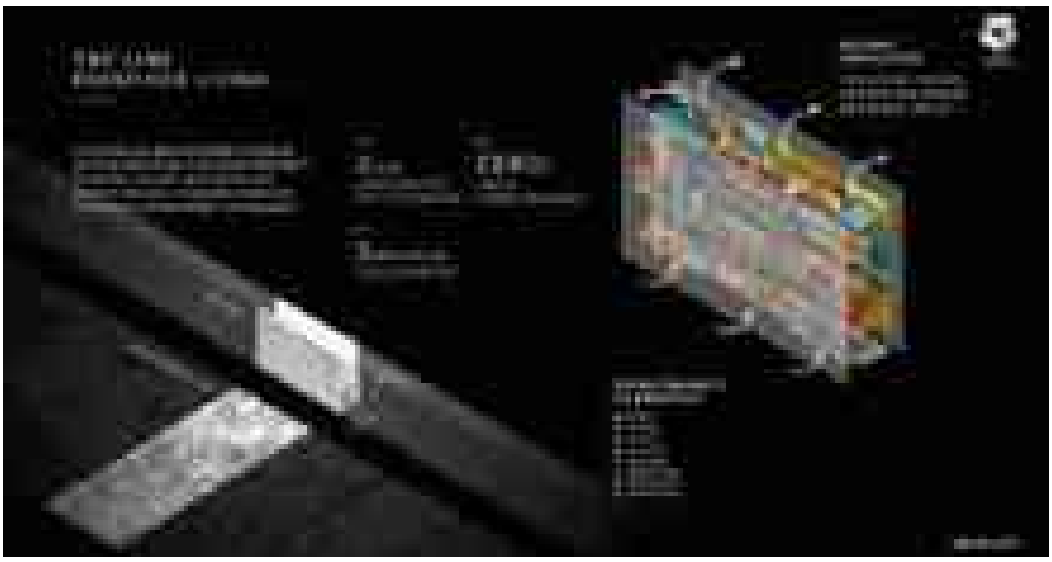


Figure 5 – Concept of the modules that make up The Line, source: [19].

The purpose of integrating AI as a management and executive system is precisely to achieve a sustainable city and its development, as well as to create the first city that, as an urban structure, will improve the quality of life of its inhabitants by taking over simple aspects of daily life. The project consists of a series of modules arranged within two elongated buildings that define a central street and are interconnected along their entire length. The modules contain the essential functions of any city and urban structure: housing, business, retail, healthcare, cultural, hospitality facilities, and spaces for leisure activities (Figure 5), all within immediate accessibility to every resident, following the five-minute circle concept, similar to the 15-minute neighbourhood idea. This spatial infrastructure is currently under construction, with completion planned for 2030, making it one of the most ambitious projects today. The core of The Line's operation is the technology embedded in each key sector of this urban environment. Positioning technology as the foundation of future city management and maintenance is a process that fundamentally changes previously known ways of urban life. Although many technologies have long been integrated into some aspects of life, they have never been central elements, but rather tools that accelerate and simplify specific, well-defined tasks. Here, technology and AI are interwoven throughout the urban structure from the construction phase, based on the concepts [20-23]:

- **Renewable energy.** The city will be powered by electricity from renewable sources such as solar, wind, and hydrogen, aiming to reduce carbon emissions and footprint.
- **Modular construction.** Prefabricated building components manufactured off-site and assembled on-site, reducing waste, speeding up construction, and ensuring quality.
- **3D printing.** Technology to construct certain buildings with high precision and minimal waste, allowing innovative architectural and construction solutions.
- **Augmented Reality (AR).** Technology that facilitates planning, project management, ad hoc decision-making, and visualization of different solutions, identified problems, and project improvements.
- **Robots and automated systems.** Robots will perform tasks such as assembling structural elements, improving productivity and workplace safety. Automated systems will reduce labour requirements and speed up construction.
- **Artificial intelligence.** AI will serve as a technological tool for urban development from planning to system maintenance, resulting in optimized costs and procurement.
- **Drones.** Monitoring construction and capturing video for remote supervision, increasing safety and enabling easier schedule tracking.

Integration of technologies that enable AI to manage the city involves embedding the following [20-25]:

- **Smart infrastructure.** Urban infrastructures connected via sensors and technology for monitoring, supervision, and resource management. This includes smart grids for energy, resource, and waste management.

- **High-speed transit system.** Infrastructure for rapid travel across The Line, enabling transit from one end to the other in 20 minutes (exceptionally fast for a 170 km length).
- **Zero-gravity urbanism.** Vertical spatial distribution of functions to minimize land occupation while maximizing movement speed within modules.
- **Renewable energy.** The city will be supplied with energy from sustainable sources such as solar, wind, and hydrogen.
- **Augmented Reality (AR) and Virtual Reality (VR).** Technologies that will enhance education, work, and entertainment.
- **Artificial intelligence.** Integration of AI into everyday life through sectors such as healthcare, households, and automated urban services. AI systems will manage the city and perform tasks such as energy optimization, predictive maintenance, and overall service improvement.
- **Robots.** Daily tasks, from grocery delivery and logistics to cleaning and household chores, will be handled by robots, freeing residents from these duties.
- **Autonomous vehicles.** Autonomous public electric transport will enable movement throughout The Line, reducing the need for private cars and mitigating traffic congestion. These vehicles will be aligned with the city's intelligent structure, evolving according to residents' needs.
- **City digital twin.** A digital replica of the city will serve as the primary system for developing AI during monitoring and comprehensive city management, supporting future planning. The digitalized structure combined with AI provides the basis for planners, evaluators, governing bodies, and urban administration.

In considering the selected technologies for constructing and managing The Line, it is essential to be aware of the current state of AI development. This city is fundamentally designed to be an urban environment that, once the capabilities are reached, will be managed AI. Until then, the technology developed up to the moment of implementation will evolve alongside the urban tissue and structure. The Line is an ambitious project and a demonstration of technological power and potential, and if successful, it could serve as a considerate model for the environment and a benchmark for future urban development. Even if a fully autonomous AI city is not achievable, the interaction and presence of technological systems within human environments is expected. Certainly, the realization of an urban environment project like The Line provides an urban structure within which AI technology can adapt and integrate more easily and rapidly, offering insights useful for existing urban environments worldwide. Likewise, AI will be integrated into urban spaces in a manner that prioritizes human development—serving human needs, for the benefit of humans, and with humans at the centre.

5. Conclusion

The examined aspects of the topic demonstrate how AI can be integrated into cities to create AI-driven urban environments, highlighting both the complexity and potential risks involved in achieving sustainable urban spaces and future development. While The Line project has been a focal point of public attention for some time, the need to improve existing urban fabrics should not be overlooked. The approach to planning an AI city must be interdisciplinary, with planners required to expand their skill sets. Collaboration among diverse professionals—developers, engineers, planners, architects, sociologists, political scientists, lawyers, economists, and others—is essential to achieve project goals. Their varied expertise enables experimental interventions in virtual representations of urban structures. Additionally, these digital twins provide feedback loops, allowing data collection for more informed decision-making. Decisions are currently made by humans, but with future AI development, these responsibilities are expected to be gradually assumed by AI systems. A key conclusion of this research is the necessity of localizing AI algorithms to ensure that integration into existing urban structures does not disrupt the identity of the local context. The Sustainable Development Goals, outlined in the 2015 United Nations declaration and reinforced by the 2022 UN Habitat urban development program, provide a solid framework for planning the development of AI cities. Nevertheless, the unknown potential of AI underscores the importance of human oversight until such systems can be reliably considered autonomous and trustworthy.

Literature

[1] UN General Assembly: *"Transforming our world: the 2030 Agenda for Sustainable Development"*, A/RES/70/1, 21, 2015, https://www.refworld.org/legal/resolution/unga/2015/en/111816 [accessed: June 2024].

[2] Merriam-Webster. (n.d.): *"Artificial intelligence"*, In Merriam-Webster.com dictionary, https://www.merriam-webster.com/dictionary/artificial%20intelligence [accessed: May 2024].

[3] Yigitcanlar, T., Desouza, K. C., Butler, L., Roozkhosh, F.: *"Contributions and Risks of Artificial Intelligence (AI) in Building Smarter Cities: Insights from a Systematic Review of the Literature"*, Energies 13, 2020, no. 6: 1473, https://doi.org/10.3390/en13061473.

[4] Allam, Z., Dhunny, A. Z.: *"On Big Data, Artificial Intelligence and Smart Cities"*, Cities, 2019, 89. 80-91, https://doi.org/10.1016/j.cities.2019.01.032.

[5] Szpilko, D., Jimenez Naharro, F., Lăzăroiu, G., Nica, E., de la Torre Gallegos, A.: *"Artificial intelligence in the smart city — a literature review"*, Engineering Management in Production and Services, 2023, 15(4), 53-75, https://doi.org/10.2478/emj-2023-0028.

[6] Cugurullo, F., Caprotti, F., Cook, M., Karvonen, A., Mcguirk, P., Marvin, S.: *"Artificial Intelligence and the City: Urbanistic Perspectives on AI"*, Routledge, London, New York, 2023, https://doi.org/10.4324/9781003365877.

[7] Greenfield, A.: *"Radical Technologies: The Design of Everyday Life"*, Verso, London, New York, 2017.

[8] UN Habitat & Mila: *"AI & Cities: Risks, Applications and Governance"*, UN Habitat, 2022, https://unhabitat.org/ai-cities-risks-applications-and-governance [accessed: May 2024].

[9] United Nations: *"New Urban Agenda"*, 2017, ISBN: 978-92-1-132731-1.

[10] United for Smart Sustainable Cities: *"Guiding principles for artificial intelligence in cities"*, Published in Switzerland Geneva, 2024, ISBN: 978-92-61-38151-6.

[11] United Nations Educational, Scientific and Cultural Organization: *"Key facts: UNESCO's Recommendation on the Ethics of Artificial Intelligence"*, 2023 (Adopted on 23 November 2021), France.

[12] Cugurullo, F.: *"Urban Artificial Intelligence: From Automation to Autonomy in the Smart City"*, Frontiers in Sustainable Cities, 2020, 2:38. https://doi.org/10.3389/frsc.2020.00038.

[13] Application *Uber*. https://www.uber.com/ [accessed: June 2024].

[14] Application *Alexa* https://developer.amazon.com/en-US/alexa [accessed: June 2024].

[15] Application *Siri* https://www.apple.com/siri/ [accessed: June 2024].

[16] Musset, A.: *"Neom et The Line (Arabie saoudite) utopie futuriste ou cauchemar urbain?. L'Information géographique"*, 2023, 87, 139-161. https://doi.org/10.3917/lig.871.0139.

[17] Batty, M.: *"The Linear City: illustrating the logic of spatial equilibrium"*, Computational Urban Science, 2022, 2. http://dx.doi.org/10.1007/s43762-022-00036-z.

[18]	*NARA SPACE Technology* website, https://ep.naraspace.com/post/the-dream-city-project_will-neom-city-really-be-realized [accessed: June 2024].
[19]	*NARA SPACE Technology* website, https://ep.naraspace.com/post/the-dream-city-project_will-neom-city-really-be-realized [accessed: June 2024].
[20]	*NEOM* website, https://www.neom.com/en-us/regions/theline [accessed: June 2024].
[21]	*"HRH Crown Prince Mohammed Bin Salman Announces Designs for The Line, The City Of The Future In Neom"*. (2022, July 25) NEOM website, https://www.neom.com/en-us/newsroom/hrh-announces-theline-designs [accessed: May 2024]. [21] NEOM website, The Line Vision, https://thelinevision.com/ [accessed: May 2024].
[22]	Illankoon, K.: *"Revolutionizing Construction Technologies: The Line (NEOM)"*, Construction Business News, 2023, https://www.cbnme.com/news/revolutionizing-construction-technologies-the-line-neom/ [accessed: June 2024].
[23]	Farag, A.A.: *"The Story of NEOM City: Opportunities and Challenges"*, In: Attia, S., Shafik, Z., Ibrahim, A. (eds) New Cities and Community Extensions in Egypt and the Middle East. Springer, Cham, 2019, https://doi.org/10.1007/978-3-319-77875-4_3.
[24]	Dr. Refaei, Mohamed Diaa Mohamed.: *"AI Governance In Neom City: Exploring Legal Personality For Smart Robots And A Framework For Ethical Innovation"*, Educational Administration: Theory and Practice, 2024, 30(5), 2569-2576. https://doi.org/10.53555/kuey.v30i5.2443.
[25]	Ashehri, R.: *"Governance Of Artificial Intelligence In Ksa (Neom As A Model)"*, International Journal of Advanced Studies, 2019, 9. 64, https://doi.org/10.12731/2227-930X-2019-1-64-81.

Regenerative planning and territorial transitions: Reimagining wastelands for circular urban futures

Elena Ferraioli[1]

1 Ms., Iuav University of Venice
eferraioli@iuav.it

Abstract

The accelerating climate crisis, coupled with fragmented urbanization and unsustainable land use, challenges traditional planning paradigms and calls for systemic and regenerative approaches. This research introduces the concept of *"planning for circularity"* as a strategic framework to reinterpret wastelands—not as marginal voids, but as active components of a new territorial metabolism.

Through the integration of circular economy, urban metabolism, and circular soil management, the study explores how planning can transform spatial fragmentation and land abandonment into opportunities for ecological and socio-economic rebalancing. Rather than proposing fixed solutions, it offers a conceptual and operational rethinking of territorial planning based on adaptive, systemic, and place-sensitive approaches.

The research develops along two complementary directions. The first is a critical analysis of the legacy of linear planning and the emergence of circular and metabolic paradigms, advocating a shift from expansionist logics to spatial re-integration. The second consists of a comparative reading of six European experiences (Amsterdam, Rotterdam, Brussels, London, Stockholm, and Prato), focusing on how cities are experimenting with regulatory tools, planning strategies, and governance mechanisms to address the regeneration of disused spaces.

What emerges is that circular regeneration does not unfold spontaneously but depends on a set of enabling conditions—normative flexibility, strategic visioning, integrative planning tools, and soil-sensitive approaches—that allow urban voids to be re-embedded within dynamic territorial processes. These practices contribute to advancing a regenerative planning culture aligned with key Sustainable Development Goals, including SDG 11 (Sustainable Cities), SDG 12 (Responsible Consumption), SDG 13 (Climate Action), and SDG 15 (Life on Land).

Ultimately, *planning for circularity* is proposed not merely as a technique for managing land or resources, but as a transformative orientation of planning itself—capable of reconfiguring the relationship between space, use, and value, and of opening new paths toward equitable and sustainable urban futures.

Keywords

Regenerative planning; wastelands transformation; circular and metabolic approaches; soil management; innovative policy instruments.

1. Introduction: Urban disruption and the urgency of territorial rethinking

In an era marked by unprecedented environmental degradation, resource exhaustion, and spatial fragmentation, cities and territories face mounting pressure to rethink their development trajectories. The legacy of linear and extractive growth models has generated discontinuous urban fabrics, degraded soils, and an accumulation of residual spaces—commonly referred to as wastelands—that embody both the structural inefficiencies of traditional planning and the failure to address urban metabolism in a systemic way. Historically, urban planning has reinforced these dynamics by focusing on spatial expansion and land-use optimization, often neglecting the interdependence between ecological processes and territorial configurations. This has resulted in a proliferation of underutilized, abandoned, and marginal spaces, which, rather than being treated as mere voids, can be reframed as strategic assets for circular urban transitions. Reimagining these wastelands as catalytic spaces demands a shift in perspective—one that embraces planning as a regenerative and integrative practice capable of governing flows, managing ecological limits, and reconfiguring socio-territorial relations. Within this evolving framework, the integration of circular economy, urban metabolism, and circular soil management emerges as a key strategy for transforming both the material and spatial dimensions of contemporary urbanism. These three paradigms, while distinct in their origins, converge in their call for resource loops, territorial resilience, and the reactivation of latent values embedded in space. Yet their operational uptake within planning remains fragmented, often hindered by regulatory inertia, disciplinary silos, and the lack of long-term visions. This paper aims to bridge this gap by exploring how spatial planning can embed circular principles to unlock regenerative potential, particularly in relation to soil and wastelands. Through a critical synthesis of theoretical paradigms and a comparative analysis of European case studies, the paper addresses three interrelated research questions: (1) How can planning integrate circular economy, urban metabolism, and soil management in a coherent and transformative way? (2) Which policies, tools, and practices are needed to implement regenerative governance strategies for wastelands? (3) What lessons can be drawn from applied cases to inform scalable and context-sensitive approaches to planning for circularity?

2. Beyond linear growth: Circularity as a guiding principle for spatial transitions

The dominance of linear development models—based on extract-produce-consume-dispose logics—has profoundly shaped urbanization patterns, driving ecological degradation and fostering unsustainable spatial configurations. Land consumption, waste generation, and infrastructural obsolescence have become defining features of urban and peri-urban territories. In this context, circularity emerges as a strategic principle for rethinking territorial development and addressing interconnected ecological, social, and resource crises.

Circularity calls for a systemic reconfiguration of planning, moving beyond efficiencyoriented interventions to establish new relationships between urban systems and ecological processes. This includes rethinking production and consumption patterns while also redefining spatial organization, governance frameworks, and policy tools. Despite the growing relevance of circular economy (CE) and urban metabolism (UM), their territorial application remains fragmented. CE focuses on closing material loops and enhancing productivity [1,2,3], while UM highlights interdependencies between human activity and biophysical flows [4,5]. Both have evolved into normative planning frameworks capable of reshaping socio-ecological urban metabolism [6].

Applied to spatial planning, CE and UM support new imaginaries—such as "circular development" [7]—that promote cross-sectoral, place-based strategies linking infrastructure design, ecological regeneration, and inclusive governance. Space itself must be reinterpreted as an active agent in circular transitions: not a passive container, but a medium that shapes and mediates flows and practices [8,9]. Spatial circularity requires engagement with these socio-technical and symbolic configurations to reveal the entanglements between infrastructures, land use, and everyday practices.

Peri-urban areas are particularly strategic in this regard, functioning as interfaces for material recovery, ecosystem regeneration, and spatial experimentation. These areas often host wastelands—marginal, residual, or neglected spaces with strong regenerative potential. Through circular strategies such as decentralized infrastructures or nature-based solutions, planning can reimagine these zones as adaptive, multifunctional landscapes [10,11].

Yet, moving from experimentation to systemic change remains challenging. Regulatory silos, political short-termism, and institutional inertia hinder the consolidation of circularity within mainstream planning [12]. Addressing these barriers requires a transformative agenda rooted in local knowledge, institutional innovation, and participatory governance. Aligning circularity with spatial justice, stewardship, and policy integration reinforces planning's central role in shaping regenerative transitions [13,14], while advancing global goals such as SDGs 11, 12, and 13.

Ultimately, circularity must be understood as a dynamic and adaptive principle that challenges conventional planning rationales and enables plural, future-oriented visions. Through the integration of CE, UM, and regenerative land practices, planning can reshape territories as evolving socio-ecological systems, capable of learning and adapting in the face of uncertainty.

3. Wastelands as strategic interfaces for regeneration

In contemporary urban and territorial systems, *wastelands* emerge as ambiguous and evolving spaces, both materially and conceptually. While the term may appear self-explanatory, the literature reveals a remarkable variety of definitions and interpretations. Over fifty different terms have been used in urban studies to describe abandoned, marginal, or transitional spaces [15,16,17]. Scholars broadly agree in framing wastelands as byproducts of urbanization, industrial decline, and territorial obsolescence, yet no shared operational definition exists [18,19,20].

This conceptual diversity spans multiple disciplines. Some definitions highlight wildness, informality, or the lack of planned function [21]; others emphasize the dual meaning of *waste* as both "unusable" and "improperly used" [20]. This semantic tension

has led to a rich vocabulary— *terrain vague* [22], *derelict land* [23], *drosscape* [18], *wastescapes* [24], along with terms like liminal spaces, edgelands, or industrial ruins—each expressing specific spatial, temporal, ecological, or socio-political nuances.

From a planning perspective, three conceptual frameworks are especially useful in capturing this complexity. Kevin Lynch (1990) [19] describes wastelands as unavoidable elements of urban processes—vacant, degraded, or stigmatized spaces reflecting cycles of growth and decline. Ignasi de Solà-Morales (1995) [22] highlights the latent potential of undefined spaces in his concept of *terrain vague*. Alan Berger (2006) [18] introduces *drosscape* to depict sprawling zones of spatial waste produced by consumer-driven development, distinguishing between waste, wasted, and wasteful spaces.

Building on these contributions, this research proposes a revised taxonomy that embraces the **relational, processual, and contextual** character of wastelands. Two main categories are identified:

(1) *Underused spaces*, such as partially occupied industrial buildings or vacant parking lots;
(2) *Abandoned spaces*, including contaminated or decommissioned lands in need of remediation.

These can be further refined into:

- **Functional wastelands**, resulting from the collapse or withdrawal of productive uses;
- **Administrative wastelands**, shaped by legal or regulatory barriers;
- **Transitional wastelands**, in states of partial deprogramming or awaiting redefinition.

Rather than a rigid classification, this framework serves as a dynamic lens to interpret spatial discontinuities and the socio-economic and planning processes behind them. Wastelands gain meaning only when situated within broader spatial and temporal cycles—investment, disinvestment, and reinvention.

Additionally, three paradigms guide the reinterpretation of wastelands in planning and design:

- The **anthropocentric** perspective, which sees wastelands as socio-cultural constructs, tied to memory, identity, or marginalization;
- The **ecological** perspective, inspired by Clément's *Third Landscape* (2004) [25] emphasizing spontaneous biodiversity and ecological potential;
- The **circular** perspective, which reframes wastelands as metabolic nodes aligned with principles of reuse, adaptation, and regeneration [26].

Together, these perspectives contribute to redefining wastelands not as failures or voids, but as **strategic interfaces**—thresholds of transformation. Within regenerative planning frameworks, they offer fertile ground for innovation, resilience, and circular territorial transitions.

4. Learning from practice: European insights and scalable innovations

4.1. Planning for circularity: Policy gaps and emerging levers

In the last decade, circularity has become a central reference in European urban agendas, often framed as a solution to resource depletion, environmental degradation, and spatial fragmentation. However, despite its conceptual appeal, circularity still struggles to consolidate itself as a systemic planning paradigm. Existing policies often operate in silos, focusing on sectoral waste reduction rather than promoting spatial and governance innovation. While the EU Circular Economy Action Plan and the Urban Agenda for the EU have provided valuable frameworks, the integration of circularity into spatial planning practices remains fragmented and experimental. Nonetheless, several levers are emerging at the intersection of planning, environmental regulation, and innovation policies. Regulatory tools (such as green zoning codes, reuse-oriented building standards, and soil remediation laws) are increasingly combined with fiscal incentives, circular procurement schemes, and collaborative planning instruments. In some urban contexts, planning authorities are beginning to redefine land use strategies by linking material circularity to spatial regeneration objectives. Moreover, experimental platforms such as Living Labs and circular hubs are testing new approaches to multi-actor coordination and territorial activation, highlighting the importance of adaptive governance, place-specific design, and long-term visioning.

4.2. Translating circularity into spatial practice: Tools and governance models

While policy frameworks offer a discursive foundation, the real shift occurs when circularity becomes embedded in spatial instruments and territorial processes. Cities like Rotterdam, Amsterdam, and Brussels are progressively integrating circular goals into urban plans, land policies, and redevelopment schemes, mobilizing different types of tools. Strategic masterplans articulate long-term visions that link decarbonization, land reuse, and circular economy clusters. Regulatory instruments—such as zoning overlays, bonus mechanisms for deconstruction, and material passports—are being adjusted to encourage the reuse of buildings and infrastructures. Meanwhile, collaborative design tools—such as scenario-based planning, adaptive roadmaps, and public-private innovation pacts—help align spatial transformation with ecological and economic regeneration.

Governance models play a crucial role in this process. Rather than relying solely on top-down planning, successful initiatives tend to activate hybrid coalitions involving public institutions, knowledge actors, private developers, and civil society. These coalitions often coalesce around shared goals: reducing land consumption, revitalizing derelict areas, and fostering new economies of reuse and repair. Circularity

is thus translated into spatial practice not through a fixed blueprint, but through a dynamic configuration of instruments, actors, and adaptive strategies. This multidimensional operationality suggests that planning for circularity is not a separate domain, but a transversal logic capable of reorienting planning itself (see *Figure 1*).

Figure 1 – Enabling conditions, tools and operational models for regenerative territorial transitions. Author's elaboration.

4.3. European case insights: Comparative patterns and operational lessons

The comparative analysis of six European cities—Stockholm, Amsterdam, Rotterdam, London, Brussels, and Prato—offers concrete insights into how circularity can be operationalized in diverse urban contexts. These cases were selected for their pioneering approaches to brownfield regeneration, resource efficiency, and integration of circular principles into spatial governance While each city follows a specific trajectory, some recurring patterns emerge (see *Table 1*).

These six cities were selected through a qualitative case-study approach inspired by policy analysis and grounded in empirical observation. Although not designed as a strict comparative framework—due to the heterogeneity of legal, planning, and institutional systems—they were analyzed through a shared analytical grid structured around seven operational dimensions: (i) timeframe and decision-making context; (ii) planning and governance tools; (iii) coordination and collaboration mechanisms; (iv) regulatory instruments; (v) economic and fiscal tools; (vi) technicaloperational instruments; (vii) enabling factors and contextual drivers.

The analysis relied on multiple data sources, including planning documents, urban strategies, policy reports, academic literature, site visits, and informal testimonies, particularly in the Dutch, English, and Italian contexts. This triangulation of sources allowed for the identification of crosscutting patterns, as well as city-specific configurations of circular regeneration practices.

Stockholm and Amsterdam exemplify strong alignment between circular policies and landuse planning, often supported by material flow analyses and life-cycle-based urban strategies. Rotterdam and London stand out for their focus on industrial ecology and the reconfiguration of port areas into circular innovation districts. Brussels combines

strong regulatory instruments with pilot programs for community-led reuse, while Prato demonstrates how even mid-sized cities can activate circularity through targeted actions in textile districts and underused industrial zones. Across all cases, planning instruments are most effective when embedded within broader institutional frameworks and accompanied by enabling conditions—such as legal flexibility, multi-level governance, and local capacity building.

However, the analysis also reveals limitations. In some contexts, circularity remains confined to symbolic projects or marginal spaces, generating what could be defined as a "circularity fix": the rhetorical appropriation of sustainability goals without systemic impact. To overcome this risk, cities must embed circularity into mainstream planning, transforming it from a design trend into a guiding rationale for territorial transition. This implies fostering integrated spatial visions, long-term land strategies, and governance models that are capable of transforming residual spaces—particularly wastelands—into strategic assets for a regenerative urban future.

Table 1 – Governance and planning tools to support circular regeneration and the planning for circularity paradigm across European case studies. Author's elaboration.

Category	Subcategory	Description	Stockholm	Amsterdam	Rotterdam	London	Bruxelles	Prato
Levers	Regulations	Rules to guide circularity	X	X	X	X	X	X
	Financial incentives	Subsidies and fiscal tools for the transition		X	X	X		X
	Circular procurement	Tenders and circular procurement requirements	X	X		X		X
	Capacity building	Empowerment of actors, networks, and competencies	X	X	X	X	X	X
Tools	Territorial strategies and visions	Strategic plans, urban visions	X	X	X	X	X	X
	Urban planning instruments	Zoning, regulations, permits	X	X	X	X	X	X
	Collaborative decisionmaking processes	Co-design, publicprivate platforms	X	X	X	X	X	X
	Operational support tools	Indicators, GIS, monitoring tools	X	X	X	X	X	X
Contextual Factors	Territorial model	Eco-district or experimental configuration	X	X	X		X	X
	Governance and land ownership	Ownership, access, land management	X	X	X	X	X	X
	Risks of instrumentalisation	Circularity fix, green gentrification	X	X	X	X	X	X

5. Conclusion: Toward a shared agenda for regenerative planning

The transition toward circular development models must be understood not as a mere optimization of resources, but as a structural transformation of how cities manage space, material flows, and socio-environmental dynamics. This shift directly contributes to the implementation of several Sustainable Development Goals (SDGs), notably SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), by promoting circular economies, reducing land take, and enhancing adaptive reuse of urban spaces. Regenerative planning reframes urban systems as evolving metabolisms, where soil, buildings, andinfrastructures are not static assets but dynamic elements subject to reuse, adaptation, and reintegration. However, deeply entrenched planning paradigms still rely on linear, efficiency-driven logics that inhibit the emergence of circular practices. Wastelands—underused or derelict spaces— are symptomatic of these rigidities yet also represent latent opportunities for spatial and economic innovation. As shown by the cases of Amsterdam, Brussels, Stockholm, and Prato, enabling circular regeneration requires regulatory flexibility, long-term land strategies, and governance frameworks that align urban planning with socio-ecological goals.

A shared agenda for regenerative planning must go beyond sectoral recycling policies, embedding circularity as a foundational principle within territorial development. This entails rethinking land governance, overcoming speculative dynamics, and expanding the scope of reuse to include a wide range of neglected spaces—from industrial areas to vacant public facilities. Planning, in this sense, becomes a catalyst for urban transition: a tool not just for regulating land use, but for enabling circular economies, fostering resilience, and guiding cities toward a sustainable and adaptive future.

Literature

[1] Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production, 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

[2] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

[3] Kirchherr, J., Reike, D., & Hekkert, M. (2023). Revisiting circular economy definitions: A systematic review of 221 definitions. Resources, Conservation and Recycling, 181, 106112. https://doi.org/10.1016/j.resconrec.2022.106112

[4] Kennedy, C., Pincetl, S., & Bunje, P. (2010). The study of urban metabolism and its applications to urban planning and design. Environmental Pollution, 159(8–9), 1965–1973. https://doi.org/10.1016/j.envpol.2010.10.022

[5] Lucertini, G., & Musco, F. (2020).Circular urban metabolism framework. OneEarth, 2(2), 138–142.

[6] Athanassiadis, A., and Kampelmann, S. (2021). "Opportunities and Limits of Circular Economy as Policy Framework for Urban Metabolism," in A Research Agenda for Urban Metabolism. Editors S. Barles and P. Marty.

[7] Williams, J. (2020). The Role of Spatial Planning in Transitioning to Circular Urban Development. Urban Geogr. 41, 915–919. doi:10.1080/02723638.2020.1796042

[8] Corboz, A., 1998. Il territorio come palinsesto. In P. Viganò & S. Bernardo, eds. Ordine sparso: saggi sull'arte, il metodo, la città e il territorio. Urbanistica Franco Angeli editore, pp. 185–6.

[9] Bahers, J. B., Durand, M., & Claveau, F. (2022). Urban metabolism: New perspectives on resource flows in cities. Ecological Modelling, 468, 109918. https://doi.org/10.1016/j.ecolmodel.2022.109918

[10] Amenta, L., & Lucertini, G. (2019). Urban metabolisms and circular economy interrelations. Analysing
three examples of EU-funded projects. Bollettino del Centro Calza Bini, 19(1), 185–210.

[11] Tapia, C. (2021). Spatial planning for regenerative circularity: Bridging resource flows and local dynamics. Regional Studies, 55(7), 1103–1120. https://doi.org/10.1080/00343404.2021.1905053

[12] Williams, J. (2019). Circular Cities. Urban Stud. 56, 2746–2762. doi:10.1177/0042098018806133

[13] Drobnik, T., Schwaab, J., and Grêt-Regamey, A. (2020). Moving towards Integrating Soil into Spatial
Planning: No Net Loss of Soil-Based Ecosystem Services. J. Environ. Manage. 263, 110406. doi:10.1016/j.jenvman.2020.110406

[14] Verga GC and Khan AZ (2022) Space Matters: Barriers and Enablers for Embedding Urban Circularity Practices in the Brussels Capital Region. Front. Built Environ. 8:810049. doi: 10.3389/fbuil.2022.810049

[15]	Hall, M.C., 2013. The ecological and environmental significance of urban wastelands and drosscapes. In M. J. Zapata & M. C. Hall, eds. Organising waste in the city. Bristol: Policy Press, pp. 21–40.
[16]	Marini, S., 2010. Nuove terre: architetture e paesaggi dello scarto. Quodibet, ed., Macerata.
[17]	Gandy, M., 2013. Marginalia: Aesthetics, Ecology, and Urban Wastelands. Annals of the Association of American Geographers, 103(6), pp.1301–1316.
[18]	Berger, A., 2006. Drosscape: wasting land urban America Princeton., Princeton Architectural Press, New York.
[19]	Lynch, K., (1990). Wasting away M. Southworth, ed., New York: Random House.
[20]	Di Palma, V., 2014. Wasteland: A History.Yale University Press., Yale
[21]	Gandy, M., 2013. Marginalia: Aesthetics, Ecology, and Urban Wastelands. Annals of the Association of American Geographers, 103(6), pp.1301–1316.
[22]	De Solà-Morales, I., 1995. Terrain vague. The MIT Press,Cambridge, Massachusetts, pp.118–123.
[23]	Oxenham, J.R., 1966. Reclaiming derelict land. F. and Faber, ed., London
[24]	Amenta, L., Van Timmeren, A. (2018). Beyond wastescapes: Towards circular landscapes. Addressing the spatial dimension of circularity through the regeneration of wastescapes. Sustainability, 10(12), 4740.
[25]	Clément, G., (2004). Manifeste du Tiers paysage. Editions Jean-Michel Place, Paris.
[26]	Viganò, P., 2013. Viaggio in Italia. La costructione di un racconto. In S. Marini & V. Santangleo, eds. Viaggio in Italia. Roma: ARACNE editrice S.r.l., pp. 15–19.

Strengthening resilience to floods in Montenegro: A review of legislation, strategies, and EU integration

Ivana Ćipranić[1]

Marija Jevrić[2]

Milena Ostojić[3]

Olga Ćalasan[4]

Goran Sekulić[5]

1	Associate professor, Faculty of Civil Engineering, University of Montenegro *ivanac@ucg.ac.me*
2	Associate professor, Faculty of Civil Engineering, University of Montenegro *marijaj@ucg.ac.me*
3	3 Teaching assistant, Faculty of Civil Engineering, University of Montenegro *milenao@ucg.ac.me*
4	Teaching assistant, Faculty of Civil Engineering, University of Montenegro *olgac@ucg.ac.me*
5	Full professor, Faculty of Civil Engineering, University of Montenegro *sgoran2000@gmail.com*

Abstract

In recent decades, Montenegro has experienced an increasing frequency and severity of flooding events, raising concerns about the growing impact of climate change on hydrological risks in the region. Montenegro has recently faced an increasing frequency and intensity of floods, a trend strongly influenced by the impacts of climate change. This paper provides an overview and analysis of the national legislative and strategic framework for flood risk management, with particular reference to the EU Floods Directive (2007/60/EC), which sets out the principal requirements for the assessment and management of flood risks within the European Union. The paper examines how Montenegro has transposed these requirements into its legal system, focusing on the Law on Waters, the Rulebook on the detailed content of the preliminary flood risk assessment and flood risk management plan, the Law on Hydrometeorological Service, the Law on Hydrographic Services, and the Law on Protection and Rescue.

In addition, the analysis reviews strategic documents that address disaster risk reduction and climate adaptation, including the National Strategy for Emergency Situations, the National Climate Change Strategy until 2030, the Water Management Strategy 2016–2035, and the National Strategy for Sustainable Development until 2030. These instruments collectively outline measures for prevention, preparedness, response, and long-term resilience building.

Keywords

Floods, climate change, legislation, strategies, risk management

1. Introduction

This paper encompasses an analysis of the main national legislative acts, as well as Directive 2007/60/EC [1] on the assessment and management of flood risks, which represents the EU's overarching framework document in this field. To provide a comprehensive legal basis, the review includes all relevant primary and secondary legislation of Montenegro, together with other national policy documents that, while not formally part of the legislative framework, play an important role—such as the National Plan for Flood Protection and Rescue [2].

The following documents are examined in greater detail in the subsequent chapters:

- The Floods Directive (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007, on the assessment and management of flood risk) [1];
- The Rulebook on the detailed content of the preliminary flood risk assessment and the flood risk management plan ("Official Gazette of Montenegro," No. 69/15) [3];
- Legislative acts: the Law on Waters [4]; the Law on Hydrometeorological Services [5]; the Law on Hydrographic Services [6]; the Law on Protection and Rescue [7];
- Strategic documents: the National Strategy for Emergency Situations [8]; the National Climate Change Strategy until 2030 [9]; the Water Management Strategy for the period 2016–2035 [10]; the National Strategy for Sustainable Development until 2030 [11].

2. The Floods Directive

The Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, establishing a framework for Community action in the field of water policy, requires the development of river basin management plans for each water district in order to achieve good ecological and chemical status and to contribute to reducing the impacts of floods. The purpose of this Directive is to establish a framework for assessing and managing flood risks with the aim of reducing their adverse consequences on human health, the environment, cultural heritage, and economic activity [1].

The Directive—commonly referred to as the "Floods Directive"—obliges EU Member States to map flood-prone areas, assess risks to property and populations in affected zones, and define appropriate and coordinated measures for reducing these risks. It also requires that the public be given access to information on flood risks and the related measures, thereby strengthening transparency and public participation in planning processes. Additionally, Member States must ensure practical coordination of flood risk management within international river basins, including with non-EU countries such as Montenegro, in a spirit of solidarity that avoids actions likely to increase risks in neighboring states. The Directive further emphasizes the need to take climate change processes and sustainable land-use practices into account. Its implementation follows a phased approach, with clearly defined timelines [1].

In accordance with the Floods Directive, Member States were required to:

1. Prepare preliminary flood risk assessments by December 2011, including descriptions of significant past floods and potential future events;

2. Develop hazard maps and flood risk maps by December 2013, identifying areas where floods could cause serious consequences;

3. Adopt flood risk management plans by December 2015, applicable for the 2016–2021 period, outlining measures for flood prevention, protection, and preparedness.

The described process is schematically shown on Figure 1 [12].

Figure 1 – The Floods Directive (2007/60/EC) implementation cycle [12]

The preparation of river basin management plans under Directive 2000/60/EC and flood risk management plans under the Floods Directive are integral elements of an integrated river basin management approach. These processes should harness synergies and mutual benefits while respecting environmental protection objectives set by Directive 2000/60/EC, ensuring efficient and rational resource use, even where the responsible authorities or management units differ under the two directives [1].

3. The rulebook on the detailed content of the preliminary flood risk assessment and the flood risk management plan

The Rulebook on the detailed content of the preliminary flood risk assessment and the flood risk management plan ("Official Gazette of Montenegro," No. 69/15) defines the scope and content of preliminary flood risk assessments, the preparation of hazard and risk maps, and the development, updating, and implementation of flood risk management plans [3].

The preliminary flood risk assessment includes the following elements [3]:

1. Maps of water areas at appropriate scales, with delineated sub-basins, as well as maps of coastal zones, showing topography and land use;
2. A description of past floods that caused significant adverse impacts on human health, the environment, cultural heritage, and economic activities, and are likely to recur in the future, considering flood extent, pathways of floodwaters, and the damages caused;
3. A description of past significant floods in areas where, due to changes in conditions (e.g., urbanization, designation of protected areas), major damages could occur in the future;
4. The impact of climate change on flood occurrence;
5. An assessment of potential adverse consequences of future floods on human health, the environment, cultural heritage, and economic activities, taking into account topography, river location, hydrological and geomorphological characteristics, natural flood retention areas, the effectiveness of flood defense structures, the location of settlements, areas of economic activity, and long-term development plans;
6. Required data (records, long-term development studies); and
7. Conclusions on flood risks.

The Rulebook also introduces terminology related to flood probability, including [3]:

- *Areas of significant flood risk*—zones where floods may cause considerable damage to human health, the environment, cultural heritage, or the economy;
- *Low-probability floods*—river floods with a return period of at least 500 years, or standing water floods with a water level recurrence of at least 500 years;
- *Medium-probability floods*—river floods with a return period of 100 years, or standing water floods with a recurrence of 100 years;
- *High-probability floods*—river floods with a return period of 10 years, or standing water floods with a recurrence of 10 years.

This Rulebook incorporates all three main guidelines of the Floods Directive regarding the content of preliminary assessments, along with optional provisions on potential adverse flood impacts. Its scope is expanded by explicitly requiring data on the influence of climate change on flood occurrence. As such, it provides a thorough and comprehensive framework for the information and data to be included in preliminary assessments, reflecting the requirements of Article 4 of the Directive and, in some cases, exceeding them. It can therefore be concluded that the provisions on preliminary flood risk assessment have been successfully integrated into Montenegro's national legal framework through this Rulebook [3].

4. Legislative Acts

The legal framework, policies, and accompanying strategies for reducing disaster risk, including floods, in Montenegro are defined by the following laws:

- Law on Waters ("Official Gazette of Montenegro," Nos. 27/07 and 48/15) [4];
- Law on Hydrometeorological Service ("Official Gazette of Montenegro," No. 26/10) [5];
- Law on Hydrographic Services ("Official Gazette of Montenegro," No. 26/10) [6];
- Law on Protection and Rescue ("Official Gazette of Montenegro," Nos. 13/07, 32/11, and 54/16) [7].

4.1. The Law on Waters

The **Law on Waters** ("Official Gazette of the Republic of Montenegro," No. 27/07, and "Official Gazette of Montenegro," Nos. 32/11, 47/11, 48/15, 52/16, 02/17, 80/17, 84/18) stipulates that flood protection is organized and implemented in accordance with general and operational flood protection plans, both for waters of national significance and for those of local importance. The framework for long-term planning and flood risk management, as prescribed by the EU Floods Directive [1], has been transposed into this law. It requires: preparation of preliminary flood risk assessments, designation of areas significantly at risk, development of flood hazard and risk maps, and adoption of flood risk management plans [4].

The law defines a *flood* as the temporary covering of land not normally covered by water, caused by rivers, torrents, intermittent streams, or lakes, excluding floods from sewer systems. *Flood* risk is defined as a combination of the probability of a flood event and its potential adverse effects on human health, the environment, cultural heritage, and economic activity [4].

The law mandates a **general plan for protection against harmful effects of waters**, which includes: preventive measures during high-water periods, methods of institutional organization, responsibilities of protection managers, monitoring methods, and early warning systems. Annual operational plans must also be prepared: nationally by the Water Administration under the Ministry of Agriculture and Rural Development, and locally by municipal authorities with Ministry approval [4].

Flood protection at the national level is coordinated by the Ministry of Agriculture and Rural Development and the Water Administration, in cooperation with the Directorate for Emergency Situations, the Ministry of Interior, the Institute of Hydrometeorology and Seismology, the Environmental Protection Agency, and licensed companies. A dedicated Flood Protection Headquarters, headed by the Director General of the Directorate for Water Management, oversees this work [4].

Article 95b introduces a mandatory six-year review cycle for all assessments, with particular emphasis on the impacts of climate change on potential floods within river basins. The law also regulates flood defense works, erosion and torrent control,

drainage, and post-flood remediation. Preventive measures include construction and maintenance of protective structures, afforestation, terracing, and riverbed cleaning [4]. In emergencies of the highest flood risk (fourth-level danger), actions are carried out under the National Flood Protection and Rescue Plan [2], coordinated by the Ministry of Interior through its Directorate for Emergency Situations.

4.2. The Law on Hydrometeorological Service and Law on Hydrographic Services

These laws define the responsibilities of the Institute for Hydrometeorology and Seismology of Montenegro. The Institute is mandated to **prepare emergency hydrometeorological information** and warnings before atmospheric or hydrological hazards, conduct urgent observations and measurements, issue rapid communications, monitor forecasts, collect and analyze data, and inform responsible institutions. It issues regular and emergency reports on weather, climate, and water conditions in written, tabular, or graphical form, distributed via electronic networks, mail, or the media [5, 6].

4.3. The Law on Protection and Rescue

The Law on Protection and Rescue establishes the legal basis for developing and strengthening national capacities to mitigate the effects of natural and other disasters, including floods. It also promotes regional and international cooperation in prevention, risk reduction, and disaster response. The law defines the rights and obligations of municipalities in this field, including risk assessments, early warning systems, and preparation of protection and rescue plans [7].

