INTERNATIONAL JOURNAL OF DISASTER RISK MANAGEMENT (IJDRM)

UDC: 614.8.069

ISSN (printed) 2620-2662
ISSN (online) 2620-2786

SCIENTIFIC-PROFESSIONAL SOCIETY FOR DISASTER RISK MANAGEMENT,
BELGRADE, THE REPUBLIC OF SERBIA

INTERNATIONAL JOURNAL OF DISASTER RISK MANAGEMENT (IJDRM)

Vol. 6 • № 2

Belgrade, 2024

PUBLISHER

Scientific-Professional Society for Disaster Risk Management (https://upravljanje-rizicima.com/), Dimitrija Tucovića 121, Belgrade, Serbia with support of the International Institute for Disaster Research (IDR), Belgrade.

E-mail: ijdrm@gmail.com

Website - http://internationaljournalofdisasterriskmanagement.com/

EDITORIAL BOARD

Editor-in-Chief

Prof. Dr. **Vladimir M. Cvetković, PhD**, vmc@fb.bg.ac.rs; vladimirkpa@gmail.com, vladimir.cvetkovic@unileoben.ac.at

Department for Disaster Management and Environmental Security, Faculty of Security Studies, University of Belgrade, Gospodara Vucica 50, 11040 Belgrade, Serbia; Scientific-Professional Society for Disaster Risk Management, Belgrade; International Institute for Disaster Research, Belgrade; Safety and Disaster Studies, Department of Environmental and Energy Process Engineering, Montanuniversität of Leoben, Franz Josef-Straße 18, 8700 Leoben, Austria.

ORCID - https://orcid.org/0000-0002-3450-0658

Web-site - https://vladimircvetkovic.upravljanje-rizicima.edu.rs/

International editorial board

Professor Rajib Shaw, PhD
Graduate School of Media and Governance, Keio University Shonan Fujisawa Campus (SFC), Japan.

Professor Kevin Ronan, PhD
Clinical Psychology School of Health, Medical and Applied Sciences, CQUniversity, Rockhampton, Australia.

Professor & Director, Naim Kapucu, PhD
School of Public Administration, University of Central Florida, 4364 Scorpius Street, USA.

Full professor Eric Noji, MD, MPH, DTM&H(Lon), PhD
Distinguished University Professor and Senior Consultant in Emergency Medicine, King Saud University Hospitals and College of Medicine, Washington, D.C., USA.

Full Professor Igor Khripunov, PhD
Center for International Trade and Security School of Public and International Affaires University of Georgia in Athens (UGA) 120 Academic Building, Athens, GA 30602, USA.

Damon P. Coppola, PhD
Disaster Management Specialist, Pacific Disaster Center, and Principal, Shoreline Risk, Hawaii, USA.

Prof. Dr. Eng. Alexandru Ozunu, PhD
Dean of the Faculty of Environmental Science and Engineering, "Babeş-Bolyai" University, Romania.

Prof. Dr. Dimitar Dimitrov, PhD
Head of National and Regional Security Department, Dean of Faculty 'Economics of Infrastructure' at University of National and World Economy (UNWE), Sofia, Bulgaria.

Assoc. Prof. Rositsa Velichkova, PhD
Department Hydroaerodynamics and Hydraulic Machines, Technical University of Sofia, 1000 Sofia, 8 Kl. Ohridski Ave, Bulgaria.

Full Prof. Miroslav Vesković, PhD
European Commission, Joint Research Centre, Inter-institutional, International Relations and Outreach, Brussels/Belgium.

Assoc. Prof. Rita Mano, PhD
Department of Human Services, University of Haifa, Mount Carmel, Haifa 31995, Israel.

Assoc. Prof. Igal M. Shohet, PhD
Ben-Gurion University of the Negev, Department of Structural Engineering, Beersheba, Israel.

Assist. Prof. Blaz Komac, PhD
Head of the Department of Natural Hazards, Anton Melik Geographical Institute ZRC SAZU, Slovenia.

Prof. Caroline Brassard, PhD
Lee Kuan Yew School of Public Policy in Singapore.

Prof. Lamiaa A Fiala, Mbbch, MPH, DrPH, MSc.Edu, PhD
Public Health & Preventive Medicine Community Medicine Dept. Faculty of Medicine, Suez Canal University Ismailia, Egypt.

Giulia Roder, PhD
Department of Land, Environment, Agriculture and Forestry, University of Padova, Agripolis, viale dell'Università 16, 35020 Legnaro, Italy

Assoc. Prof. Adem Ocal, PhD
Independent