Under this law, the Ministry of Interior adopted by-laws on the content and methodology of risk assessments and protection plans. The Directorate for Emergency Situations proposes, and the Government adopts, **national protection and rescue plans**. These plans serve as the organizational framework for safeguarding people, property, cultural heritage, and the environment, guiding state and local institutions, businesses, and other legal entities in carrying out their obligations. They specify the organization, measures, resources, and responsibilities necessary for effective protection and rescue operations [7].

5. Strategic documents addressing flood risk in Montenegro

The key strategic documents relevant to flood risk management in Montenegro are:

- National Strategy for Emergency Situations [8];
- National Climate Change Strategy until 2030 [9];
- Water Management Strategy for the period 2016–2035 [10];
- National Strategy for Sustainable Development until 2030 [11].

5.1. The National Strategy for Emergency situations

Adopted by the Government of Montenegro in December 2006, this strategy establishes the state's approach to dealing with all types of disasters and provides a framework for coordinated action by state and other institutions in responding effectively to various natural, technological, and other hazards. It was developed with the participation of multiple stakeholders and covers natural, technological, and biological risks. The strategy lays a solid foundation for building and improving the disaster risk reduction system and highlights the importance of integrating risk reduction measures in highly vulnerable areas and among socially sensitive groups. It provides an overview of the risks threatening Montenegro, the preparedness of institutions, and the organizational framework for disaster protection [8].

5.2. The National Climate Change Strategy until 2030

Adopted in 2015, the National Climate Change Strategy until 2030 addresses natural hazards such as floods and landslides. However, it does not establish clear connections between these hazards and the impacts of climate change, leaving a gap in integrating hazard-specific risk assessments with climate projections [9].

5.3. The Water Management Strategy for the period 2016–2035

The Water Management Strategy (2016–2035) provides an assessment of the current state of water management, defines objectives and guidelines, outlines measures to be implemented, and projects long-term development for the sustainable management of water resources. It contains a comprehensive set of measures for the prevention and mitigation of flood risks, structured across four main areas [10]:

1. 1. Protection from floods caused by surface waters;
2. 2. Protection from groundwater-related floods;
3. 3. Regulation of the water regime and flood control;
4. 4. Protection against erosion and torrents.

Floods are explicitly addressed as a natural hazard within the strategy, with emphasis on the importance of risk assessments in the broader framework of flood risk management and defense measures. They are primarily analyzed in the context of climate change and its impacts on river flows, surface water, and groundwater resources [10].

6. Conclusion

The analysis presented in this paper demonstrates that Montenegro has established a relatively comprehensive legislative and strategic framework for the assessment and management of flood risks, largely aligned with the principles and requirements of the EU Floods Directive (2007/60/EC) [1]. The incorporation of preliminary flood risk assessments, hazard and risk mapping, and the preparation of management plans into national law—particularly through the Law on Waters [4] and the supporting Rulebook [3] —reflects a significant step toward harmonization with European standards. Additionally, the roles of the Hydrometeorological Service [5], Hydrographic Services [6], and the Law on Protection and Rescue [7] provide institutional mechanisms for monitoring, early warning, and coordinated response to flood-related hazards.

Strategic documents, such as the National Strategy for Emergency Situations and the Water Management Strategy 2016–2035 [8], further reinforce this framework by outlining preventive, protective, and adaptive measures. However, gaps remain, most notably in the National Climate Change Strategy until 2030 [9], which fails to adequately connect climate projections with hydrological risks. This omission is increasingly significant given the observable trend of more frequent and severe floods in Montenegro, consistent with broader regional impacts of climate change.

Overall, while Montenegro has made important progress in embedding EU flood risk management principles into its legislation and policies, effective implementation and continuous revision remain essential. In particular, integrating climate change considerations more systematically across all strategic documents, strengthening inter-institutional cooperation, and ensuring that plans are operationalized at both national and local levels will be critical. Addressing these challenges will not only enhance Montenegro's resilience to flooding but also contribute to sustainable development and fulfillment of the country's international obligations.

Literature

[1]	European Commission. (2007). Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks. (https://eur-lex.europa.eu/eli/dir/2007/60/oj)
[2]	National Plan for Flood Protection and Rescue (2019); Government of Montenegro. (https://faolex.fao.org/docs/pdf/mne228849.pdf)
[3]	Rulebook on Detailed Content of the Preliminary Flood Risk Assessment and Flood Risk Management Plan (2015); Official Gazette of Montenegro, No. 069/15; Government of Montenegro. (https://www.gov.me/dokumenta/92cf58c1-b5a8-4f0a-bdcf-87ef9a5439d6)
[4]	Law on Waters (2007); Official Gazette of Montenegro, No. 27/2007; Government of Montenegro. (https://www.gov.me/dokumenta/684b12ac-dc8e-4fc5-87f8-1549e03bf116)
[5]	Law on Hydrometeorological Services (2010); Official Gazette of Montenegro, No. 026/10 from 07.05.2010; Government of Montenegro. (https://www.meteo.co.me/zakoniipravilnici/Zakon%20o%20hidrometeoroloskim%20poslovima.pdf)
[6]	Law on Hydrographic Services (2010); Official Gazette of Montenegro, No. 26/10 from 07.05.2010; Government of Montenegro. (https://www.epa.org.me/images/zakoni/zakon%20o%20hidrografskoj%20djelatnosti.pdf)
[7]	Law on Protection and Rescue (2007); Official Gazette of Montenegro, No. 13/2007; Government of Montenegro. (https://me.propisi.net/zakon-o-zastiti-i-spasavanju/)
[8]	National Strategy for Emergency Situations (2006); Government of Montenegro. (https://www.gov.me/dokumenta/7207f32a-91e0-4741-b2d2-607683f771b7)
[9]	National Climate Change Strategy until 2030 (2015); Government of Montenegro. (https://www.gov.me/dokumenta/cd1130f8-668b-4fbd-a094-20a04af536aa)
[10]	Water Management Strategy (2017); Government of Montenegro. (https://www.gov.me/dokumenta/d5953b00-3220-48b7-a5b8-28f4f26dbe23)
[11]	National Strategy for Sustainable Development until 2030 (2016); Government of Montenegro. (https://www.gov.me/dokumenta/67dc487e-097d-41d2-8fd5-7827a19a1f5a)
[12]	https://inundatii.ro/en/floods-directive-implementation-1st-cycle/ (last accessed on 13th September 2025)

Institutionalisation of the methodology for damage and loss assessment in agriculture

Ljiljana Popović[1]

Mirjana Laban[2]

Sandra Nedeljković[3]

1 Associate professor, University of Novi Sad, Faculty of Technical Sciences, Department of Industrial Engineering and Management
ljiljana.popovic@uns.ac.rs

2 Full professor, University of Novi Sad, Faculty of Technical Sciences, Department of Civil Engineering and Geodesy
mlaban@uns.ac.rs

3 MA in Political Science, Ministry of Construction, Transport and Infrastructure
sandra.nedeljkovic@mgsi.gov.rs

Abstract

Serbia is increasingly investing efforts in disaster risk reduction (DRR) and climate change adaptation (CCA), particularly within the agricultural sector, which remains highly vulnerable to natural hazards such as floods, droughts, storms, and other extreme events. However, the absence of a comprehensive and standardized system for post-disaster data collection and analysis has significantly hindered evidence-based planning and the development of effective resilience strategies. Existing national guidelines, dating back to 1987, no longer meet current needs or reflect international standards. To address this gap, an intersectoral working group, led by the Ministry for Public Investments with technical support from the Food and Agriculture Organization of the United Nations (FAO), adapted FAO's methodology for damage and loss assessment (DLA) in agriculture to the Serbian context. This methodology provides a robust and systematic approach to identifying, analysing, and quantifying the impacts of disasters across crop and livestock production, forestry, fisheries, and aquaculture. The methodology is also harmonized with the Post-Disaster Needs Assessment (PDNA) approach, ensuring compatibility with internationally recognized recovery and response frameworks. The guidelines represent a critical step toward institutionalizing disaster data systems in Serbia's agriculture-related sectors. They contribute to enhanced preparedness, more efficient recovery planning, and strengthened sectoral resilience. In the long term, this methodological framework will support climateresilient development by enabling data-driven decision-making at all governance levels.

Keywords

Disaster Risk Reduction, Agriculture, Damage and Loss, Climate Resilience, Post Disaster Needs Assessment, Methodology, Serbia

1. Introduction

Disasters triggered by natural hazards increasingly affect agriculture, which remains one of the most vulnerable sectors to climate variability and extremes. Accurate and timely assessment of damages and losses is essential not only for planning recovery interventions but also for reducing disaster risk, informing adaptation strategies, and strengthening resilience of rural communities and national food systems. The Food and Agriculture Organization of the United Nations (FAO) has developed a standardized methodology for Damage and Loss Assessment (DLA) in agriculture [1], widely recognized as an international benchmark. This methodology distinguishes between damages, defined as the destruction or partial destruction of physical assets and losses, defined as the reduction of economic flows resulting from disasters. By applying this conceptual distinction, FAO provides a harmonized framework for monitoring and reporting across all subsectors of agriculture, including crops, livestock, forestry, fisheries, and aquaculture.

At the global level, the *Sendai Framework for Disaster Risk Reduction 2015–2030* [2] emphasizes the critical role of reliable and comparable disaster loss data in monitoring progress toward reducing risks and enhancing resilience. One of its global targets (Target C) explicitly calls for reducing direct disaster economic losses in relation to gross domestic product, while Target E highlights the importance of national and local disaster risk reduction strategies that are evidencebased. Similarly, the *Sustainable Development Goals* (*SDGs*) [3], particularly Goal 2 (Zero Hunger), Goal 11 (Sustainable Cities and Communities), and Goal 13 (Climate Action), underscore the necessity of robust disaster loss assessment systems to support sustainable development and climate resilience. The alignment of national methodologies with FAO and Post-Disaster Needs Assessment (PDNA) standards [4] therefore represents not only a technical improvement but also a contribution to Serbia's progress in achieving international commitments.

In Serbia, however, the assessment of disaster impacts on agriculture has historically relied on the *Unified Methodology for Assessing Damage from Natural Disasters* [5], adopted in 1987 during the Socialist Federal Republic of Yugoslavia. While pioneering at the time, this methodology no longer reflects contemporary socio-economic conditions, evolving climate challenges, and the need for alignment with international practices. The devastating floods of 2014, which prompted the application of the *Post-Disaster Needs Assessment* (*PDNA*) methodology in Serbia, clearly demonstrated both the urgency and the complexity of modernizing national frameworks for disaster loss assessment.

In response, the Government of Serbia established an inter-ministerial working group tasked with drafting a new *Regulation on the Unified Methodology for the Assessment of Damages, Losses, and Needs Following Natural and Other Hazards*. Within this regulatory initiative, a sector-specific methodology for agriculture was developed, explicitly aligned with FAO and PDNA standards and accompanied by proposals for institutional adjustments, legal reforms, and capacity-building measures for local self-governments. The ultimate goal of this effort is to ensure that damage and loss assessments in agriculture are consistent, internationally comparable, and usable for both national decision-making and global reporting requirements.

The aim of this paper is to present the process of institutionalization of the DLA methodology in Serbia's agriculture sector. It reviews the comparative analysis of FAO and Serbian methodologies, examines the existing legal and institutional framework, and discusses proposals for regulatory alignment, institutional adjustments, and capacity

development. The discussion emphasizes the importance of harmonization with international standards, not only to ensure consistency of reporting and improved statistical practices, but also to strengthen Serbia's contribution to global disaster risk reduction and sustainable development agendas.

2. Comparative analysis of methodologies

The assessment of damages and losses in agriculture has been addressed differently in the FAO methodology [1] and in the methodologies applied in Serbia [5]. While both approaches aim to capture the full scope of disaster impacts, they diverge in conceptual definitions, classification, and assumptions that underlie the calculation of damages and losses.

The FAO methodology defines damage as the total or partial destruction of physical assets and infrastructure in disaster-affected areas, expressed in terms of replacement or repair costs. In agriculture, this includes standing crops, perennial crops, farm machinery, irrigation systems, livestock shelters, fishing vessels, pens, and ponds. Loss, in contrast, is defined as the reduction in economic flows resulting from a disaster, such as reduced crop and livestock production, lower revenues, higher input costs, and unexpected expenditures.

A key feature of the FAO methodology is the classification of damages and losses into three categories:

- Production damage - referring to destroyed inputs and outputs of agricultural production;
- Asset damage - referring to physical destruction of infrastructure, equipment, and tools;
- Production losses - referring to the gap between expected and actual value of production.

These categories are assessed separately for each agricultural subsector: crops, livestock, forestry, aquaculture, and fisheries (Table 1).

Table 1 – Results of measured noise on workplace whit ARW-95 instrument

		DAMAGE	LOSS
Crop production * Livestock Fisheries* Aquaculture * Forestry	PRODUCTION	The value of destroyed, stored products and raw materials/production inputs before disaster	The difference between the expected value of production and the actual value of production, as well as short-term costs incurred during and immediately after disaster
	ASSET	Value of replacement or repair of destroyed agricultural and forestry infrastructure and infrastructure in the field of aquaculture and fisheries.	

In Serbia, the methodology historically applied is the *Unified Methodology for Assessing Damage from Natural Disasters* (1987) [5]. This methodology considers:

- Direct damages to fixed and working assets (land, buildings, equipment, perennial crops, forests, livestock, raw materials, semi-finished and finished products);
- Costs resulting from direct damages, such as repair expenses and additional agricultural measures;
- Indirect damages, which include estimated loss of income from reduced or destroyed production.

This system treats potential yield reduction as *indirect economic damage* rather than a distinct category of losses. Moreover, it does not report damages and losses sectorally, but rather by type of asset (land, buildings, equipment, crops, forests, livestock).

In 2019, the Government of Serbia initiated work on new *Guidelines for the Assessment of Needs in the Agricultural Sector Following Natural and Other Disasters*, which explicitly separate the concepts of damage and loss, thereby addressing a major conceptual gap of the 1987 methodology. These Guidelines adopt the FAO approach more closely, defining damages as impacts on assets, infrastructure, crops, and animals, and losses as impacts on production flows, quality reduction, and additional recovery costs.

When examining the key similarities and differences, it becomes clear that both methodologies ultimately encompass the same types of damages and losses, but the FAO approach establishes a clearer conceptual separation and more precise categorization. While the FAO methodology classifies damages and losses by agricultural subsectors, such as crops, livestock, forestry, fisheries, and aquaculture, the Serbian framework continues to group them primarily by asset type. In terms of terminology, FAO explicitly distinguishes between damages and losses, whereas the older Serbian system referred to production shortfalls merely as indirect economic damages. This distinction also extends to reporting practices: the FAO methodology requires that data be presented separately for each subsector, while the Serbian system consolidates damages across different categories of assets. Although both methodologies may arrive at similar overall values of damages and losses, these differences in classification and reporting significantly affect how results are structured, interpreted, and compared at the international level. For this reason, harmonization of Serbian practice with FAO standards is essential to ensure international comparability and alignment with global disaster risk reduction and reporting frameworks.

Table 2 – Comparison of FAO and Serbian Methodologies

Aspect	DAMAGE	LOSS
Definition of damage	Destruction of physical assets and infrastructure, valued as replacement or repair cost	Direct damages to fixed and working assets (land, buildings, equipment, crops, livestock, forests)
Definition of loss	Reduction of economic flows due to disaster (e.g., lower yields, revenues, increased costs)	Treated as *indirect economic damage* rather than a distinct category
Classification	Production damage, asset damage, production losses	Direct damages, costs, and indirect damages
Reporting structure	Sector-based: crops, livestock, forestry, fisheries, aquaculture	Asset-based: land, buildings, equipment, crops, forests, livestock
Conceptual distinction	Clear separation between damage and loss	Partial overlap: losses interpreted as indirect damages
Recent developments	Applied globally as an international standard	Draft Guidelines (2024) introduce clear separation between damage and loss and move closer to FAO standards

3. Legal and institutional framework in Serbia

The legal and institutional framework for assessing damages and losses in Serbia is primarily regulated by the *Law on Recovery after Natural or Other Hazards* (2015) [6]. This law sets the basis for organizing the recovery process and defines the conditions under which state aid is granted to citizens and commercial entities affected by disasters. It also introduces the principle that material damage is recognized only when it exceeds the recovery capacities of individuals or local governments, thus ensuring that national support is directed to the most severe events.

The law distinguishes between individuals and commercial entities in terms of eligibility for assistance. For households, compensation is linked to technical criteria such as the extent and duration of flooding, and is provided to meet basic existential needs. Commercial entities, including agricultural holdings, are subject to stricter conditions: they must demonstrate that damage resulted from non-insurable risks and that all prescribed protective measures were implemented. This reflects an expectation that businesses should rely more strongly on insurance instruments and risk management practices, while state aid primarily serves to protect the population's essential needs.

Institutionally, the recovery process in Serbia is coordinated at several levels. At the national level, the Government of the Republic of Serbia plays a central role by declaring disasters and adopting state aid and reconstruction programs. The Ministry for Public Investments acts as the main coordinating body, responsible for organizing needs assessments, verifying damage assessments submitted by local self-governments, and managing procurement and reconstruction activities.

Local self-governments are responsible for conducting field assessments through damage assessment commissions, collecting reports, and submitting consolidated data to the Ministry. Autonomous provinces may also provide assistance from their budgets under the same legal framework. Additionally, the Government maintains a Commission for Determining Damages from Natural Disasters, which acts as a second-instance body in cases of appeals against local decisions.

The 2014 floods represented a turning point in applying international standards within the national system. With support from the European Union, the United Nations, and the World Bank, a Post-Disaster Needs Assessment (PDNA) mission was conducted in Serbia [7], leading to the organization of a donor conference in Brussels and mobilization of substantial international aid. This experience highlighted both the strengths and limitations of the existing Serbian framework. While the national system provided an established mechanism for field assessments and legal procedures, it lacked alignment with international methodologies in terms of conceptual clarity and reporting structures.

In summary, Serbia's legal and institutional framework provides a well-defined mechanism for recovery and assistance distribution, but it remains anchored in methodologies and practices developed more than three decades ago. The reliance on the 1987 *Unified Methodology for Assessing Damage from Natural Disasters* continues to shape reporting, even though it no longer reflects the requirements of modern disaster risk reduction and international comparability. This discrepancy underscores the importance of adopting new regulations that harmonize national practice with global standards, while also strengthening the capacities of institutions at both national and local levels.

4. Proposals for institutional adjustments

Efforts to institutionalize the methodology for assessing damages and losses in agriculture in Serbia have led to the preparation of a *Draft Regulation on the Unified Methodology for the Assessment of Damages, Losses, and Needs Following Natural and Other Hazards*. This draft regulation, developed by the Ministry for Public Investments together with the Interministerial Working Group, is designed as a comprehensive legal framework that integrates international standards while also maintaining the operational efficiency of existing institutions.

The draft regulation is fully aligned with the Post-Disaster Needs Assessment (PDNA) methodology, recognized as a global standard for assessing disaster impacts, and incorporates the terminology and processes defined in FAO's technical guidance for the agricultural sector. The regulation foresees the adoption of sectoral annexes, including one for agriculture, which will ensure harmonization of national practice with FAO and PDNA methodologies. Until this regulation is adopted, however, the outdated 1987 Guidelines remain in force, underscoring the urgency of finalizing the regulatory process.

One of the most important findings of the working group is that the existing institutional framework itself does not require fundamental revision. The roles of the Ministry for Public Investments, line ministries, and local self-governments are well established and function effectively within the current system. What is needed, however, is significant capacity building at the local level. Local governments are the first line of response in damage assessment, yet many lack the expertise and training required to apply new methodological standards. To address this, proposals have been made for regional training programs covering areas such as good governance in disaster risk reduction, procedures for agricultural damage and loss assessment, and disaster risk assessment. In particular, training for members of local damage assessment commissions and agricultural extension services is identified as a priority, ensuring that assessments are conducted consistently and in accordance with the new methodology.

Beyond training, the proposals also emphasize the importance of continuous exchange of information and best practices between local self-governments, ministries, and the Statistical Office. Platforms such as the Standing Conference of Towns and Municipalities are seen as valuable mechanisms for facilitating such exchange, given their existing networks in agriculture, rural development, and civil protection.

Another crucial aspect of institutional adjustment relates to statistical reporting. Both the existing guidelines and the draft regulation emphasize the obligation to collect and report statistical data on damages and losses in agriculture. The new regulation builds upon this by introducing updated procedures aligned with PDNA standards, thereby strengthening the quality and reliability of reporting. This is expected to improve not only national data systems but also Serbia's ability to contribute to international monitoring frameworks such as the Sendai Framework and the SDGs.

Institutional adjustments in Serbia are therefore directed not toward redesigning the existing system, but toward strengthening its functionality. The emphasis is placed on adopting the draft regulation and its sectoral annexes, developing capacities of local self-governments through specialized training, and improving statistical reporting procedures. Together, these measures provide the foundation for a more coherent, resilient, and internationally comparable system of agricultural damage and loss assessment.

5. Discussion and conclusion

The process of institutionalizing a standardized methodology for assessing damages and losses in agriculture in Serbia reflects both progress and remaining challenges. On the one hand, the comparative analysis demonstrates that the Serbian draft guidelines now largely mirror the FAO and PDNA frameworks, especially in establishing a clear distinction between damages and losses and in broadening coverage across agricultural subsectors. This alignment represents a critical step toward harmonization with international practice, ensuring that data produced nationally can be meaningfully compared and integrated into global monitoring systems such as the Sendai Framework indicators and the Sustainable Development Goals.

At the same time, certain structural and procedural issues remain. The reliance on the 1987 methodology for more than three decades has created entrenched reporting patterns that are difficult to transform quickly. While the institutional framework itself is functional and does not require major restructuring, the capacity of local self-governments, responsible for conducting field assessments, varies significantly. Without systematic training, unified guidelines risk being applied inconsistently, which would undermine the reliability of national reporting. Moreover, the lengthy political process of adopting the new regulation continues to delay full implementation of the methodology, leaving a gap between international commitments and domestic practice.

The benefits of harmonization are nevertheless clear. By adopting the draft regulation and sectoral annexes, Serbia will achieve methodological consistency across sectors, strengthen the quality of statistical reporting, and improve its ability to mobilize both national and international support in times of disaster. Enhanced training and knowledge-sharing mechanisms will contribute to building local capacities, while clearer classification and reporting rules will generate data that are more transparent, comparable, and useful for decision-making.

In conclusion, institutionalization of the DLA methodology in agriculture is not merely a technical adjustment but a strategic step toward building resilience in the sector and in society as a whole. It aligns Serbia with global standards, facilitates evidence-based policymaking, and supports the country's obligations under the Sendai Framework and the SDGs. The forthcoming period should therefore prioritize the formal adoption of the regulation, targeted investment in capacity development, and continued collaboration between national authorities, local governments, and international partners. Only through these combined efforts can Serbia ensure that agricultural damage and loss assessments become a robust tool for disaster risk reduction and sustainable development.

Literature

[1] Food and Agriculture Organization of the United Nations (FAO). Methodology for Damage and Loss Assessment in Agriculture. FAO, Rome, 2020.

[2] United Nations Office for Disaster Risk Reduction (UNDRR). Sendai Framework for Disaster Risk Reduction 2015–2030. UNDRR, Geneva, 2015.

[3] United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. UN, New York, 2015.

[4] European Union, United Nations Development Programme and World Bank. Post-Disaster Needs Assessment Guidelines Volume A. World Bank, Washington, D.C., 2013.

[5] Federal Bureau of Statistics SFRY. Unified Methodology for Assessing Damage from Natural Disasters. Official Gazette of SFRY, No. 27/1987.

[6] Republic of Serbia. Law on Recovery after Natural or Other Hazards. Official Gazette of RS, No. 112/2015.

[7] World Bank, European Union & United Nations. Serbia Floods 2014 – Post-Disaster Needs Assessment. Belgrade, 2014.

[8] Minucci, G. (2016). Assessing adaptive capacity of water management organizations. The case study of the municipality of Tomave (Bolivia). *J of Risk Research*, 19(7): p. 847–872.

Analysis of the sustainable urban mobility in the municipality of Kiseljak

Nermin Palić[1]

Grgo Luburić[2]

Dejan Štekić[3]

Lejla Viteškić[4]

Edin Džumhur[5]

Dario Šušnja[6]

Benjamin Hasanović[7]

Ernis Hadžajlić[8]

Minela Balija[9]

Valentin Đotlo[10]

Adrian Bonjak[11]

1	Doc.dr., Head of the Traffic and Transport Engineering Study Program, University College „CEPS-Center for Business Studies“ Kiseljak *nermin.palic@ceps.edu.ba*
2	Red. prof. dr., University of Zagreb, Faculty of Transport and Traffic Sciences *grgo.luburic@fpz.unizg.hr*
3	MA, Municipality of Kiseljak *dejan2701@gmail.com*
4	Student, University College „CEPS-Center for Business Studies“ Kiseljak *burinalejla@gmail.com*
5	Student, University College „CEPS-Center for Business Studies“ Kiseljak *edin.dzumhur82@gmail.com*
6	Student, University College „CEPS-Center for Business Studies“ Kiseljak *darecare40@gmail.com*
7	Student, University College „CEPS-Center for Business Studies“ Kiseljak *bhasanovic19@gmail.com*
8	Student, University College „CEPS-Center for Business Studies“ Kiseljak *ernis_hadzajlic9@hotmail.com*
9	Student, University College „CEPS-Center for Business Studies“ Kiseljak *minelabalija33@gmail.com*
10	Student, University College „CEPS-Center for Business Studies“ Kiseljak *dotlovalentin95@gmail.com*
11	Student, University College „CEPS-Center for Business Studies“ Kiseljak *adrianbosnjak18@gmail.com*

Abstract

The paper analyzes sustainable urban mobility in the Municipality of Kiseljak, aiming to identify the current state, key challenges, and opportunities for improving the transport system. The introductory sections present the basic concepts of sustainable urban mobility plans and provide essential information about the municipality. Particular attention is given to the vision and strategic goals in urban mobility, which include improving transport safety, accessibility, and efficiency, as well as reducing environmental impacts. The analysis covers various aspects of mobility, including the road network, intersections, stationary traffic, signage, accessibility for persons with disabilities, safety, the number of motor vehicles, urban and freight transport, non-motorized mobility, electromobility, and levels of air and noise pollution. Several challenges have been identified, such as congested roads, underdeveloped public transport, and limited infrastructure for cyclists and pedestrians. Based on these findings, a set of recommendations is proposed, including improvements to traffic infrastructure, the development of public transport, promotion of non-motorized mobility, and the implementation of environmentally friendly solutions. The aim of the paper is to contribute to the creation of a more sustainable, safer, and more accessible transport system in the Municipality of Kiseljak. The work was conducted through the 1FUTURE platform, involving academy, students and the public sector via task assignments and regular reporting.

Keywords

Sustainable urban mobility, transport system, Municipality of Kiseljak, environmental impact, urban planning, 1FUTURE platform.

1. Introduction

Sustainable urban mobility is a key element of contemporary urban planning, aiming to ensure efficient, safe, environmentally friendly, and socially equitable movement of people and goods within urban areas. In the context of growing urban populations, increased motor vehicle use, air pollution, noise, traffic congestion, and accidents, sustainable mobility approaches are essential to preserve quality of life. This concept promotes public transport, walking, cycling, electromobility, and the integration of smart and innovative solutions that reduce the negative impacts of traffic on the environment and public health, while also enhancing economic efficiency and social inclusion. The Municipality of Kiseljak was selected for this study due to its unique geographical location, demographic structure, and traffic characteristics, making it a representative case for exploring sustainable mobility in smaller urban areas in Bosnia and Herzegovina. Despite its relatively small population, Kiseljak faces challenges typical of larger urban centers, including a rising motorization rate, limited public transport capacities, underdeveloped pedestrian and cycling infrastructure, traffic safety concerns, and environmental pollution. The research on urban mobility in Kiseljak was initiated through a collaborative approach involving students, professors, and municipal representatives. The project began with consultations and interviews with local citizens to define a vision for sustainable mobility tailored to the municipality's specific needs. Students were organized into six working groups, each responsible for different aspects of the study—from traffic system analysis and public transport to pedestrian accessibility and innovative solutions—while professors and municipal representatives provided guidance and relevant data. All tasks, progress, and results were coordinated and shared through the 1FUTURE platform, allowing participants to submit their findings, communicate asynchronously, and receive real-time feedback, ensuring a structured and efficient workflow. The objectives of this research are to analyze the current state of urban mobility in Kiseljak, identify key challenges including traffic safety, accessibility, infrastructure for people with special needs, environmental pollution, and noise, and propose concrete measures and strategies to improve the sustainability, efficiency, and accessibility of the local transport system.

2. Methodological overview

The research on sustainable urban mobility in the Municipality of Kiseljak was conducted through a participatory and multidisciplinary approach, combining qualitative and quantitative methods. The process began with contextual analysis, assessing Kiseljak's geographical position, demographic profile, and traffic system characteristics. This provided the basis for identifying challenges typical of both smaller municipalities and larger urban centers, such as rising motorization, limited public transport, underdeveloped cycling and pedestrian infrastructure, and traffic safety issues.

To ensure inclusiveness, the study employed consultations and interviews with citizens, municipal representatives, students, and professors to co-create a vision for sustainable mobility. Data collection involved detailed analyses of the road network, intersections, parking facilities, freight and passenger transport, non-motorized mobility,

electromobility, and environmental factors such as air pollution and traffic noise. Students were divided into six working groups, each focusing on specific aspects (traffic safety, accessibility, infrastructure, innovative solutions, etc.), while academic staff and local authorities provided guidance and expertise.

Findings were systematically coordinated through the 1FUTURE platform, which enabled structured reporting, asynchronous communication, and real-time feedback. This collaborative framework allowed for the integration of diverse perspectives and datasets into a comprehensive assessment. Finally, the results were synthesized into strategic objectives and recommendations, focusing on safety, inclusivity, environmental sustainability, and the introduction of innovative mobility solutions.

3. Defining vision and objectives of the Municipality of Kiseljak in the field of urban mobility

Sustainable Urban Mobility Plans (SUMP) are strategic documents aimed at creating efficient, safe, accessible, and environmentally friendly transport systems in urban areas. [1] Their development relies on an integrated and participatory approach, involving local authorities, experts, citizens, and civil society organizations.

The research in the Municipality of Kiseljak began with an initial assessment of the municipality's context. Kiseljak, located in central Bosnia and Herzegovina within the Central Bosnia Canton, covers approximately 165 km^2 and lies strategically between Sarajevo and Travnik. The main road M5 passes through the municipality, connecting the capital with western regions, while regional roads R442 and R443 link Kiseljak to nearby municipalities such as Kreševo, Fojnica, Hadžići, and Visoko. Despite a relatively small population of around 20,713 (2013 census), Kiseljak faces challenges typical of larger urban areas, including high motorization, limited public transport, underdeveloped cycling and pedestrian infrastructure, and traffic safety and pollution issues.

To define a vision and objectives tailored to these challenges, consultations were held with local citizens, municipal representatives, and experts, including students and professors. This participatory process ensured that the municipality's needs and priorities were accurately reflected in the planning.

Following these consultations, the we adopted the following vision: "The Municipality of Kiseljak, a place of comfortable living, accessible and safe for all residents, focused on promoting non-motorized forms of mobility while gradually introducing innovative solutions. Through small but meaningful steps, the municipality seeks to enable simpler and healthier movement, adapted to local needs for improved quality of life.".

To operationalize this vision, three strategic objectives were established. The first focuses on creating a safe, accessible, and inclusive municipality for all residents, with measures to improve traffic safety for vulnerable users, ensure accessibility for people with disabilities, and develop multimodal infrastructure such as bicycle parking and bike-sharing systems. The second objective emphasizes promoting comfortable and healthy living through the expansion of walking and cycling networks, environmental monitoring of air quality and noise, and encouragement of low-emission transport alternatives. The third objective aims to implement innovative solutions, including digital platforms for bike sharing, sensor technologies to monitor traffic and air quality, and mobile applications to enhance transportation organization and citizen information.

These steps illustrate a clear, chronological path from context assessment to participatory planning, vision formulation, and the establishment of concrete objectives. Achieving these goals requires collaboration among the public sector, citizens, educational institutions, and the business community, ensuring that Kiseljak develops into a functional, safe, and environmentally conscious urban area with sustainable mobility at its core.

4. Assesment of mobility in Kiseljak Municipality

The mobility system in Kiseljak Municipality plays a crucial role in shaping urban life, economic activities, and regional connectivity. Understanding its current state is essential for planning sustainable transport solutions, improving traffic safety, and promoting alternative modes of travel. This analysis examines the municipality's road network, intersections, parking infrastructure, public and freight transport, non-motorized mobility, and emerging trends such as electromobility, as well as related environmental aspects including air quality and traffic noise. By assessing these elements, the study provides a foundation for strategic interventions aimed at enhancing accessibility, efficiency, and the overall quality of urban mobility in Kiseljak.

4.1. Road infrastructure and traffic organization

The condition and organization of road infrastructure are the backbone of sustainable mobility in Kiseljak, shaping both safety and efficiency of movement. Positioned on a key regional corridor, the municipality must balance local needs with heavy transit flows, making infrastructure quality and traffic management crucial. Assessing roads, intersections, signage, accident trends, vehicle ownership, and traffic volumes highlights bottlenecks and provides a basis for strategies to ease congestion, improve flow, and promote greener transport solutions.

The municipal road network (including main, regional, local, and unclassified roads) totals 290 km. Of this, 25 km are main roads connecting Kiseljak with Sarajevo, Ilidža, Busovača, Vitez, Travnik, and Zenica. Additionally, 20 km of regional roads link Kiseljak municipality with Kreševo, Visoko, and Fojnica. According to 2020 data, out of the total road and street network in Kiseljak, 130 km (53%) is well-paved, while 115 km (47%) of paved roads are in poor condition or not paved at all. [2].

In recent years, roundabouts have become the predominant type of intersection in Kiseljak. Previously, most intersections were conventional, mostly T-junctions, but reconstruction processes have converted many into roundabouts. According to the municipality's urbanization plan, most roundabouts are newly constructed, driven by the development of a bypass, new residential complexes, and shopping centers in the city center. Currently, Kiseljak has eight roundabouts, half of which are on the M5 main road; three are smaller and not directly on the main road (two near new residential complexes and one near the Kiseljak Health Center), and the eighth is located on the regional road R443a, providing a direct connection to the highway (Lepenica). This type of intersection is characterized by short waiting times, fewer conflict points, reduced congestion, and improved traffic flow. [3]

Figure 1 – Some of the intersections in Kiseljak Municipality (Google Maps)

Traffic signage in modern urban areas is a fundamental tool for regulating and controlling traffic, and its importance is particularly notable in smaller towns located on key regional roads, as is the case with Kiseljak. The only traffic light in Kiseljak is located at the intersection in front of the Municipal building, where streets connect to the main M5 road and regional road R443. This intersection experiences high traffic volumes and requires automated traffic management to prevent congestion and potential collisions. The traffic light is equipped with standard light indicators, as well as additional pedestrian signals. Its operation is controlled by a programmed module that allows variable light cycles according to analyzed traffic loads throughout the day.

According to the Kiseljak Police Station report, the number of traffic accidents was 451 in 2017, decreasing to 300 in 2018, and continuing to decline to 250 in 2024, indicating a positive trend in traffic safety improvement. The most common causes identified were speeding and driving under the influence of alcohol. [5-6]

In 2013, there were 8,370 registered vehicles, approximately one vehicle per 2.4 inhabitants. By 2024, the number of vehicles increased to 8,409, indicating a higher degree of motorization among the population. [7]

Figure 2 – Number of registered vehicles in Kiseljak Municipality for 2024 [7]

According to data from JP Ceste Federacije BiH for 2024, the average annual daily traffic (AADT) on the main road passing through Kiseljak Municipality is 13,691 vehicles. The highest traffic volume was recorded in August, with a total of 476,914 vehicles, averaging 15,384 vehicles per day. In contrast, the lowest traffic occurred in January, with 364,433 vehicles. During the day, traffic is most intense during two periods: from 10:00 to 11:00 and from 16:00 to 17:00. [8]

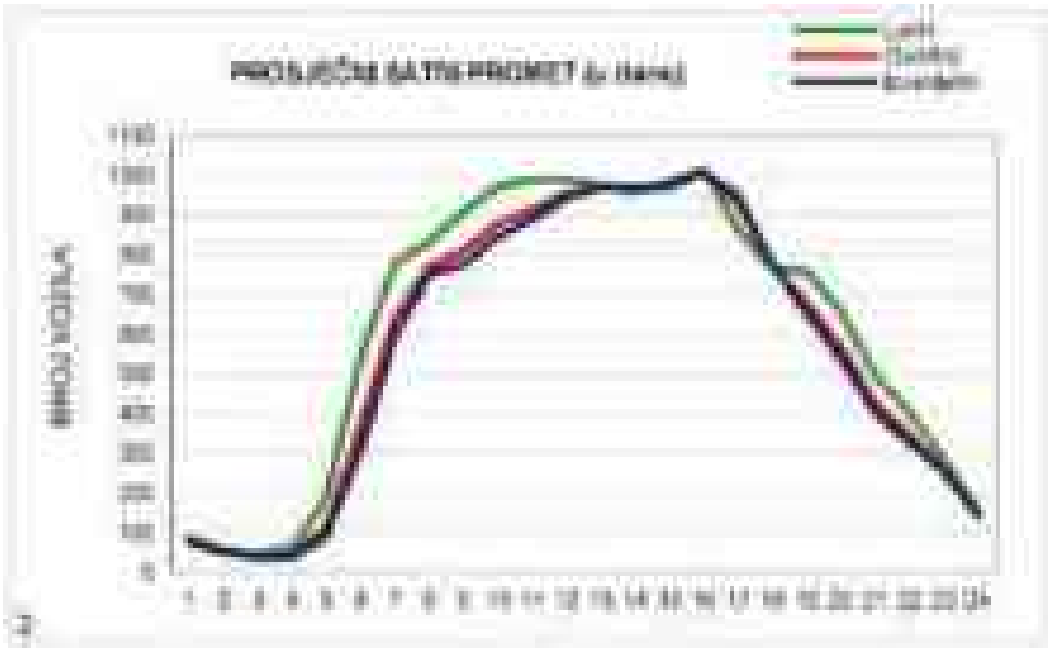


Figure 3 – Average hourly traffic in Kiseljak for 2024 [8]

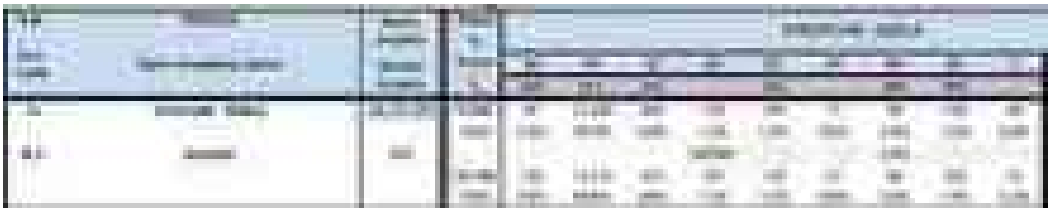


Figure 4 – AADT and daily traffic distribution (DTDs) with vehicle composition in 2024 [8]

4.2. Stationary traffic and infrastructure: for persons with disabilities

With limited public transport options, parking supply and regulation directly influence traffic flow, congestion, and the quality of life in the city center. At the same time, providing safe and barrier-free access for persons with disabilities remains a critical societal priority, requiring continuous investment and systematic planning to create a fair and sustainable urban environment.

Kiseljak Municipality manages public parking areas under its jurisdiction, while maintenance is carried out by the Department for Economy, Urban Planning, Environmental Protection, and Communal Services. This department is responsible for maintaining cleanliness of public areas, including parking lots, as well as other municipal services such as road maintenance, public lighting, and stormwater drainage. In the city center, there are about 1,000 marked and unmarked public and private parking spaces. Additionally, in front of businesses and shopping centers, there are numerous organized parking lots supporting commercial activities. The new Kiseljak Health Center under construction will have 200 parking spaces. Parking fees apply to approximately 20% of public spaces at a rate of 1 KM/hour. The introduction of parking fees in the city center, which hosts the majority of public institutions, services, and banks, aims

to ensure turnover of parking spaces for both service users and residents, preventing long-term unnecessary use. The main public parking lot of Kiseljak Municipality has a total of 100 spaces, including four designated for persons with disabilities. [4]

Figure 5 – Available Parking Spaces in the Central Urban Area of Kiseljak (authors using Google)

Accessibility of public spaces for persons with disabilities is not only a technical but also a societal issue. Although Kiseljak has made some progress, such as lowered curbs on most sidewalks and crossings in the city center, numerous challenges remain that require a systematic approach and continuous investment. Access to key institutions—such as municipal buildings, health, and educational facilities—is often enabled through ramps, and these main centers are equipped with elevators. Special attention is needed for visually impaired users, as the city currently lacks adequate signage, including tactile surfaces and audible traffic signals. This situation significantly compromises their independence and safety in traffic. It is also important to note the presence of the local War Veterans' Association (RVI), which has 118 members, highlighting the need to ensure equal access to all public spaces, including sidewalks, intersections, parking areas, and public transport stops. By providing a safe and accessible environment for all, Kiseljak Municipality not only fulfills legal and moral obligations but also contributes to building a more humane and equitable society.

4.3. Public and freight transport

Public urban transport in Kiseljak Municipality is underdeveloped, which significantly affects the quality of urban mobility, especially in the context of sustainable development. Currently, Kiseljak lacks an organized and functional system of public urban transport that would enable efficient and regular movement of residents within

the urban area as well as toward suburban settlements. Passenger transport primarily relies on intercity bus lines, with additional organized school bus lines for students.

The absence of urban public transport is partially compensated by taxi services, functioning as public individual non-line passenger transport. There are two taxi stands in Kiseljak, each with five parking spaces, both located near the main bus station. There is no unified tariff system for taxi services. The number of taxi vehicles ranges between 10 and 15, operated by independent taxi drivers, providing a flexible response to citizens' needs.

In Kiseljak Municipality, freight transport and logistics are carried out primarily by road. The main flows run along the M5 main road, which passes through the municipality and connects central Bosnia and Herzegovina with major regional centers. This road plays a crucial role in the movement of goods and passengers, especially freight transport, which uses this corridor daily.

According to amendments to Kiseljak's Spatial Plan, the expansion of the urban areas of Azapovići and Bukovica has been planned for business purposes, including the development of road infrastructure. These areas are designated as logistics centers to support the development of transport and storage capacities in the municipality.

On average, 644 freight vehicles, or more than 26 per hour, pass through Kiseljak daily, placing a considerable burden on the road infrastructure. To ease congestion in the town center, a bypass road with a tunnel approximately 600 meters long has been planned. This project aims to redirect transit traffic away from the urban area, improving traffic flow and safety in the center of Kiseljak. [9]

Additionally, in May 2024, Lidl Bosnia and Herzegovina began constructing its first logistics and distribution center in Lepenica, Kiseljak Municipality. The investment, worth over €100 million, represents Lidl's largest investment in Bosnia and Herzegovina to date and is expected to create more than 200 jobs.

4.4. Non-motorized mobility and electromobility

The surfaces most commonly used for pedestrian traffic are sidewalks, which are mainly built along streets and roads in the urban area of Kiseljak municipality. In rural areas (village settlements), the percentage of sidewalks is also at a relatively high level. Overall, the condition of sidewalks varies, as there are locations where improvements have been made through street reconstructions and other works.

Along the banks of the Fojnica and Lepenica rivers, within the entire scope of the "Kiseljak III" urban area, a pedestrian path (2.25 m) and a bicycle path (2.00 m) are planned along a stretch of approximately 1,140 m. The installation of ramps and other movable barriers is also proposed to prevent vehicles from entering pedestrian zones. [10]

In Kiseljak, cycling is gradually being established as an alternative, healthier, and more environmentally friendly mode of mobility. Certain parts of the city's infrastructure are already being spontaneously used for this purpose, even though they are not yet formally marked as bike lanes. One example is the central City Park in Kiseljak, where residents cycle daily, using the wide and flat pedestrian paths that naturally accommodate cyclists. Another frequently used location is the newly opened road section starting from the roundabout near Motel Max and leading toward the Bingo shopping center and the newly built hospital. Although not yet open to motorized traffic, this

section—with its modern pavement and wide sidewalks—offers ideal conditions for cycling. Residents have already recognized its potential and use it for walking, running, and cycling, which points to a real need for formalization and further development of cycling infrastructure.

Electromobility, as an important component of sustainable mobility and greenhouse gas reduction, is still in its early stages of development in Kiseljak municipality. Currently, there are only two charging stations for electric vehicles: one near Hotel Bank and another in front of the University College "CEPS – Center for Business Studies" Kiseljak.

4.5. Environmental impacts of mobility

In Kiseljak, air quality varies throughout the year, with significant deterioration during the winter months due to a combination of heavy traffic, the use of fossil fuels for heating, and unfavorable meteorological conditions. Although there is no local monitoring station, nearby data show similar pollution patterns, with high levels of PM10 and PM2.5 often exceeding limits and posing health risks, especially for vulnerable groups. Noise is most severe along the M5 road, where daily peaks regularly surpass the 55 dBA limit, intensified by heavy vehicle traffic (over 600 per day). These issues point to the need for systematic air and noise monitoring.

5. Challenges and recommendations for urban mobility in Kiseljak Municipality

The Municipality of Kiseljak faces **several barriers** to achieving sustainable urban mobility. Nearly half of the road network (47%) remains in poor condition despite recent reconstruction efforts. The absence of a comprehensive public transport system limits accessibility, particularly for residents without cars, reinforcing reliance on individual motorized transport. Inadequate pedestrian and traffic signaling, especially for persons with disabilities and visually impaired users, highlights shortcomings in inclusive planning. Increasing vehicle ownership and high traffic intensity (over 13,000 vehicles daily on the M5) generate congestion, air pollution, and noise. Non-motorized mobility remains underdeveloped, with fragmented cycling infrastructure, while electromobility is still in its early phase, with only two charging stations. Heavy freight traffic through the town center adds further strain, underscoring the urgent need for a bypass.

Despite these challenges, several positive developments offer **opportunities** for improvement. The number of traffic accidents has declined in recent years, reflecting enhanced road safety measures. Planned infrastructure investments, including the bypass and logistics zones, create prospects for easing congestion and stimulating economic growth. Additionally, major private sector investments, such as Lidl's logistics and distribution center, signal future potential for strengthening the local transport and logistics system.

To build a more sustainable and efficient mobility system, Kiseljak should prioritize a set of **strategic measures**. These include strengthening and modernizing public transport, improving road conditions, and redesigning intersections to enhance traffic flow and safety. Accessibility for vulnerable groups must be expanded, alongside the development of dedicated cycling infrastructure and further support for electromobility. Construction of the bypass and logistics centers should be accelerated to reduce freight pressure in the urban core. Finally, adopting smart digital mobility management systems, together with pollution and noise reduction measures, will be crucial for improving sustainability, safety, and overall quality of life for residents.

6. Conclusion

The analysis of urban mobility in Kiseljak Municipality shows that the local community is positioned at an important transport crossroads of Bosnia and Herzegovina, with a developed road infrastructure and a favorable geographic location. However, numerous challenges limit the development of sustainable forms of mobility, including underdeveloped public transport, low availability of cycling and pedestrian infrastructure, and limited accessibility for people with special needs. Despite visible progress in areas such as the construction of roundabouts, improvements in traffic safety, and a reduction in accidents, Kiseljak still records high levels of motorization and traffic load, particularly along the M5 main road. The municipality's vision, focused on promoting non-motorized and innovative forms of mobility, provides a positive framework for future development. The key to success lies in coordinated action by local authorities, citizens, experts, and the private sector to implement concrete measures—such as introducing public transport, expanding cycling lanes, and adopting digital solutions—aimed at achieving safer, healthier, and more accessible mobility for all residents.

A notable contribution of this study is the active participation of both students and municipal representatives in task assignments, consultations, and regular reporting, which illustrates how collaborative engagement between academia, governance, and the community can generate practical and innovative solutions for sustainable urban mobility through the 1FUTURE platform.

Literature

[1] European Commission: *"Mobility and Transport: Sustainable urban mobility planning and monitoring"*, 2024, Retrieved from: https://transport.ec.europa.eu/transport-themes/urban-transport/sustainable-urban-mobility-planning-and-monitoring_en

[2] Općina Kiseljak, "*Strategija razvoja Općine Kiseljak 2021-2027 – nacrt"*, 2020, Retrieved from: https://www.opcina-kiseljak.org/web/wp-content/uploads/2022/08/NACRT-Strategija-razvoja-opcine-Kiseljak-Radna-verzija-.pdf

[3] Općina Kiseljak, "Službeni glasnik Općine Kiseljak, 2010, Vol.9, No.3, Retrived from: https://www.opcina-kiseljak.org/web/wp-content/uploads/2023/05/br3_2010.pdf

[4] Općina Kiseljak, "Strategija razvoja Općine Kiseljak 2013-2020 – nacrt", 2013, Retrieved from: https://www.sogfbih.ba/sites/default/files/javni_dokument/2021-06/Kiseljak%20-%20Nacrt%20Strategije%20razvoja%202013%20-%202020.pdf

[5] Artinfo.ba, "Kiseljak u crnoj statistici", 2015, Retrieved from: https://artinfo.ba/index.php/vijesti/2309-kiseljak-u-crnoj-statistici

[6] Artinfo.ba, *"Kiseljak: Dok policija tvrdi da se broj prometnih nesreća značajno smanjio, brza vožnja odnosi nove živote",* 2019, Retrieved from: https://artinfo.ba/index.php/sport/17733-kiseljak-dok-policija-tvrdi-da-se-broj-prometnih-nesreca-znacajno-smanjio-brza-voznja-odnosi-nove-zivote

[7] Agencija za identifikacijske/identifikacion isprave/dokumente, evidenciju i razmjenu podataka, *"Bilten za mjesec 2.2024 – sekcija C. Izvod iz evidencije motornih vozila I dokumenata za registraciju"*, 2024, Retrieved from: https://www.iddeea.gov.ba/wp-content/uploads/2024/03/BiltenVozila_Februar_2024.pdf

[8] Javno preduzeće Ceste Federacije BiH d.o.o. Sarajevo, *"Intenzitet prometa na mreži magistralnih cesta Federacije Bosne i Hercegovine"*, 2025, ISSN 2831-1337

[9] Kiseljak.info, *"Kiseljak: Održana prezentacija projekta obilaznice Kiseljak II – Izgradnja tunela i trase"*, 2024, Retrieved from: https://www.kiseljak.info/2024/02/ztukiseljak-odrzana-prezentacija-projekta-obilaznice-kiseljak-ii-izgradnja-tunela-i-trase/

[10] Općina Kiseljak, *"Izmjene i dopune regulacijski plan "Kiseljak III""*, Služba za gospodarstvo, urbanizam, zaštitu okoliša i komunalne poslove, 2021

Construction waste management as a regulatory and environmental challenge in Montenegro

Snežana Rutešić[1]

Željka Beljkaš[2]

Miloš Knežević[3]

Stefan Rutešić[4]

1	Assoc. Prof., Faculty of Civil Engineering, University of Montenegro *snezanar@ucg.ac.me*
2	Assist. Prof., Faculty of Civil Engineering, University of Montenegro *zeljkab@ucg.ac.me*
3	Prof., Faculty of Civil Engineering, University of Montenegro *milosk@ucg.ac.me*
4	Student, Faculty of Civil Engineering, University of Montenegro *stefanrutesic@edu.ucg.ac.me*

Abstract

The management of construction waste represents a significant ecological, economic, and social challenge in modern urban environments. With the intensive growth of construction activity, inadequate disposal of this waste can lead to serious environmental consequences. On the other hand, in the context of the circular economy, construction waste represents a poorly utilized resource, where valuable materials such as concrete, metal, and wood are not reintegrated into the production cycle. This paper aims to analyze the existing legal framework regulating construction waste management in Montenegro, identify its shortcomings, and propose possible improvements in line with European standards. The core legal act is the Law on Waste Management, accompanied by strategic documents such as the National Waste Management Strategy and the State Waste Management Plan. However, the existence of legislation alone does not guarantee the success of the system; it only provides its foundation. There is a gap between advanced legislation on paper and weak implementation in practice. Implementation challenges include low recycling rates, a lack of organized landfills for construction waste, the prevalence of illegal dumping sites, and limited incentives for applying circular economy principles in construction, including mandatory use of recycled materials in public procurement and incentives for green building projects, among others. Key regulatory prerequisites for improving the construction waste management system include: strengthening inspection mechanisms, introducing economic incentives for recycling, and developing sustainable infrastructure solutions. In addition to enhancing legal regulations, broader societal mobilization is needed to reframe construction waste as a valuable resource rather than a burden.

Keywords

Construction &demolition waste (CDW), regulatory framework, EU directives

1. Introduction

Development based on the principles of sustainability and environmental protection is a commitment expressed in the Constitution of Montenegro, in which, among other things, Montenegro declared itself as an ecological country. Accordingly, Montenegro is a signatory to the most important international documents, policies and goals related to the concept of sustainable development, such as: UN Agenda 21 (1992), Kyoto Protocol (1997), UN Millennium Development Goals (2000), UN Agenda 2030 (2015), The Paris Agreement (2016) and Sofia Declaration (2018). In addition, as a candidate country for European Union membership, Montenegro faces the challenge of adapting to European standards in the field of environmental protection, particularly in waste management. EU directives in this area emphasize the importance of hierarchy in waste management. At the top of the hierarchy, the primary goal of the waste management system is the prevention of waste generation, i.e. reducing the amount and harmfulness of waste already in the production and consumption phase. If waste does occur, priority is given to preparation for reuse and recycling, which ensures the return of materials to production flows and reduces pressure on natural resources. The next level represents waste utilization, which is acceptable only when the previous options are not feasible. At the bottom of the hierarchy is waste disposal in landfills, considered the last and least desirable option, since it does not contribute to the circular economy and carries significant risks for the environment.

It is estimated that construction &demolition waste (CDW), generated during the construction, reconstruction, and demolition of buildings, constitutes a significant portion of total waste. In the European Union, CDW accounts for about 40% of all waste generated [1], while in Montenegro, these percentages ranged from 9 to 30% between 2011 and 2023 [2]. Although there are no directives exclusively addressing CDW, in European Union legislation, the Waste Framework Directive 2008/98/EC [3] and the Landfill Directive 1999/31/EC [4] include specific provisions in this area. These directives define the obligation of member states to ensure reuse, recycling, and other forms of processing for at least 70% of the mass of CDW. This promotes the transition to a circular economy, reduces landfill disposal, and encourages the use of recycled construction materials in new projects.

The achievement of the set goal depends on establishing an efficient waste management system, which must primarily have an adequate structure. The system's structure includes clearly defined institutional competences and appropriate regulations, enabling coordination and reducing misunderstandings among actors [5]. Additionally, flexibility in change management, i.e., the ability to adapt to new technologies and market conditions, enhances the system's capacity to respond effectively to changes [6]. Technological factors, such as the use of Building Information Modeling (BIM) and digital tools, allow for better waste flow planning and optimization of recycling processes [7]. External factors include economic conditions, such as the availability of financial resources and market incentives, which directly affect operational efficiency [8–11], as well as social and public factors, such as community engagement and contractor behavior, which promote compliance and help reduce illegal waste disposal [12]. Therefore, the efficiency of the CDW management system results from the interaction of internal structural and technological factors with external economic and social influences.

Research into legal frameworks forms the basis for investigating other aspects of CDW management. Effective regulation is essential for minimizing environmental impact and promoting sustainable practices in the construction industry [13–16]. However, the effectiveness of the established framework depends on the commitment of stakeholders and the enforcement of existing laws [17–20]. Therefore, cooperation among all key participants, including waste management organizations, government bodies, and academia, is necessary[21]. This paper analyzes the legal framework for CDW management in Montenegro, aiming to identify its weaknesses and provide recommendations for improvement in line with European standards. The topic is motivated by Montenegro's international obligations, the EU accession process, and the pursuit of sustainable development goals. At the same time, efficient CDW management helps reduce pressure on natural resources and land, while creating opportunities for the economic benefits of the circular economy.

2. Hypothesis and methodology

The following research hypothesis guides the study of CDW management legislation in Montenegro: The legislative framework of Montenegro in the field of CDW management is largely harmonized with relevant EU directives and includes key mechanisms for achieving the goals of a circular economy for CDW. This hypothesis assumes that existing laws and bylaws provide a legal and institutional framework for waste prevention, recycling, and disposal control, while their actual effectiveness may depend on implementation, monitoring, and the engagement of key actors.

The research is descriptive-analytical, with a comparative assessment of Montenegrin legislation and relevant EU practices. Primary sources include current laws, regulations, and strategic documents, while secondary sources consist of statistical data from Monstat, reports from the Environmental Protection Agency, and scientific literature. The main method for analyzing system efficiency is a SWOT analysis of the normative framework, evaluating the strengths, weaknesses, opportunities, and threats of regulations governing CDW management. The analysis also considers plan implementation, monitoring, and public participation, in order to identify key weaknesses and potential improvements to the system.

3. Results and analysis

3.1. Normative framework for construction waste management

The normative framework for CDW management includes strategies, laws, and plans that define legal norms and principles for managing all types of waste, while the narrower framework consists of specific regulations for CDW management. There is no

strategy exclusively dedicated to CDW management; however, two key strategic documents related to waste management should be highlighted. The National Strategy for Sustainable Development until 2030 (adopted in 2016) proposes general measures for CDW management, declaratively aimed at reducing CDW and increasing recycling. In addition, the Waste Management Strategy until 2030 (adopted in 2015) sets out specific goals, including: strengthening institutions, enforcing laws, improving waste registration, introducing economic instruments, constructing waste management infrastructure, expanding collection and recycling systems, establishing systems for special waste streams, utilizing waste for energy, eliminating illegal dumping, and raising public awareness.

The Law on Waste Management (2024) [22] is the most important legislation in this field, defining waste types and classification, planning, management conditions and methods, as well as other matters relevant to waste management. The law promotes waste prevention, reuse, recycling, and material processing, and sets out the conditions and procedures to be followed by collectors, transporters, traders, and intermediaries of waste, as well as the requirements for obtaining permits for waste processing and/or disposal. By transposing the provisions of EU waste directives [4–3, 23] and in accordance with Montenegro's EU accession agreement [24], the law establishes goals for reducing waste generation and/or disposal, increasing collection and recycling rates, among others. Waste management is carried out in accordance with the State Waste Management Plan (valid for up to six years), as well as local municipal and non-hazardous CDW management plans. The participation of numerous inspection bodies is foreseen, with competences primarily determined and divided according to the type of waste, its origin or disposal site, the processing method, and specific activities associated with the waste.

One of the by-laws specifically addressing CDW is the Rulebook on Handling Construction Waste [25], which allows temporary storage of materials by waste type on construction sites until the completion of works, for a maximum of one year. The law requires investors/contractors to prepare a CDW management plan when prescribed, and to keep records of waste types and quantities. It also defines the rights and obligations of investors and contractors regarding the transfer of waste to collectors and the possibility of on-site processing. Additionally, it regulates the handling of cement-asbestos waste in a manner that prevents the release of asbestos fibers into the environment.

Further obligations in waste management arise from laws in other areas, such as environmental protection, nature protection, air protection, spatial planning, and building construction. While not detailed here, these laws are harmonized with the primary legal framework.

3.2. SWOT Analysis of the regulatory framework

The comprehensiveness of the normative framework is one of the fundamental conditions for the effective implementation of regulations. The assessment of the framework's comprehensiveness in CDW management is carried out through an analysis of mechanisms that enable its application and regulation across all phases of waste management. Furthermore, harmonization with EU regulations is mandatory for all EU candidate countries, and the adoption of national laws cannot be carried out without a detailed analysis of compliance with European directives.

Table 1 – SWOT analysis of the regulatory framework

Category	Strengths	Weaknesses
Waste Prevention	• The law promotes sustainable development principles and extended producer responsibility. • CDW producers, must apply technological procedures and use materials in ways that prevent waste generation or minimize waste. • Waste prevention programs are defined, encouraging product reuse and repair activities, including for construction materials.	• No specific economic incentives to reduce CDW generation. • No direct obligations for designers or investors to use recycled materials. • The waste prevention program is not yet adopted, and no penalties are defined for non-submission.
Waste Management Planning	• Procedures for content, adoption, and reporting of the National Waste Management Plan and local municipal and non-hazardous CDW plans are defined. • Local CDW plans must include: assessment of CDW quantities, facility locations or temporary storage sites with deadlines, illegal dump remediation measures, and separate collection/ transport program. • Investor CDW plans are required if project volume >2,000 m^3 or CDW involves hazardous substances; plans must follow prescribed content, receive Agency approval, be publicly disclosed, and maintained in a registry; environmental inspection oversees preparation.	• •National and local plans: no penalties for non-compliance, public notification required but participation/impact procedures undefined, implementation reports lack specified content. • CDW management plans: no detailed quality assessment criteria, no methodology to verify volume thresholds, public participation limited to Agency-approved plans, approval deadlines not specified.
Waste Generation	• Obligation for non-hazardous CDW producers to pay a fee per ton of disposed waste • Regulation specifies CDW that can be reused on-site (up to 50 m^3) if technically and safely feasible	• No obligation to keep accurate records of CDW generated on-site • No precise sanctions for concealing actual CDW quantities
Waste Collection & Accumulation	• Separate collection of CDW fractions required: wood, mineral materials (concrete, brick, ceramics), metal, glass, plastic, gypsum • On-site storage allowed until construction completion, max one year, without environmental contamination • Framework conditions, deadlines, and record-keeping for temporary storage defined; municipalities pay annual fees for non-compliant sites; funds used for CDW treatment facilities, equipment, transport, and remediation of illegal dumps	• Regulation lacks detailed technical standards for on-site containers/temporary storage (e.g., covering, shelters, weather protection) • No defined method to control proper use of funds collected from temporary storage fees

Category	Strengths	Weaknesses
Final Waste Disposal	• Disposal at unauthorized sites prohibited; only inert and non-hazardous CDW allowed at inert waste landfills • Disposal facilities must be approved and comply with spatial plans • Remediation of existing illegal dumps mandatory • Special conditions for cement-asbestos waste disposal, with measures to prevent asbestos fiber and dust emissions	• State communal inspectorate not yet established • Measures to prevent illegal CDW disposal are not fully developed • No clear control or monitoring of CDW landfills regarding contamination and long-term impacts
EU Directive Compliance	• Full compliance with EC Regulation 1013/2006. • Partial alignment with key EU waste directives (Waste Framework, Landfills, Packaging, WEEE, Batteries, Single-use Plastics, ELVs, Asbestos, POPs, Mining Waste).	• Partial compliance mainly with general waste directives, not CDW-specific. • Some discrepancies pending implementing regulations.

Opportunities	Threats
• "Polluter pays" principle and extended producer responsibility incentivize waste reduction. • Potential sub-acts with financial incentives: reduced VAT for recycling, investment funds, green public procurement etc. • Inclusion of recycling requirements in building permits; promotion of LEED and similar standards. • Growth of green economy and jobs; public-private partnerships for modern CDW facilities. • Awareness campaigns for construction firms, investors, and citizens.	• Insufficient recycling capacity; facilities outdated/lacking. • Weak law enforcement due to limited supervision. • Delays in implementing strategic plans. • Illegal waste disposal or burning; high recycling costs. • Low market demand for recycled materials. • Political reluctance to adopt stricter regulations. • Public distrust in strategic and legislative measures.

3.3. Discussion and recommendations

Based on the previous analysis, it can be said that the normative framework lays the foundations for a CDW management system, but it does not provide the tools for its effective implementation. This is reflected in the fact that the Waste Management Law of 2016 failed to achieve the prescribed target for non-hazardous construction material by 2020, as required under the EU directive. Comparing available statistical data, in 2020 a total of 250,466.90 t of CDW was generated, while only 38,925.60 t was processed, which represents about 16%. Between 2021 and 2023 this percentage ranged from 13.7 to a maximum of about 34%, and in 2023 it amounted to about 22%.

Furthermore, effective waste prevention requires direct incentives for key actors, such as reduced VAT on recycled materials, green public procurement mandates, and subsidies for recycling infrastructure. These measures would promote the adoption of innovative technologies [26], sustainability standards (e.g., LEED, BREEAM, LCA) [27–28], and eco-friendly materials [29–30], thereby advancing circular economy goals.

In addition, although the normative framework clearly defines responsibilities, introduces the obligation of preparing plans in certain cases, and promotes transparency through their publication, it can be said that adequate mechanisms for quantity control have not been established. The waste information system has still not become fully operational, although some data on issued permits and registers in the field of waste management has existed earlier, without the possibility of generating reports for specific segments. For example, the register of approvals for waste management plans for 2025 includes all waste management plans of waste producers, but CDW management plans are not singled out. Moreover, in 2025 a total of 109 approvals were issued according to this register, while only 66 were recorded in the new information system. Under the previous Waste Management Law of 2011, there was no obligation for public disclosure of approvals and management plans. In the new system, plans for which approval was given are not accessible. Without more detailed regulations and supervision, CDW management plans risk becoming only a formality rather than an effective tool for reducing waste.

This issue is further compounded by the slow implementation of state plans and discontinuity in planning. The first plan was the Waste Management Master Plan (2005), which proposed a regional waste management concept with four regional landfills covering several municipalities. Areas were identified for the construction of sanitary landfills in order to reduce the number of uncontrolled dumpsites, along with proposals for the development of recycling centers and transfer stations. However, the plan soon faced public criticism due to insufficiently studied conditions of planned locations and potential environmental damage. After some time, the State Waste Management Plan for 2008–2012 was adopted, followed by the plan for 2015–2020. Montenegro is currently in the process of preparing a new State Waste Management Plan for 2025–2029. A draft of this plan was presented in March 2025 and is currently under public consultation, although its adoption was initially announced for December 2024. This indicates frequent changes in approach and strategy, particularly concerning the necessary infrastructure and its location.

Closely related to this is the issue of underdeveloped infrastructure for waste treatment and disposal. According to reports of the Environmental Protection Agency, between 2017 and 2023 there was only a slight increase in waste management infrastructure. Existing infrastructure consists of 2 regional non-hazardous waste landfills, 4 recycling centers (mostly for primary selection and sorting), 5 facilities for end-of-life vehicle processing, 4 transfer stations, 12 recycling yards, 2 medical waste treatment facilities, and 2 facilities for processing electrical and electronic waste. Only in 2024 was the preparation of a feasibility study for the construction of a facility for the recovery of CDW planned, with no further public information available.The lack of adequate infrastructure is also reflected in the persistence of illegal CDW dumpsites. According to the official register of uncontrolled disposal sites for 2023 [31], 126 locations (excluding Podgorica) in Montenegro have been identified where CDW has been illegally disposed of for extended periods, either separately or mixed with municipal waste. The total estimated amount exceeds 410,000 m^3, or about 500,000 t (about 98% of which is mixed waste). This quantity represents about 90% of the total construction and municipal waste generated in 2023, according to official Monstat data [2]. This clearly points to a systemic problem in CDW management, where waste is not recycled but is largely illegally dumped in nature, often along roads, waterways, and in close proximity to settlements. This situation not

only poses a direct risk to the environment and human health but also highlights the lack of effective mechanisms for control, monitoring, and treatment of this specific waste stream, despite the existence of clear European regulations and national obligations in this field.

Another challenge lies in the fragmented inspection system. Waste management inspection and oversight are designed as coordinated activities of several inspectorates with specifically defined competences, with each inspection responsible for certain types of waste or disposal sites. Such a fragmented structure may result in a lack of clear responsibility, overlapping inspections, and reduced efficiency in detecting and sanctioning irregularities. Inspection of CDW management is the responsibility of the state communal inspector and the local communal inspector, or the environmental inspector in the case of hazardous CDW. Although the new law was adopted in 2024, the state communal inspectorate has not yet been established, so inspection measures are currently carried out only by local communal inspections.

Finally, despite the established normative framework, there is a clear lack of public trust in project implementation. Although European practices and conventions aimed at ensuring transparency and public participation have been adopted (the Aarhus Convention and the EIA Directive 2011/92/EU), their application is often perceived as a formality, leading to dissatisfaction at the final stage of preparing plans and programs, and later at the beginning of their implementation. Waste management issues have been the source of numerous social tensions, protests, and blockades, particularly after 2015 when the state began implementing the new regional landfill system. The main cause has been the NIMBY effect ("Not In My Backyard"), which is understandable given negative experiences with existing landfills and fears of environmental disasters.

At the end of this discussion, it is evident that although the Waste Management Law was adopted in alignment with EU directives, achieving further progress will require the adoption of European practices that are not yet legally binding, such as the EU Construction and Demolition Waste Protocol (2016) and the methodology for waste measurement, which are essential for more effective implementation of the law.

4. Conclusion

In conclusion, while Montenegro's legislative framework for CDW management is largely aligned with EU directives and incorporates the key mechanisms to support a circular economy, its practical application faces challenges due to operational shortcomings. The absence of effective monitoring systems for mandatory measures—such as fees for temporary storage, waste management plans, and storage by fractions—compromises the system's functionality and transparency. Therefore, the initial hypothesis that the framework is harmonized with EU standards can be considered only partially confirmed, as its real-world efficacy depends fundamentally on enforcement, reliable oversight, and the active engagement of all key actors.

To bridge this gap, a focused dual strategy is essential. Short-term priorities must include introducing concrete financial incentives to promote recycling, strengthening inspection oversight to ensure compliance, and accelerating the development of recycling infrastructure. Concurrently, long-term success hinges on building public trust through sustained transparency and meaningful inclusion in planning processes. Only through this comprehensive approach can the normative framework transition from a formal structure into a fully functional and effective system.

Literature

[1] García, C.J. et al., "Techno-economic and environmental assessment of construction and demolition waste management in the European Union," Publications Office of the European Union, Luxembourg, 2024.

[2] Statistical Office of Montenegro - MONSTAT, "Waste statistics: Data," 2023. [Online]. Available: https://www.monstat.org/uploads/files/otpad/2023/Tabele.zip.

[3] European Union, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste (Waste Framework Directive), vol. L312/3, European Union, 2008.

[4] European Union, Directive 1999/31/EC of the European Parliament and of the Council of 26 April 1999 on the landfill of waste, vol. L182/1, European Union, 1999.

[5] Zhao, X.,"Stakeholder-Associated Factors Influencing Construction and Demolition Waste Management: A Systematic Review," Buildings, vol. 11, no. 4, p. 149, 2021.

[6] Harison, E. & Barkai,O., "Improving The Organization Of Waste Management Sites: An Operational Perspective," Journal of Business & Economics Research, vol. 10, no. 11, p. 651–658, 2012.

[7] Saka, A. et al., "Integrated BIM and Machine Learning System for Circularity Prediction of Construction Demolition Waste," 2024. [Online]. Available: arxiv.org/abs/2407.14847.

[8] Venes, H. et al., "An economic assessment model of construction and demolition waste management based on system dynamics: a case study in the city of serra - es," Environmental Engineering and Management Journal, vol. 22, no. 5, pp. 859-870, May 2023

[9] Rosado, L. P. & Penteado, C. S. G., "Municipal management of construction and demolition waste: influence of disposal fees," Ambiente & Sociedade, vol. 23, 2020.

[10] Zhang,H. et al., "Integrated Benefits of Sustainable Utilization of Construction and Demolition Waste in a Pressure State Response Framework," Sustainability, vol. 16, no. 19, p. 8459, 2024.

[11] Won, J., Cheng, J.C.P. & Lo, M.C., "A Comparative Study on Economic Policies for Construction and Demolition Waste Minimisation," in World Sustainable Built Environment Conference, Hong Kong, China, 2017.

[12] Liu, J., Yi, Y., & Wang, X, "Exploring factors influencing construction waste reduction: A structural equation modeling approach," Journal of Cleaner Production, vol. 276, p. 123185, 2020.

[13] Zakhilwal, S. A., Shirzad, W. & Behsoodi, M. M, "A Comprehensive Review of Engineering Strategies for Environmental Sustainability in Sustainable Waste Management," International Journal of Current Science Research and Review, vol. 7, no. 10, pp. 7456-7468, 2024.

[14] Amararathne, M. R. O. V. & Bandara, K. P. S. P. K., "Assessment of effective waste recycling practices to minimise construction and demolition waste in Sri Lankan construction industry," in World Construction Symposium – 2024 : 12th World Construction Symposium, Sri Lanka, 2024.

[15] Armistead, S. J. & Babaahmadi, A., "Navigating regulatory challenges, technical performance and circular economy integration of mineral-based waste materials for sustainable construction: A mini review in the European context," Waste Management & Research, vol. 43, no. 5, pp. 674-683, 2024.

[16] Iordachi, V., "Sustainable construction waste management - challenges and opportunities in promoting the circular economy," in Economic growth in the conditions of globalization: conference proceedings: International Scientific-Practical Conference, XVIIth edition, Chisinau, 2023.

[17] Frempong-Jnr, E. Y., Ametepey, S. O. & Cobbina, J. E., "Impact of stakeholder management on efficient construction waste management.Smart and Sustainable Built Environment.," Smart and Sustainable Built Environment, vol. 12, no. 3, p. 607–634, 2022.

[18] Shooshtarian, S. et al., "The impact of regulations on construction and demolition waste market creation and stimulation: Australian stakeholders' perception," IOP Conference Series: Earth and Environmental Science, vol. 1101, no. 6, p. 062012, 2022.

[19] Lu, W. & Tam, V. W. Y., "Construction waste management policies and their effectiveness in Hong Kong: A longitudinal review," Renewable & Sustainable Energy Reviews, vol. 23, pp. 214-223, 2013.

[20] Tran, N. M., Bùi, P. T. & Le-Hoai, L., in Proceedings of the Third International Conference on Sustainable Civil Engineering and Architecture. Lecture Notes in Civil Engineering, 2024.

[21] Kim, N. I. & Kim, K. C., "A framework to develop and improve construction and demolition waste management through the collaborative action of organizations, governments, and academia," Journal of Environmental and Earth Science, vol. 8, no. 2, pp. 26-39, 2023.

[22] Crna Gora, Zakon o upravljanju otpadom, Službeni list Crne Gore, br. 034/24, 092/24., Službeni list Crne Gore, 2024.

[23] European Union, Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste, and Directive (EU) 2018/852 amending Directive 94/62/EC on packaging and packaging waste, vol. L150/109, European Union, 2018.

[24] European Union – Montenegro, Stabilisation and Association Agreement between the European Union and Montenegro, vol. L195/3, European Union, 2010.

[25] Crna Gora, Pravilnik o postupanju sa građevinskim otpadom, vol. 020/25, Government of Montenegro (Crna Gora), 2025.

[26] Wu, J. L. & Deng, Y. B., "Construction Waste Recycling Technology Management Based on Circular Economic Theory," Applied Mechanics and Materials, vol. 260–261, p. 1009–1012, 2012.

[27] Salvi, S. et al. "Innovation Methodologies and Techniques Applied in Green Construction Through Sustainable Waste Materials," in Innovations in Energy Efficient Construction Through Sustainable Materials, R. González-Lezcano, Ed., IGI Global Scientific Publishing, 2024, pp. 129-158.

[28] Almusaed, A. et al, "Assessing the Impact of Recycled Building Materials on Environmental Sustainability and Energy Efficiency: A Comprehensive Framework for Reducing Greenhouse Gas Emissions," Buildings, vol. 14, no. 6, p. 1566, 2024.

[29] Muntean, R., Felseghi, R. & Cobîrzan, N., "Eco-Responsibility and Circular Economy in the Green (Sustainable) Built Environment," in Circular Economy Implementation for Sustainability in the Built Environment, IGI Global Scientific Publishing, 2023, pp. 57-83.

[30] Schützenhofer, S. et al., "Improvement of Environmental Sustainability and Circular Economy through Construction Waste Management for Material Reuse," Sustainability, vol. 14, no. 17, p. 11087, 2022.

[31] Crna Gora, Agencija za zaštitu životne sredine, "Informacija o stanju životne sredine u Crnoj Gori za 2023. godinu (Environmental Status Report of Montenegro for 2023)," Agencija za zaštitu životne sredine, Podgorica, 2024.

Characteristics of the regional economy in the face of globalization, tourism and tradition

Xhorxhina Prendi[1]

Sherif Bundo[2]

Brixhilda Çekrezi[3]

1 Assistent Lecture, Faculty of Economie, Luarasi University, Albania
xhorxhina.prendi @luarasi-univ.edu.al

2 Dean of Faculty of Economie, Luarasi University, Albania
sherif.bundo@luarasi-univ.edu.al

3 Student, Faculty of Economie, Luarasi University, Albania
brixhilda.cekrezi@luarasi-univ.edu.al

Abstract

This study examines the dynamics of the regional economy in the Western Balkans in the context of globalization, tourism, and tradition. It highlights the vulnerability of small economies characterized by agriculture, tourism, and limited industrial diversification, where periodic seasonality and emigration significantly affect growth. The paper raises critical questions about whether diversification, traditional economic practices, and the preservation of cultural identity can serve as stabilizing factors in the face of global risks such as limited financial resources, low technological capacity, and modest regional cooperation. Using correlation data between Albania, Kosovo, and neighboring countries, the study identifies weak economic integration and dependency on larger economies (EU, Turkey, China) as structural challenges. It argues that improved fiscal alignment, joint infrastructure projects, sustainable tourism, renewable energy, and support for organic agriculture and traditional products could strengthen resilience. Moreover, tradition—through gastronomy, handicrafts, and cultural exchange—can become both an economic resource and an instrument of regional integration. The article concludes that regional economies, while facing fragmentation and low cooperation, possess untapped potential in human creativity, natural resources, and cultural heritage that, if strategically mobilized, can ensure sustainable growth and a distinct identity within globalization processes.

1. Introduction

The regional economy and with it the economy of neighboring countries is being exposed to several risks related to fractionation, or limited demand. Due to being exposed as an economy with a development profile of agriculture, tourism and other secondary branches, and because an extreme periodicity and seasonality is observed in the development of tourism, an important research question is posed for economic researchers to solve: Is there a chance that this regional economy will be synchronized and well-diversified so that the seasonality of tourist developments does not force food industrialization but maintains the supply for good nutrition with characteristic seasonal products and as close as possible to organic production? This is a problem with many variables, but not without a solution. On the other hand, the expansion of globalization and integration are posing a series of other risks to small regional economies related to the lack of specialization, low yields, limited financial resources and low technical and technological level. Without a doubt, in the depth of these arguments, integration processes are accompanied by loss of identity, shrinkage of features, and decline of traditional and specific characteristics. In this perspective, the study of these phenomena constitutes a modest contribution. The central problem that is posed for solution is: involvement in globalization and integration can be accompanied by consolidation and preservation of the identity and characteristic profile of regional economies. Just as the Balkan region itself is a region that has several diversifying characteristics at once, such as geographical, economic, cultural, linguistic, monetary, political, institutional, historical, ethnographic and anthropological, and that these characteristics serve to increase stability and coherence in the face of deep global storms and crises, can this diversifying character be preserved and serve even more to reduce risks and increase the well-being of its inhabitants?

Due to this limitation, supply, production, business is partly motivated for expansion and expansion. What are some of the other common characteristics of the regional economy? What impact do factors such as: terrain, language, culture, lifestyle, diversity have on it? Can these factors be seen as complementary that instead of inhibiting serve as accelerators of economic development?

One of the main elements of sustainability in economic development is diversification? Can fractionation and fragmentation serve as factors of sustainability? Can the low level of technological development, a premise for rapid progress, serve to highlight unexpressed potentials, opportunities for high growth rates? Can the strong emigration of the population of these countries serve as a factor in improving the coefficient of economic penetration? Such numerous questions are worth discussing and debating at a conference like ours today, to see once again how environmental protection prevails over some of the economic factors after which society has often run like crazy. The race after interest, after maximizing profits, after strong political and institutional ties with small interest and clientelist groups has caused us to partially lose one of the great advantages of our regional economies, the advantage of a clean environment, of bio-nature, undamaged and preserved over the centuries.

2. Projections of a regional growth

Some of the other characteristics of the regional economy are: very high emigration, falling birth rate, human vitality, (suffering peoples progress more, and faster, it is enough to find the path of development, climate and the true motive of growth: for example, high construction rates). Infrastructural deficiencies, low access to markets, undeveloped areas, abandoned regions and lack of priorities in public investments. Public investments dictated more by subjective factors determined by electoral interests, individual influence/ preference, than by rational analysis and regional studies.

Criminal economy of drugs, arms trade and fraud (pyramid firms). Privatizations without rational criteria and effectiveness criteria have caused costs and have delayed economic growth. The economic growth of our economies has always been modest. Statistically low growth rates (average 2-4%). But with a low base, the growth in relative figures is large. Europe and America, Japan and the Dragons of Asia today grow by 0.5-1.2%, because they have reached the peaks of development. In developing economies, the spaces are larger. The problem always lies in finding the optimum. By studying government programs and public debates, of course this has been a partial study, we conclude that the failure to respect the strategies of rotations, or their formal drafting, has damaged.

Our countries have great advantages. Advantages such as: Creative spirit (poor people have more initiatives than rich countries, because they start with the mentality that we have nothing to lose), taking on risks, great lack of capital commitment, etc. All of these condition higher security. The market, currently limited, with an integration strategy can quickly turn into an interesting market with stimulating demand. Organic products, placed in the preferences of the European consumer and tomorrow even more in demand due to the global warming factor, create a suitable climate to expect the transfer of capital from other countries with hot climates to inhabited or little or no inhabited areas in our countries. We see that villages and areas abandoned due to lack of attention and strong emigration, will be the object of strong infrastructural investments, the cultivation of organic agriculture, and the breeding of livestock with high parameters of adaptation to nature.

The demand for a larger but well-oriented market that could reach up to 8 million. The Albanian network in the world, with successful and talented people, like Jews, a significant potential factor, with declining remittances.

3. Our countries have weak economic cooperation

Weak correlation of our neighboring economies, an indicator of the low level of economic cooperation. Why does this low level of correlation and cooperation occur? For several factors. First, because our economies have been influenced by the climate of political relations and economic cooperation and this has created a continuation. Second, market demands and the expansion of integrations, openness, globalization have caused economic movements to be oriented on two fronts: on the one hand, regional economies are directed towards imports from the economies of large countries, towards China and Turkey, but also towards Italy and Germany. This is natural due to the

phenomenon of arbitrage, the law of equal pricing. On the other hand, our economies have not created advantages for expanding exports towards those countries from which they import or towards countries with a significant market, towards the EU. Thirdly, the integration process as a phenomenon that was thought to melt the ice, that it would build new models, has lasted too long. This phenomenon is now considered to have lasted beyond reasonable time frames to be faced by the psychological factors that dominate economic behavior. This, the EU countries have neglected.

Where should we aim? What is the correlation that expresses the economic ties between Albania and the KS? What about between the two countries with other countries? What is the interest, that these two economies have a high or low correlation? A high correlation easily transmits systemic crises to each other. A low correlation makes them independent, unconnected? A strong or very strong correlation? Is there a level of correlation that is suggested to serve as a floor? What is the average or lowest correlation of the Balkan countries with each other? The Balkans have stronger ties with the EU economy, with Turkey or with China?

Country	Albania	Kosova	North Macedonia	Montenegro	Croatia	Greece	Italy
Albania	**1**	0,478	0,512	0,357	0,443	0,612	0,665
Kosova	0,478	**1**	0,772	0,379	0,371	0,444	0,455
North Macedonia	0,512	0,772	**1**	0,332	0,359	0,611	0,388
Montenegro	0,357	0,379	0,332	**1**	0,522	0,351	0,577
Croatia	0,443	0,371	0,359	0,522	**1**	0,511	0,588
Greece	0,612	0,444	0,611	0,351	0,511	**1**	0,633
Italy	0,665	0,455	0,388	0,577	0,588	0,633	**1**

Source: Calculations by authors

Can we talk about the flexibility of the correlation of our countries between quarters and months? What about energy correlation? To see the degree of influence and dependence winter/summer, or spring/autumn when the hydrological rainfall has extremes of flow.

We judge that there are other factors that can improve the correlation coefficient of regional economies with each other? Among them, we suggest that fiscal approximations, without drastic changes, without major changes and oscillations, the same infrastructural tracks and obstacles of barriers that demotivate investments in technology, would be a move in the right direction. Public investments common, major, harmonized, well thought out. Care for biodiversity as a rare feature. Investments in sectors with a high degree of intelligence, AI, ... Strong public investments in joint regional projects, Balancing imports with exports, priorities in tourism development, special tourist products away from giant tourist installations, Investments in renewable energy, investments in transport, especially in the creation of transport axes from Central Europe to the Mediterranean. Exports of Albanian products to the countries of the region are modest. There is a lack of an orienting compass which we often consider as the locomotive of development and

with a special profile of economic cooperation. We are more concerned about the incoming tourist flows than about the export of products to this market. Bio products, essential oil products that are in demand in European markets, the development of handicrafts and strong support for tradition and culture. To increase the standards of local products, encouraging the production of olive oil and the processing of rare metals with high technology. Large reserves of high-quality livestock products and encouraging prices. Agencies to solve the difficulties and standardization of products for export, in support of small producers. Farmers, artisans, small workshops, small factories, organic producers, craftsmen, have neither the knowledge nor the staff to solve the demands of the European market and standardization.

There is a risk that all these initiatives of bilateral cooperation in the space of our small countries will lose credibility as long as they remain at the central and rhetorical level, without concrete long-term results for the population in general and with the truncated perspective of a larger project, that of the fastest integration into the European space. The time has come for institutions to create the appropriate instruments for monitoring agreements and initiatives undertaken, the appropriate additional mechanisms for strengthening cooperation at the local level and by private actors in order to give life to real and long-term cooperation in the Albanian-speaking regional space.

Are free trade agreements sufficient to factor in and create the identity of the locomotive in the economic development of our countries? There are a considerable number of cooperation agreements, free trade agreements, even within the framework of CEFTA, but most of them are not alive.

Do we have the same traditional behaviors that influence and condition demand? Which ones? Family economies, large traditional, or fractional? Emigrant movements? The trend for construction? The fashion of the same businesses is either a transfer of capital from one branch of the economy to another without much imagination. We believe that the same businesses in the same neighborhood, on the same street in a city, in the same cities, or in similar places, indicate a lack of vision and orientation. The number of cafes for the same area, for the same number of inhabitants, the number of bakeries, bakeries, pharmacies, bakeries, ready-made clothing stores, fuel distributors, etc., indicate a low level of flexibility and slowness of economic orientation. In such circumstances, the implementation of strong policies serves to encourage new behaviors. In the Albanian economy, the policy of encouraging investments in olive cultivation and increasing olive oil production has led Albania to rank among the countries with a moderately high production of olive oil per capita and to approach Spain, Greece, Italy, etc. The ability to adapt? The ability to adapt to changes, demands, and global movements, to integrate into small and large groups of countries and peoples, is another characteristic.

Transport in our economies is one-sided, only automobile transport. Businesses are micro-units, small and very few medium-sized. Rural economies, where there is potential, are unintegrated with the market. In Albania, these areas are large. The number of livestock heads has a decreasing trend.

Traditional economy? Can economic development be sustainable based on the promotion of the traditional economy?

We think that from a traditional perspective, cooperation can be even greater and have a stronger impact on our economies. Not only can we consider tradition a source of development and investment, but also a factor of approximation and integration.

What do we mean when we say traditional economy? There are some countries that in the process of integration into the EU have preserved and created their profiling in these collaborations. Greece has preserved the tradition of feta cheese, Italy has preserved its advantages in the field of gastronomy, pastries, etc., France with wines, and so on. We judge that our regional economies can also create a specific profile. Our countries can be promoters of Balkan events, festivals, championships, exchanges of folklore groups, cooperation in the fields of education, culture, tradition, history. Commonalities can unite us more than they divide us. Of course, this is a broad topic of discussion and the time available is not enough to carry out exhaustive treatments.

Literature

[1]	Fredrich Ebert: NDIKIMI i SHQIPËRISË NË RAJON NË HAPËSIRËN SHQIPFOLËSE, Autorë: Dorian Jano, Enri Hide, Klodjan Rama, Ben Andoni, Botues: Friedrich-Ebert-Stiftung
[2]	Gjevori, Elvin (2018) "Kin state non-interventionism: Albania and regional stability in the Western Balkans", Nations and Nationalism 24 (1): 171–193.
[3]	Shaban Murati, Botimi: "Hije në diplomacinë shqiptare" (2012: 247). Referuar:
[4]	Beshku, Klodiana (2016) "Perceptime të Intelektualëve mbi Performancën e Politikës së Jashtme Shqiptare (2013-2015)", Qendra e Ekselencës, Ministria e Punëve të Jashtme, Maj, Tiranë, fq. 20.
[5]	Klodjan RAMA, Ndikimi ekonomik i politikë së jashtëme të Shqipërisë, ndaj shqiptarëve në të gjithë rajonin e Ballkanit
[6]	World Bank (2017), Job Creation Picks Up, Western Balkans Regular Economic Report, No.12.
[7]	http://documents.ëorldbank.org/curated/en/477511510774559876/pdf/121417-ËP-PUBLIC.pdf.
[8]	Marrëveshja e nxitjes dhe mbrojtjes së ndërsjelltë të investimeve, nënshkruar më 3 maj 2016. Marrëveshja ndërministrore për bashkëpunim në fushën e Industrisë, Tregtisë dhe Standard-izimit", nënshkruar më 30.09.2010.
[9]	Marrëveshja "Për shmangien e tatimit të dyfishtë lidhur me tatimet dhe mbi të ardhurat mbi kapitalin dhe për parandalimin e evazionit fiskal" nënshkruar më 28.3.2014 dhe hyrë në fuqi më 11 Mars 2015 37 "Marrëveshja mbi bashkëpunimin dhe ndihmën e ndërsjellë, në çështjet doganore" të vitit 2009.
[10]	"Marrëveshja për Bashkëpunim në Fushën e Turizmit" mes MTI & Ministria e Turizmit Kulturës Rinisë dhe Sporteve të Shqipërisë nënshkruar më 09.05.2006.
[11]	"Memorandumi i Mirëkuptimit për hapjen e bashkëpunimit në infrastrukturën e cilësisë mes MTI & METE, nënshkruar më 06.02.2007 40Marrëveshja "Për shkëmbimin dhe mbrojtjen e ndërsjelltë të informacionit të klasifikuar, nënshkruar më 07.11.2012 dhe ratifikuar me ligj nr. 5/2013, datë 25.02.2013
[12]	Marrëveshja "Për bashkëpunimin në fushën e veterinarisë, nënshkruar më 16.11.2012 dhe miratuar në parim me VKM-në nr. 947, datë 26.12.2012
[13]	Memorandum Mirëkuptimi" mes MTI-Departamentit të Metrologjisë së Kosovës dhe Drejtoria e Përgjithshme e Metrologjisë të Shqipërisë, nënshkruar më 26.11.2012 43 Laërence, Z.R., Frasheri, E., and Qazi, M. (2014).
[14]	Integration in the Balkans: Albania and Kosovo. Report in the frame of the Economic Groëth in Albania Project at the Center for International Development at Harvard University. Cambridge M.A. USA.

T6

Education and Communication

Addressing evolving active attacks threats using integrated training curriculum

Amer Smailbegović[1]

Mirzo Selimić[2]

1 Doc.dr., Technical advisor, DTCare NGO
amer@dtcare.org

2 Doc.dr., Director, University College „CEPS-Center for Business Studies“ Kiseljak
mirzo.selimic@ceps.edu.ba

Abstract

Increasing reach of various extremist narratives via social media and the availability of firearms and explosive-making components on the black market, particularly in the Western Balkans creates a potentially dangerous environment, particularly for the emergency services personnel. Given the lack of funds and specific training to respond to an active attack scenario, the ramifications of such event could have disastrous consequences. Undergraduate, graduate and even post-graduate students are deficient in the type, duration and quality of practical skills development, particularly in the hands-on occupations such as fire, rescue, emergency and law-enforcement services. Recent introduction of the Texas State University's ALERRT (Advanced Law Enforcement Rapid Response Training) program and subsequent training of certified instructors has created the possibility of teaching an add-on CRASE (Civilian Response to Active Shooter Events) program within the local educational institutions, the majority of which are woefully underequipped and undertrained to address such emergencies. Both ALERRT and CRASE type training in the region are adapted to include enhanced first-aid/casualty evacuation modules, situational awareness, first response, incident command and communication strategies. The presented skill-development outlines some of the new approaches in the adoption of effective strategies to address the new threats. The key factor was to re-establish the mentoring and hands-on elements in the curriculum development and engagement of various subject matter experts (SMEs) to deliver and evaluate specific skills (i.e. incident command). Another crucial element is the collaborative research outreach with various research institutions, foundations, networking organizations and educational partners in the region to create cohesive, modular and interoperable programs in public safety.

Keywords

Practical skills, Public safety, Integrated training curriculum, Emergency service

1. Introduction

A spate of mass-shooting / active-attack events that have occurred in public schools in Serbia, Croatia and Bosnia and Herzegovina have left the authorities and administrators scrambling to adopt new strategies and procedures to curb such incidents. In a relatively short order, the Western Balkan region experienced multiple active attacks: Vladislav Ribnikar Elementary School in Belgrade, Serbia (May 2023), villages of Dubona and Malo Orasje (May 2023), Daruvar retirement home in Croatia (July 2024), Sanski Most High School in Sanski Most, Bosnia and Herzegovina (August 2024); Precko Elementary School in Zagreb, Croatia (December 2024), Cetinje, Montenegro (2022 and January of 2025). The final toll was over 50 dead and many more wounded.

For over twenty years, the United States dealt with the mass-shooting crisis, that reached nearly epidemic levels by 2023. [1] With an increasing number of attacks and mounting casualties, a novel and thorough approach to policing, resistance and response was needed – hence the Advanced Law Enforcement Rapid Response Training (ALERRT) was introduced in 2002 as a partnership between Texas State University, San Marcos, Texas Police Department and the Hays County, Texas Sheriff's Office to address the need for active shooter response training for first responders [2] Texas State University ALERRT (Advanced Law Enforcement Rapid Response Training), created in 2002 in the aftermath of the active shooter event at Columbine High School in 1999, quickly expanded across the variety of agencies and institutions in the USA, and was also adapted for the training of civilians via the CRASE (Civilian Response to Active Shooter Events) program.

DTCare, a non-sectarian, non-governmental organization, operating in Bosnia and Herzegovina since 2020, contacted ALERRT Center to organize introductory active-shooter training for Bosnia and Herzegovina's fragmented law enforcement system and also address wider community impact through ALERRT's specially tailored community-outreach program called CRASE – Civilian Response to Active Shooter Events. The specialized course takes the elements of the law-enforcement training and presents it to the civilian audience on how to best protect themselves and others until the law enforcement arrives. The CRASE program is intended for public institutions, schools, hospitals etc. – all potential soft-targets for an active shooter attack.

2. Training curriculum

ALERRT utilizes a two-phase process of response, thoroughly described in Blair and Martindale *Chain of Survival* [2]. The first phase is referred to as Stopping the Killing. During this phase, the primary focus of officers is on preventing the attacker from creating more casualties. This involves moving quickly toward the location of the attacker to affect an arrest (in USA it often involves the use of deadly force). Skills taught for this phase include arriving at the attack site, moving toward the crisis location, entering the location, interior movement, and room entry. During this phase, officers will bypass injured and uninjured victims to quickly close with and arrest attacker.

After the attacker has been stopped, the second phase, Stop the Dying, begins. The responders are first taught to provide basic point-of-wounding care to prevent the injured from dying at the scene, and then to transport the injured to an appropriate level of medical care. This is often a Level I trauma center in the US. Skills taught during this phase include bleeding control, basic airway management, prevention of hypothermia, simple triage, patient movement, and transporting victims in patrol cars.

Both phases of the coursework include short lectures, skills practice blocks, and extensive scenario-based training and the similar approach is used in the teaching of non law enforcement coursework like CRASE.

3. Practical training challenges

At the cessation of hostilities in 1995, Bosnia and Herzegovina probably had some of the best trained and effective emergency services that bore the brunt of assistance and response in the wartime contingencies. That tremendous talent and skill was lost in the post-conflict period as the institutions of higher learning were preoccupied with the reconstruction and reintroduction of various degree programs. Given the lack of funds and interest of various faculties, development of practical skills and practical education has dropped to the present all-time lows. Undergraduate, graduate and even post-graduate students are deficient in the type, duration and quality of practical skills development, particularly in the hands-on occupations such as fire, rescue, emergency and law-enforcement services [3]

The lack of hands-on education results in an increased financial and temporal burden in the emergency services, as they have to perform extensive on-the-job training procedures, which in turn reduces their own effectiveness and cohesion. It is important to note that the victims of mass-shootings have a very limited time-window to survive the incident [2]. In the short-emergency-response jurisdiction such as the United States (national average: 3-4 minutes), the stabilization of victims on-site provides an important element in their overall survival outlook. However, in the Western Balkans, where the professional medical response time is often in excess of 15 minutes [4] the reliance on in-situ assistance and stabilization is of paramount important. Even more importantly, actively denying and resisting the active attacker appear to be better, preventive options than reliance or expectations of an expedient response by the law enforcement or emergency services.

The primary areas of practical skills expertise development therefore are in the law-enforcement and security fields, firefighting, workplace safety, medical services and information technology. The key factor was to re-establish the mentoring and hands-on elements in the curriculum development and engagement of various subject matter experts (SMEs) to deliver and evaluate specific skills (i.e. incident command). Another crucial element is the collaborative research outreach with various research institutions, foundations, networking organizations and educational partners obtained through the ERASMUS+ program on the EU level or via DTCare's network with the U.S. partners, such as ALERRT or DHS.

4. Complicating factors

The Western Balkans region is awash with firearms, ranking in the top of firearms (and light weapons) ownership in the world [5] many of them residual from the Yugoslav succession wars (1990-1995) as well as a considerable cultural component, particularly in Serrbia and Montenegro [6]. It is expected that the eventual cessation of hostilities in Ukraine will result in additional infusion of firearms and military equipment in the region [7]. Also, taking into consideration long-duration and manifestation of post-traumatic stress disorder (PTSD) and generational trauma of Yugoslav succession wars [8] the prime risk envelope for active-attack is exponentially increasing.

Coupled with an increasing reach of various extremist narratives (BIRN, 2023) via social media and the availability of firearms and explosive-making components in the Western Balkans, the current situation depicts a potentially dangerous environment, particularly for the emergency services personnel. Given the lack of funds and specific training to respond to an active attack scenario, the ramifications of such event could have disastrous consequences. Undergraduate, graduate and even post-graduate students are deficient in the type, duration and quality of practical skills development, particularly in the hands-on occupations such as fire, rescue, emergency and law-enforcement services [9].

5. Implementation

With the increasing risk, one has to approach civilian active shooter response (CRASE) training with an emphasis on the avoid and deny aspects, and less so on the defend portion (given that even in the light of a successful defense against the active shooter, an individual may still be charged with capital offense(s), at the discretion of the prosecutor, if they used disproportionate level of force against the attacker).

To date, four (4) CRASE workshops were taught in Bosnia and Herzegovina – two (2) at the institutions of higher learning, one (1) in the public administrative building and one (1) in the corporate setting (banking, private security etc.). Additionally, in November of 2024 and July of 2025, ALERRT / DTCare have conducted two Level I Train-the-Trainer classes in Kiseljak, Bosnia in conjunction with CEPS College for the six law enforcement agencies in Bosnia and Herzegovina. Our successful delivery of these initial classes has laid the groundwork for deeper collaboration in the region.

On the civilian side, particularly within the university / high-school teaching curriculum, the avoidance of the attack is generally the most applicable, but also the least one implemented or thought about. Majority of the schools and public buildings (i.e. hospitals, post-offices, public administration buildings) are very lax on security, usually have only one entrance, no clear evacuation routes and would present a potential death-trap during an active shooter response. To effectively address this – one needs to show exact examples and try to illicit response from the audience about the potential threats and ways to overcome them within a particular institution and their floor plans.

Denial of an active armed attack with locking, hiding, barricading etc. are also complex given that many of the internal doors don't have functional locks and many of the doors are outward opening (or double-swing) making them very difficult to effectively

lock out or barricade. One of the saving graces is that many of the public buildings still carry in inventory many of the heavy Yugoslav furniture which could make for effective anti-personnel barricades, capable of withstanding much of the currently available arsenal. However, given the soft-nature of the new architectural and public spaces, one has to emphasize the situational awareness and various avoidance / distraction strategies.

Given legal repercussions, the "defend" portion of the CRASE curriculum is addressed but framed within the context of an ambiguous framework of self-defense. Given that the considerable portion of the populace still vividly remembers the effects of Yugoslav-dissolution war, the issue of self-preservation is relatively ingrained into the common psyche and more attention should be given to making the surroundings safer and harder. Also, a significant accent is given on the first-aid portion (stopping the dying part) with the proper application of bandages, makeshift bandages, tourniquets and movement to safety.

There are very few courses offered on first aid, triage and such, which further complicates the potential victim assistance in the wake of an active shooter event. The four-month military conscription service ended in 2005 in Bosnia and Herzegovina; since then the neighboring countries (Croatia and Serbia) have re-instituted military conscription in 2024, with an accent onto emergency preparedness and first aid. There are no such plans in Bosnia and Herzegovina given the lack of national-level cohesion and agreement on the defense or emergency matters.

6. Concluding remarks

Based on the limited interaction with the CRASE training participants (16 hours cumulative in Bosnia and Herzegovina) and practice-based curriculum taught at CEPS College to the students of Criminal Justice and Security undergraduate curriculum, it is evident that there is a need for active-shooter / preparedness instruction at various levels, but particularly at the collegiate level. Many of the current college students are completely devoid of situational awareness and life-saving skills which would be needed for utilization in an active attack scenario.

Given that there are currently no plans to re-institute military or national service training in Bosnia and Herzegovina, instituting a basic hands-on emergency response curriculum in the institutions of higher learning would be at least suitable base to provide some life-saving skills that could be implemented in an emergency. It is therefore recommended to integrate the CRASE training curriculum at all educational levels, especially given the lack of other courses or training (i.e. first aid) in Bosnia and Herzegovina.

Literature

[1] Donnelly, M., Grigorian, A., Inaba, K., & al., e. (2023). Trends in mass shootings in the United States (2013–2021): A worsening American epidemic of death. The American Journal of Surgery; Volume 226, Issue 2., 197-201.

[2] Blair, J., & Martindale. (2024). The Chain of Survival: Responding to an Active Attack. San Marcos, TX: TPPP, LLC.

[3] Smailbegovic, A., & Brown, A. (2024). Former paramilitary organizations as a proxy for civil defense: Bosnia and Herzegovina and Lebanon. *Security Dialogues*, Vol 14 No. 2.

[4] Sljivo, A., Jevtic, T., Terzic-Salihbasic, S., & al., e. (2024). Out-of-hospital cardiac arrest (OHCA) in Bosnia and Herzegovina in the period 2018 -2022: current trends, usage of automated external defibrillators (AED) and bystanders' involvement. Medicinski Glasnik, 21(2), , 267–273.

[5] Grillot, S. (2010). Guns in the Balkans: controlling small arms and light weapons in seven Western Balkan countries. *Journal of Southeast European and Black Seas Studies*. , DOI: 10.1080/14683857.2010.486945.

[6] Cvetkovic, V. (2006). Serbian society and gun culture. *Sociologija 48 (1)*, DOI: 10.2298/SOC0601039C.

[7] Januta, A. (2025, May 2025). *What happens to all the guns in Ukraine post-war?* Retrieved from Kyivindependent.com: https://kyivindependent.com/as-ukraines-peace-talks-gather-steam-experts-plan-ahead-for-post-ceasefire-gun-control/

[8] Comtesse, H., Powell, S., Soldo, A., & al., e. (2019). Long-term psychological distress of Bosnian war survivors: an 11-year follow-up of former displaced persons, returnees, and stayers. *BMC Psychiatry 19.*

[9] Smailbegovic, A., & Korajlic, N. (2021). *Compendium on crisis management in Western Balkans : selected articles on regional crisis management : 2019-2021*. Sarajevo, Bosnia and Herzegovina: University of Sarajevo, Faculty of Criminalistics, Criminology and Security Studies.

Importance of communication in disaster risk management

Edisa Nukić[1]

Aida Krlić[2]

Jelena Marković[3]

Zvjezdan Karadžin[4]

1	PhD, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Bosnia and Herzegovina *edisa.nukic@untz.ba*
2	BSc safety eng., Master student *aida__krlic@hotmail.com*
3	PhD, University of Tuzla, Bosnia and Herzegovina, Faculty of Mining, Geology and Civil Engineering *jelena.markovic@untz.ba.*
4	PhD, University of Tuzla, Bosnia and Herzegovina, Faculty of Mining, Geology and Civil Engineering *zvjezdan.karadzin@untz.ba.*

Abstract

Media plays an invaluable role in disaster preparedness and response by raising public awareness and disseminating critical information. Both traditional (print and electronic) media and modern digital platforms are essential for warning, educating, and mobilizing support for recovery efforts. While traditional mass media have historically reported on catastrophic events, the digital age created new opportunities for crisis communication through electronic media and social networks.

Effective communication in crisis aims to empower citizens, foster risk understanding and cooperation between citizens, emergency responding organizations and media. The main focus of crisis communication is comprehensive exchange of information and viewpoints among involved organizations, public groups, media, and other stakeholders.

This paper explores the critical role of crisis communication in disaster risk management, with a particular emphasis on use of mass media during crisis situations, specifically examining how residents of Tuzla Canton utilized and trusted mass media, primarily social media and internet portals, during catastrophic floods. The research was conducted to assess the use of information technologies in crisis communication during natural disaster with the aim of clarifying how high-quality information sources can help during such events. A survey assessed citizens' experiences with electronic media during emergencies and their trust in these platforms within Bosnia and Herzegovina, considering the challenges faced by institutions in communicating during analysed natural disaster. Ultimately, this study seeks to identify both the positive and negative aspects of crisis communication via social media.

Keywords

Disaster Risk Management, Crisis Communication, Electronic Media, Social Networks

1. Introduction

Bosnia and Herzegovina (BiH) is a country with very high flood risk, which is documented in the Risk Assessment on natural or other disasters, which defines that "floods represent the greatest danger to the community and its population" and the assessed flood risk is ranked as "very high". The Assessment states that floods in many areas can cause significant material damage, major damage to infrastructure and environment, damage to public health, including loss of human life[1].

The 2014 floods are considered one of the worst disasters in the country's recent history, and during and after these events, questions of communication, public information and coordination were frequently raised, with special attention paid to shortcomings and opportunities for improvement. Many media outlets addressed this issue, including Radio Free Europe which in the article "Floods: Absence of Accountability and Crisis Communication" analyzes communication and response failures during the floods, providing insight into how media and the public perceived information; the internet portal "Klix" publishes an article dealing with the role of media and social networks in spreading information during the crisis, while "Al Jazeera Balkans" explores the relationship between media and competent institutions during the floods, focusing on the aspect of information exchange and reporting accuracy.

The idea that "communication is an important form of aid and can be as important to survivors as food, water and shelter" is the foundation of discourse on humanitarian technology - and increasingly of humanitarian discourse in general. According to the World Disasters Report from 2013, self-organization in the digital world offers possibilities that were not achievable in the analog past. Disaster-affected populations now have greater access to information, and many of their information needs during crisis can be met by mobile technologies [1].

FEMA frameworks guide how to respond to disaster emphasizing a “whole community approach” where communication should be accessible to everyone emphasizing key principles as timelines to prevent rumours and misinformation, clarity, consistency to avoid confusion and audio-centric as to be tailored to needs of different groups [2]. The United Nations Office for Disaster Risk Reduction (UNDRR) considers risk communication as critical components of disaster risk reduction and in its guidelines, aligned with Sendai Framework, recommends “whole of society” approach that moves beyond one-way information dissemination [3,4]. The International Federation of Red Cross and Red Crescent Societies (IFRC) approach to disaster communication centers on human dignity and community empowerment emphasizing two-way communication, communication accessible to all but above all putting people first [5].

This paper analyses the attitudes of the Tuzla Canton (TC) population and their level of trust in the operation of mass media, primarily social media and internet portals, during disasters, as well as the positive and negative aspects of crisis communication through social media. Additionally, it explores the importance of good communication and quality information sources in managing the risk of catastrophic events.

[1] Risk Assessment of Bosnia and Herzegovina from Natural or Other Disasters, March 2011 (updated 2017 and 2019)(https://msb.gov.ba/PDF/13072022.pdf)

2. Communication during catastrophic events

In crisis situations, people suffer significantly due to inaccurate information or misperception of risk. Within communication, as an integral factor of risk management, participants and exposed groups should be adequately informed with developed objective risk perception and the ability to reduce consequences or risk probability. In the context of natural disasters, technological disasters or other crisis situations, effective communication between all relevant actors - authorities, rescue services, media, civil protection services and the population - can be crucial for reducing negative consequences and protecting lives and property. Some research (Slovic and Sandman) suggests that public perception of risk isn't exclusively based on scientific data but instead it is shaped by qualitative characteristics that fall into two main factors: dread risk (risks are perceived as more dreadful if they are uncontrollable, catastrophic, fatal, and have an unequal distribution of risks and benefits) and unknown risk (as risks are more threatening if they are new or unknown) [6].

The increase in the frequency and consequences of both floods and other natural hazards caused by climate change in Bosnia and Herzegovina highlights the urgent need to reduce existing risks through economic, social, cultural, and environmental measures that address issues of exposure and vulnerability, thereby strengthening resilience [7]. The natural disaster analysed in this paper emphasized the importance of communication in crisis situations, particularly regarding informing the public and reassuring endangered population that the situation is under control.

2.1. Reporting floods in BiH

The floods that affected BiH in May 2014 found the protection and rescue system structures unprepared, and citizens were deprived of adequate and timely information related to the catastrophic event that occurred. The floods revealed that there was no synergy between the bodies that manage water, and thus the flooding risks, and the bodies that deal with the protection and rescue of people and material goods [8]. On May 15, 2014, the State Council of Ministers adopted a Decision to request international assistance[2]. The Rapid Reaction Team (RRT) for Civil Emergency Planning (CEP) was on the ground. In their report after this disaster, it is stated there is a need for training in disaster management (especially regarding coordination, cooperation and information management). They also noted that insufficient information flow led to communication problems, which significantly affected coordination and cooperation, early warning, flood management and other necessary tactical and operational response activities [9]. After the catastrophic floods, the Civil Protection structures identified the need for "the Federal Civil Protection Administration to prepare and adopt an appropriate regulation that will regulate public relations and crisis communication procedures during natural and other disasters".

[2] Crisis Management – The Case of the 2014 Floods in BiH; Parliamentary Assembly of BiH; October 20, 2015.(https://www.parlament.ba/Publication/Read/4728?title=upravljanje-krizom---primjer-poplava-u-bosni-i-hercegovini--2014.-sa-osvrtom-na-spremnost-bosne-i-hercegovine-za-prijem-veceg-broja-izbjeglica-&pageId=0)

According to research by the INFOHOUSE Association Sarajevo from March 2016, which focused on printed media during this catastrophic event, the general assessment is that media reported intensively in the first months immediately after the floods, but reporting was not always consistent and detailed. According to the research, media gave high priority to floods in the first months. Although floods were a prominent topic, only 6% of publications were biased, which is a relatively positive finding. Media mainly used official sources of information, such as state and local officials, while there was very little investigative journalism. The analysis shows that, although media reacted quickly and gave high priority to flood reporting, reports were not sufficiently in depth and investigative. Also, in competition with new forms of media, print media must invest in quality and thorough information to maintain relevance and financial sustainability [10].

3. Survey on the importance of communication in disaster risk management

The subject of this research is the use of modern social media in communication process during emergency situations, and examining population attitudes about the role of social networks in preparedness and response of affected communities during catastrophic events. A survey was conducted to investigate citizens experiences with electronic media information during emergency situation and to determine the level of trust in electronic media in BiH [11].

3.1. Methodology

Research study included quantitative and qualitative analyses. The goal of quantitative analysis is to draw conclusions from collected data and gain understanding of general trends. Results are presented in percentages. Qualitative analysis served to understand respondents' experiences, opinions and attitudes. Results are visually presented through histograms and graphs for easier understanding. The survey research was conducted anonymously and combined through online questionnaire and printed questionnaire. The online questionnaire was created via Google Forms platform, and could be accessed via link:

https://docs.google.com/forms/d/e/1FAIpQLSf4Sve0CYsBURXsxurpuNiNs-PlRg_c4nuagmDtkYbWpLFioNQ/viewform

The questionnaire consists of 14 closed-ended questions. The online questionnaire provides the possibility for quick and efficient completion, while responses are collected automatically and anonymously, and the results are displayed graphically. Printed questionnaires were used because a certain portion of the population prefers this method of participation in research. The research began during the last week of March 2023, and data collection continued until the end of July 2023. The online questionnaire collected

77 responses, while the printed questionnaire collected 30 responses, totalling 107 responses. For the population of over 350,000 citizens[3], which is deemed large enough, Cochran's sample size formula[4] is used in Eq. (1) to determine minimum sample size required for conducting a survey. In the calculations, confidence level is set to 0.95, and margin of error e is set to 0.1. This implies that the Z-value is equal to 1.96 with respect to the Central Limit Theorem[5] and specified confidence level. To ensure that maximum value n is obtained in Eq. (1) for the specified parameters, estimated population proportion p is set to 0.5. Since calculated value of minimum sample size n is 96 in Eq. (1), the sample size of 107 participants in the conducted survey is deemed valid for the subsequent analysis.

(1)

Where n is minimum sample size required for conducting a survey, Z is the value associated with specified confidence level based on the Central Limit Theorem, and p is the estimated population proportion.

Chi-square test[6] is used in Eq. (2) to check if there is a statistically significant difference between the gender distribution in the sample and the analyzed population. For this purpose, Null Hypothesis and Alternative Hypothesis are defined as follows:

Null Hypothesis H_0: *Gender distribution in the sample is not significantly different than gender distribution in the analyzed population.*

Alternative Hypothesis H_1: *Gender distribution in the sample is significantly different than gender distribution in the analyzed population.*

In the conducted survey, 61 participants were women and 46 participants were men. These values are defined as the observed frequencies of women O_w and men O_m in Eq. (2). According to the FBiH Institute of Statistics, approximately 51% of the TK population are women and approximately 49% are men. These values are used to calculate expected frequencies of women E_w and men E_m in Eq. (2) for $n=107$ survey participants.

(2)

or two analyzed categories $n_C=2$, degree(s) of freedom df are defined as follows:

$$df = n_C - 1 = 2 - 1 = 1 \tag{3}$$

For calculated $\chi 2=1.55$ in Eq. (2) and $df=1$ in Eq. (3), p-value is equal to 0.231. Since $p>0.05$, there is not enough statistical evidence to reject null hypothesis, nor to confirm alternative hypothesis. This implies that there is not enough evidence to dispute that g*ender distribution in the sample is not significantly different than gender distribution in the analyzed population.*

[3] http://www.statistika.ba/
[4] https://www.sciencedirect.com/science/article/pii/S2772906024005089
[5] https://www.sciencedirect.com/topics/mathematics/central-limit-theorem
[6] https://www.sciencedirect.com/topics/medicine-and-dentistry/chi-square-test

3.2. Research participants structure

The first set of questions from the questionnaire relates to demographic information as age, gender and education level of respondents. These questions do not affect the final research results, but it is certainly interesting to look at these indicators as they determine the structure of research participants (Figure 1).

Figure 1 – Age, gender, and educational background of the respondent

The largest number of respondents is aged 25-34 (43%), followed by aged 18-24 (25%), which is expected given that the online survey was distributed via email mainly to student populations and via Facebook social network, where the mentioned population is again most represented. Following are respondents aged 35-44 (17%), then 45-54 (10%) and 55-64 (4%) while only about 1% of respondents are aged 64 and over. Analysing the gender, women showed slightly greater interest in participating in the research (57%) compared to men (43%). Regarding the education level, 54% of respondents have higher education, of which 44% have a bachelor's degree, 8% have a master's degree, and 2% have a doctoral degree. 38% have a high school diploma, and 8% have an elementary school diploma. Since statistical bulletins only record completed certain levels of education, it was not possible to precisely determine the representativeness of the sample according to this criterion.

3.3. Preferences, information and trust in media

The survey on preferences, trust, and informedness began with a set of questions (Figure 2). Most respondents, 43% chose television, then social networks through which 35% of respondents were informed, and internet portals 21%. The electronic medium that was least used was radio, by only 1% of respondents, which is a small percentage considering the great influence of this medium on risk perception, as was the case in 2000 during the broadcast of a radio drama about the Modrac Dam failure [12]. 48% respondents trust the population that publishes pictures and information on social networks when reporting and presenting information, followed by press conferences of government and civil protection officials with 36%, and 16% trust journalists. This indicates an evident lack of trust in governmental and civilian structures.

Figure 2 – Source of information, level of trust and information about government channels

When asked if they know that the Federal Civil Protection Administration has its accounts on social networks, 56% of respondents answered no, and 44% answered yes.

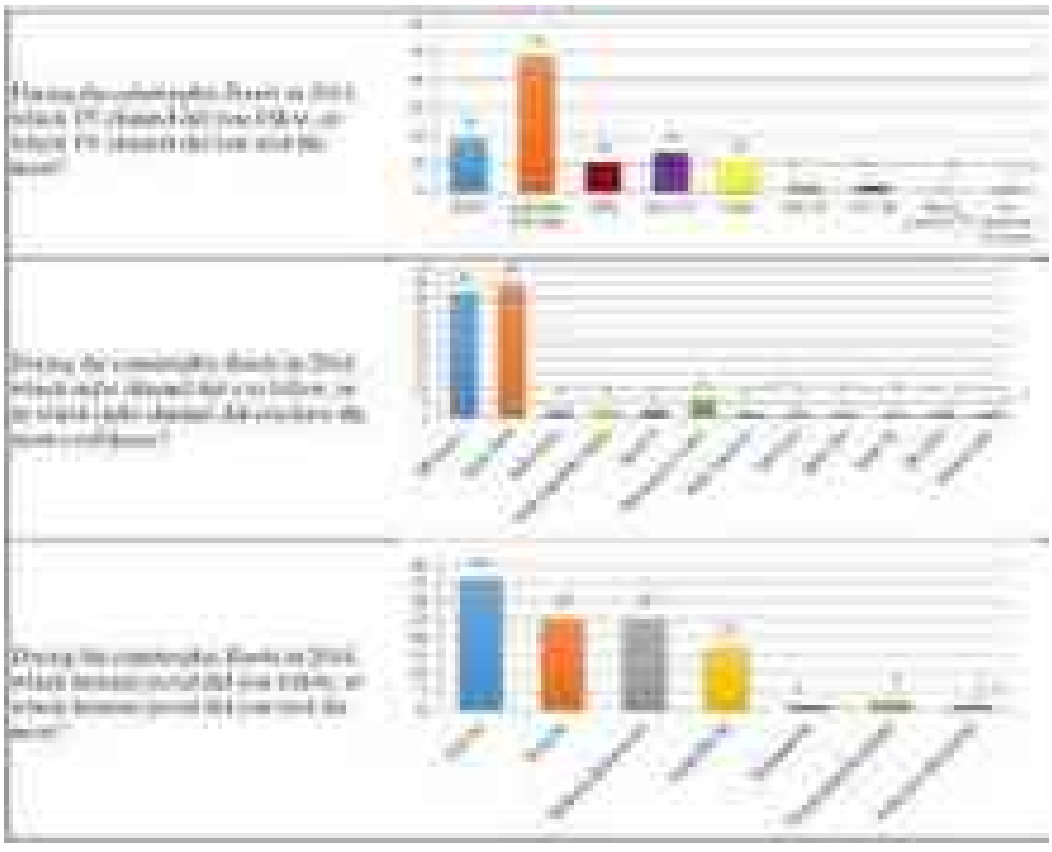


Figure 3 – Breakdown of most-consumed media during the disaster (total count - absolute numbers)

Analysing which TV channel was most watched during the catastrophic floods, answers were offered for the most consumed TV channels in the Federation of BiH, public broadcasters and those in private ownership. The TV channel that respondents watched most was Federal Television 45%, then BHRT 18%, followed by Nova TV 13% and OBN 9%. Hayat was watched by 9% of respondents, Face TV and RTV TK by 2% of respondents each. Only 1 respondent watched all listed TV channels and only 1 did not watch any.

Radio was the least popular electronic medium among respondents, yet it was still followed during catastrophic events. It could be concluded that was done without much attention or that the reason was not informative but entertainment content. The radio channels that respondents followed were diverse: Radio FBiH was followed by 42% of respondents, and BH Radio 1 by 39% of respondents. The other 9 radio channels were followed by a small number of respondents from 1% to 3%, while 5% of respondents did not listen to radio at all. (Figure 2)

Internet availability, as well as the speed of news transmission via the internet, have led to widespread use and following of news through internet portals. The internet portals that respondents followed most were klix.ba (34%), avaz.ba (23%) and balkans.al-jazeera.net (23%). 16% of respondents answered that they followed federalna.ba, while 1% followed tuzlanski.ba. 1% of respondents answered that they followed all mentioned internet portals, and 2% did not follow any internet portal. It is interesting that, although the research was conducted in the TC area, only 1 respondent followed the offered local portal, which indicates the trust that is still in media sources with a longer tradition that have national influence, but also greater reach.

Following set of questions was related to perception of social networks role in emergencies and catastrophic events (Figure 3). Although almost half of respondents answered that they have the most trust in the population that published pictures and information on social networks, the majority of respondents, as many as 79%, answered that they have never used social networks, while 21% answered that they have used social networks for the purpose of informing and spreading information about catastrophic events and emergency situations.

More than half of respondents, 53%, answered that they would seek help via social networks during an emergency situation if they were able to do so, 37% of respondents answered that they are not sure while 10% of respondents answered that they would not. More than half of respondents, 52%, answered that they are not sure that state services would urgently respond to a request for help via social networks during an emergency situation, while 30% of respondents answered no, and 18% answered yes to the question. This corresponds to answers to the previous question. A large majority of respondents, as many as 72%, expect that the use of social networks during emergency situations will increase in the future, 23% answered they are not sure, while only 5% of respondents answered no.

The last question in the survey related to opinions about disadvantages when using social networks in emergency situations. 60% of respondents believe that the biggest disadvantage when using social networks in emergency situations is the possibility of publishing false information, 22% of believe that they may not function during an emergency situation, 16% thinks that social networks are not a reliable source of information. Only 1% of respondents believe that the biggest disadvantage when using social networks in emergency situations is the possibility of abusing social networks in emergency situations for personal gain, and 1% thinks is untimely and ineffective reaction of competent authorities. (Figure 3)

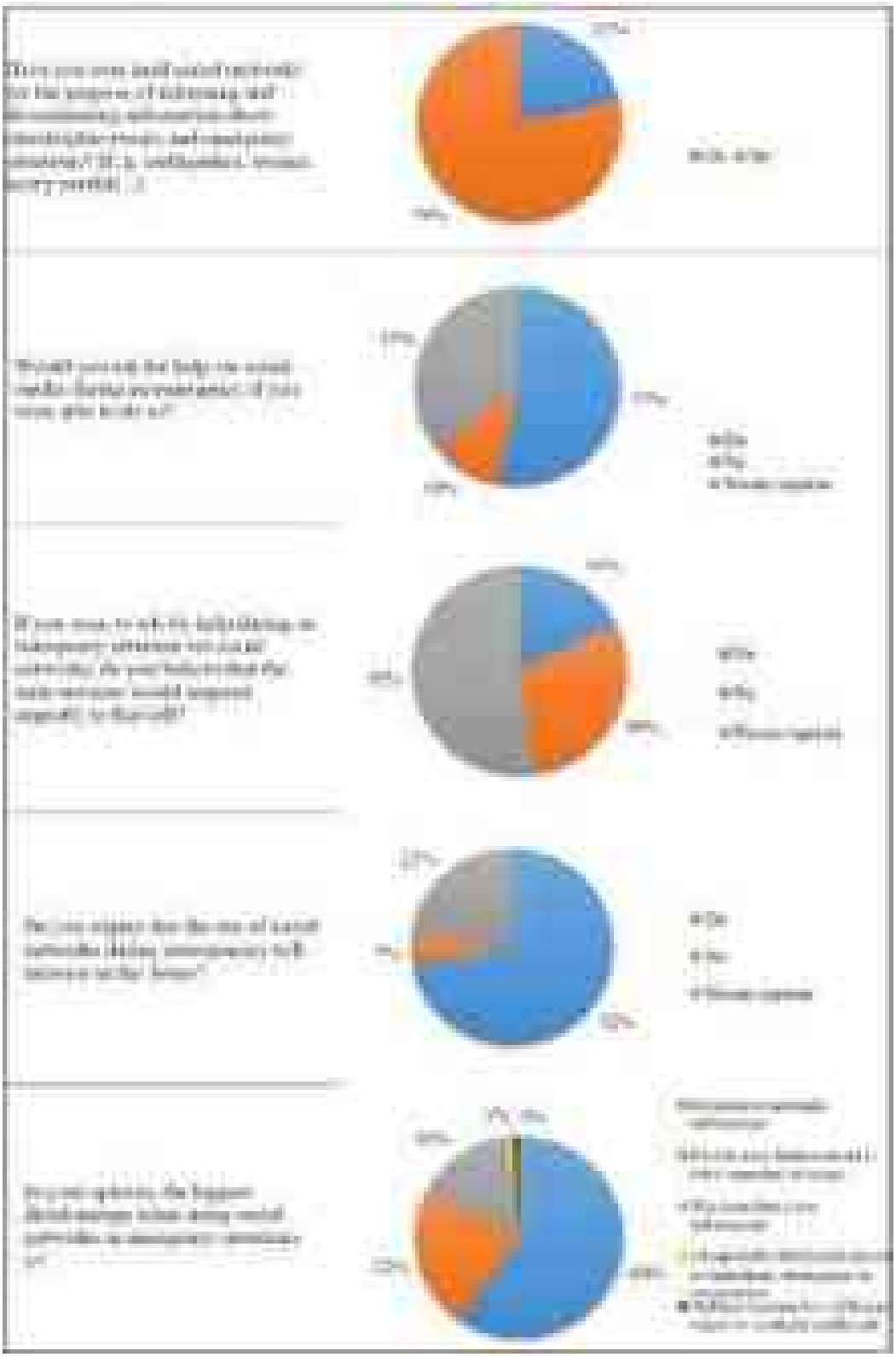


Figure 4 – Perception of social networks in emergencies/catastrophic events

3.4. Synthesis of research results

The population participating in this research is quite heterogeneous in terms of gender structure and age of respondents, given that there is an almost equal number of women and men, and the age structure includes all age groups from 18 to 64 years. This age range includes the working-age population, which is expected to be most involved in protection and rescue activities. The educational structure largely includes persons with secondary and higher education, over 89%. This is important because the level of general education has a significant impact on understanding risk, but also on the development of critical thinking and analytical skills, which ultimately contributes to confidence in this research. According to respondents, the main source of information during the catastrophic floods was television (43%) and social networks (35%).

Almost half of respondents (48%) say they had the most trust in the population publishing pictures and information on social networks, which also shows concerning data about distrust towards government officials and Civil Protection. This could be explained by insufficient appearance of government representatives and protection and rescue system structures in the media space at key moments, which is why the population turns to alternative sources due to the need and search for "moment-to-moment" information. Citizens turned to social media aiming to reduce uncertainty and regain control. Research outcomes can be aligned with Slovic's and Sandman's insights on risk perception: for TC residents floods were "dread risk" since they were uncontrollable, sudden with catastrophic potential what made them feel helpless and frightened. At same time it was "unknown risk", although floods are common phenomenon for BiH, in 2014 there were no clear official information and warnings with rapid escalation of crisis what created sense of unknown risk causing public anxiety. This can be related to social media usage by TC residents during the crisis, as their actions were driven not only by the objective hazard but also by the subjective outrage and other qualitative factors that shaped their risk perception.

Although almost half of respondents answered that they had the most trust in the population that published pictures and information on social networks during the catastrophic floods of 2014, the majority of respondents, as many as 79%, answered that they have never used social networks for the purpose of informing and spreading information about catastrophic events and emergency situations. More than half of respondents (56%) know that the Federal Civil Protection Administration has its accounts on social networks (Facebook, Instagram, YouTube). Although more than half of respondents would seek help via social networks, only 18% believe that state services would urgently respond to a request for help sent through this channel, while 52% answered that they are not sure. This result shows a low degree of trust among the population in the ability of government services to act urgently during an emergency situation on requests sent through this channel, i.e., to respond to "unofficial" requests via social networks.

It is significant that 72% of respondents expect that the use of social networks during emergency situations will increase in the future. Only 5% think the opposite. Six out of ten respondents cited the possibility of spreading false information as the biggest disadvantage of using social networks during emergency situations. At the time of the analysed disaster in BiH, this was confirmed - as reported by Večernji list: "Due to unverified information, disinformation and the race for more 'likes' via social networks,

people in panic left certain areas where the swollen river did not pose a threat. Even in such situations, portals eager for sensationalism presented false information, therefore in crisis situations it is extremely important to know exactly who provides official information".[7]

Certain risks and messages about them can become "viral" and disproportionally influential through media and social channels. SARF model explains that "virality" of social media posts isn't just about objective risk factors but instead result of processes that magnify or attenuate risk signals [13]. Therefore, to prevent misinformation multi-faceted strategy should be implemented that would address outrage and distrust, include proactive and clear communication, make partnership with local liders and involves citizens (with system that enables two-way communication).

Finally, it can be concluded that most respondents believe that the use of social networks during emergency situations will increase in the future because social networks represent a fast and efficient way of transmitting information compared to traditional media. Social media provide the population with the possibility of independently publishing information, photographs, videos during an emergency situation. The population distributes information via social networks during emergency situations out of a desire to warn others and out of the belief that they can thus help those in danger.

This research confirmed that, despite the increase in internet and social network use, television and radio still play a significant role in disasters in Bosnia and Herzegovina, mainly due to their reach, traditional trust (especially in public broadcasters), but also due to their ability to function when other communication networks are down. During the analysed flood, in the most severely affected areas, only radio stations were a source of information and broadcasted warnings about water levels, gave instructions on behaviour, informed about the distribution of food and aid, shared appeals for help and were the only communication channel with cut-off persons, which is a fact that must be taken into account when planning responses to future disasters.

4. Conclusion

Traditional and digital media play a crucial role in disaster preparedness and response, raising public awareness and enabling timely dissemination of key information. Digital channels, especially social networks, provide new opportunities for interactive and rapid communication, but with challenges such as misinformation and distrust in official sources. Proactive disaster misinformation management is necessary and can be conducted using the Social Amplification Framework (SARF) approach by first monitoring social channels to identify emerging rumours. Then, proactively debunking myths from trusted sources to break flow of misinformation and prevent negative public consequences [13].

[7] https://www.vecernji.ba/vijesti/uloga-medija-u-zastiti-od-poplava-1182048 - okrugi stol "Uloga i značaj medija u prevenciji i zaštiti od poplava" u Šamcu

Research conducted in Tuzla Canton during the floods shows that citizens still trust public services most, but simultaneously actively use social networks for information and coordination of assistance. Trust in government institutions on these platforms is limited, indicating the need to improve their communication and transparency.

Civil Protection at all levels in Bosnia and Hercegovina should implement early warning system that is designed and implemented in accordance with the principles and goals of the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic, integrated system that is multi-hazard and people-centric.

An integrated approach that combines traditional and digital media, supported by clear procedures, education and strategies for dealing with disinformation, is necessary for effective management of emergency situations and crises. This can ensure quality, two-way communication between competent authorities and the population, which is crucial for timely response and community mobilization in emergency situations.

Literature

[1]	World Disasters Report 2013: Focus on technology and the future of humanitarian action, ISBN 978-92-9139-197-4, https://www.ifrc.org/sites/default/files/WDR-2013.pdf
[2]	FEMA National Response Framework, https://www.fema.gov/emergency-managers/national-preparedness/frameworks/response
[3]	UNDRR "Risk Communication", https://www.undrr.org/risk-communication
[4]	The Sendai Framework for Disaster Risk Reduction 2015-2030 https://www.undrr.org/implementing-sendai-framework/what-sendai-framework
[5]	IFRC Guide to Community Engagement and Accountability, https://www.ifrc.org/document/cea-guide
[6]	Perception of risk, P. Slovic , SCIENCE, VOL. 236, 280-285, https://www.researchgate.net/publication/325954197_The_perception_of_risk
[7]	Ferhatbegovic E., Markovic J., Nukic E.: "GIS-based Flood Vulnerability Assessment in Spreca River Basin", The Albanian Journal of Economy & Business Special Issue, 2025, 56-71, ISSN Print 2219-3200.
[8]	Nukic E., Markovic J., Zepic F.: "Challenges in Flood Risk Management in Bosnia and Herzegovina", 8th Scientific-professional conference SECURITY AND CRISIS MANAGEMENT -THEORY AND PRACTICE / International Forum "Safety for the Future" 2022; Sremska Kamenica, Republic of Serbia, 2022, DOI: 10.70995/MJYJ4951
[9]	Euro-Atlantic Partnership Council (EAPC), Civil Emergency Planning Committee (CEPC): Report of the Rapid Reaction Team for Civil Emergency Planning for Bosnia and Herzegovina; Sep. 2014
[10]	INFOHOUSE Association, "How the media reported on floods in Bosnia and Herzegovina", Sarajevo, March 2016 (https://www.brana.ba/)
[11]	Krlic A.: "The Importance of Communication in Disaster Risk Management", Master thesis, Faculty of Mining, Geology and Civil Engineering, University of Tuzla, Tuzla, 2025
[12]	E. Nukic, Guest lecture University of Novi Sad, Case study, "Risk management from catastrophic events during floods in 2014 - Modrac lake dam " within K-FORCE Erasmus+ Project (www.kforce.gradjevinans.net/images/Fajlovi/Open_Lectures/5/K-FORCE_PTT_Edisa_Nukic.pdf).
[13]	Kasperson, R. E., et al. (1988). "The social amplification of risk: A conceptual framework." Risk Analysis. https://www.researchgate.net/publication/279397338_The_social_amplification_of_risk

Nature experience areas and informal educational processes

Heike Molitor[1]

1 Professor of Environmental Education and Education for Sustainable Development, University for Sustainable Development Eberswalde (HNEE)
heike.molitor@hnee.de

Abstract

Through free play, children acquire competencies that are essential for their personal development. When they engage in play within (urban) nature experience areas, they are also afforded specific encounters with nature that are relevant to their healthy growth and development.

This article aims to elucidate the (nature-based) experiential opportunities available to children in nature experience areas as informal educational processes, and to relate these to the concept of Education for Sustainable Development (ESD). The discussion is situated within the context of a pilot and development project funded by the Federal Agency for Nature Conservation with support from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, titled "Nature Experience Areas in Major Cities – The Case of Berlin."

Within the scope of the project, children were observed in the nature experience spaces and engaged through photo walks as a means of inquiry. In addition, parents, educational professionals, and designated caretakers were interviewed to enable a qualitative and quantitative description of how these areas are utilized.

In Germany, approximately 77% of all children and adolescents grow up in urban environments. Urban population growth, along with the resulting decline in green spaces, has led to a progressive reduction in available play areas. Increasingly, children are cared for by adults in institutional settings and/or participate in structured afternoon activities (organized childhood, domestication). Consequently, children have fewer opportunities to independently and systematically explore their surroundings. This has resulted in the emergence of spatial "islands" lacking meaningful interconnection (spatial fragmentation).

Keywords

Education for Sustainable Development, nature experience areas, informal educational processes, personal development

1. Introduction

In free play, children acquire skills that are important for their personality development. If they play in (urban) nature experience areas (NEA), children can also have specific nature experiences that are relevant for their healthy growing up. From the point of view of social work, urban areas for experiencing nature must also be considered as places of informal education.

The aim of this article is to present the (nature) experience possibilities of children in nature experience areas as informal educational processes in the context of social work and to relate them to the concept of education for sustainable development. This is being done primarily against the back-ground of a testing and development project funded by the Federal Agency for Nature Conservation with funds from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety entitled 'Nature Experience Areas in Large Cities using the Example of Berlin'. The 'Stiftung Naturschutz Berlin' implemented three NEA pilot sites in Berlin (2015-2018) and the Eberswalde University of Sustainable Development carried out the scientific monitoring (2015-2020) by means of a variety of empirical studies [1]. The children were observed in the nature experience rooms and questioned by means of a photo tour. In addition, parents, teachers and caregivers were interviewed in order to be able to describe the use of these nature experience areas qualitatively and quantitatively.

In Germany, about 77% of all children and adolescents grow up in an urban environment [2]. In this context, childhood in urban areas plays a special role. The self-determined and autonomous play of children tends to decrease. The area for playing is becoming less and less due to the population growth of cities and an associated reduction in green areas [3]. In addition, adults are increasingly taking over the care of children in institutions and/or in structured offers in the afternoon (organised childhood, domestication). The children thus appropriate their environment less independently and systematically. For the children, island areas develop without direct reference to each other [3]. In-creased use of media (computer and internet, smartphones, etc.) usually leads to a lack of exercise, obesity and reduced contact with nature [3;4].

2. Nature experience areas

Nature experience areas (NEA) are near-natural, poorly designed open areas that offer children, primarily between the ages of six and twelve, opportunities for free play without adult supervision [5]. Ideally, the areas are located in the immediate vicinity of the living area in order to be independently accessible to the children [5;6]. Nature experience areas are structured in a variety of ways, dense woody structures alternate with open clearing areas. About half of the areas are left to succession (free development), the remaining area is extensively maintained [6].

Figure 1 – View into nature experience areas [photos: Molitor]

Various natural materials (animals, plants, sticks, etc.) stimulate the children's imagination. However, as with playgrounds, the provisions on land safety apply [1]. Ideally, the areas are planned by the children and co-designed within the scope of their possibilities [5]. Schemel [7] assumed a minimum size of 1ha, better 2ha. In an urban context, this minimum size is hardly feasible due to the increased competition for area. The concept of nature experience areas was first developed at the end of the 1990s [5] and was incorporated into the Federal Nature Conservation Act [8] in 2010. In the years that followed, the concept was adapted, especially to the urban context.

Nature experience areas offer not only children, but also plants and animals' opportunities for development. The rather extensive cultivation creates niches for biological diversity. A monitoring of three NEA in Berlin over three and four years respectively has shown that these areas have a species-rich flora and fauna as well as a mixture of different vegetation areas with a high level of structural diversity, which are positive for a high level of biodiversity, despite and because of the child's play. This opens up the opportunity for children to experience nature in a variety of ways. The child's play leads to slight signs of wear and tear (trails or bark damage to woody plants), but also to a certain dynamism and a higher biodiversity over time (e.g., stepping plants) [1]. Compared to a playground, which also fulfils important functions for children, nature experience areas are habitats for all living beings and serve to preserve or enhance natural capital. In the discussion about strong or weak sustainability and the question of the substitutability of natural capital, NEA deserve a specific consideration. Play for children can be designed with and without nature, the children's recreational function is given in any case. In the sense of the concept of weak sustainability, the "average benefit or the average welfare of people" [9:5] is retained in relation to a classic playground (with swings, climbing frame and sandpit without many natural elements). From the perspective of strong sustainability, natural capital is worth preserving and requires increased investment in it [9]. This makes concepts such as NEA, which enable both human welfare and the preservation and care of (cultivated) natural capital, are significant.

The original concept of the NEA [7] did not provide for pedagogical support for the children. In urban nature experience areas, this approach has been extended to include the recommendation of "minimal pedagogical care" with reference to a social institution [10]. The so-called caregiver was used to mediate between the different user groups [1]. This person has the task of offering demand-oriented (initial) play activities or festivals in the NEA so that potential users get to know the NEA and reduce threshold fears. In addition, targeted information and networking is part of the carer's area of

responsibility, the better known the NEA, the more likely it is that it will be used [1]. The range of tasks also includes maintenance measures to maintain the area, cleanliness, safety and documentation as well as the attractiveness of the NEA. This can include collecting rubbish, checking play structures and gardening activities [1].

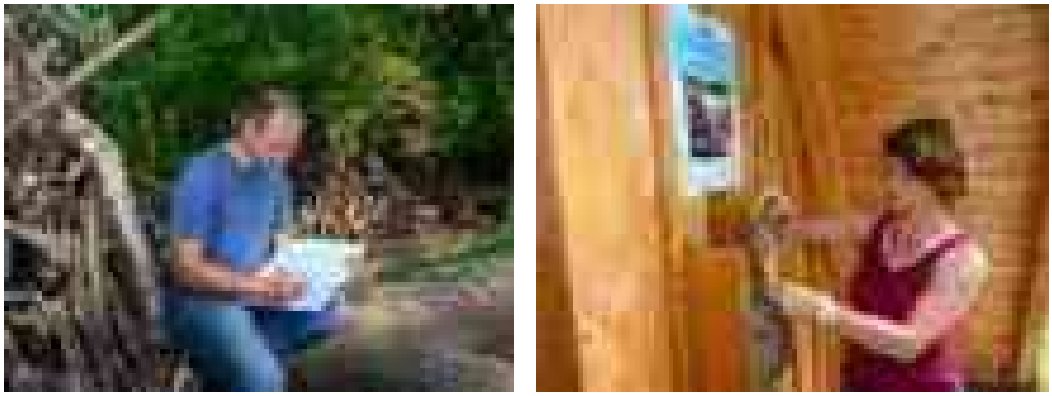


Figure 2 – Activities of caregivers (photos: U. Wessollek)

Children are involved in the planning, implementation and operation of a nature experience area. They can contribute their wishes and ideas from the very beginning and thus help shape the NEA. When the NEA is completed, there will be ongoing opportunities to further involve the children in the care or maintenance of the area by, for example. Planting, watering and garbage collection campaigns. The participation of the children in this phase is carried out by the caregiver. These creative possibilities are associated with the children's experiences of self-efficacy. Involving the children also leads to more acceptance among their parents [1].

Urban nature experience areas are ideally located in residential areas or maximal 300 to 500 meters away from them, so that the children can reach the NEA independently and safely. Ideally, NEA should be provided in particular to urban areas that tend to have a lower socio-economic status among their neighbours (indicators are e.g. unemployment, long-term unemployment, transfer receipt, child poverty). This makes it clear that NEA should be created primarily where there are few opportunities to use private greenery [1]. Nature and natural structures offer children who need diverse stimulating environments for their holistic development good framework conditions through relative continuity on the one hand and constant change on the other. Consequently, environments that appear the same or familiar and yet always new are preferred, especially due to the seasonal changes and the diversity in shape and colours (no living being is like the other). Children prefer things that react recognizably and are appropriately complex. Their needs for reliability, security, orientation, curiosity, imagination and adventure are thus served [11]. For personality development, the relationship to oneself, to other people and to the physical environment or nature is essential [11]. Sensual experiences in particular are important developmental factors. With reduced sensory experiences or contact with nature, attention problems, a higher degree of physical and emotional illnesses can become apparent, and the distance from nature and the insight into the necessity of using and protecting nature to secure our living conditions can decrease (nature deficit disorder) [12]. Children and adolescents with a lot of contact with nature have a higher environmental awareness and attitudes towards the environment are more positive [13].

In particular, the freedom without direct influence of adults makes spending time in nature attractive for children in that they learn to recognize their own strengths and weaknesses [14] and experience self-efficacy [15]. In NEA, many children also exhibit more complex play behaviour than, for example, on conventional playgrounds [10; 16; 13]. This is also due to the various landscape elements in the NEA, which significantly encourage children to play. Children in NEA play together more often, report enthusiastically about their activities [17] and create imaginative and unique play worlds by creatively integrating the phenomena of nature [18; 19]. Children thus construct their own learning path [20]. You will therefore need areas for free play and experiences of nature, especially in the vicinity of their living environment, in order to be able to reach them easily.

Spending time in nature has a health-promoting effect. Children who exercise a lot outdoors are often more resistant to diseases, better developed motor skills and suffer less from obesity [13]. Healthy psychological development is positively influenced by extensive contact with nature in childhood. Free, self-determined, independent play, especially with the natural elements (earth, water, plants and animals) has an important role for the children and promotes the development of psychological resilience [11; 17; 21].

3. Dimensions of nature experience in nature experience areas

One result of the project's research is the identification of dimensions of nature experience. To this end, approximately 60 photo interviews were conducted with children between the ages of seven and twelve. The children photographed places in the NEA that they found very or not very attractive, or where they liked to be alone. They were then asked what exactly they did there based on the photos. The interviews were evaluated qualitatively [22].

In NEA, children have a variety of experiences of nature that can be qualitatively differentiated. Even if nature experience areas are only manageably large, they offer opportunities for diverse experiences in and with nature (see Figure 3) [22].

The aesthetic dimension of experiencing nature includes positive as well as negative sensory perceptions of colours, shapes, smells, patterns of living beings and the landscape [23; 1]. Nature itself as well as loose material, the 'huts' built from it and views (e.g. from clay hills) are perceived positively. Aspects such as the perceived lack of order, such as rotten logs, undergrowth or garbage, lack of view or darkness and narrowness, appear negative [1].

The exploratory nature experience dimension includes the examination or intensive observation of animals and plants of the children with all the senses. In particular, amphibians, mammals, spiders and insects (dead or alive) are of particular interest. An appreciative basic attitude of the children is recognizable [23; 1].

Figure 3 – Dimensions of the experience of nature in NEA [22: 47]

The *instrumental dimension of experiencing nature* is understood to be a short- or long-term benefit of nature for children [23]. Nature is used or actively appropriated and/or shaped in the way it is found. Edible fruits are also relevant here as a taste pleasure. Retreats in quieter areas are 'usable' places for processing emotions. Nature is also sometimes used as a play backdrop with brought or imaginary play objects [1].

Under the *ecological nature experience dimension* activities such as species protection measures, rescuing animals or watering plants during drought are included, which are to be seen in the context of nature conservation. The children empathically care for plants and animals [1; 23; 24; 25]

The *adventurous dimension of experiencing nature* is the playful discovery and testing of children's own dexterity and the associated diverse experiences of self-efficacy [24; 1]. Children are fascinated by the possibilities of hiding from others (sometimes as a secret culture such as secret passages), climbing or constructing and designing buildings [1].

The *game-related nature experience dimension* includes a play behavior with (sharing) nature. This is mainly done freely and self-determinedly in role-playing, which is supported by natural materials (e.g., fighting) [25; 1].

The *subject-related nature experience dimension* includes the active engagement with a plant or animal with a relationship is established [1]. The relationship design is geared towards one animal species or group of animals, since the relationship subject, such as the beetle, is no longer the same as the day before. Nevertheless, an intense bond can develop for the moment [ibid.].

The *resistant dimension* of experiencing nature encompasses dangers perceived by children in real life [ibid.]. Some of the children develop coping strategies (e.g., avoiding nettle). They also actively deal with the so-called risks and learn how to deal with them [14]. The resistant dimension of experiencing nature encompasses the ambivalence of nature, the unpredictability on the one hand and the recreational opportunities combined with positive aesthetic experiences on the other. [11; 26]

4. NEA as areas of informal education (for sustainable development)

Informal learning is understood to be rather unplanned, incidental, often unconscious or implicit learning, beyond non-formal and formal educational processes, which rather include planned (partly recognised) learning [27]. Informal educational contexts are particularly suitable for developing competences, sustainable knowledge, planning and implementing sustainable projects and self-efficacy [28].

Against this background, free play is an informal learning opportunity for children to develop creative skills. The dimensions of nature experience (NEAD) describe specific experiences that can also strengthen the Competencies in the context of sustainability [29]. In this way, children learn to deal with risks and uncertainties (resistant NEAD). They learn to participate in collective decision-making processes or to think and act with foresight (game-related NEAD, adventurous NEAD, ecological NEAD). They learn how to motivate themselves and others to become active (ecological NEAD) and to develop empathy for others (subjective NEAD, sometimes also aesthetic NEAD). In many of the dimensions of nature experience there is also the competence to be able to plan and act independently or with others (e.g., exploratory NEAD, game-related NEAD, instrumental NEAD). This acquisition of skills takes place casually, unplanned, from within the children and represents an important basis for the development of important key competencies for sustainability.

Since nature experience areas can be understood as places of strong sustainability due to the equal habitat of children, animals and plants, the place of learning itself is also an important environment for the acquisition of the above-mentioned skills. NEA can thus also become areas for thinking and acting in the relationship between humans and nature [30]. Sustainability can be interpreted here as shaping the relationship of communities and/or individuals to their natural environment with the recognition that the resources of nature and thus also of the playing surface must be preserved. Land use and 'nature consumption' must be designed on NEA in such a way that a stay with nature experiences is also possible in the future [31]. Nature experience areas are thus not only places of experiencing nature, but also places of potential sustainability.

Likewise, the children's opportunities for participation in the planning, establishment and operation of an NEA are important aspects in learning how children can participate. Their voice and perspectives are relevant [30], so that self-efficacy can be experienced. In this context, NEA could also be understood as a field of social work. There are many references to the field of action community work or health-related community work, because the NEA in the district establishes the social connection of people (children and adults) with their interests in use as a spatial reference [32].

5. Conclusion

Nature experience areas can be understood as informal places of learning for sustainable development, in which children can experience nature in a variety of ways and thus develop or strengthen key skills for sustainability. Against this background, it seems necessary to include areas for experiencing nature (more systematically than before) in urban planning processes in order to create good conditions for the free play of children combined with diverse experiences of nature. In this way, NEA are important building blocks for a healthy upbringing of city children and can have a supportive effect on the fields of action of social work. Here, the caregiver can be an important link to stakeholders in social work through his or her information and networking work and general responsiveness for the various stakeholders. Social inequalities cannot be abolished with education alone [33: 21], but places of learning such as nature experience areas can contribute to increasing individual opportunities, developing one's own personality and enabling social participation. In this way, areas for experiencing nature can contribute to the (e.g., social area-oriented) fields of action of social work and tie in with the following claim: "holistically, i.e., taking the responsibility of the individual as a person seriously, life-worldly, i.e., including the environment and fair participation in it and in the long term, i.e., meaningfully beyond day-to-day business" [34: 30]. Here it is important to work hand in hand and forge new socio-ecological cooperation for the benefit of the children.

Literature

[1] Molitor, Heike/Peters, Jürgen/ Martens, Dörte/ Pretzsch, Maren/ Friede, Claudia/ Hei-mann, Jutta/ Wilitzki, Annemarie (2020): Naturerfahrungsräume in Großstädten Flächenentwicklung – Kindernutzung – rechtliche Rahmenbedingungen. Bundes-amt für Naturschutz (Hrsg.), BfN Skripten 560. Bonn-Bad Godesberg.

[2] World Bank (2018): Urban population. United Nations Population Division. https://da ta.world-bank.org/indicator/sp.urb.totl.in.zs [Zugriff: 5.4.2022]. [Accessed: 5.4.2022].

[3] Blinkert, Baldo (2016): Urbane Kindheit und Räume. In: Braches-Chyrek, Rita/Röhner, Charlotte (Hrsg.): Kindheit und Raum. Opladen: Verlag Barbara Budrich, S. 65–84.

[4] Medienpädagogischer Forschungsverbund Südwest (2021): KIM-Studie 2020. Kind-heit, Inter-net, Medien. Basisuntersuchung zum Medienumgang 6- bis 13-Jähriger. www.lfk.de/fileadmin/PDFs/Publikationen/Studien/KIM-Studie/kim-studie-2020.pdf [Zugriff: 30.05.2022].

[5] Schemel, Hans-Joachim (Hrsg.) (1998): Naturerfahrungsräume. Ein humanökologischer Ansatz für naturnahe Erholung in Stadt und Landschaft (Angewandte Landschaftsökologie, Bd. 19.). Bonn-Bad Godesberg: Münster BfN-Schriftenvertrieb.

[6] Stopka, Irma/Rank, Sandra (2013): Naturerfahrungsräume in Großstädten Wege zur Etablierung im öffentlichen Freiraum. Bonn – Bad Godesberg. BfN Skripten 345. www.bfn.de/sites/default/files/BfN/service/Dokumente/skripten/skript345.pdf [Zugriff: 30.05.2022].

[7] Schemel, Hans-Joachim (2008): Das Konzept der städtischen Naturerfahrungsräume. In: Bundesamt für Naturschutz (Hrsg.): Kinder und Natur in der Stadt. Spielraum Natur: Ein Handbuch für Kommunalpolitik und Planung sowie Eltern und Agenda-21-Initiativen. Bonn – Bad Godesberg: BfN Skripten 230, S. 79–92.

[8] BNatSchG (2009): Gesetz über Naturschutz und Landschaftspflege. Bundesnatur-schutzgesetz vom 29.07.2009 (BGBl. I S. 2542), zuletzt geändert durch Artikel 1 des Gesetzes vom 4.3.2020 (BGBl. I, S. 440).

[9] Döring, Ralf (2004): Wie stark ist schwache, wie schwach ist starke Nachhaltigkeit. Wirtschaftswissenschaftliche Diskussionspapiere, 8. https://www.econstor.eu/bitstream/10419/22095/1/08_2004.pdf [Zugriff: 31.05.2022].

[10] Blinkert, Baldo/Reidl, Konrad/Schemel, Hans-Joachim (2008): Naturerfahrungsräume im besiedelten Bereich – Ergebnisse eines Forschungsprojektes. In: Bundesamt für Naturschutz (Hrsg.): Kinder und Natur in der Stadt. Spielraum Natur: Ein Hand-buch für Kommunalpolitiker, Planer sowie Eltern und Agenda-21-Initiativen. BfN-Skripten 230. Bonn – Bad Godesberg, S. 119–136.

[11] Gebhard, Ulrich (2009): Kind und Natur. Die Bedeutung der Natur für die psychische Entwicklung, 3. Aufl. Wiesbaden: Springer Verlag

[12] Louv, Richard (2006): Das letzte Kind im Wald. Geben wir unseren Kindern die Natur zurück! Weinheim: Beltz Verlag.

[13] Raith, Andreas/Lude, Armin (2014): Startkapital Natur. Wie Naturerfahrung die kindliche Entwicklung fördert. München: Oekom Verlag.

[14] Renz-Polster, Herbert/Hüther, Gerald (2013): Wie Kinder heute wachsen. Natur als Entwicklungsraum; ein neuer Blick auf das kindliche Lernen, Denken und Fühlen. Weinheim: Beltz Verlag.

[15] Bandura, Albert (1977): Self-efficacy. Toward a unifying theory of behavioral change. In: Psychological Review 84, S. 191–215.

[16] Martens, Dörte/Friede, Claudia/Molitor, Heike (2019): Nature Experience Areas: Re-discovering the Potential of Nature for Children's Development. In: Cutter-Mackenzie, Amy/Malone, Karen/ Barratt Hacking, Elisabeth (Hrsg.): Research Handbook on Childhoodnature. Assemblages of Childhood and Nature Research, Cham: Springer Natur Switzerland, S. 1469–1500.

[17] Schemel, Hans-Joachim (2005): Kooperation mit städtischer Verwaltung und Vertretern der Bürgerschaft. In Reidl, Konrad/Schemel, Hans-Joachim/Blinkert, Baldo (Hrsg.): Naturerfahrungsräume im besiedelten Bereich. Ergebnisse eines interdis-ziplinären Forschungsprojekts. Nürtingen: Hochschulbund Nürtingen/Geislingen, S. 159–172.

[18] Luchs, Antje/Fikus, Monika (2013): A comparative study of active play on differently designed playgrounds. In: Journal of Adventure Education & Outdoor Learning 13, S. 206–222.

[19] Martens Dörte/Molitor Heike (2020): Play in Appropriate Natural Environments to Support Child Development (Fomento del desarrollo infantil mediante el juego en entornos naturales apropiados). In: Psyecology 11, 3, S. 363–396. https://doi. org/10.1080/21711976.2020.17820 40 [Zugriff: 31.05.2022].

[20] Truscott, Julia (2020): Toward a Pedagogy for Nature-Based Play in Early Childhood Educational Settings. In: Cutter-Mackenzie, Amy/Malone, Karen/Barratt Hacking, Elisabeth (Hrsg.): Research Handbook on Childhoodnature. Assemblages of Childhood and Nature Research. Cham: Springer Natur Switzerland, S. 1521–1545.

[21] Hart, Roger (1979): Children's experience of place, New York: Irvington Publishers.

[22] Molitor, Heike/ Martens, Dörte (2021): Kinderspiel und Stadtnatur – Emprisch ermittelte Naturerfahrungsdimensionen in Naturerfahrungsräumen. In: Umweltpsychologie 25, 2, S. 38–63.

[23] Bögeholz, Susanne (1999): Qualitäten primärer Naturerfahrung und ihr Zusammenhang mit Umweltwissen und Umwelthandeln. Schriftenreihe „Ökologie und Erziehungswissenschaft" der Arbeitsgruppe „Umweltbildung" der Deutschen Gesellschaft für Erziehungswissenschaft 5. Opladen: Leske+Budrich.

[24] Lude, Arnim (2001): Naturerfahrung & Naturschutzbewusstsein. Eine empirische Studie. Forschungen zur Fachdidaktik 2. Insbruck: Studien-Verlag.

[25] Meske, Mara (2011): „Natur ist für mich die Welt". Lebensweltlich geprägte Naturbil-der von Kindern. Wiesbaden: Verlag für Sozialwissenschaften.

[26] Kaplan, Stephen (1995): The restorative benefits of nature. Toward an integrative framework. In: Journal of Environmental Psychology 15, S. 169–182.

[27] Dohmen, Günther (2001): Das informelle Lernen. Die internationale Erschließung einer bisher vernachlässigten Grundform menschlichen Lernens für das lebenslange Lernen aller. Bundesministerium Bildung und Forschung (Hrsg.). Bonn: BMBF Publik.

[28] Göll, Edgar (2016): Informelles Lernen vor Ort – mit Vernetzung über Rio plus 20 hinaus. In: Brodowski, Michael/Verch, Johannes (Hrsg.): Informelles Lernen vor Ort als Beitrag zur nachhaltigen Kommunal- und Regionalentwicklung. Opladen: Verlag Barbara Budrich, S. 25–44.

[29] Haan, Gerhard de/Harenberg, Dorothee (1998): Bildung für eine nachhaltige Entwicklung – Gutachten zum Programm. Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung (BLK), 72, Bonn.

[30] Schubert, Susanne (2021): Nachhaltigkeit und Offene Kinder- und Jugendarbeit. In: Deinet, Ulrich/Sturzenhecker, Benedikt/von Schwanenflügel, Larissa/Schwerthelm, Moritz (Hrsg.): Handbuch Offene Kinder- und Jugendarbeit. Wiesbaden: Springer Fachmedien GmbH, S. 811–825.

[31] Albrecht, Peter-Georg (2015): Nachhaltige Soziale Arbeit …geht nur ökonomisch und politisch. In: Sozial Extra 39, 4, S. 10-15.

[32] Liedholz, Yannick (2021): Berührungspunkte von Sozialer Arbeit und Klimawandel. Perspektiven und Handlungsspielräume. Opladen: Barbara Budrich Verlag.

[33] Rahn, Peter (2017): Bildung … und das gute Leben von Kindern. Eine sozialpädagogische Betrachtung. In: Fischer, Sabine/Rahn, Peter: Kind sein in der Stadt. Bildung und ein gutes Leben. Opladen: Verlag Barbara Budrich, S. 13–26.

[34] König, Joachim (2012): Nachhaltigkeit in der Sozialen Arbeit. Konzeptionelle, praktische und empirische Implikationen aus pädagogischer Sicht am Beispiel der Jugendsozialarbeit. In: Blätter der Wohlfahrtspflege 1, S. 27–32.

Instagram as a communication and educational tool in civil engineering: Connecting students, academia, and industry

Jovana Topalić[1]

Anka Starčev-Ćurčin[2]

Suzana Draganić[3]

1 Research Associate, Faculty of Novi Sad, University of Novi Sad
jovanatopalic90@uns.ac.rs

2 Associate Professor, Faculty of Novi Sad, University of Novi Sad
astarcev@uns.ac.rs

3 Assistant Professor, Faculty of Novi Sad, University of Novi Sad
suzanav@uns.ac.rs

Abstract

This paper presents the use of Instagram as a communication and educational tool at the Department of Civil Engineering and Geodesy, Faculty of Technical Sciences in Novi Sad. Recognising Instagram's potential to visually engage students, promote civil engineering studies, and foster connections with industry professionals, the Department strategically integrated this social media platform into its educational and promotional activities. Through practical examples, this paper illustrates how Instagram facilitates direct communication between academia, students, and industry representatives. Special emphasis is placed on demonstrating the mutual benefits for students and industry partners, including knowledge sharing, professional networking, and student motivation. Finally, recommendations are provided for further enhancement of this approach in engineering education.

Keywords

Instagram, educational tool, communication, students, academia, industry, civil engineering

1. Introduction

In contemporary higher education, digital communication platforms have become essential tools for enhancing student engagement and bridging the gap between academic institutions and industry [1-3]. According to a systematic literature review published by the American Society for Engineering Education, over 40 million students globally use social media platforms such as Facebook, Twitter, LinkedIn, and Instagram as part of their academic journey [4].

While Facebook has historically dominated educational applications, recent studies indicate a growing role for Instagram in engineering contexts, particularly due to its visual and interactive format [4]. This shift reflects the potential of Instagram to influence student motivation, academic engagement, and professional development through informal yet impactful communication channels. Generation Z, characterised by digital fluency and a preference for visual and immediate forms of communication, represents the dominant demographic in undergraduate education and responds particularly well to dynamic and visual content shared on platforms like Instagram [5].

Recognising these trends, the Department of Civil Engineering and Geodesy at the Faculty of Technical Sciences in Novi Sad strategically integrated Instagram as a tool for communication, education, and outreach. Over a six-month period (from December 2023 to July 2024) the Department employed a targeted campaign to connect students, academic staff, and industry professionals through engaging content formats such as construction site visits, alumni interviews ("30 Seconds with an Alumnus"), faculty Q&A sessions ("Coffee with a Professor"), student project showcases, and videos addressing University admission and enrolment exam preparation.

This initiative aligned with broader Education 4.0 principles that emphasise personalised, flexible, and technology-integrated learning. The Department's Instagram campaign was performed around three pillars: student engagement and real-world experience, student-centred communication and outreach, and professional insights and preparation for future generations. The campaign was effective in addressing both the educational and emotional needs of students, reinforcing the relevance of civil engineering, and increasing the visibility of the study program. These efforts contributed to a measurable increase in student engagement and interest, with notable growth in social media interaction and enrolment indicators [5].

This paper examines how Instagram has been utilised to educate, engage, and foster a digital academic community network within civil engineering, thereby reinforcing the discipline's contemporary relevance and accessibility. Through practical examples, the paper illustrates how Instagram facilitates direct communication between academia, students, and industry representatives. Special emphasis is placed on demonstrating the mutual benefits for students and industry partners, including knowledge sharing, professional networking, and student motivation. Finally, recommendations are provided for further enhancement of this approach in engineering education.

2. Methodology

2.1. Research design

This research employed a mixed-methods approach that combined quantitative Instagram analytics with qualitative content analysis. The objective was to explore Instagram's potential as a communication and educational platform within civil engineering, particularly in connecting students, academic staff, and industry professionals. The study was conducted after the active months (December/July), focusing on the performance and impact of the Instagram profile: **@ftn_gradjevinarstvo**.

2.2. Data collection

Data collection was conducted using Instagram's native analytics tools and systematic content sampling:

- **Instagram Analytics:** Metrics such as follower trends, post frequency, and engagement rates per content category were extracted using Instagram Insights
- **Content Sampling**: The analysis included various types of thematic content, including interviews with alumni, informal academic conversations, field visits, student project presentations, application guidance, and expert consultations. These formats were selected for their relevance to academic, professional, and student engagement.

2.3. Quantitative analysis

The quantitative component analysed digital engagement and growth indicators directly through Instagram Insights:

- **Engagement Metrics:** Interaction patterns were assessed based on user responses to specific content types.
- **Growth Indicators:** Trends in profile reach and visibility were monitored across the research period, with attention to variations linked to content themes

2.4. Qualitative analysis

The qualitative analysis relied on thematic coding and interaction mapping:

- **Thematic Coding:** The posts were categorised into content domains such as academic communication, professional development, admissions-related content, and student-led activities.
- **Interaction Mapping:** Analysis included the identification of interactions with students and industry representatives through comments, questions, and direct messages, organised according to thematic relevance.

3. Results and discussion

3.1. Quantitative results

During the six-month campaign (December 2023 – July 2024), the Department's Instagram profile demonstrated significant growth and high audience engagement (Figures 1 and 2).

Figure 1 illustrates a steady increase in followers, rising from approximately 600 at the campaign's start to 1,830 by July 2024.

Figure 2 provides a comparative overview of average engagement rates across key content formats featured on the Instagram profile. The analysis reveals that certain formats not only drove higher viewership and interaction but also played a strategic role in strengthening educational value, institutional identity, and cross-generational academic dialogue:

- "30 Seconds with an Alumnus": Averaged ~2,100 views per video, with strong sharing activity. This dynamic video format consistently achieved high visibility and was widely shared among followers. Its appeal lay in showcasing successful alumni who shared personal academic journeys, favourite subjects, and heartfelt advice for prospective students. By combining authenticity with inspiration, this format bridged the gap between academic experience and professional achievement, making it particularly engaging for both current and future students.
- "Coffee with a Professor": This type of content was very interesting because of the questions which the students asked. Designed as a short-form, conversational segment, this format offered students a rare glimpse into the personalities and perspectives of their professors. Featuring short responses to student-submitted questions, these clips humanised faculty members and encouraged informal yet intellectually stimulating interaction. The approachable tone and relaxed setting made it one of the most resonant formats for strengthening student-faculty connections.

- "Show Me the Project": This segment spotlighted real-life engineering projects developed by students and alumni, effectively translating academic concepts into practical, industry-relevant applications. Through behind-the-scenes insights and visual documentation of ongoing work, this format enhanced the profile's educational value while reinforcing the real-world impact of civil engineering studies.

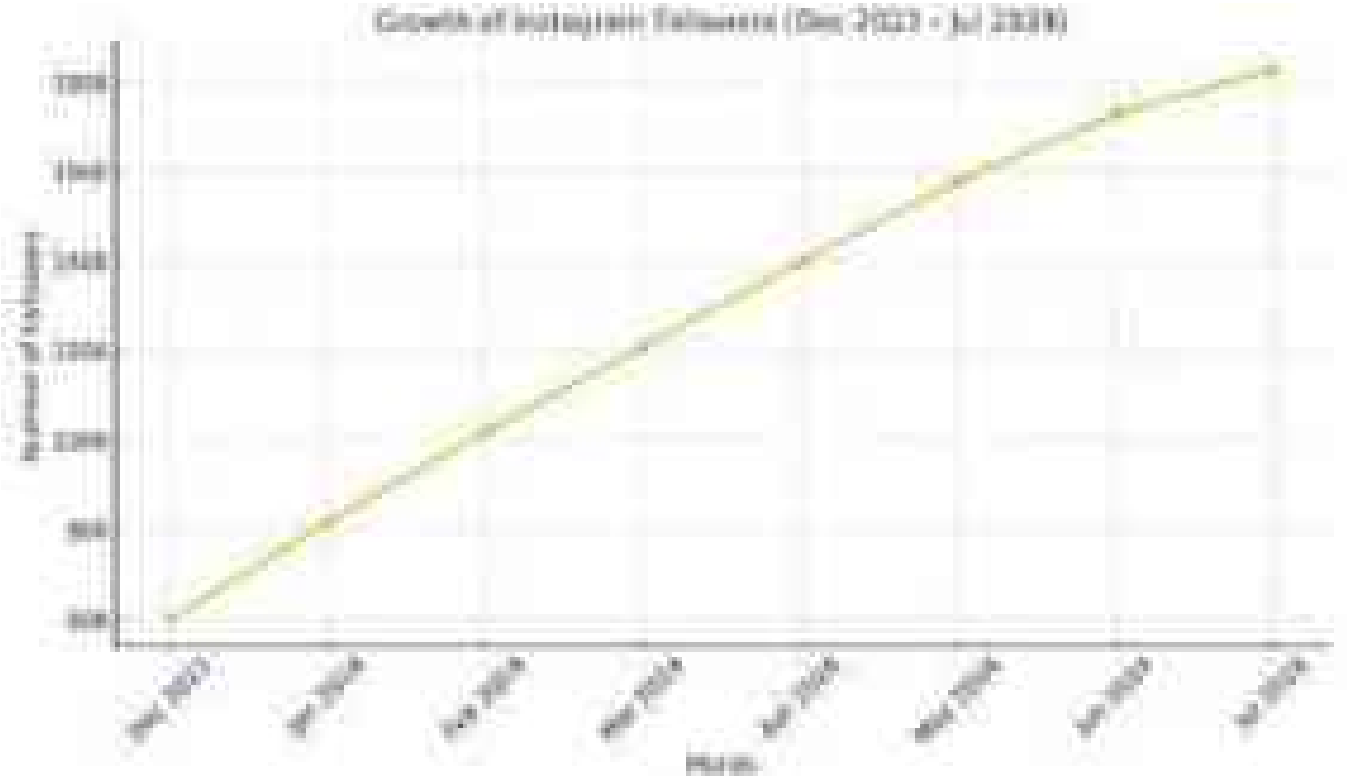


Figure 1 – Growth of Instagram followers from December 2023 to July 2024

Engagement rates remained relatively stable throughout the campaign. Compared with the civil engineering industry benchmark of **2.75%** engagement [6], the Department's Instagram activity clearly outperformed sector averages.

Figure 3 illustrates the posting frequency across the most active months, highlighting the continuity and consistency of content dissemination on the Instagram platform. The data reflects a sustained effort to maintain audience engagement through regular updates, supporting long-term visibility and follower retention within the digital academic community.

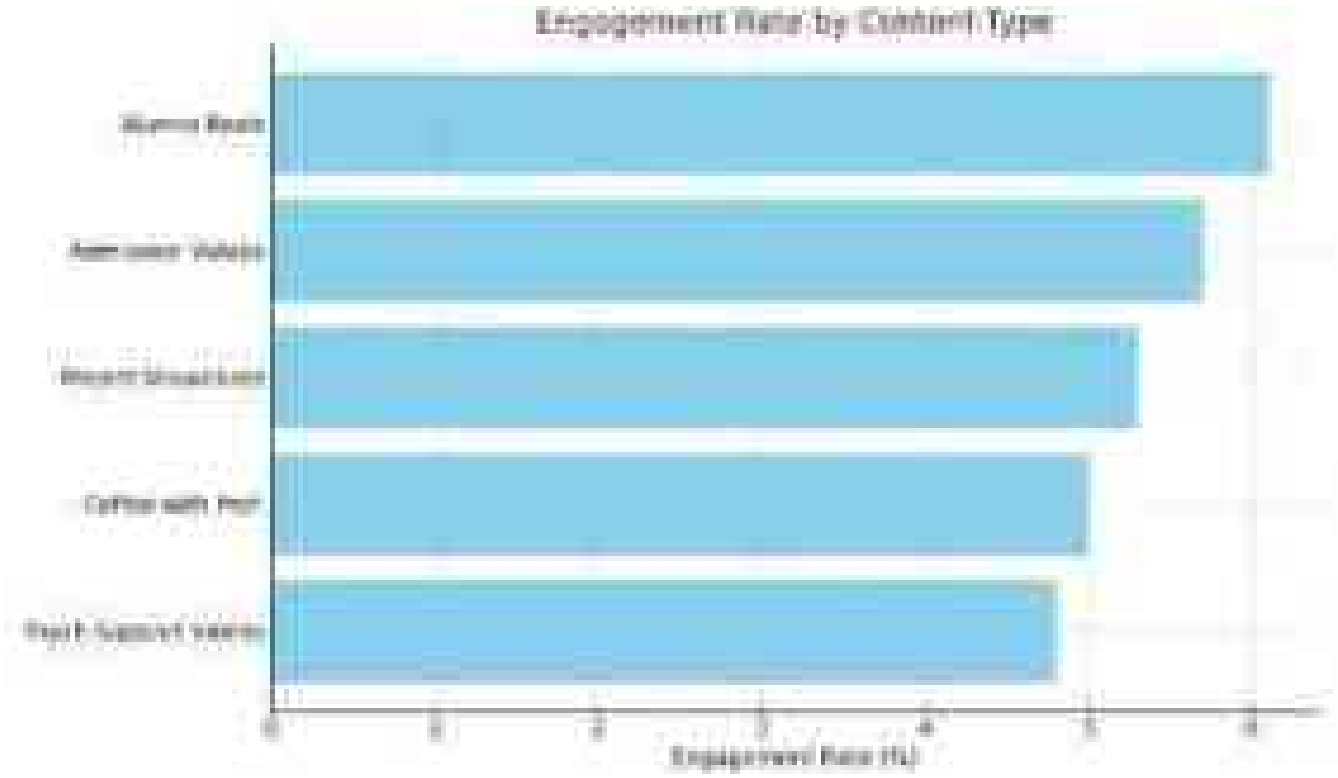


Figure 2 – Average engagement rate by content format

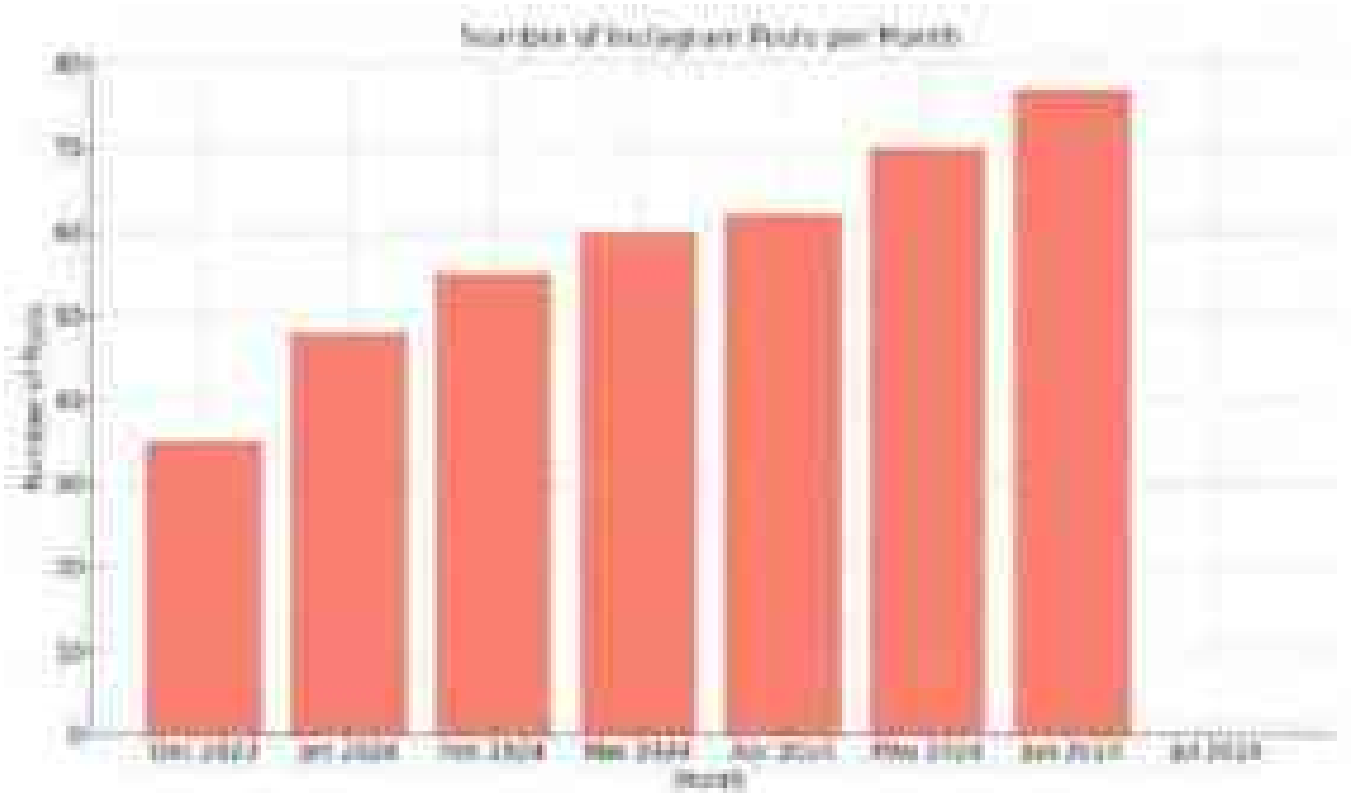


Figure 3 – Distribution of Instagram posts per month during the campaign

3.2. Qualitative insights feedback collected from student messages and post comments revealed recurring themes

- Accessibility: Students reported that short, informal videos made academic content "easier to digest."
- Relevance: Alumni videos helped prospective students' "picture" their own futures in the profession.
- Trust and relatability: Posts featuring real student voices and personal experiences were perceived as more credible than institutional advertising.

These outcomes resonate with trends identified [6], where Gen Z students demand transparency, personalisation, and authentic storytelling. By responding to these expectations, the Department successfully redefined how civil engineering is presented to future students, shifting from abstract curricula to tangible, people-centered experiences.

Moreover, Instagram proved to be not just a promotional platform but an educational and emotional support tool, helping reduce anxiety related to entrance exams and academic choices. Content featuring psychologists and peer advice was among the most commented, especially during the admission period.

These findings support the growing argument that social media, when used strategically, can serve as an effective bridge between academia, industry, and prospective students, especially in traditionally low-engagement fields such as civil engineering.

3.3. External benchmarking: niche enrollment trends

To contextualise findings, insights were drawn from [6]. Their study highlights several relevant trends:

- Personalisation Demand: 83% of Gen Z students prefer personalised content, while only 17% receive it
- Social media: 75% of respondents use Instagram for college insights, reinforcing Instagram's central role

These external benchmarks were used to assess whether the content strategy developed by the Department aligned with broader generational preferences and trends in student decision-making.

3.4. Comparative interpretation

To better understand the relevance and effectiveness of the Instagram strategy used, a comparative interpretation is conducted using publicly available educational trend data. Specifically, the engagement outcomes are informed by reports [6] on Gen Z's expectations in the college selection process.

While the campaign emphasised authenticity, personalisation, and real-life academic content, Niche data confirmed that 83% of Gen Z students seek personalised communication, and 75% rely on Instagram as a trusted source of college-related insights. This parallel demonstrated that the Department's strategic content choices—short-form interviews, student-led videos, and real-world field visits—resonated strongly with the behavioral patterns of the target audience. The alignment validates that digital outreach was not only contextually appropriate but also grounded in broader generational needs and search behavior.

The comparison served as a validation framework for interpreting engagement trends and determining content effectiveness within a broader educational and generational context.

4. Conclusion

This study demonstrates the effective use of Instagram as a multifaceted communication and educational tool within the context of higher education in civil engineering. By leveraging the platform's visual and interactive features, the Department of Civil Engineering and Geodesy at the Faculty of Technical Sciences in Novi Sad successfully bridged gaps between students, academia, and industry over a six-month targeted campaign.

Quantitative metrics showed significant growth in both followers and engagement rates, with key content formats—such as alumni interviews and project showcases—outperforming industry benchmarks. Qualitative feedback highlighted the importance of relatability, authenticity, and clarity, confirming that Generation Z students respond positively to transparent and personalised messaging.

The alignment between the Department's campaign outcomes and broader enrollment behaviour trends, as described in Niche's research on Gen Z preferences, reinforces the strategic value of such digital initiatives. Instagram proved capable not only of enhancing student motivation and academic visibility but also of easing the admissions experience and improving perceptions of civil engineering as a modern and dynamic profession.

These findings support the notion that higher education institutions, particularly in technically oriented disciplines such as engineering, must continually adapt to digital communication norms. Social media, when thoughtfully curated and pedagogically grounded, can become a core element of outreach, education, and identity-building in academia.

5. Acknowledgement

This research has been supported by the Ministry of Science, Technological Development and Innovation through Contract No. 451-03-136/2025-03/200156.

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-137/2025-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project "Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad 2025" (No. 01-50/295).

Literature

[1] Gulzar, M. A., Ahmad, M., Hassan, M., & Rasheed, M. I.: *"How social media use is related to student engagement and creativity: investigating through the lens of intrinsic motivation"*, Behaviour & Information Technology, 2021, 41(11), 2283–2293. https://doi.org/10.1080/0144929X.2021.1917660

[2] Ye, Hady & Li, Ruyang: *"The Role of Social Media in Promoting Academic Engagement and Enhancing Management Efficiency"*, Academic Journal of Science and Technology, 2024, 10. 185-191. 10.54097/k9mvbg17.

[3] Pandita A, Kiran R.: *"The Technology Interface and Student Engagement Are Significant Stimuli in Sustainable Student Satisfaction"*, Sustainability. 2023; 15(10):7923. https://doi.org/10.3390/su15107923

[4] Momin, Khondhaker & Kittur, Javeed & Rouf, Tahrima: *"Exploring the Use of Social Media in Engineering Education -Preliminary Findings from a Systematic Literature Review"*, 2023, ASEE PRISM.

[5] Topalić J., Starčev-Ćurčin A., Draganić S.: *"GENERATION Z: HOW TO PRESENT CIVIL ENGINEERING STUDIES TO FUTURE STUDENTS"*, 14th International Scientific Conference Science and Higher Education in Function of Sustainable Development – SED 2025, Kopaonik

[6] https://www.niche.com/about/enrollment-insights/how-the-class-of-2026-is-redefining-the-college-search-3-trends-to-know, Date accessed 05.09.2025.

The GREEN Program, KAOSPILOTS, Game|Changers, and Zeleno Doba cases for bridging industries, academia, and communities to grow regenerative leaders for the Western Balkan

Sergey Dmitriev[1]

Eva Vitorović[2]

1 Volunteer, NGO Zeleno Doba
dmitriev.sergey@gmail.com

2 Co-Founder and Program Coordinaror, NGO Zeleno Doba
eva.zelenodoba@gmail.com

Abstract

Industries and academia are steady institutions with their organisational design keeping current operations well, but lacking flexibility to experiment on the frontier of techno-social innovations to deal with environmental and other issues of the polycrisis. This paper explores The GREEN Program (USA) and KAOSPILOT (Denmark)—that exemplify how small businesses and NGOs can grow collaborative environments and learning ecosystems between industries and universities to educate new generation of leaders with attitude towards care for the planet and societies. The GREEN Program (TGP) is a company dedicated to empowering sustainability leaders through hands-on, real-world learning experiences focused on the world's most urgent sustainable development challenges. TGP has engaged over 4,000 students and professionals from more than 470 universities, offering short-term programs combining exclusive industry exposure, and adventure travel. It leverages the world as a classroom, aligning its curriculum with the SDGs providing access to industry facilities and local experts. KAOSPILOT is a globally recognised institution, specializing in meaningful entrepreneurship. Its programs are designed to develop changemakers capable of navigating complexity and driving social and environmental impact. The program emphasizes process/business design, fostering crossdisciplinarity. As the authors has both local and international experience e.g. in the similar to mentioned above formats – ad-hoc research and education program Game|Changers (an international community initiative that was active in 2010-2013, in cooperation with Pixelache platform it gathered TGP's founders and KAOSPILOT representative at the un-conference on re-engineering education in Finland) they suggests how advances of the described cases can be applied in the region's context e.g. a Serbian ecological NGO Zeleno Doba work with ERASMUS+ Youth Exchange programs, nurturing local regenerative leaders and leveraging programs such as 1FUTURE and ECOPRISE for cooperation with Northern and Western Europe partners as well as post-Yugoslavian and Albanian global diasporas.

Keywords

Regenerative leadership, learning ecosystems, the world as a classroom, meaningful entrepreneurship, adventure travel, ad-hoc education, community, industry university relations.

1. Introduction: The inertia of incumbents in an age of polycrisis

The 21st century is characterized by a "polycrisis"—a convergence of interconnected global challenges including climate change, biodiversity loss, social inequality, and geopolitical instability [1]. Addressing these multifaceted issues requires an unprecedented level of innovation, collaboration, and adaptive leadership. However, the two primary engines of societal progress—academia and industry—often operate with an institutional inertia that hinders their ability to respond effectively.

Universities, with their disciplinary silos and long curriculum development cycles, can be slow to integrate the interdisciplinary, action-oriented knowledge required to tackle complex sustainability problems. Industry, driven by quarterly returns and operational efficiency, often prioritizes incremental improvements over the disruptive, systemic changes needed for a truly sustainable transition. This creates a critical gap: a deficit of leaders who can navigate the complex space between established disciplines and sectors, translating systemic understanding into tangible, regenerative action.

This paper argues that smaller, more agile entities like specialized educational companies, non-governmental organizations (NGOs), international networks, and even informal communities can act as crucial intermediaries, creating dynamic learning ecosystems [2] that bridge the gap between academia and industry. We explore following exemplary models: The GREEN Program (TGP) and Kaospilot [3]. By analyzing their core principles and methodologies, we aim to extract actionable insights. Furthermore, drawing on our experience with collaborative initiatives like the Game|Changers program (North Europe), and non-formal education trainings by the Global Ecovillages Network [5,6] provided on the Balkans by NGO Zeleno Doba (Serbia) as well as ongoing ECOPRISE project (a partnership for future - oriented social entrepreneurship through Ecovillage Design, funded by the EU) we propose a framework for applying these insights within the specific context of the Balkan region, leveraging existing networks and programs to cultivate a new generation of regenerative leaders.

2. Pioneering models: creating collaborative learning ecosystems

To understand how to bridge the institutional divide, we turn to two organizations that have successfully redesigned the learning experience to be more fluid, impactful, and relevant to contemporary challenges.

2.1. The GREEN Program (TGP): The World as a Classroom

Founded in 2009, The GREEN Program (TGP) operates on a powerful premise: the most effective way to learn about sustainability is to experience it firsthand. TGP designs and delivers short-term, high-impact educational programs focused on the UN Sustainable Development Goals (SDGs). These are not traditional study-abroad tours; they are immersive deep dives into the world's sustainability hotspots.

Core Methodologies:

- **Experiential and Site-Specific Learning:** Instead of reading about geothermal energy in a textbook, students travel to Iceland to visit a geothermal power plant, speak with its engineers, and analyze its socio-economic impact on the local community. This model transforms abstract concepts into tangible, memorable experiences.
- **Direct Industry Access:** TGP has cultivated partnerships with leading companies and infrastructure facilities globally. This provides students with exclusive, behind-the-scenes access to the real-world application of sustainable technologies and business models, demystifying industry operations and fostering direct dialogue with professionals.
- **Capstone Projects with Community Impact:** A central component of every TGP program is a capstone project where interdisciplinary teams of students develop innovative solutions to a real-world challenge faced by the local community. These projects are presented to and critiqued by local stakeholders and industry experts, ensuring relevance and providing invaluable real-world feedback.
- **Adventure Travel as a Pedagogical Tool:** TGP integrates cultural immersion and adventure activities (e.g., glacier hiking, jungle trekking) into its curriculum. This serves not only to attract students but, more importantly, to build group cohesion, foster resilience, and create a profound, emotional connection to the natural environments they are studying to protect.

By positioning the "world as a classroom," TGP effectively dissolves the walls between the university lecture hall and the industrial facility, creating a fluid learning environment where theory and practice are in constant dialogue.

2.2. KAOSPILOT: Designing for Meaningful Entrepreneurship

Established in 1991 in Aarhus, Denmark, Kaospilot is a hybrid business and design school with a focus on leadership, creativity, and social impact. It eschews traditional teaching methods in favor of a learning-by-doing philosophy that prepares its graduates—the "Kaospilots"—to lead and launch projects and businesses that are not only profitable but also purposeful.

Core Methodologies:

- **Project-Based Learning:** The curriculum is built around real projects for real clients, ranging from startups and NGOs to municipalities and multinational corporations. Students learn project design, process facilitation, and business modeling by applying these skills directly to complex, often ambiguous, challenges.
- **Holistic Skill Development:** The program is structured around three core pillars: Creative Business Design, Creative Project Design, and Creative Process Design. This is complemented by a deep focus on personal development, including leadership training, team dynamics, and value clarification. The goal is to develop the whole person, not just the professional.
- **Meaningful Entrepreneurship:** Kaospilot actively fosters an entrepreneurial mindset grounded in creating positive change. It encourages students to identify societal needs and build ventures that provide social, cultural, and environmental value alongside economic returns.
- **Cross-Disciplinary Collaboration:** By bringing together students from diverse backgrounds and having them work in teams on complex projects, Kaospilot inherently cultivates the collaborative and communication skills essential for navigating today's interconnected problems.

Kaospilot serves as a powerful example of an institution designed from the ground up to produce change agents. It prioritizes the "how" of learning and leading over the "what" of specific knowledge domains, producing adaptive, value-driven individuals and teams capable of creating new solutions rather than just managing existing systems.

2.3. Ad-hoc formats and local action: The cases of Game|Changers and Zeleno Doba

The principles embodied by TGP and Kaospilot are not exclusive to formally constituted programs. They also thrive in more fluid, community-driven formats, demonstrating the adaptability of the learning ecosystem model. Our own experience is rooted in such initiatives.

- Game|Changers: An Ad-Hoc Education and Research Platform: The Game|Changers initiative (active 2010-2013) operated as an international, ad-hoc community for research and education [7]. Rather than a fixed curriculum, it functioned as a convener of people and ideas. A key event, held in cooperation with the Pixelache platform in Helsinki [8], was an "un-conference" focused on re-engineering education. This event was pivotal, as it brought together disparate innovators in the same room, including the founders of The GREEN Program and a representative from Kaospilot. Game|Changers illustrates the power of temporary, low-overhead platforms to create fertile ground for cross-pollination, sparking conversations and collaborations that would not occur within institutional silos. It serves as a precedent for how ad-hoc education can build valuable community and intellectual capital.

- Zeleno Doba: On a local level, the Serbian ecological NGO Zeleno Doba ("Green Age") exemplifies how experiential, purpose-driven learning can take root in community contexts. Through Erasmus+ Youth Exchanges and Training Courses, the organization brings together young people from across Europe to collaboratively address local environmental and social challenges—from sustainable agriculture to circular economy and regenerative practices.
  By focusing on hands-on engagement, community dialogue, and youth empowerment, Zeleno Doba translates global sustainability concepts into tangible, local action, positioning young people as active change-makers in their regions.
  As part of its strategic plan aligned with Erasmus+ accreditation, Zeleno Doba is now scaling its approach by establishing:
    - 2–3 Rural Learning Hubs across Serbia as centers for non-formal education and international collaboration;
    - Mobile Learning Units that reach youth with fewer opportunities, including NEETs, in underserved or remote areas.

These hubs and mobile formats will serve as bridging spaces—connecting EU-based educational partners with local communities in the Western Balkans while offering meaningful learning experiences rooted in regenerative values. Zeleno Doba thus acts as both a host and connector, curating environments where experiential learning, civic participation, and ecological awareness can flourish. In doing so, it contributes to a broader learning ecosystem that nurtures regenerative leadership from the ground up.

Together with initiatives like Game|Changers, this case illustrates how agile, communitybased formats can effectively bridge the gap between industry, academia, and society, cultivating transformative leadership across diverse contexts.

3. Localizing innovation: A framework for the Balkans

The success of TGP and Kaospilot is not confined to their specific geographies. Their core principles—experiential learning, real-world problem solving, interdisciplinary collaboration, and a focus on purpose—are universally applicable. As authors involved in the ad-hoc educational program Game|Changers and active in Zeleno Doba projects, we have seen the power of such nontraditional formats firsthand.

We propose a model for adapting and applying these insights within the Balkan context, spearheaded by local grass roots communities, student organizations, art residencies, hack spaces, and coworkings as well as regional networks like the European Ecovillage Network, the South-Eastern Ecovillage Network, ECOLISE; global grass-root initiatives like ecoversities, U4Earth, Regen Tribe, and projects like 1FUTURE, ECOPRISE, CURISOIL where the main role is executed by traditional well established institutions like universities.

The Regional Opportunity: The Western Balkans face a unique set of challenges, including post-industrial environmental degradation, significant "brain drain" of talented youth, and the need for new, regenerative models. This context creates a ground for educational and practical innovation that can empower young people to become agents of change within their own communities.

A Proposed Framework:

1. Leverage Existing Structures: Utilize the ERASMUS+ Youth Exchange program as a primary vehicle. These programs provide a funded, internationally recognized framework for short-term, non-formal educational projects, perfectly aligning with the TGP model of intensive, thematic learning experiences.

2. Adopt a Hybrid Model: Combine TGP's "world as a classroom" approach with Kaospilot's focus on "meaningful entrepreneurship." An ERASMUS+ project could, for example, bring together youth from Serbia, Germany, and Albania for a 10-day program focused on circular economy solutions for agricultural waste in a rural Serbian region.

    a. Days 1-3 (TGP-style): Immersion and analysis. Visit local farms, waste management facilities, and small businesses. Meet with municipal leaders and local entrepreneurs.

    b. Days 4-7 (Kaospilot-style): Ideation and project design. Facilitated workshops on business modeling, project management, and community engagement to develop concrete, small-scale social enterprise concepts.

    c. Days 8-10: Prototyping and pitching. Develop and present viable project proposals to a panel of local stakeholders, potential mentors, and NGO partners.

3. Activate Networks for Support:

    a. 1FUTURE and ECOPRISE Cooperation: Engage with existing international partners in Northern and Western Europe to bring in expertise, mentorship, and different cultural perspectives.

    b. Diaspora Engagement: Actively tap into the highly skilled post-Yugoslavian and Albanian global diasporas. These professionals can serve as remote mentors, guest lecturers, and potential investors, providing a crucial bridge between local challenges and global expertise and resources.

4. Focus on nurturing regenerative leaders, teams, and communities: The ultimate goal is not just to complete a project but to cultivate a mindset. This means emphasizing skills like systems thinking, empathy, care, resilience, and collaborative leadership. The aim is to empower local youth to see themselves as capable creators of a regenerative future for their region, rather than simply as recipients of external aid or candidates for emigration.

5. Self-sustaining evolving student communities of practice: cases of AIESEC (an international student organization that provides abroad internships and youth conferences since 1948 and implements SDGs since 2015) [9], Organization of Serbian Students Abroad (OSSI, established in 1997), and the Game|Changers program show how students themselves can run, develop and update organizational and community structures if such a cyclic model was introduced to

them from the initial part of their experiences within these communities and organizational frameworks. So the framework can function in a two-year cycle, where in first year students act as active learners and in the second year – as curators-organizers.

In this seeding article authors do not introduce any evaluation metrics for the framework suggesting that it should be drafted after review by potential partners.

4. Discussion and implications

The models of The GREEN Program, Kaospilot, and Game|Changers program along with the proposed adaptations, highlight several key implications for the future of education and community-industry-academia collaboration.

First, they demonstrate that agile intermediaries are essential. Small, focused organizations as well as local communities and their international networks can move faster and take more risks than large universities or corporations, creating the experimental spaces where true innovation occurs. They act as translators and connectors, building bridges that larger institutions are often too cumbersome to construct on their own.

Second, the paradigm of education must shift from knowledge transfer to ecosystem cultivation. An effective 21st-century education immerses students in a rich learning ecosystem of peers, mentors, real-world challenges, and diverse environments. This experiential approach fosters not just competence, but character and commitment.

Third, the concept of regenerative communities and leadership must move to the forefront. This goes beyond sustainability as a technical problem of "doing less harm." Regenerative leadership is about actively improving the health and resilience of the systems—ecological, social, and economic. It is a proactive, creative, and holistic approach that the methodologies of TGP, Kaospilot, Game|Changers and Zeleno Doba are uniquely suited to develop.

Potential challenges to this approach include securing long-term funding beyond project based grants, scaling these high-touch models without diluting their impact, and gaining formal recognition or academic credit from traditional universities. However, by demonstrating tangible outcomes—empowered youth, new social enterprises, and strengthened communities—these initiatives can build the momentum needed to influence and reform the larger systems. We believe that in the face of polycrisis universities as well as other educational and research institutions should embrace planetary vision [10], so caring not only for people interest, act from broader postanthropocenic (e.g. symbiocenic [11]) perspectives. Leadership from this perspective becomes more practice of care adopting a new kind of culture dimension – regenerative culture [12].

5. Discussion and implications

The gap between the operational focus of industry and the theoretical orientation of academia is a significant barrier to addressing the polycrisis. This paper has showcased The GREEN Program, Kaospilot, Game|Changers and youth exchanges by Zeleno Doba as examples of how this gap can be bridged through innovative educational models that are experiential, project-based, and purposedriven. They demonstrate that by treating the world as a classroom and focusing on the development of meaningful entrepreneurship, it is possible to cultivate the adaptive, resilient, and regenerative communities and leaders we so urgently need.

The proposed framework for applying these models via organizations like Zeleno Doba, using ERASMUS+, 1FUTURE, ECOPRISE, and diaspora networks, offers a concrete pathway for regional initiative. It is a call to action to move beyond traditional structures and invest in creating dynamic learning ecosystems. By doing so, we can bridge the divide between research and practice, and between business and academia, to collaboratively create regenerative present and futures.

Literature

[1]	Lawrence, M., Homer-Dixon, T., Janzwood, S., Rockström, J., Renn, O., & Donges, J. F.: *"Global polycrisis: the causal mechanisms of crisis entanglement"*, Global Sustainability, 7, e6, 2024.
[2]	Smitsman, A., Laszlo, A. and Luksha, P.: *"Evolutionary learning ecosystems for thrivable futures: Crafting and curating the conditions for future-fit education"*. World Futures, 76(4), 2020, pp.214-239.
[3]	Windeløv-Lidzélius, C.: *"Chapter 5 - The School as a Living Lab – The Case of Kaospilot"*, in Digital Participation through Social Living Labs. M. Dezuanni, M. Foth, K. Mallan and H. Hughes, Chandos Publishing, 2018, pp77–96, ISBN 9780081020593.
[4]	Lähdemäki, J.: *"Case Study: Kaospilots—From Passive Listeners to Global Change Agents"*. In: Cook, J.W. (eds) *Sustainability, Human Well-Being, and the Future of Education*. Palgrave Macmillan, Cham, 2019, pp. 375–396.
[5]	Farkas, J.:*"'Very Little Heroes' History and Roots of the Eco-Village Movement"*. Acta Ethnographica Hungarica, 62(1), 2017, pp. 69-87.
[6]	Schwab, A. K., Roysen, R.:*"Ecovillages and other community-led initiatives as experiences of climate action"*. Climate Action, 2022 1(1), pp. 1-4.
[7]	Dmitriev S.: *"Ad-hoc Education&Research Approach for 'Gardening' Learning Ecosystems"*, In: Dragićević Šešić M., Cordonnier S. (Ed*) Subaltern knowledge in cultural practices: fostering fairness, cooperation and care*, University of Arts in Belgrade, Belgrade, 2024, p.265-286.
[8]	Berglund, E.: *"Science, Art and Other Ways of Knowing: A Proposal from a Struggle Over a Helsinki Green Space"*. in: Plüschke-Altof, B., Sooväli-Sepping, H. (eds) Whose Green City?. Sustainable Development Goals Series., 2022, Springer, Cham.
[9]	Louro, R. S. G.: *"The role of education towards sustainable development: The case study of AIESEC & Harvesting Future Leaders' Education Project in Jakarta, Indonesia"*, Doctoral dissertation, ISCTEInstituto Universitario de Lisboa, Portugal, 2019.
[10]	Luksha, P., Taddei, F.: *"Manifesto for the Planetary Mission of the University"*, Learning Planet Institute, 2023.
[11]	Albrecht, G. A.: *"Earth emotions: New words for a new world. In Earth Emotions"*, Cornell University Press, 2019
[12]	Wahl, D. C.: *"Designing Regenerative Cultures"*, Triarchy Press, 2016

T7

Other

Integrating the analysis of adaptive capacity into an anticipatory method for risk and vulnerability assessment

Alexander Cedergren[1]

Henrik Hassel[2]

1 Associate professor, Division of Risk Management and Societal Safety, Lund University, Sweden
alexander.cedergren@risk.lth.se

2 Professor, Division of Risk Management and Societal Safety, Lund University, Sweden
henrik.hassel@risk.lth.se

Abstract

To ensure the continuous delivery of services that are critical to society, it is essential that organisations responsible for the operation of critical societal functions work systematically to prevent and prepare for a wide range of potential crisis situations. A central component of this work is the use of assessments and analytic tools that support preparedness planning and decisionmaking for proactive risk reduction. Most of these tools are anticipatory in nature: they aim to identify hazards, vulnerabilities, challenges, and conditions that may arise in the future, and to develop measures that either prevent their occurrence or increase the chances of effective response and recovery. Risk and Vulnerability Assessment (RVA) and Business Continuity Management (BCM) are frequently used approaches, mainly building on an anticipatory perspective. In Sweden, these approaches have become a cornerstone of systematic crisis management, particularly within public organisations. Over the past years, the authors have contributed to the development, implementation, and evaluation of a framework combining RVA and BCM, adapted to the Swedish municipal context. While anticipatory approaches are an essential element for strengthening crisis preparedness, many potential hazards cannot be anticipated. Therefore, organisations must increasingly consider how to manage unforeseen disruptions and crises. Traditional RVA and BCM approaches rarely include an assessment of an organisation's ability to cope with unexpected events and conditions, i.e., its adaptive capacity. This paper therefore proposes a way to complement our previously developed anticipatory RVA/BCM framework with an explicit assessment of adaptive capacity. By integrating anticipatory and adaptive perspectives, organisations can strengthen their ability to manage not only foreseeable events and conditions but also those that are difficult, or even impossible, to anticipate. Integrating the analysis of adaptive capacity within established RVA/BCM practices also offers a pragmatic and feasible approach, avoiding the need for separate, standalone assessment tools that focus exclusively on one of the perspectives.

Keywords

Adaptive capacity; Resilience; Business Continuity Management; BCM; Risk and Vulnerability Assessment; Public sector

1. Introduction

Modern societies face numerous of threats to human life and health, economic stability, and critical functions, ranging from cyber-attacks to pandemics and floods. To prepare for such threats, organisations often use anticipatory tools like Risk and Vulnerability Assessments (RVAs) to identify hazards and take preparedness measures. In Sweden, municipalities are required by law to conduct RVAs, and over the past two decades, these assessments have become central to local crisis management. More recently, RVAs have been supplemented by Business Continuity Management (BCM). Originating from the private sector, BCM focuses on ensuring critical operations and enabling recovery through continuity plans.

However, the growing complexity and unpredictability of crises limit the effectiveness of such anticipatory approaches. Many disruptions cannot be foreseen or planned for, as highlighted by the COVID-19 pandemic, which showed that even prepared organisations must adapt to rapidly changing conditions and uncertainties [1]. This accentuates the need to complement anticipatory approaches with the development of adaptive capacity to manage unforeseen events.

Adaptive capacity refers to an organisation's ability to adjust its models, plans, and behaviours in response to surprises [2]. While widely discussed in research, sometimes as part of the resilience concept, adaptive capacity is rarely integrated into practical crisis management efforts. For example, assessment of adaptive capacity is typically not integrated as part of Swedish municipalities' RVAs, which means that these crisis preparedness efforts mainly focus on known threats at the expense of unforeseen ones.

The aim of this paper is to address this weakness by suggesting an extension of an existing RVA/BCM framework, by incorporating an assessment of adaptive capacity. The goal is not to replace the existing framework, but to expand its scope by adding a perspective that guide the organisation in assessing how well it can adapt under pressure and uncertainty. The suggestion builds on a literature review and several years of collaborative research with Swedish municipalities [3]–[5]. The central research question is: How can adaptive capacity be assessed and integrated into an existing RVA/BCM framework in the public sector? The aim is to develop a framework that is both theoretically grounded and practically useful, addressing not only known risks but also how organisations can cope with the unexpected.

1.1. Background

Risk and Vulnerability Assessments (RVAs) are a central element of proactive crisis management, used to identify potential threats, estimate their likelihood and impact, and guide preparedness measures. Rooted in an anticipatory approach, they focus on mapping future scenarios and suggesting ways to reduce risks; in particular, by addressing system vulnerabilities.

Business Continuity Management (BCM) complements RVAs by shifting the focus from scenarios to ensuring continuity of critical operations regardless the cause of the disruption. Guided by standards such as ISO 22301:2019, BCM includes a number of central elements, such as the Business Impact Analysis (BIA), where critical processes

are assessed in terms of their Maximum Tolerable Period of Disruption (MTPD) and corresponding Recovery Time Objectives (RTO). These assessments are used as a basis for developing continuity plans that help the organisation to sustain operations during disruptions.

Anticipatory approaches such as RVA and BCM work well for known or recurring threats, but their effectiveness is limited when crises are unpredictable. Recent research stresses that organisations must be able to adapt when plans do not match actual crisis conditions or when new challenges arise. In other words, anticipatory and adaptive approaches should be seen as complementary and mutually reinforcing [6].

While adaptive capacity is widely discussed across several fields or research, practical tools for applying it in the public sector remain scarce. Current RVA and BCM processes rarely assess an organisation's readiness to adapt, leaving a gap between research and practice. Bridging this gap requires approaches that combine the strengths of anticipatory planning with explicit assessments of adaptive capacity.

1.2. Extending an existing RVA/BCM framework

This paper seeks to unify anticipatory and adaptive perspectives by extending an existing RVA/BCM framework with an assessment of adaptive capacity (Part III below). The existing framework was developed over 3,5 years in close collaboration between researchers and practitioners, following an Action Design Research (ADR) methodology. Each step of the method was iteratively designed, tested, and refined with input from end-users. A central challenge was balancing theoretical rigor with practical feasibility. While grounded in state-of-the-art theory, the framework was designed to be usable across diverse public services, such as health care, pre-schools, urban planning, and elderly care, often by professionals with limited crisis preparedness experience. The resulting RVA/BCM framework is summarised below, with further detail provided in [5].

1.2.1. Part I: Mapping the organisation

This part of the framework draws on BCM principles, adapted for a municipal setting. The aim is to identify functions, dependencies, and back-up solutions through four main steps: (1) List organisational functions and qualitatively describe the consequences of disruptions, (2) Estimate time-criticality using a 7-level scale, (3) Map dependencies (e.g., staff, facilities) and back-up solutions, rating their robustness (1–4) and strength of dependency (1–3), and (4) Suggest initial risk-reduction measures, such as addressing gaps in back-up solutions.

1.2.2. Part II: Analysing undesirable events

This part shifts the focus to event-specific analysis, following risk management principles through the following three main steps: (1) Identify and describe events (e.g., power outage, mass casualty accident) in terms of severity, extent, duration, and speed of onset, (2) Assess capability to maintain prioritised functions (scale 1–4) and expected consequences (scale 1–5), and (3) Assess event causes and likelihood on a 5-level scale, including the level of confidence (3-level scale).

1.2.3. Part III: Assessing adaptive capacity

This part introduces an adaptive perspective, complementing the anticipatory focus of Parts I and II. Details are developed in later sections.

1.2.4. Part IV: Identifying and evaluating improvements

The final part combines findings from the previous parts and guides decision-making through the following steps: (1) Rank the criticality of functions, dependencies, and events (scale 1–4), supported by visualisation tools, (2) Propose measures to prevent, mitigate, or recover from events, or improve adaptive capacities, with responsibilities and timelines assigned.

2. Review of existing methods for assessing adaptive capacity

Many methods for assessing adaptive capacity have been proposed, but they are rarely combined with anticipatory approaches. From a review of 21 such methods, it can be concluded that they vary in scope and perspective [7]. Broadly, they fall into two categories: retrospective methods that analyse how adaptations occurred in past events, and proactive methods that examine organisational characteristics shaping adaptive capacity. Since the RVA/BCM framework is proactive, its adaptive capacity component should also follow this logic.

Proactive methods often decompose adaptive capacity hierarchically, making a distinction between broad high-level themes and more concrete attributes or metrics. Some focus on subabilities or processes needed for adaptation, while others emphasise organisational factors that influence it. Certain approaches remain at a conceptual level, offering flexibility but requiring users to define context-specific metrics. In this paper, we propose a framework tailored for public sector organisations. Adaptive capacity is broken down into two levels: high-level themes and concrete guiding questions used to support practical assessments. While designed for municipalities, the guiding questions can be adapted for use in other contexts.

3. Integrating assessment adaptive capacity into existing RVA/BCM framework

The high-level themes and guiding questions used in this paper are derived from a literature review on factors enabling or impeding adaptive capacity [3]. Not all factors from the review are included; instead, the selection focuses on those shown in previous empirical work to be particularly relevant for public sector organisations, ensuring applicability to the RVA/BCM framework.

Building on [3], [8], the framework is organised into six themes: Resources and diversity, Governance and decision-making, Information management and social networks, Culture and leadership, Monitoring and learning, and Collective commitment and mutual support. Each theme is operationalised into guiding questions integrated into the RVA/BCM framework. These questions help practitioners assess how strongly each theme characterises their organisation.

3.1.1. Resources and diversity

Adaptive capacity is supported by buffers, slack, and redundancy, such as extra human or material resources and multiple viable courses of action [9]. Part I of the RVA/BCM framework captures some of these resources through the mapping of dependencies and back-up solutions. However, effective use of resources also depends on asset literacy, which refers to the awareness, willingness, and competence to recognise and mobilise available assets. This capability can be strengthened by systematically mapping and raising awareness of resources [10].

In addition to redundancy, diversity is another enabler of adaptation. Role diversity and crosstraining allow individuals to take on multiple or improvised functions [11], [12], while diversity of perspectives, i.e. different problem frames and viewpoints, broadens organisational responses [13].

To assess these enablers of adaptive capacity, the RVA/BCM framework is extended with three guiding questions: (A1) To what extent are staff familiar with and able to mobilise available resources, including resources they do not use on a regular basis? (A2) To what extent are diverse roles, competencies and perspectives represented in the organisation to provide multiple and complementary skills and viewpoints? (A3) To what extent are staff trained, authorised, and willing to take on alternative roles when needed to handle a crisis situation?

3.1.2. Governance and decision-making

A recurring theme in the literature is how organisational structures shape adaptation in complex and unexpected situations. Decentralised [9], [10] and modular [14] structures are often seen as beneficial, as they promote local self-organisation and prevent higher levels from being overloaded during crises. Yet, decentralisation can also create fragmentation if local actions of different units conflict with each other or with overarching goals [15]. Scholars therefore emphasise balancing autonomy with coordination to avoid silos and sub-optimisation [9].

Polycentric structures, with multiple semi-independent centres of decision-making, are one proposed solution, enabling both vertical and horizontal coordination through existing networks [14], [16]. While structural design is beyond the scope of the RVA/BCM framework, the literature often highlights the value of combining autonomy with cross-level coordination. Empirical studies also suggest that while top management should decide the "what", frontline staff are in the best position to decide the "how" [8], reflecting Weick and Sutcliffe's idea of "deference to expertise" [17].

To capture these dimensions of adaptive capacity, the framework is supplemented with the following three guiding questions: (B1) To what extent can units autonomously make decisions and take creative actions outside pre-existing plans and procedures in crisis situations? (B2) To what extent are mechanisms in place to coordinate actions with other units across organisational levels? (B3) To what extent can expertise rather than hierarchy influence decision-making in crisis situations?

3.1.3. Information management and social networks

Research highlights the critical role of communication, social networks, and connectivity in fostering adaptive capacity [9], [10], [14]. Strong inter-personal and inter-organisational ties enable rapid resource and knowledge sharing, support collaboration under pressure, and provide redundancy, thereby enhancing resilience [14]. To capture these enablers, the RVA/BCM framework is extended with the following three guiding questions: (C1) To what extent are quick communication channels available, both horizontally and vertically? (C2) To what extent is information openly shared across units in a structured way that minimizes bottlenecks, silos, and overload? (C3) To what extent are inter-personal relationships established with staff in other units (internal or external)?

3.1.4. Culture and leadership

Trust, empowerment, and supportive leadership are commonly recognised as key enablers of adaptive capacity [18]. Leaders play a central role in fostering an environment where employees feel engaged, motivated, and free to act creatively without fear of negative consequences, often described as psychological safety [6]. Such conditions enhance flexibility, initiative, and timely decisionmaking during crises [12], [19].

To incorporate these factors, the RVA/BCM framework is supplemented with the following guiding questions: (D1) To what extent is trust established between various staff categories and levels? (D2) To what extent can staff take improvised actions in a crisis event without risk of negative repercussions? (D3) To what extent do managers contribute to psychological safety and empowerment of staff?

3.1.5. Learning and experiential knowledge

Prior experience and organisational memory are key enablers of adaptive capacity [8], [18]. Effective responses to novel or surprising situations often draw on lessons from past event, highlighting the importance of a learning-oriented mindset that treats failures as opportunities for improvement, encourages experimentation, and tolerates mistakes [9].

In practice, rigid rules may be inadequate during unexpected events, making practical knowledge and creative reuse of resources, referred to as bricolage, essential [19]. However, reliance on experience can also involve risks, such as overconfidence or use of outdated practices. Organisational learning requires capturing individual insights systematically and institutionalising them to prevent informal work-arounds from masking systemic issues [15].

To incorporate these factors into the RVA/BCM framework, the following guiding questions are proposed: (E1) To what extent does the organisation proactively monitor its environment for early warning signals of potential threats? (E2) To what extent are experiences from exercises and previous disruptions followed up by evaluations and learning about how to handle future disruptions and crises? (E3) To what extent do staff pay attention to the risk of relying on outdated practices and question the relevance of available procedures?

3.1.6. Collective commitment and mutual support

Empirical studies emphasise that maintaining a clear understanding of common organisational goals during crises is critical for adaptive capacity [8]. Clear, focused goals help staff align their actions with the organisation's overall direction without prescribing detailed procedures, fostering shared understanding and coordinated responses [9], [10].

Adaptive capacity is also strengthened through inter-organisational networks or semiautonomous units that share resources and support one another when individual capacity is exceeded [20]. This is referred to as reciprocity, where units assist each other, even when the benefits for the own unit is limited, in pursuit of shared long-term goals [16]. More broadly, teamwork and a sense of collective purpose further enhance adaptability [6], [8], [12].

To capture these factors, the framework is extended with the following three guiding questions: (F1) To what extent are clear goals and priorities available to guide the response in the case of disruptions? (F2) To what extent do staff work as a team in the event of disruptions, disregarding organisational or administrative boundaries? (F3) To what extent do staff support other units, without expectations of immediate return?

4. Use of guiding questions to assess adaptive capacity

The guiding questions outlined above are answered by using a five-level Likert-type of rating scale. It is used by the same group participating in Parts I and II of the RVA/BCM framework, where the results are plotted in a grid as illustrated in Figure 1a, which is integrated in Part III of the RVA/BCM framework. Importantly, the grid is used to investigate the development of adaptive capacity over time for a specific organisational unit (see Figure 1b), whereas comparisons across units should be done with caution. The grid highlights the attributes of adaptive capacity in which the unit is strongest, providing a foundation for identifying and prioritising areas for improvement.

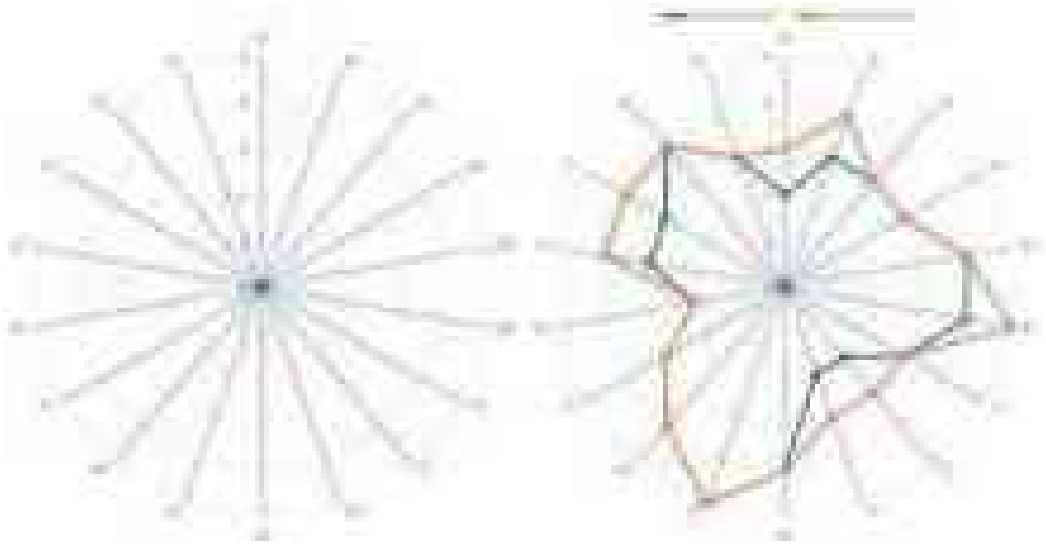


Figure 1a and 1b – Grid for presenting assessment of adaptive capacity based on guiding questions

5. Discussion and concluding remarks

Previous research has shown that applying the initial components of the RVA/BCM framework provides clear benefits, including greater risk awareness and improved prioritisation [4], [5]. At the same time, preparedness efforts often turn out to be of limited value during real disruptions, as many events fall outside anticipated scenarios and existing plans rarely match actual developments. To address these shortcomings, this paper presents a way to extend the framework by proposing guiding questions that capture key attributes of adaptive capacity, which have been identified in a literature review of enabling and impeding factors [3]. The extended framework thus builds on two complementary perspectives: an anticipatory and an adaptive one. Together, these parts provide a more comprehensive assessment of organisational capacity to cope with both expected and unexpected disruptions.

Although the added part increases the time required for applying the framework, we argue that its value is significant, as it addresses dimensions rarely included in RVA or BCM. Future research should validate the framework by comparing assessments of adaptive capacity with organisational performance during actual crises.

Literature

[1] N. R. Sikula, J. W. Mancillas, I. Linkov, and J. A. McDonagh, "Risk management is not enough: a conceptual model for resilience and adaptation-based vulnerability assessments," *Environ. Syst. Decis.*, vol. 35, pp. 219–228, 2015, doi: 10.1007/s10669-015-9552-7.

[2] D. D. Woods, "Resolving the Command–Adapt Paradox: Guided Adaptability to Cope with Complexity," in *Compliance and Initiative in the Production of Safety: A Systems Perspective on Managing Tensions & Building Complementarity*, J.-C. Le Coze and B. Journé, Eds. Springer Briefs in Safety Management, 2024, pp. 73–87.

[3] H. Hassel and A. Cedergren, "Enabling and Impeding Factors for Organizational Adaptive Capacity - A Review of the Literature," in *Proceedings of the 32nd European Safety and Reliability Conference*, 2023, doi: 10.3850/978-981-18-5183-4_r06-02-345-cd.

[4] A. Cedergren and H. Hassel, "Using Action Design Research for Developing and Implementing a Method for Risk Assessment and Continuity Management," *Saf. Sci.*, vol. 151, no. 105727, pp. 1–15, 2022.

[5] H. Hassel and A. Cedergren, "Integrating risk assessment and business impact assessment in the public crisis management sector," *Int. J. Disaster Risk Reduct.*, vol. 56, no. 102136, pp. 1–14, 2021, doi: 10.1016/j.ijdrr.2021.102136.

[6] B. Fagerdal, H. B. Lyng, V. Guise, J. E. Anderson, and S. Wiig, "No size fits all – a qualitative study of factors that enable adaptive capacity in diverse hospital teams," *Front. Psychol.*, vol. 14, 2023, doi: 10.3389/fpsyg.2023.1142286.

[7] H. Hassel and A. Cedergren, "Facing the unexpected: a literature review on methods for assessing organizational adaptive capacity," *Environ. Syst. Decis.*, vol. 45, no. 27, pp. 1–27, 2025, doi: https://doi.org/10.1007/s10669-025-10017-2.

[8] A. Cedergren and H. Hassel, "Building organizational adaptive capacity in the face of crisis: Lessons from a public sector case study," *Int. J. Disaster Risk Reduct.*, vol. 100, no. 104235, 2024, doi: https://doi.org/10.1016/j.ijdrr.2023.104235.

[9] E. Barasa, R. Mbau, and L. Gilson, "What is resilience and how can it be nurtured? A systematic review of empirical literature on organizational resilience," *Int. J. Heal. Policy Manag.*, vol. 7, no. 6, pp. 491–503, 2018, doi: 10.15171/ijhpm.2018.06.

[10] S. Tracey, T. L. O'Sullivan, D. E. Lane, E. Guy, and J. Courtemanche, "Promoting Resilience Using an Asset-Based Approach to Business Continuity Planning," *SAGE Open*, vol. 7, no. 2, 2017, doi: 10.1177/2158244017706712.

[11] J. Lundberg and A. Rankin, "Resilience and vulnerability of small flexible crisis response teams: implications for training and preparation," *Cogn. Technol. Work*, vol. 16, pp. 143–155, 2014, doi: 10.1007/s10111-013-0253-z.

[12] A. V. Lee, J. Vargo, and E. Seville, "Developing a Tool to Measure and Compare Organizations' Resilience," *Nat. Hazards Rev.*, vol. 14, no. 1, 2013, doi: 10.1061/(asce)nh.1527-6996.0000075.

[13] G. Minucci, "REACT, A New Conceptual Framework for Assessing Organisation's Adaptive Capacity," in *Enabling Adaptive Water Management to Face Drought Risk in a Changing Climate*, B. Pernici, S. Della Torre, B. M. Colosimo, T. Faravelli, R. Paolucci, and S. Piardi, Eds. Cham, Switzerland: Springer Nature, 2021, pp. 53–70.

[14] D. J. Yu *et al.*, "Toward General Principles for Resilience Engineering," *Risk Anal.*, vol. 40, no. 8, pp. 1509–1537, 2020, doi: 10.1111/risa.13494.

[15] H. B. Lyng *et al.*, "Balancing adaptation and innovation for resilience in healthcare – a metasynthesis of narratives," *BMC Health Serv. Res.*, vol. 21, no. 759, 2021, doi: 10.1186/s12913-021-06592-0.

[16] D. D. Woods, "The theory of graceful extensibility: basic rules that govern adaptive systems," *Environ. Syst. Decis.*, vol. 38, pp. 433–457, 2018, doi: 10.1007/s10669-018-9708-3.

[17] K. E. Weick, K. M. Sutcliffe, and D. Obstfeld, "Organizing for High Reliability: Processes of Collective Mindfulness," *Res. Organ. Behav.*, vol. 21, pp. 81–123, 1999.

[18] J. Gupta *et al.*, "The Adaptive Capacity Wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society," *Environ. Sci. Policy*, vol. 13, pp. 459–471, 2010.

[19] S. McManus, E. Seville, J. Vargo, and D. Brunsdon, "Facilitated Process for Improving Organizational Resilience," *Nat. Hazards Rev.*, vol. 9, no. 2, 2008, doi: 10.1061/(asce)1527-6988(2008)9:2(81).

[20] R. I. Cook and B. A. Long, "Building and revising adaptive capacity sharing for technical incident response: A case of resilience engineering," *Appl. Ergon.*, vol. 90, pp. 1–4, 2021.

A multilevel account of adaptations and adaptive capacity – A case study of an incident in the health care sector

Henrik Hassel[1]

Alexander Cedergren[2]

Lovisa Vallin[3]

1 Professor, Division of risk management and societal safety, Faculty of Engineering, Lund University
henrik.hassel@risk.lth.se

2 Associate professor, Division of risk management and societal safety, Faculty of Engineering, Lund University
alexander-cedergren@risk.lth.se

3 Research assistant, Division of risk management and societal safety, Faculty of Engineering, Lund University
lovisa.vallin@risk.lth.se

Abstract

Organizations that provide essential services to society must not only be able to anticipate and prepare for hazards and threats that can be foreseen but also develop a capacity to adapt when unexpected events and conditions arise. Adaptive capacity becomes visible when organizations face unexpected events. However, there is a significant gap when it comes to understanding what characterizes an adaptive organization as well as how adaptive capacities can be developed and sustained over time. Several cases can be found in the research literature, but additional empirical work is needed to establish an evidence-based approach to the proactive assessment of adaptive capacity. In particular, there is a lack of knowledge regarding how contextual factors affect what factors are crucial for adaptive capacity. Additionally, there is also a lack of understanding of the interplay between different system levels of an organization, ranging from individual or team level to unit or organizational or even multi-organizational level. To address this knowledge gap, the present paper reports findings from an empirical case study of a major water leak at a Swedish hospital. The water leak case consisted of a sudden main water pipe break occurring at the department of medical imaging causing internal flooding at multiple floors in the hospital. A quick response was organized to both deal with the flooding (stop the leak, protect equipment) but also to adapt the operation to emerging conditions. In the paper, we present the adaptations that took place, factors that enabled a quick adaptive response, and factors that hindered adaptations from taking place. In particular, factors on different organizational levels are highlighted.

Keywords

Adaptations, adaptive capacity, health care, enabling factors, case study

1. Introduction

Organizations that deliver essential services to society need to be able to deal with both foreseen events but also events or conditions that have not been foreseen [1]. Dealing with unexpected events requires organizations to adapt, and escalating challenges arising from Volatility, Uncertainty, Complexity and Ambiguity (VUCA) [2] place increasing demands on their adaptive capacity. Adaptations are here defined as "modification of planned activities, including procedures, goals, use of resources, tasks or roles" [3]. Since "adaptive capacities exist before changes and disruptions call upon those capacities" [4], they can be proactively nurtured.

In order for an organization to develop adaptive capacities, they need in-depth knowledge about what factors contribute to improved adaptive capacity, as well as what strategies could be adopted to promote these factors. Previous research from different research disciplines and from different application areas, have aimed to identify and understand such factors (e.g. [5-8]). But the empirical evidence base is rather weak and fragmented [9]. Therefore, additional empirical research is clearly needed to provide a better understanding about both generic and context-specific factors that contribute to adaptive capacity. This is what the present paper aims to accomplish.

An aspect particularly challenging is the fact that adaptive capacity is a multi-level concept, where capacity on one system level does not necessarily lead to capacity on other levels and can even become an obstacle to change [10, 11]. This is in line with Lyng et al [10] who claim that "a successful adaptation at one organizational level (micro, meso, macro) may turn out to be maladaptive at a different organizational level". More specially, there are cases where "adaptations introduce a barrier for innovation.... where the ability to adapt...reduces the motivation to innovate". In their research, Lyng et al [10] found that some adaptations were of the "fire-fighting" type and were found to "mask system deficiencies". Doerfel et al [11] have a similar view where they argue that "successful resilience processes undermine pressure on policy-makers to mitigate threats". This points to the fact that when learning from empirical cases about factors that contribute to adaptive capacity, it is necessary to assume a systems perspective where multiple levels of the system are studied, including how they interact.

The aim of this paper is to contribute with additional empirical insights concerning adaptations and factors that contribute to adaptive capacity. This is done through a case study where a sudden internal flooding in a health care facility is studied.

1. Method

The paper uses a case study methodology where the unit of analysis is the Department of medical imaging at the hospital in Lund, Sweden, and its response to a sudden water leak causing an internal flooding. Data were collected through 11 semi-structured interviews with a total of 12 respondents (6 male and 5 female). An initial interview, with department management, was conducted in May 2024 and the remaining interviews were conducted in June and July 2025. Purposive sampling took place to make sure the interviews included respondents with knowledge about the event and the

adaptations that were carried out. Both frontline staff level and several management levels were included. An appropriate selection of respondents was ensured by successively consulting the respondents to identify additional respondents with central roles in the response and adaptations taking place. All interviews were recorded and transcribed.

An interview guide was developed and used to structure the interviews. Four overarching questions with a range of sub-questions, were used: 1) What is the normal responsibility of your department/unit? 2) How was your department/unit affected by the internal flooding and what immediate actions were taken? 3) How were the department's/unit's critical commitments affected and what measures (adaptations) were taken to make sure the critical commitments were upheld? 4) What planning and preparedness activities had been taken place to manage this type of event? A thematic analysis, using the Nvivo software, was then used to analyse the interview data. One of the authors performed the coding, which was then grouped into broader themes inspired by previous literature on enabling factors for adaptive capacity, while at the same time allowing additional themes emerging from the data.

3. Results

3.1. Event and context description

Early in the morning of March 27, 2023, a main pipe containing pressurized cooling water burst without warning in a main corridor on the fifth floor at the university hospital in Lund. The leak occurred due to corroded bolts resulting in large amounts of water pouring out and spreading both horizontally on the fifth floor and vertically down to lower floors, e.g. through stairwells and elevator shafts, causing a comprehensive internal flooding. The leak occurred in the premises of the Department of medical imaging affecting numerous rooms containing a variety of small-scale and large-scale imaging equipment. Due to difficulties in locating where to shut off the cooling water, the leak continued for around two hours.

Immediate actions included moving mobile equipment and protecting stationary equipment from becoming inundated. Available material, such as towels and blankets, were used to steer the water away from clinical examination rooms and water was diverted towards drainage points. However, due to the sheer quantity of the water, it was unavoidable that the water entered areas where sensitive, high voltage, imaging equipment were located. Equipment running the risk of being inundated was shut down. After a while, the cleaning services department arrived with industrial water vacuum machines to remove the water. In the end, the shut off valve was found, and the leak stopped.

The affected equipment was used for both acute medical examinations, semi-acute and more long-term planned examination. Although no immediate consequences for patients arose, a lot of planned and semi-acute treatments were delayed implying delayed diagnosis and treatment. Some of the equipment that was most heavily damaged by the water had to be discarded and a lot of material used for examinations was also water damaged and had to be thrown away. The staff workload increased both in the short

run, to respond to the immediate effects, but also in the long run, to operate with less equipment and fewer facilities available. Furthermore, increased risk of accidents for the staff were realized, e.g. due to wet floors in the vicinity of high-voltage equipment.

Several respondents claim there was very limited procedural planning in place, in terms of routines, procedures, etc., that could be called upon as the flooding occurred. As such, the event clearly was an unexpected one. A generic crisis response plan was in place which mainly included routines for how to activate higher management levels and how to inform other units that may be affected. This crisis response plan existed both digitally and physically printed and included telephone numbers to relevant staff. Some respondents claim the crisis response plan was useful and enabled them to contact the relevant staff, while some claim that since the plan is not updated continually, it included names and numbers that were obsolete.

A range of concrete adaptations were carried out to minimize the negative consequences and to both maintain as high medical services as possible and to recover as quickly as possible. Adaptations included the following actions and measures. First, the demands for treatment were reduced by cancelling planned and semi-acute treatments. Staff immediately started to call patients, and staff were also sent to the main entrance to inform patients that their appointments had been cancelled. Second, the flow of patients, in particular acute patients, were diverted to other hospitals having similar equipment as the hospital in Lund. The emergency medical care was informed that Lund could no longer accommodate specific types of patients. Since the other hospitals operate very close to their capacity limits, planned treatments also had to be cancelled in these hospitals in order to accommodate the increased flow of acute patients. Third, in order to ramp up the capacity at the hospitals receiving a larger influx of patients, doctors and nurses from the hospital in Lund were sent to these hospitals, in particular the hospital in Malmö. Fourth, within the hospital in Lund, it was also possible to re-locate some of the medical imaging devices and run treatment from temporary locations. Obviously, this was only possible for the smaller, mobile devices. Fifth, since some equipment was damaged or located in areas that were not possible to enter, alternative equipment was used to perform treatments. This required both staff with competencies of handling this alternative equipment and that some staff were able to build new protocols.

3.2. Enabling and impeding factors

3.2.1. Resources

From the data it is clear that material and human resources are key to being able to adapt successfully to unexpected events. Several conditions are crucial, including that spare capacity, redundancies and buffers need to *exist*, these internal and external resources must be *located* and *mobilized*, and in case alternative resources are used, staff must be able to *master* this equipment.

In general, the affected units operate close to their limits, which is also the case for the hospitals located in the vicinity of Lund. As argued by one respondent: “In terms of occupancy percentage on equipment, it is very high. So, it is not that there are medical devices and lab rooms that are empty and idle, they are used all the time”. However, by

cancelling planned, non-acute treatments, more of the equipment could be made available for acute treatment. As such, in relation to the more critical and acute aspects of the hospital services, there are some buffers and redundancies. In many cases, the redundant equipment is not identical to the primary equipment used, but in many cases the same examination can be performed after some adjustments.

The redundancies and buffers existed both internally at the hospital in Lund but also through collaborations with hospitals in the vicinity of Lund. The fact that there are at least five other hospitals within a 50 km radius is certainly a condition that facilitates this cross-hospital redundancy, and something that would perhaps not be possible for hospitals located in other regions.

The mere existence of redundancies and buffers are, however, not enough to ensure adaptive capacity. Respondents also address the ability to identify and quickly mobilize these extra resources. The identification and mobilization of resources is enabled by a range of other factors. Firstly, respondents stress the need for staff to have knowledge about available resources or of whom to contact to gain access to resources. They noted that such knowledge is often gained through workplace experience. Respondents also mention that certain staff played a particularly important role as facilitators. One staff member, who did not have a managerial role, was broadly engaged in operational tasks on a daily basis and could act as a type of information broker who could activate resources. This was not a pre-planned but rather an improvised role enabled by the management levels who allowed this improvisation since it clearly was affecting the response in a positive way.

Secondly, having the relations, networks and inclination to contact relevant people is also mentioned as crucial to mobilize necessary resources. Being able to talk directly to low-level staff ensures quick mobilization rather than having to use the hierarchical chain of demand which typically delays the response. In the case studied, there seems to have been a mix of directly engaging with low-level staff and having to go through higher management levels. Still, in both cases, personal networks and pre-established relations were key.

Thirdly, since it is often new or alternative equipment that is used, which not necessarily is identical to the primary equipment, staff need to know, or quickly learn, how to use the alternative equipment. In the case studied, it was the staff who normally operate the medical imaging device that introduced the unexperienced staff to the devices, enabling them to do many of the same examinations they normally carry out on the primary equipment.

3.2.2. Experience

Experience is one of the themes most commonly brought up as a source of adaptive capacity. There is a range of different types of experiences, both personal and organization, that respondents bring up as positive for the ability to carry out adaptations during the studied event.

First, even though the internal flooding, as such, was an unexpected event, the measures taken to minimize the consequences were not always unprecedented. In particular, there is plenty of experience from redistributing the flow of patients between hospitals and between units. One respondent argues “we always have an ongoing collaboration with them [Malmö]” and another respondent claim that “we are collaborating with all the other angiographical X-ray units in Scania [region] that deals with that type of patients

which means we help each other across the border. I would say that part is already established". The redistribution of the patients come from a volatility of the conditions surrounding medical practices, e.g. variation in the number of patients that require health care, variation in the availability of personnel and the fact that medical imaging devices are sometimes out of operation (unplanned or due to planned maintenance). This in turn means there are plenty of experiences of collaborating across units and hospitals. Calibrating the load across the different units is being done on a daily basis which means communication channels were well-established before the event took place.

Secondly, in addition to the patients moving around, the staff also rotates continually between the different hospitals. One respondent argues that: "All our doctors are circulating between Malmö and Lund. It is essentially the same hospital". This in turn means that as the event required the transfer of examinations, including the staff, from Lund to Malmö, the staff came to a familiar environment which they have experience from. Another reason for moving around both staff and patients is that the health care is slimmed and operates close to its capacity limits, which means collaboration is essential also in the day-to-day operation.

Thirdly, as mentioned previously, in order to free up capacity to deal with most acute health care needs, medical prioritizations had to be conducted. Since medical prioritizations are inherent in any acute medical practice, plenty of such experience exist as captured by the following quotation: "It is part of our everyday reality, both for better and worse, that healthcare is currently under considerable strain. We were used to that. In this case it was more about having to do it within the constraints and resources available to us, so it wasn't particularly unusual".

Several other types of experiences were also mentioned as beneficial for the response to the internal flooding event. Staff have a lot of experience of operating from premises that are not their usual premises. A reason for this is constant renovation and maintenance requiring everyday adaptations. Furthermore, with experience from the workplace comes the build-up of a personal and professional network which respondents claim they can capitalize on to speed up communication processes during the response. Finally, with experience comes the realization that conditions are volatile requiring constant re-planning or needs of not following the plan. Experience grows a mindset of being open to deviating from the plan and knowing how to do so in a successful way. Although the event as such put the organization under extreme stress, the practice of re-organizing and making quick decisions is part of the everyday work conditions.

3.2.3. Commitment, trust and collaboration

Another source of adaptive capacity includes the high level of commitment and collaboration characterizing the hospital. From the interviews it was clear that practically everyone helped out to manage the event, as noted by two respondents: "People came from everywhere saying 'Can we do something? Can we help?'" and "They really bent over backwards to solve the situation". The response from the staff was solution- and action-oriented, where some respondents arguing this may be due to the acute nature of the hospital's commitments. "We are used to just dropping whatever we have in our hands and rushing to help someone needing it...otherwise the patients could die".

Several respondents point out that many staff feel a high level of personal commitment to their professional practice. One respondent reflects on the idea that people often choose to work in hospitals because they want to do something good, to make a

difference, and to feel that their daily work is meaningful. An expression of this commitment is that many employees not working the day of the event showed up at the workplace to provide their support. At the same time, a respondent reasons that there may be a generational difference, with younger employees tending to be more individually focused at the expense of collective commitment. Yet, most respondents simply conclude that in critical situations, individuals tend to collaborate.

Another factor contributing to this commitment may be the fact that all departments are dependent on each other. Most notably, the Department of medical imaging is a central function for many other departments in the hospital, and staff in this department therefore have established networks to many other departments. More experienced staff also point out that those who have worked in the hospital for a long time have established personal networks that can be drawn on, while it would be more difficult for someone who was newly employed.

Taken together, established networks and pre-existing forms for collaboration are described as important enablers of adaptive capacity. These collaboration efforts took place on multiple levels; between individuals, between departments, and between hospitals. As mentioned, due to the proximity to the nearby hospitals and prior experiences of collaboration, redundant resources could be drawn on during the event by using the facilities and equipment at these hospitals.

Moreover, several respondents emphasize the important role of the non-prestigious culture characterizing the organization as an important enabler of adaptive capacity. For example, one respondent expressed that "Everyone is equally important; it does not matter whether the name badge says chief physician, medical secretary, or kitchen staff". A sense of team spirit is expressed by several respondents with one respondent arguing that "the team is not stronger than the weakest link". Along similar lines, it was also mentioned that the hospital has worked for many years towards creating a culture where everyone's ideas, viewpoints and suggestions are seen as equally important and where everyone feel safe to speak up. One of the managers explains that a lot of trust is placed in the staff's capability to solve problems on their own initiative and that "they will not be criticized but supported. Whatever they do, even if a mistake is made, [as a manager] you say: 'Thank you very much — you did what you could in the situation.' And that is the kind of culture we have."

Finally, one respondent highlights that the hospital managers and the high-level crisis management function expresses a high level of trust in the capability of the affected department heads to manage the situation and did not interfere in the operational response to the event "They know that we will take care of it. They know that we will fix it. So they can feel safe". This delegated response is, in turn, described as a factor contributing to quicker and more efficient response "because there is always a risk, if matters have to be passed up through several levels, that I will tell them [higher-level crisis response team] what we should prioritize, and they in turn will tell someone else what to do. That is when misunderstandings arise, or things simply become slow".

Another factor that was positive for the adaptive response was the overarching, common commitment to save lives. This commitment facilitated collaboration across units because medical prioritizations, made through dialogue, could be used when making prioritization between units. For example, some units that were not directly affected by the event cancelled non-acute examinations in favour of more acute examinations performed by other units not able to use their own equipment.

3.2.4. Formal/centralized vs informal/relational response

While the organization formally comprises several hierarchical levels, managers describe an ongoing effort of building a flat organization with emphasis on trust in its staff. This aligns with the response to the event, by allowing heads of the immediately affected departments to take a prominent role in the response. An established level of trust in their capability made this possible.

While this decentralized response worked well in some respects, challenges were also noted. Formal structures became an obstacle to a quick response, e.g. when staff asked the cleaning department to use their cleaning machines to suck up water. One respondent describes that, while the stairs looked like water falls, the cleaning department responded that he needed to place an order before they could help, and specify all relevant room numbers, in order to comply with internal billing: "So I have to go in, start a computer—but I can't start the computer because... there's water everywhere, there are no computers available, everything is flooded. So I have to place an order, write an order, and indicate the room numbers for this". Since this respondent had a personal relation with higher-level managers, he could get the cleaners in action, but with some time delay.

A similar challenge emerged in connection with the water shutdown. One respondent describes how he attempted to address the leak through formal channels by contacting the service desk for maintenance requests asking them to send someone to stop the water flow. However, the service desk staff possessed limited operational knowledge, making it difficult for them to assess the severity of the incident. When informed of the water leak, the service desk followed a standardized procedure indicating a one-hour response time for water leaks, without fully appreciating the scale or urgency of the situation. The respondent emphasizes that, due to his established professional relationships, he was able to directly contact a person who knew where to shut off the water, thereby significantly reducing the time until the water was stopped. Using the words of the respondent: "I managed to get hold of an old-timer who's been in that building since the dawn of time, and I had to call him and ask, and he could tell me where to shut off the water".

From a broader perspective, this respondent reflects on how this incident illustrates a shift from relationship-based to a more standardized technology-based troubleshooting. Historically, operational disruptions were managed effectively through established personal knowledge of colleagues' roles and responsibilities as well as local knowledge about the sharp end operations. Over time, however, this approach has been increasingly replaced by formalized procedures in which incidents are reported to a service desk with limited insight into operational contexts. The respondent argues that such a formalized approach works well in non-acute situations as it ensures a consistent response and that there should always be someone on duty to report incidents to. However, as situations become urgent requiring a quick rather than a standardized approach, the technology-based troubleshooting breaks down. The respondent emphasizes that "these relationships between different professions must be maintained. For example, in a hospital, everyone has a role; everyone is important. You must be able to reach each other in a situation where you are needed. And this is increasingly being eroded; walls are being built up."

Concluding remarks

The response to the internal flooding highlights a range of positive factors for adaptive capacity, in many cases echoing previous literature. Examples include the role of experience, influence of flat organizational structures, necessity of established social networks, commitment to a common goal and units' willingness to down-prioritize their own goals in order for other units' to achieve more pressing goals. New insights relate in particular to the down-sides of use of modern, standardized internal service management platforms which has the upside of consistent and transparent treatment of incidents but at the expense of issues of dealing with out-of-the-ordinary, acute requests. Finally, in relation to measuring adaptive capacity, the study indicates that one should be cautious doing that with respect directly to the magnitude of consequences that arise, which is for example done when defining adaptive capacity (or resilience) as a recovery time or similar. There are numerous more or less random factors that also affect the consequences, such as whether the timing of the event was advantageous (e.g. few acute medical treatments) or disadvantageous (e.g. high health care demands). Comparing across cases therefore always need to be done with extreme caution.

Literature

[1] Linkov, I., Bridges, T., Creutzig, F., Decker, J., Fox-Lent, C., Kröger, W., Lambert, J.H., Levermann, A., Montreuil, B., Nathwani, J., Nyer, R., Renn, O., Scharte, B., Scheffler, A., Schreurs, M., and Thiel-Clemen, T. (2014). Changing the resilience paradigm. *Nature Climate Change*, 4(6): p. 407–409.

[2] Bennett, N. and Lemoine, J. (2014). What VUCA really means for you. *Harvard business rev*, 92(1/2).

[3] Hassel, H. and Cedergren, A. (2025). Facing the unexpected: a literature review on methods for assessing organizational adaptive capacity. *Environment Systems and Decisions*, 45: p. 27.

[4] Woods, D. (2019), *Essentials of resilience, revisited, in Handbook on resilience of socio-technical systems*, M. Ruth and S. Goessling-Reisemann, (Eds), Elgaronline.

[5] Barasa, E., Mbau, R., and Gilson, L. (2018). What is resilience and how can it be nurtured? A systematic review of empirical literature on organizational resilience. *Int J of health policy & manag*, 7(6): p. 491.

[6] Fagerdal, B., Lyng, H., et al. (2023). No size fits all – a qualitative study of factors that enable adaptive capacity in diverse hospital teams. *Frontiers in Psychology*, 14 (1142286).

[7] Juvet, T.M., Corbaz-Kurth, S., Roos, P., Benzakour, L., Cereghetti, S., Moullec, G., and Weissbrodt, R. (2021). Adapting to the unexpected: Problematic work situations and resilience strategies in healthcare institutions during the COVID-19 pandemic's first wave. *Safety science*, 139(105277).

[8] Minucci, G. (2016). Assessing adaptive capacity of water management organizations. The case study of the municipality of Tomave (Bolivia). *J of Risk Research*, 19(7): p. 847–872.

[9] Yu, D.J., Schoon, M.L., Hawes, J.K., Lee, S., Park, J., Rao, P.S.C., Siebeneck, L., and Ukkusuri, S.V. (2020). Toward general principles for resilience engineering. *Risk Analysis*, 40(8): p. 1509–1537.

[10] Lyng, H.B., Macrae, C., Guise, V., Haraldseid-Driftland, C., Fagerdal, B., Schibevaag, L., Alsvik, J.G., and Wiig, S. (2021). Balancing adaptation and innovation for resilience in healthcare–a metasynthesis of narratives. *BMC health services research*, 21(1): p. 1–13.

[11] Doerfel, M.L., Kim, M., Kwestel, M., Yoon, H., and Quow, J. (2022). Resilience organizing: a multilevel communication framework. *J of Communication*, 72(6): p. 605–618.

Towards more mature method development processes in societal safety and resilience

Henrik Hassel[1]

Alexander Cedergren[2]

Magnus Hagelsteen[3]

1	Professor, Division of risk management and societal safety, Faculty of Engineering, Lund University, *henrik.hassel@risk.lth.se*
2	Associate professor, Division of risk management and societal safety, Faculty of Engineering, Lund University, *alexander-cedergren@risk.lth.se*
3	Lecturer, Division of risk management and societal safety, Faculty of Engineering, Lund University, *magnus.hagelsteen@risk.lth.se*

Abstract

In developing societal safety and resilience, countries like Sweden face increasing challenges due to trends such as escalating climate change, changing security climate, increased societal complexity, and downsizing of public sectors. These trends stress the importance that methods used to improve safety and resilience should be based on strong evidence that they will lead to positive impacts. However, previous research shows that methods in the field typically are not building on each other or evaluated in systematic ways. Hence, the underlying evidence is weak, and it is possible to question the degree of knowledge evolution in the field making selection of which method to use in a particular context problematic. To encourage more systematic and comprehensive method development and evaluation processes, this paper proposes a maturity model for method development and evaluation that can be used to support longitudinal processes of going from a promising, innovative idea to a fully developed and proven method with positive impacts supported by strong evidence. The model draws on fields with significantly longer traditions of iterative, up-scaling artefact development processes, such as public, personal and occupational safety, software product development, Pharmaceutical product and drug development, and design science research); while also accounting for idiosyncrasies of societal safety, such as the practical difficulties of testing and collecting data on the effects of using a particular method. In the paper, the different levels of the maturity model are demonstrated and exemplified. We believe that the proposed maturity model can support knowledge and method evolution in the field of societal safety and resilience as well as providing recommendations of how to systematically carry out an evidence-based method development end evaluation process.

Keywords

Societal safety, Disaster risk reduction, Civil preparedness, Method development, Evaluation, Maturity models

1. Introduction

Europe is currently witnessing a quick change in geopolitical conditions which has created an urgent need to take actions for increased security, safety and resilience. Ensuring the functionality of the civil society and critical societal functions is key for the long-term societal security, safety and resilience as well as to support the military defense. In Sweden, the work to re-establish the civil defense has intensified significantly. In parallel to the increasing need to re-establish civil defense, a range of other challenges exist when it comes to building a society that is safe, secure and resilient with respect to a broad range of hazards and threats, for example, escalating climate change. Additionally, there is high competition when it comes to using financial resources to proactively assess and manage future risks compared to using the resources to address other societal needs, such as schools, health care, military defense, etc.

The current trends, challenges and intensified need for civil defense stress the importance that the activities performed to understand and strengthen societal safety, security and resilience must give rise to desired effects as well as doing this with as little resources as possible – i.e. both effective and efficient. The activities performed should be based on strong evidence that they in fact will give, or at least have a high chance of giving, rise to positive impacts. However, previous research shows that it is highly uncertain to what extent societal safety interventions, such as performing Risk and Vulnerability Assessments in municipalities, in fact strengthen societal safety, security and resilience [1, 2]. In particular, many of those who perform the RVAs in practice argue the assessments have little effect on what is being done to reduce risks and vulnerabilities even though a lot of time and efforts are devoted to performing and documenting the assessments.

The basis for effective societal safety interventions often comes from various types of anticipatory analytic activities, such as risk assessments, vulnerability assessments, and resilience assessments. In a review in the closely connected field of disaster risk reduction, Tehler, Cedergren [3] showed that methods for risk, vulnerability and resilience assessment typically are not building further on previous method proposals in the scientific literature; rather they typically are developed more or less in isolation from previous method proposals. Clearly, the underlying evidence is weak of whether the methods used to strengthen societal safety are in fact effective and cost-efficient.

We argue that evaluation should be addressed more systematically and comprehensively when methods are developed in the field of societal safety. To address this identified weakness, this paper suggests a maturity model of method development and evaluation. A maturity model describes a sequence of well-defined levels or stages for the desired evolution of a class of objects [4, 5] – in our case from a less mature, crude, rudimentary and superficial method development and evaluation process to a more mature, thorough and corroborated one. More specifically, the aim of the maturity model is to be useful to support longitudinal processes of developing a promising, innovative method or concept to a fully developed method with high chance of positive impacts supported by strong evidence and understanding of why the method works. The maturity model could either be used by researchers as a support to develop and evaluate methods, or by practitioners or authorities in order to judge how mature a particular method is, potentially influencing whether a particular method is selected or not for use in a particular setting.

The proposed maturity model will be developed based on ideas and concepts from fields with a longer tradition of iterative, up-scaling processes of developing tools, methods and products. In particular, we base the model on insights from the areas of public, personal and occupational safety, software product development, Pharmaceutical product and drug development, and design science research; while at the same time adapting the model to the idiosyncrasies of societal safety, such as the practical difficulties of testing and collecting data about the impacts of methods [6]. In the paper, the different levels of the maturity model are demonstrated and exemplified. We hope that the proposed maturity model can support knowledge evolution in the societal safety field as well as to organize systematic, evidence-based method development processes.

2. Conceptual and theoretical background

2.1. Evaluation and maturity models

Broadly speaking, evaluation can be defined as: "the process of determining the merit, worth and value of things" [7]. Furthermore, a classic, more detailed definition is proposed by Weiss who sees evaluation as measuring "the effects of a program against the goals it set out to accomplish as a means of contributing to subsequent decision making about the program and improving future programming" [8]. In some fields, evaluation is rather straightforward in the sense that effects can be isolated and observed in a straightforward way; however, Hale, Guldenmund [9] and Carlsson, Henningsson [10] argue that systematic evaluations are rarer in areas where complexity is high, effects are difficult to isolate and there is scarcity of relevant outcomes to study. Similar challenges have been noted in the area of societal safety. For example, Almklov and Antonsen [11] argue that "aspects of societal safety are notoriously hard to specify, quantify and measure".

There is no single definition of what a maturity model entails but Wendler [4] points out that two components are necessary. First, a set of levels or stages must be defined describing the hierarchical progression or evolution of some object. Secondly, one or several criteria for how to measure an object's performance or capabilities must be specified, in terms of conditions, processes or application targets. A definition that meets these conditions is the one proposed by Becker, Knackstedt [5] arguing that a "maturity model consists of a sequence of maturity levels for a class of objects. It represents an anticipated, desired, or typical evolution path of these objects shaped as discrete stages". Hernantes, Maraña [12] further argue that maturity models define the goals to be met at each stage and the policies that need to be implemented to get from the beginning stage of maturity to the highest level of maturity" where typically the last stage is some type of complete or ideal stage.

2.2. Product, process and method evaluation across mature disciplines

There are several areas where evaluation with respect to products, processes or methods seem to have reached far in terms of maturity. Although each discipline has its own idiosyncrasies, making straightforward transfer to other disciplines challenging, this paper has used insights from five disciplines or application areas as a source of inspiration for how to define a maturity model for evaluating risk, vulnerability and resilience assessment methods. The five disciplines/application areas are 1) Public, personal and occupational safety interventions, 2) Software development, 3) Pharmaceutical product development, and 4) Design Science Research (DSR). From each area, key papers or reports were identified and key lessons learned were gathered. Due to the page limitations of the paper, the detailed findings of the literature review will not be presented. Rather, the key takeaways will be presented below as maturity and contextual dimensions.

3. A maturity model for evaluating risk and resilience assesment methods

Although the different areas of application approach and describe evaluation in different ways using different concepts, there are also many common traits when it comes to recommendations on how evaluation should be conducted and contextual factors affecting the evaluation process. These commonalities will in particular be used as a point of departure for the maturity model proposed in this section while at the same time taking the unique features of method development in societal safety into account.

The maturity model will be built around *maturity dimensions* and *contextual dimensions*. Maturity dimensions are defined as independent but complementary ways to increase the maturity of a method. In order to develop a fully mature method, progression must be made with respect to all dimensions. Furthermore, the process of increasing the maturity of a method can be done in different ways where the chronological emphasis on the different maturing dimensions can vary. This in turn depends on the contextual dimensions which are defined as characteristics of the context of the method development which affects the possibility and effectiveness of adopting different strategies to method evaluation.

3.1. Maturity dimensions

Below, the maturity dimensions of the maturity model are described.

Level of naturalism: The first dimension concerns to what extent the evaluation takes place in a naturalistic/real-world environment compared to an artificial/theoretical environment. On the one hand of the spectrum, a completely artificial evaluation is non-empirical where logical reasoning and argumentation is used to support a method.

On the other hand of the spectrum, a naturalistic evaluation is an empirical evaluation where the method is applied in its intended context by "real tasks", "real users" and "real systems" [13]. In between there is a continuum where an evaluation can be made more and more realistic through the use of small-scale, table-top tests, simulations, laboratory tests and experiments. The people involved in testing the method could be proxies for real users (such as students) or as a step towards higher level of naturalism, methods can be tested by "real people" but in a hypothetical setting.

Effect exploration and understanding: The second dimension concerns whether the effects of using the method are explored, described, and understood. At the one end of the extreme, no effects are described at all, e.g. only providing a demonstration that a method can be applied in a particular context. On the other hand of the extreme, the effects of a method can be understood by comparing the use of the method in a systematic randomized control trials; i.e. against a control group there the method has not been used to conform that effects that arise comes from the method use rather than from other confounding factors. In between these two extremes, effects can be described e.g. using program theory, or effects can be described by explicitly comparing some factors of relevance before and after method application.

Amount of evidence: The third dimension concerns the amount of evidence that supports the efficacy/effectiveness of the method. At the one end of the scale there are little amount of evidence which could correspond to a brief, single argument, a single experiment with few participants or a demonstration in a single case study. At the other end of the scale there would be an abundance of evidence where e.g. the method is tested in numerous cases in different contexts.

Independence of involved actors: The fourth dimension concerns who are involved in conducting the method evaluation. Typically, evaluations start with the method developers themselves leading the evaluation task. Additionally, the evaluation could involve practitioners that themselves have been part of the method development. However, with more mature method evaluation, both researchers and practitioners that have not been involved in the method development are involved and these should ideally have no stakes and play and be independent from the researchers who developed the method to reduce any motivational biases.

Partial or complete evaluation: The fifth dimension concerns whether the method evaluation is partcial or complete in the sense that it covers all parts, phases or steps of the method. At the one end of the scale, method evaluation can focus on some minor aspect or single step of the method and then as the method evaluation matures, additional steps are evaluated. At the other end of the scale, all facets or steps of the method have been evaluated.

Mechanism exploration and understanding: The final, sixth, dimension concerns to what extent the mechanisms behind the effects of the method are explored and understood. At the one end of the scale, mechanisms are not explored or understood at all. This would essentially be a black box where some effects of the method have been indicated or even proven but with no explanation of why they arise. At the other end of the scale, there is a detailed understanding of and strong knowledge about how the method gives rise to some intended effects in one or several types of contexts. One essential benefit of such an understanding is that it is easier for potential users to understand whether the method is likely to give rise to intended effects in their particular context of application, which might be slightly different compared to the context where the method has been tested and evaluated.

3.2. Contextual dimensions

There are some contextual dimensions that will affect how easy it is to make progress on some of the maturity dimensions or which affect which dimensions that should be prioritized in order to achieve a more mature method development processes. These are briefly described below:

Access to real users/practitioners: in some cases, there are plenty of users that can be easily accessed and where it is cheap to involve them. Developing digital tools, games, medicines etc., potential users can often be found through online activities where a user is often a single individual. On the other hand, for methods in the field of societal safety, the user is often an organization (often of a particular type), which means the pool of users is much smaller. In addition, it may be much more difficult to attract interest from an organization compared to an individual when it comes to testing and evaluating a method. Consequently, naturalistic evaluation will then be much more difficult.

Amount of previous research: In some cases, a lot of previous research has been conducted on similar methods or parts of the method being developed. This means that some aspects of the method might already been tested and corroborated leading to partially high maturity already at the start of the method evaluation.

Possibility of joint research efforts: In order to achieve the independence dimensions as well as achieved large amounts of evidence, a requirement is often that several research groups are working with similar research objective. These different research groups can cross-validate and build further on each other's research findings, thus creating more mature method evaluation. On the other hand, a single research group working with a unique method would have more difficulties making progress on some maturity dimensions.

Risks involved in applications: Some real-world applications involve risk, either direct health risks, economic risks or organizational risks (e.g. issues with trust etc.). In such situations, extensive evaluation in artificial settings would be needed before the risk would be so low that naturalistic applications and evaluations would be sensible to conduct.

Possibility of using control groups: Ideally, effects should be isolated and proven by comparing to control groups; however, in many real-world settings in societal safety, it would be difficult or even impossible to identify control groups and set up an evaluation activity where effects of applying a method can be compared to a control group.

3.3. Maturity Levels

Each maturity dimension is broken down into four levels that can be rated with respect to how much progression a method evaluation process has made regarding each maturity dimension. Based on each of these ratings, a summary judgement can be made regarding the overall maturity of the method evaluations. In Table 1, the levels for each maturity dimension are described as well as the levels for the overall maturity of the method evaluation. Furthermore, in the following sub-sections, examples of each maturity level are provided. An underlying assumption of the maturity model is that in order to pass on to higher maturity levels, the evaluation carried out on previous levels should show positive results. Otherwise, there would be no reason to continue developing and evaluating the method.

Table 1 – Scale and descriptions of levels of maturity.

	Maturity level			
	1	**2**	**3**	**4**
Level of naturalism	Completely artificial	Artificial with naturalistic features	Naturalistic with artificial features	Completely naturalistic
Effect exploration and understanding	No effects described	Intended effects outlined but only rudimentary understood	Intended effects clearly described, clear indications of effects, e.g. through before/after comparison	Effects clearly described and proven in control group trials
Amount of evidence	Single case, single, weak arguments	A few cases, several medium strong arguments	Numerous cases, several, strong arguments	Broadly implemented, completely logically sound
Independence of involved actors	Only method developers involved	Limited input from external, mostly independent actors	Mostly independent actors involved but organized by method developers	Evaluation organized and performed by independent actors
Partial or complete evaluation	Single/minor part evaluated	A few parts evaluated	A majority of parts evaluated	All method parts evaluated
Mechanism exploration and understanding	No understanding of mechanisms/ black box	Limited understanding of mechanisms	Significant understanding of mechanisms	Mechanisms fully understood and proven
Overall maturity	Hypothesized	Promising	Established	Proven

Table 2 – Description of overall maturity levels.

Level 1 – Hypothesized	All maturity dimensions are scored low (1-2 on all). In a level 1 maturity, typically only artificial evaluation has been conducted with no applications, where only	the method developers themselves argue for/explore the benefits of the method, where a few parts of the method have been included in the evaluation.
Level 2 – Promising	There is medium progression on several or medium progression on a few but large progression on one. For example some type of experiments and table-top tests have been conducted where there are clear indications of effects, based on some measurements although the amount of evidence is still limited. Still,	mainly the method developers are the ones leading the evaluation process where several aspects of the method have been addressed and there are indications of the mechanisms behind the effects, although to limited extent.
Level 3 – Established	There is medium progression on all dimensions or medium progression on several but where some are still low while some correspond to large progression. For example, some naturalistic evaluations have been conducted in controlled environment (e.g. table-top test). Measurements show clear indications of positive effects,	although the amount of evidence is still limited. Evaluation is mainly carried out by the method developers. Most or all aspects of the method have been addressed and there are some, although limited, understanding of mechanism.
Level 4 – Proven	Evaluation process has essentially reached evaluation saturation where large progression has been made with respect to all maturity dimensions. The evaluation has covered all method aspects, the evaluation is naturalistic, effects are clearly described and understood	and actors involved in the evaluation are independent from them involved in developing the method. The amount of evidence must be significant although there could still be potential of exploring the use of the method in new contexts.

4. Discussion

The idea of the maturity model presented in this paper is intended to provide support in this process where we see at least three contributions: 1) The maturity model points out key dimensions that should be considered method evaluation processes in the field of societal safety. 2) The model can support processes of scaling up an evaluation process where a suggested method can be explored to see if is promising to collect data on effects and mechanisms in order to find evidence that support the methods effectiveness and efficiency. 3) The model enables communication on which maturity level a method is currently at, in order to e.g. inform the need for further research or the suitability of implementing the method in practice.

This maturity model presented in this paper should be seen as a first rough suggestion where additional developments and refinements are needed. It builds on maturity models suggested in other areas as well as how evaluation is conducted in a number of other research fields. As the maturity model is further developed, lessons should be drawn also from other fields. In addition, a number of development needs can be identified. First, the descriptions of the maturity levels for each maturity dimension are still rather vague. Ideally, each level should be described precisely in order to make judgments and ratings more consistent. Secondly, there is some vagueness concerning

the connection between the ratings on each maturity dimension and what overall maturity level that these ratings imply. One way of making the connecting clearer is to calculate a total or average score from the maturity dimension ratings and then define quantitative criteria for reaching a certain maturity level. However, such an approach assumes all dimensions are equally likely and that high score on one dimension can always compensate for low score on some other dimension which is not necessarily the case. Finally, the maturity model so far includes 4 levels where the first level essentially means no evaluation and the forth level essentially means ideal or saturated evaluation. However, in most cases the evaluation process is probably on level 2 or 3 and therefore there might be a need to further refine them.

There are also several challenges remaining that need to be further explored in order to develop as well as to use the maturity model in a sensible way. First, ideally the maturity dimensions should be independent from each other in the way that they measure succinctly different qualities of the evaluation process. However, applying the model implies this is not actually the case. For example, if the evaluation is still completely artificial based on extensive logical argumentation, the resulting rating could be level 1 on the dimension Level of naturalism but perhaps level 3 on Amount 8 of evidence (due to the extensive argumentation). However, an initial step of progressing towards more naturalistic evaluation would perhaps mean level 3 on the dimension Level of naturalism but the amount of naturalistic evidence could be really small, meaning a low rating on Amount of evidence. As such, each dimension must be rated with respect to how each of the other dimensions are rated.

It should be acknowledged that the present maturity model consists of a type of method development that also need to be evaluated. In this paper, only a very simple demonstration/exemplification has been made which means the maturity level is still very low. However, at an early research stage, this is completely natural; however, further research should be made to evaluate the model. A first step could be to use it in a full scale application/demonstration or using an expert panel from the field of societal safety to make an independent, although artificial, expert evaluation. It is important to not fall into the same trap as has been argued is significative for the field of societal safety, e.g. that proposed methods are rarely evaluated in a systematic way.

Literature

[1] Cedergren, A., Hedtjärn Swaling, V., Hassel, H., Denward, C., Mossberg Sonnek, K., Albinsson, P.A., Bengtsson, J., and Sparf, A.: *"Understanding practical challenges related to risk and vulnerability assessments – The case of Swedish municipalities"*, Journal of Risk Research, 22(6), 2018, 782–795.

[2] Eriksson, C., Denward, C., Mickelsson, L., and Hedtjärn Swaling, V.: *"Kunskap för beredskap: Vad har risk - och sårbarhetsanalys gett för effekt hittills och hur kan nyttan öka?"*, Swedish Defence Research Agency (FOI), Stockholm, p.

[3] Tehler, H., Cedergren, A., de Herve, M.D.G., Gustavsson, J., Hassel, H., Lindbom, H., and Wester, M.: *"Evidence-based disaster risk management: A scoping review focusing on risk, resilience and vulnerability assessment"*, Progress in Disaster Science, 100335, 2024.

[4] Wendler, R.: *"The maturity of maturity model research: A systematic mapping study"*, Information and software technology, 54(12), 2012, 1317–1339.

[5] Becker, J., Knackstedt, R., and Pöppelbuss, J.: *"Developing maturity models for IT management: A procedure model and its application"*, Business & information systems engineering, 1, 2009, 213–222.

[6] Hassel, H. and Cedergren, A.: *"A framework for evaluating societal safety interventions"*, Safety science, 142(105393), 2021.

[7] Scriven, M.: *"Evaluation thesaurus"*, Sage, Newbury Park, p.

[8] Weiss, C.H.: *"The Politicization of Research"*, In C.H. Weiss (Ed) The Politicization of Research, Eprentice Hall, Boston, 1972 p.

[9] Hale, A.R., Guldenmund, F.W., Van Loenhout, P.L.C.H., and Oh, J.I.H.: *"Evaluating safety management and culture interventions to improve safety: Effective intervention strategies"*, Safety Science, 48(8), 2010, 1026–1035.

[10] Carlsson, S.A., Henningsson, S., Hrastinski, S., and Keller, C.: *"Socio-technical IS design science research: developing design theory for IS integration management"*, Information Systems and e-Business Management, 9, 2011, 109–131.

[11] Almklov, P.G. and Antonsen, S.: *"The commoditization of societal safety"*, Journal of Contingencies and Crises Management, 18(3), 2010, 132–144.

[12] Hernantes, J., Maraña, P., Gimenez, R., Sarriegi, J.M., and Labaka, L.: *"Towards resilient cities: A maturity model for operationalizing resilience"*, Cities, 84, 2019, 96–103.

[13] Sun, Y. and Kantor, P.B.: *"Cross-Evaluation: A new model for information system evaluation"*, Journal of the American Society for Information Science and Technology, 57(5), 2006, 614–628.

Climate change impacts on forests

Peter Spathelf[1]

Franziska Rottig[2]

1 Professor for Applied Silviculture, Department of Forestry, Timber and Environment, University for Sustainable Development Eberswalde (HNEE)
peter.spathelf@hnee.de

2 Research Assistant, Department of Forestry. Timber and Environment, University for Sustainable Development Eberswalde (HNEE)
franziska.rottig@hnee.de

Abstract

Central European forests have been a carbon sink for decades. The future of carbon sequestration and storage in European forests will be influenced by the intensity of forest management and harvesting, as well as climate change and the severity of disturbances. Climate change magnifies the impacts of disturbance events, and a higher frequency and intensity of disturbances are very likely and have to be taken into account in forest management.

The aim of the present literature study is to give an overview on the impact of climate change on our forests and thus highlight the context of possible management options, especially for forest adaptation to climate change. First, climate change is increasing mortality of tree species and thus forest damages. Mortality is often preceded by years of tree senescence, which can be recognized by the declining vitality status (crown transparency classes of the forest health survey) and the decline in increment. Moreover, stand productivity is negatively affected with higher temperatures and drought. There are currently increasing indications that further increases in forest productivity can no longer generally be expected in Europe in the future. On the one hand, the increasingly ageing forest stands are approaching saturating increment levels, and on the other hand the frequency and intensity of disturbances is increasing, for example in the form of mortality in medium-aged spruce forests. Least, tree species ranges will shift in the upcoming years, in latitude but also altitude in mountainous regions, with consequences on the whole range of ecosystem services provision.

Keywords

Climate change impacts, Mortality, Growth, Species range, Forest ecosystem services

1. Introduction

Climate change has become a main driver of environmental change due to a significant rise of global mean surface temperatures and extreme weather events. Globally, the mean annual surface temperature has risen by more than 1.3°C in 2011-2024 compared to pre-industrial conditions (1850- 1900), and has been proven to be human-caused to a high degree [1]. Due to climate change and forest damages in many parts of Europe [e. g. 2, 3] there are current debates on forest crises, 'disaster forest', or the need for a paradigm shift in forestry [4]. There are doubts as to whether the path that European forestry has taken for many decades is the right one ('Der Holzweg') [5], the forestry sector and forest ownership as a whole are accused of serious mistakes, indeed they are considered to be part of the problem [6].

The aim of the present literature study is to give an overview on the impact of climate change on our forests and thus highlight the context of possible management options, especially for forest adaptation to climate change, which encompass the span between active management measures such as assisted migration and low-intensity so-called nature-based solutions.

2. Impacts of climate change on forest growth/ productivity, mortality, and species migration

2.1. Mortality, including timber damage

Tree mortality is a natural, continuous process in the development of tree populations, usually with a variety of causes (complex of factors) and therefore difficult to predict. Compared to the rather slow growth processes of trees, mortality is often abrupt, with potentially drastic consequences for ecosystem development. A distinction is made between disturbance-related and competition-related mortality: disturbance-related mortality often has a random character (e.g. lightning strike, infestation by pests), while competition-related mortality is one of the fundamental processes of forest development and inevitably leads to a reduction in tree numbers as the size of the trees increases. The extent to which climate change, particularly drought and heat, affects the mortality of trees has been the subject of intensive research for some time. It has been shown that drought stress-related mortality - in various forest ecosystems worldwide - has been increasing for some time [7]. Excess mortality (i.e. more than average disturbance related mortality), has risen by up to 500 % across Europe, particularly since 2016. Mortality is often preceded by years of tree senescence, which can be recognized by the declining vitality status (crown transparency classes of the forest health survey) and the decline in increment [8].

Expected abiotic impacts of climate change may interact with indirect biotic effects like changing pathogen and pest regimes. In central Europe, an increased occurrence of insect damage [2] and latitudinal range shifts of biotic disturbance agents [9] is

anticipated. It is likely that forests in Europe will increasingly suffer from further novel pests, especially alien invasive species such as the Asian longhorn beetle (Anoplophora glabripennis) [10] and the pine wood nematode (Bursaphelenchus xylophilus) [11]. In general, the disturbance risk under climate change is increasing [12]. Abiotic and biotic impacts interact with each other (e.g. Scots pine decline in the Swiss Rhone Valley) [13], but also with anthropogenic pressures of air pollution and atmospheric deposition of the past and today [14].

An illustrative and frequently used concept to explain the causes of mortality is the declinedisease theory [15]. A complex of weakening, triggering and aggravating factors triggers a disease process and leads to the death of the tree. Weakening factors such as groundwater lowering or the lack of site suitability of a tree species reduce the vitality of trees. Drought stress or severe frosts have a direct influence on the vital functions of the tree and lead, for example, to severe loss of growth (triggering factors). Reinforcing factors such as insect damage are then ultimately the cause of the lethal weakening of the tree. Drought stress as one of the most important stressors in climate change varies greatly in its effect, depending on the tree species (deciduous trees, conifers) and age of the trees (young plants, old trees), the season of occurrence (spring or summer), or the intensity (frequency of succession). Increasing summer temperatures were identified as a mortality-increasing cause for all major tree species and mixing, on the other hand, reduces significantly the mortality risk [16].

In the forest health survey (WZE), which has been conducted annually in Germany since 1984, crown transparency is recorded separately by tree species as an indicator of vitality. Until 2017, the trees with significant crown transparency were on average in the range of 20-25 %, with a sharp increase to values of >35 % in 2019 and 2020. The WZE confirms the well-known fact among tree physiologists that older trees (e.g. over 60 years old) are more vulnerable and ultimately more severely damaged than younger trees. The difference is often more than 20 percentage points [17]. Crown transparency is weakly correlated with the dieback rate of the trees and ultimately the extent of the damaged wood. Between 2003 and 2017, the proportion of damaged wood in total felling was around 10-20 % (with the exception of storm Kyrill in 2007), and during the hot drought between 2018 and 2020, it shot up to a record high of over 70 % [18].

2.2. Productivity (Timber yield)

Climate change may have positive effects on forest growth where growth has been limited by temperature and growing season, i.e. in the boreal zone and in the oceanic northwestern parts of Europe [19]. In turn, forests in the Mediterranean and South-central (continental) European regions, already limited by drought and heat, may be further impaired. The wood volume stocks of forest ecosystems in Germany has risen sharply in the second half of the 20th century [20, 21]. At the same time, harvests also increased, triggered by energy incentives for wood energy. The reasons for the growth increase are the higher nitrogen saturation of the sites, the rise in CO2, a longer vegetation period, but also improved forms of management such as the avoidance of litter raking or the mixture of tree species with complementary properties. The changed growth trends are reflected in an improved relationship between increment and tree size (referred to as relative growth rate and expresses the efficiency of growth), as well

as between tree number and tree size (expressing the density of trees per unit area) [20]. This increase in increment led to an overall increase in productivity, i.e. the volume output of the forests in relation to age.

There are currently increasing indications that further increases in forest productivity can no longer generally be expected in Europe in the future. On the one hand, the increasingly ageing forest stands are approaching saturating increment levels, and on the other hand the frequency and intensity of disturbances is increasing, for example in the form of mortality in medium-aged spruce forests [22]. This has far-reaching effects on the climate protection function of forests, as it means a decreasing sink capacity of the forest for storing CO2 [23]. The increasing likelihood of seasonal water shortage slows down tree growth: particularly for forests at lower altitudes (planar and colline levels) in Central Europe, which are particularly affected by hot temperatures and multiple dry years (hot droughts), a decline in growth is to be expected [24]. But even with saturating sinks, the overall climate protection function could still increase if more wood products are used for long-lived wood products and circular value chains with recycling.

Model calculations based on the ForClim simulation model assume a decline in forest productivity at low altitudes in Switzerland by the middle of the 21st century [25]. Finally, a possible change in the composition of tree species due to climate change is likely, e.g. from previously vigorous conifer species to less productive Mediterranean oak species such as Turkey oak, can also lead to a reduction in productivity [26]. However, although we may face more frequent disturbances with consequent loss of growing stock, in many cases the species will be regenerating. We do need to consider assisted migration, including with non-native species to compensate for the loss of spruce [27].

3. Changes in the composition of tree species and their economic consequences

In the medium to long term, climate change will have an impact on the species distribution ranges in which the tree species are well suited to climate [28]. In so-called range or distribution models, the probability of occurrence of tree species is estimated with the help of climate and soil parameters. The projection of the distribution areas of spruce in Baden-Württemberg by the end of the 21st century, for example, assuming a worst-case climate scenario (RPC8.5), shows that e.g. Norway spruce only occurs in the high altitudes of the low mountain ranges (e.g. Black Forest) and only as a mixed tree species [29]. Using a similar approach, a research group from Eberswalde University was able to predict a significant decline in the distribution area of beech in Brandenburg by the end of the century based on the SRES scenario A1B [30]. According to this scenario, forests with beech as the leading tree species will only cover around 5 % of the forest area in Brandenburg in 2095.

For Central Europe, a certain range stability of the most important tree species can still be assumed for the next 10-20 years, at least if a moderate climate scenario (e.g. RCP4.5) is anticipated [31; 30]. However, by the end of the century, many coniferous forests (tree species spruce, silver fir and larch) in particular will be lost [32]. Ideally,

as one tree species retreats, another species will take its place as a result of succession processes, as has been observed for around 15-20 years in the example of pine and the sub-Mediterranean downy oak replacing it in the inner Alpine dry valleys [33]. At lower altitudes in Germany, thermophilic tree species such as sweet chestnut, downy oak, Turkey oak and cedar in particular could become more widespread, while beech forests could migrate into the mid-mountain regions, primarily at the expense of spruce and pine [34]. Such tree species range development scenarios should already be taken into account today in forest conversion planning.

Range shifts of tree species have not only ecological but also economic consequences. In a European study, Hanewinkel et al. [35] projected that European forests could decline in value by almost a third by the end of the 21st century compared to 2010 due to a shift in the tree species spectrum from conifers to deciduous trees with a focus on Mediterranean oak species. Moreover, a significant number of tree species will not be able to resist the climatic changes (i.e. especially under RCP8.5) during their whole lifespan in the 21st century. Thus, a significant tree species bottleneck might lead to strong negative impacts on timber production, carbon storage and biodiversity conservation [28]. For Baden-Württemberg, Hanewinkel et al. [36] calculated heavy losses in NPV (Net Present Value) by the end of the 21st century due to the expected dramatic decline in spruce. The possible decline in the volume of softwood will also have a considerable impact on the use of wood, particularly in the construction industry.

4. Synthesis

The Central-European forests will become more vulnerable and are subject to change in the upcoming decades. Mortality will increase, in combination with more damages of the forests (all major tree species). Productivity will stagnate or decrease. This has consequences for the economics of forest management, but also climate protection with a likely loss of the carbon sink function of our forests.

General adaptation approaches encompass active measures such as the promotion of mixedspecies forests, advanced natural regeneration as an insurance against disturbance and the emulation of old-growth attributes such as deadwood or large old trees to enhance structural diversity [37]. The need to apply active management measures for adaptation contrasts with slow nature-based solutions, but is seen to be indispensable in the face of a rapid environmental change [34].

Literature

[1] Betts, R., Belcher, S.E., Hermanson, L., Tank, A., Lowe, J., Jones, C., Morice, C., Rayner, N., Scaife, A., Stott, P. (2023) Approaching 1.5 °C: how will we know we've reached this crucial warming mark? Nature 624, 33-35.

[2] Hlásny, T., Zimová, S., Merganičová, K., Štěpánek, P., Modlinger, R., Turčáni, M. (2021) Devastatingoutbreak of bark beetles in the Czech Republic: Drivers, impacts, and management implications. Forest Ecology and Management 490, 119075.

[3] Seidl, R., Senf, C. (2024) Changes in planned and unplanned canopy openings are linked in Europe's forests. Nature Communications 15, 4741.

[4] Spathelf, P. (2021) Mischen possible. Contribution for 'DIE WELT', 06.03.2021, S. 20.

[5] Knapp, H. D., Klaus, S. & Fähser, L. (2021) Der Holzweg. Wald im Widerstreit der Interessen. Oekom-Verlag. 477 S.

[6] Bode, W. (2019) Systemische Waldwirtschaft. Zum Paradigmenwechsel in der Forstwissenschaft. Naturschutz und Landschaftsplanung 51(05). 226-234.

[7] Allen, C. D., Macalady, A. K., Chenchouni, H. et al. (2010) A global overview of drought and heatinduced tree mortality reveals emerging climate change risks for forests. Forest Eology and Management 259. 660–684.

[8] Camarero, J. J., Gazol, A., Sangüesa-Barreda, G. et al. (2015) To die or not to die: early warnings of tree dieback in response to a severe drought. Journal of Ecology 103. 44-57.

[9] Battisti, A., Stastny, M., Netherer, S., Robinet, C., Schopf, A.,Roques, A. & Larsson, S. (2005) Expansion of geographic range in the pine processionary moth caused by increased winter temperatures. Ecological Application, 15, 2084-2096.

[10] Seidl, R., Klonner, G., Rammer, W., Essl, F., Moreno, A., Neumann, M., Dullinger, S. (2018) Invasive alien pests threaten the carbon stored in Europe's forests. Nature Communications 9, 1626.

[11] Mota, M. M., Braasch, H., Bravo, M. A., Penas, A. C., Burgermeister, W., Metge, K. & Sousa, E. (1999) First report of Bursaphelenchus xylophilus in Portugal and in Europe. Nematology, 1, 727734.

[12] Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J., Lexer, M.J., Trotsiuk, V., Mairota, P., Svoboda, M., Fabrika, M., Nagel, T.A., Reyer, C.P.O. (2017) Forest disturbances under climate change. Nature Climate Change 7, 395-402.

[13] Rebetez, M. & Dobbertin, M. (2004). Climate change may already threaten Scots pine stands in the Swiss Alps. Theoretical and Applied Climatology, 79, 19

[14] Paoletti, E., Bytnerowicz, A., Andersen, C., Augustaitis, A., Ferretti, M., Grulke, N., et al. (2007) Impacts of air pollution and climate change on forest ecosystems*Emerging research needs. TheScientificWorldJournal, 7(S1), 18.

[15] Manion, P. D. (1991) Tree disease Concept. 2nd edition. Prentice Hall, Englewood Cliffs NJ. 402 pp.

[16] Annighöfer, P., Metz, J., Schall, P. et al. (2017) Buche in Mischbeständen bei Trockenheit weniger gestresst. AFZ-DerWald 72. 13-15.

[17] BMEL (2021) Waldbericht der Bundesregierung 2021. 83 S. https://www.bmel.de/DE/themen/wald/wald-in-deutschland/waldbericht2021.html. Letzter Zugriff 04.01.2022.

[18] Spathelf, P., Ammer, C., Annighöfer, P. et al. (2022) Fakten zum Thema: Wälder und Holznutzung. AFZ-DerWald. 39-44.

[19] Nemani, R. R., Keeling, C. D., Hashimoto, H., Jolly, W. M., Piper, S. C., Tucker, C. J., et al. (2003) Climate-driven increases in global terrestrial net primary production from 1982 to 1999. Science, 300, 1560-1563.

[20] Pretzsch, H., Bieber, P., Schütze, G. et al. (2014) Changes of forest stand dynamics in Europe. Facts from long-term observational plots and their relevance for forest ecology and management. Forest Ecology and Management 316. 65-77.

[21] Spiecker, H., Mielikainen, K., Köhl, M. et al. (Eds.) (1996) Growth Trends in European Forests. Springer, Berlin. 372 pp.

[22] Bolte, A., Höhl, M., Hennig, P. et al. (2021) Zukunftsaufgabe Waldanpassung. AFZ-DerWald 4. 12-16.

[23] Nabuurs, G.-J., Lindner, M., Verkerk, P. J. et al. (2013) First signs of carbon sink saturation in European forest biomass. Nature climate change. UBLISHED ONLINE: 18 AUGUST 2013 | DOI: 10.1038/NCLIMATE1853.

[24] Thom, D., Buras, A., Heym, M., Klemmt, H.-J., Wauer, A. (2023) Varying growth response of Central European tree species to the extraordinary drought period of 2018 – 2020. Agricultural and Forest Meteorology 338, 109506. https://doi.org/10.1016/j.agrformet.2023.109506

[25] Huber, N., Bugmann, H., Cailleret, M. et al. (2021) Stand-scale climate change impacts on forests over large areas: transient responses and projection uncertainties. Ecological Applications. DOI: 10.1002/eap2313.

[26] Hanewinkel, M., Cullmann, D. A. & Schelhaas, M.-J. (2013) Climate change may cause severe loss in the economic value of European forest land. Nature Climate Change 3. 203–207.

[27] Chakraborty, D., Ciceu, A., Ballian, D., Benito Garzón, M., Bolte, A., Bozic, G., Buchacher, R., Čepl, J., Cremer, E., Ducousso, A., Gaviria, J., George, J.P., Hardtke, A., Ivankovic, M., Klisz, M., Kowalczyk, J., Kremer, A., Lstibůrek, M., Longauer, R., Mihai, G., Nagy, L., Petkova, K., Popov, E., Schirmer, R., Skrøppa, T., Solvin, T.M., Steffenrem, A., Stejskal, J., Stojnic, S., Volmer, K., Schueler, S. (2024) Assisted tree migration can preserve the European forest carbon sink under climate change. Nature Climate Change 14, 845-852.

[28] Wessely, J., Essl, F., Fiedler, K., Gattringer, A., Hülber, B., Ignateva, O., Moser, D., Rammer, W., Dullinger, S., Seidl, R. (2024) A climate-induced tree species bottleneck for forest management in Europe. Nature Ecology & Evolution 8, 1109–1117.

[29] Albrecht, A., Michiels, H.-G., Kohnle, U. (2019) Baumarteneignung 2.0 und Vulnerabilitätskarten – Konzept und landesweite Hauptergebnisse. FVA-einblick 2/2019. 9-14.

[30] Spathelf, P., Bolte, A. & Riek, W. (2016) Waldmanagement im Klimastress 2.0. AFZ-DerWald 3. 10-14.

[31]	FVA (Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg) (2022) Klimakarten 2.0. https://www.fva-bw.de/daten-und-tools/geodaten/klimakarten/klimakarten-20?tx_gdfvascripts_scriptwrapper%5Bscript_file%5D=klimakarten2019_download.php&tx_gdfvascripts_scriptwrapper%5Bscript_query%5D%5Beinheit%5D=lkr&cHash=44f-12207365c4f3f2c8d98acc80021ad. Letzter Zugriff 26.01.2022.
[32]	Hanewinkel, M., Hummel, S., Cullmann, D. (2010a) Modelling and economic evaluation of forest biome shifts under climate change in Southwest Germany. Forest Ecology and Management 259. 710-719.
[33]	Rigling, A., Moser, B., Feichtinger, L. et al. (2018) 20 Jahre Waldföhrensterben im Wallis. Rückblick und aktuelle Resultate. Schweizerische Zeitschrift für Forstwesen 169/5: 242–250.
[34]	Wissenschaftlicher Beirat für Waldpolitik (2021) Die Anpassung von Wäldern und Waldwirtschaft an den an den Klimawandel. Berlin. 192 S.
[35]	Hanewinkel, M., Cullmann, D. A. & Schelhaas, M.-J. (2013) Climate change may cause severe loss in the economic value of European forest land. Nature Climate Change 3. 203–207.
[36]	Hanewinkel, M., Cullmann, D. & Michiels, H.-G. (2010b) Künftige Baumarteneignung für Fichte und Buche in Südwestdeutschland. AFZ-DerWald 19. 30-33.
[37]	Brang, P., P. Spathelf, J.B. Larsen et al. (2014) Suitability of close-to-nature silviculture for adapting temperate European forests to climate change. Forestry 87. 492-503.

Climate change impact assessment and adaptation measures identification for the Municipality of Tirana

Vlorlinda Daja[1]

Entela Çobani[2]

Ledia Aleksi[3]

1 Msc. Vlorlinda Daja, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha, 54, 1023, Tirana, Albania
vlorlinda.daja@fin.edu.al

2 Dr. Entela Cobani, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha, 54, 1023, Tirana, Albania
entela.cobani@fin.edu.al

3 Dr. Ledia Aleksi, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha, 54, 1023, Tirana, Albania
ledia.aleksi@fin.edu.al

Abstract

Climate change poses a significant challenge to sustainable urban development, particularly in areas with high population density, rapid infrastructure expansion, and limited green spaces, which together increase cities vulnerability to climate-related risks. This study analyses the local impacts of climate change in the Municipality of Tirana and aims to identify practical and targeted adaptation measures that reduce exposure and strengthen urban resilience. Through an interdisciplinary approach, the research combines historical climate data analysis, assessments of environmental exposure and vulnerability, and fieldwork carried out across three urban zones that differ in both physical structure and socio-economic characteristics: the city center, the area near the Faculty of Medicine, and the surroundings of the Artificial Lake of Tirana. A central focus is placed on the urban heat island effect, which is used as a key indicator of thermal stress in the built environment. The results show an intensification of extreme temperature events, which pose serious implications for public health, energy consumption, and the overall liveability of the city. In response to these challenges, the study proposes a set of adaptation strategies, including the expansion of urban green spaces, the application of reflective (high-albedo) materials in construction, improved stormwater systems to manage increased rainfall, and the integration of nature-based solutions into the city's planning processes. The research also underlines the essential role of local stakeholders, decision-makers, and cross-sector collaboration in ensuring the effective implementation of these measures. In conclusion, this study contributes both analytical insight and actionable recommendations that support local policy development toward a more sustainable and climate-resilient urban future in the Municipality of Tirana.

Keywords

Climate change, environmental vulnerability, sustainable planning, Municipality of Tirana, urban heat islands

1. Introduction and objectives of the study

Tirana, Albania's capital and largest urban center, has experienced rapid urbanization and demographic growth, expanding from 11 to 27 administrative units in 2015. This expansion has intensified both opportunities and risks, making the city highly vulnerable to climate change impacts. Today, Tirana administers an area 25 times larger than before, with a population close to 900,000 inhabitants. This growth has placed significant pressure on infrastructure, housing, drainage, and public services.

The aim of this study is to examine the intersection of climate change and urban vulnerability in Tirana. More specifically, it seeks to:

1. analyze historical climate trends.
2. identify natural hazards and their socio-economic implications.
3. evaluate the Urban Heat Island phenomenon through a comparative study of three areas.
4. propose practical adaptation measures for building long-term resilience.

2. Methodology

The research adopted a mixed-methods approach to capture both quantitative data and qualitative insights:

Data Collection: Historical meteorological data (temperature, precipitation, humidity) covering the period 1990–2024 were obtained from the Current Climate Climatology of World Bank Group.

Comparative Analysis: Three representative areas of Tirana (the central district, residential neighborhoods, and peri-urban zones) were analyzed to assess the spatial variation of Urban Heat Islands (UHIs).

Policy Review: Tirana's climate strategies were compared with EU and regional adaptation frameworks to align recommendations with best international practices.

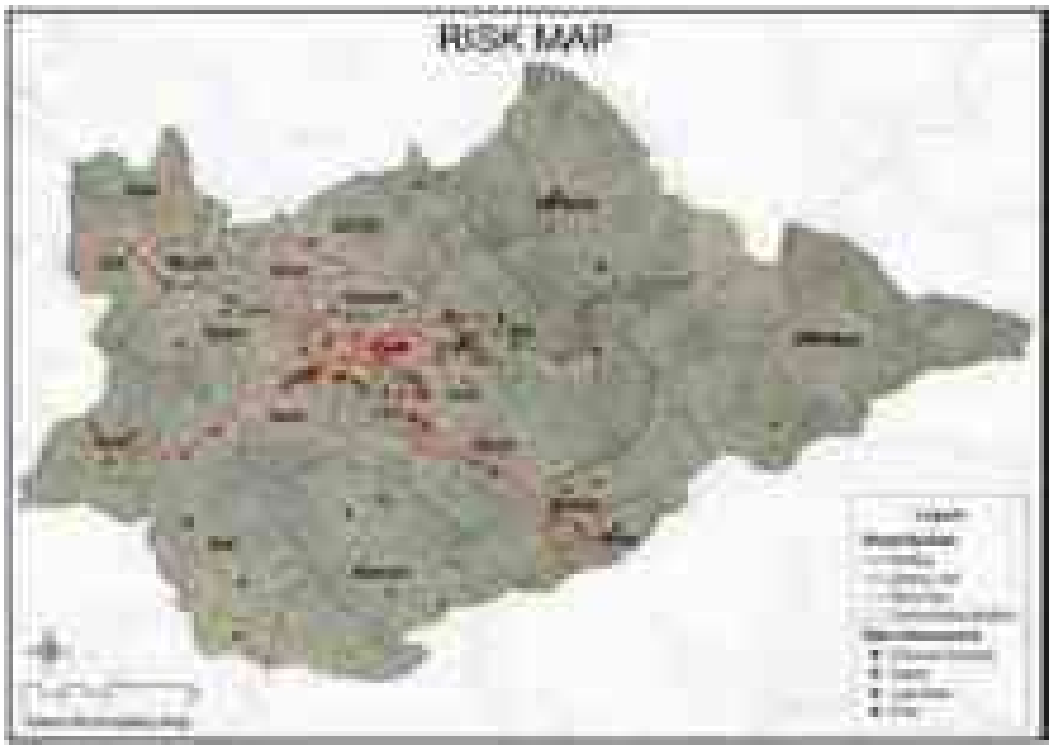
This integrated methodology ensures a comprehensive understanding of climate risks and the feasibility of proposed adaptation measures.

3. Climate challenges and exposure of Tirana Municipality

Tirana is increasingly exposed to a variety of climate hazards:

- Flooding: Seasonal floods are common, particularly in low-lying districts and along the Lana River. Informal settlements and inadequate drainage worsen the impacts.
- Heatwaves: Rising summer temperatures and the Urban Heat Island effect exacerbate health risks, especially for vulnerable groups such as the elderly, children, and those with pre-existing conditions.
- Landslides: Peri-urban hillsides face recurrent slope instability due to deforestation, poor construction practices, and heavy rainfall.
- Wildfires: Hot, dry summers increase fire risk, threatening forests and agricultural lands around the city.

These challenges are compounded by rapid urban growth, infrastructure deficits, and limited emergency response capacity, making climate adaptation an urgent priority.

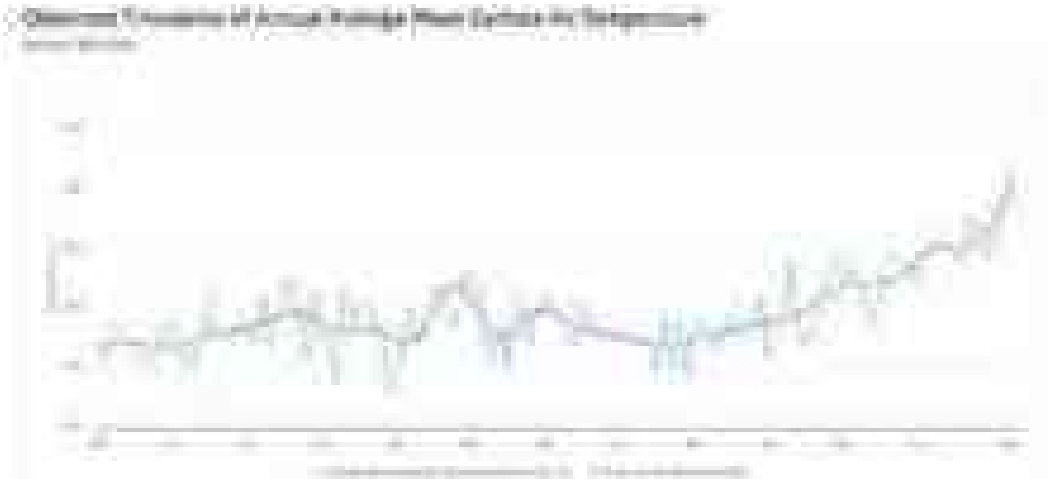


3.1. Figure 1 – Risk map for the Municipality of Tirana.[1]

[1] *National Agency for Civil Protection. (2022). Flood Risk Assessment Report.*

4. Historical temperature trends

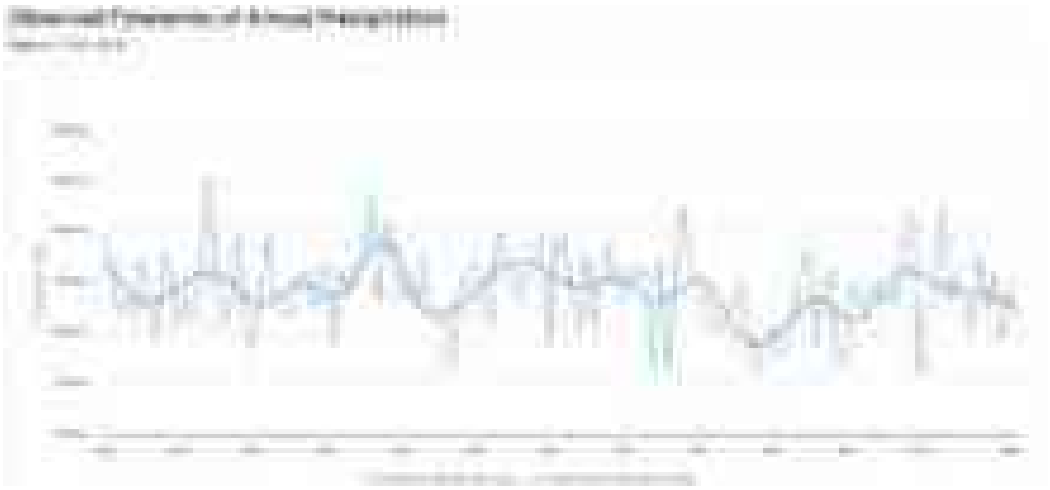
Long-term meteorological records show a significant warming trend. Over the past three decades, the mean annual temperature has risen by over 1.2 °C. Extreme heat events, once rare, are now more frequent, with maximum summer temperatures exceeding 40 °C.



4.1. Figure 2 – Average annual temperature for Tirana (historical trend)[2]

Precipitation patterns have also shifted: periods of drought alternate with episodes of intense rainfall. Annual precipitation averages 1,270 mm, but ranges from as low as 773 mm to as high as 1,770 mm. These extremes strain both water resources and flood management systems.

Such climate dynamics directly affect multiple sectors: agriculture faces uncertainty, energy demand for cooling has sharply increased, and public health systems must prepare for more heat-related illnesses.



4.2. Figure 3 – Average annual precipitation for Tirana (historical trend)[3]

[2] *The World Bank Group. (2024) Climate Change Knowledge Portal1. Retrieved from https://www.worldbank.org*
[3] *The World Bank Group. (2024) Climate Change Knowledge Portal1. Retrieved from https://www.worldbank.org*

Table 1 – Historical Climate Indicators and Recent Trends for Tirana

Indicator	Historical Range / Average	Recent Trend
Mean annual temperature	15.2 °C	+1.2 °C in last 30 years
Max summer temperature	Up to 42.2 °C	More frequent extremes
Min winter temperature	–10.4 °C	Persistent variability
Annual precipitation	1,270 mm (avg.)	773–1,770 mm (wider range, irregular)
Rainy days (≥1 mm)	~122 days/year	More intense but clustered rainfall
Relative humidity	52% annual avg.	Lower in summer (43%), higher in winter (60%
Extreme events	Rare in past	More frequent heatwaves & heavy rain

5. Urban Heat Islands (UHIS)

Urban Heat Islands (UHIs) are among the most pressing climate challenges for Tirana. Dense construction, limited greenery, and extensive asphalted surfaces create microclimates where urban temperatures are consistently higher than those of surrounding rural areas. Central districts can be 2–4 ℃ warmer, posing health risks and driving up energy demand.

Vulnerable populations, particularly low-income households with limited access to cooling, are disproportionately affected. In addition, elevated temperatures worsen air pollution and create feedback loops that intensify climate stress.

6. Comparative analysis of three representative areas

Methodology for UHI Assessment:

To evaluate the Urban Heat Island (UHI) effect, a combination of field measurements and spatial analysis was employed:

Temperature Data Collection: Air temperatures were measured for one day, using handheld digital thermometers. Measurements were taken at each of the three zones.

Land Use Classification: Each zone was mapped according to land cover (paved surfaces, buildings, vegetation, and water bodies) to correlate surface characteristics with observed temperature differences.

Comparative Analysis: Temperatures from all three zones were compared to identify maximum, minimum, and average differences, providing a clear view of the UHI intensity across Tirana.

The Urban Heat Island (UHI) effect was analyzed in three specific zones in Tirana, based on field temperature measurements:

6.1. Figure 4 – Urban Heat Island Measurement Zones in Tirana: Field Study Locations

Zone 1 – Near the Artificial Lake of Tirana

Characteristics: Large green space with dense trees and proximity to water, creating natural cooling through shading and evaporative processes.

Measured Temperature: 24 ℃

UHI Intensity: Minimal; serves as a natural reference.

Observations: The green space and water body significantly reduce local temperatures, demonstrating the cooling potential of natural environments within the urban area.

Zone 2 – Street near the Faculty of Medicine

Characteristics: Mixed urban environment with buildings, paved surfaces, and some street trees providing partial shade.

Measured Temperature: 27 ˚C

UHI Intensity: Moderate; partially mitigated by vegetation.

Observations: Shade from trees noticeably lowers temperatures compared to fully exposed urban areas. This zone represents a transitional environment between highly built-up and highly green areas.

Zone 3 – Skanderbeg Square

Sub-zone A – Exposed area (no shade)

Characteristics: Open paved area with high-density hard surfaces, no vegetation or shade.

Measured Temperature: 37 ˚C

UHI Intensity: Maximum; most severe heat stress in the study.

Sub-zone B – Shaded area near a tree

Characteristics: Same location, but under partial tree shade.

Measured Temperature: 28 ˚C

UHI Intensity: Reduced by 9 ˚C compared to exposed sub-zone.

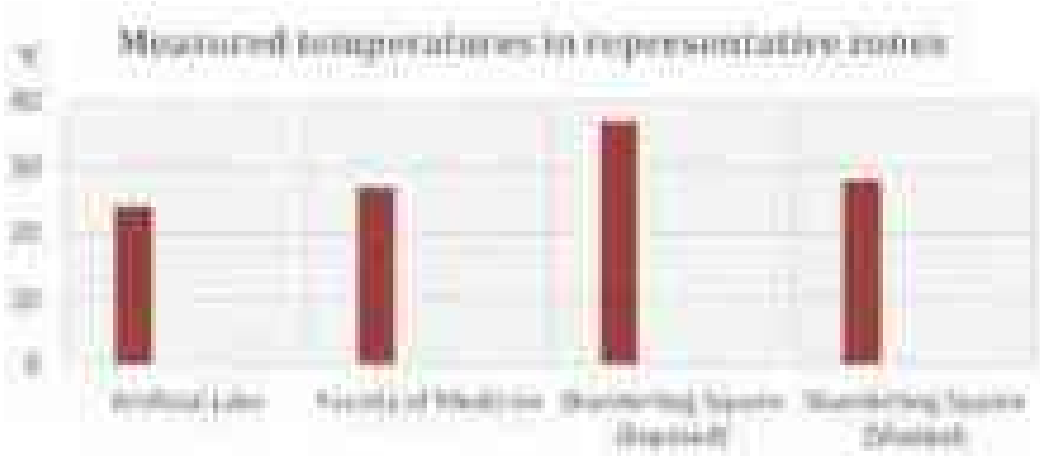
Observations: Even minor interventions like a single tree dramatically reduce local temperatures, demonstrating the effectiveness of urban greening and shading strategies.

Key Takeaways from the Field Study:

Maximum temperature difference between fully built and green/shaded areas: ≈13 ˚C (37 ˚C in Skanderbeg Square vs 24 ˚C near the Lake).

Vegetation and water bodies play a critical role in mitigating UHI effects.

Minor shading interventions can reduce heat exposure by 9 ˚C, proving simple urban planning measures can improve thermal comfort.



Graphic 1 – Field-Measured Temperatures in Tirana's Urban Heat Islands

7. Key conclusions and recommendations

The findings of this study emphasize that Tirana is at a crossroads: the combination of rapid urban growth and escalating climate hazards requires systematic, long-term action.

Short-term (1–2 years):
Improve flood maps and modernize stormwater drainage.
Launch community awareness campaigns on heat and flood preparedness.
Establish pilot projects for green roofs and rainwater harvesting.

Medium-term (3–5 years):
Expand urban green corridors.
Enforce building codes in landslide-prone areas.
Introduce electric buses and low-emission zones in the city center.

Long-term (>5 years):
Mainstream climate resilience in all municipal planning.
Secure long-term financing through EU funds and climate partnerships.
Develop a permanent monitoring system for climate indicators and adaptation effectiveness.

Technical adaptation measures are most effective when combined with active community participation and local stakeholder involvement. Concrete measures can include:

- the establishment of pilot greening projects in neighbourhoods where residents actively plant and maintain trees and vegetation.
- citizen-led monitoring of urban heat islands, using thermometers or sensors placed in different parts of the city to monitor temperature data.
- educational workshops and awareness campaigns in schools and local communities on extreme heat and flood preparedness.
- interactive digital platforms or applications where residents can report urban climate risks such as flooded areas, heat hotspots, or infrastructure damage.

These initiatives ensure that adaptation measures are context-specific, socially accepted, and more sustainable over the long term, while also strengthening the collaboration between the municipality, local actors, and the community.

Literature

[1]	Municipality of Tirana. Demography. n.d. Web. United Nations Office for Disaster Risk Reduction (UNDRR). Des Inventar Database.
[2]	Intergovernmental Panel on Climate Change (IPCC). 'Fifth Assessment Report.' Geneva, 2014.
[3]	National Civil Protection Agency of Albania. 'Flood Risk Assessment for Tirana Region.' Tirana, 2022.
[4]	United Nations Office for Disaster Risk Reduction (UNDRR). 'Making Cities Resilient Report.' Geneva, 2022.
[5]	Malltezi, J., Hanxhari, R., Zela, G., & Sulçe, S. (2015). 'Climate Change Adaptation Actions in Tirana'. Agricultural University of Tirana.
[6]	GIZ Albania. (2015). 'Vulnerability Assessment and Adaptation Action Plan for Tirana, Albania'.
[7]	Xhexhi K. and Aimar, F. (2024). 'Urban Heat Islands in Tirana, Albania - Analysis and Potential Solutions'.
[8]	World Bank. (2023). 'Albania's National Adaptation Plan First Progress Report'.
[9]	UNFCCC. (2022). 'Fourth National Communication of Albania on Climate Change'.

1Future International Symposium – Proceedings

Publisher

NVO „Građevinarstvo – Nauka i praksa (GNP)“, Montenegro

Editors

Miloš Knežević, University of Montenegro, Montenegro
Elona Pojani, University of Tirana, Albania
Mirjana Laban, University of Novi Sad, Serbia

Organizing Team

Miloš Knežević, University of Montenegro, Montenegro
Marina Rakočević, University of Montenegro, Montenegro
Snežana Rutešić, University of Montenegro, Montenegro
Željka Beljkaš, University of Montenegro, Montenegro
Jelena Pejović, University of Montenegro, Montenegro
Mladen Gogić, NGO “Građevinarstvo – nauka i praksa – GNP”
Zdenka Perović, Engineers Chamber of Montenegro, Montenegro
Elona Pojani, University of Tirana, Albania
Perseta Grabova, University of Tirana, Albania
Brunilda Kosta, University of Tirana, Albania
Mirjana Laban, University of Novi Sad, Serbia
Suzana Draganić, University of Novi Sad, Serbia

Scientific Board

Albana Çami (Hashorva), University of Tirana, Albania
Ana Trombeva Gavriloska, Ss. Cyril and Methodius University in Skopje, North Macedonia
Anni Dasho Sharko, LuarasiUniversity, Albania
Brikena Leka, University of Tirana, Albania
Brunilda Kosta, University of Tirana, Albania
Edisa Nukić, University of Tuzla, Bosnia and Hercegovina
Elona Pojani, University of Tirana, Albania
Gentiana Sharku, University of Tirana, Albania
Giulia Lucertini, Iuav University of Venice, Italy
Heike Molitor, Eberswalde University for Sustainable Development, Germany
Filippo Magni, Iuav University of Venice, Italy
Franziska Rottig, Eberswalde University for Sustainable Development, Germany
Henrik Hassel, Lund University, Sweden
Jelena Pejović, University of Montenegro, Montenegro
Joana Gjipalaj, Polytechnic University of Tirana, Albania
Johan Ingvarson, Lund University, Sweden
Kreshnik Vukatana, University of Tirana, Albania
Ljiljana Popović, University of Novi Sad, Serbia
Marina Rakočević, University of Montenegro, Montenegro
Marko Z. Marković, University of Novi Sad, Serbia
Meri Cvetkovska, Ss. Cyril and Methodius University in Skopje, North Macedonia
Miloš Knežević, University of Montenegro, Montenegro
Mirela Muça, National Agency for Scientific Research and Innovation, Albania
Mirzo Selimić, "CEPS-Center for Business Studies", Bosnia and Hercegovina
Nenad Medić, University of Novi Sad, Serbia
Nermin Palić, "CEPS-Center for Business Studies", Bosnia and Hercegovina
Oltion Marko, Polytechnic University of Tirana, Albania
Perseta Grabova, University of Tirana, Albania
Sherif Bundo, Luarasi University, Albania
Slobodan Kolaković, University of Novi Sad, Serbia
Snežana Rutešić, University of Montenegro, Montenegro
Suzana Draganić, University of Novi Sad, Serbia
Vittoria Ridolfi, Iuav University of Venice, Italy
Željka Beljkaš, University of Montenegro, Montenegro
Zvjezdan Karadzin, University of Tuzla, Bosnia and Hercegovina

Graphic Design & DTP

Miloš Nikolić, University of Montenegro, Montenegro

CIP - Каталогизација у публикацији
Национална библиотека Црне Горе, Цетиње

ISBN 978-9911-9616-0-0
COBISS.CG-ID 35906052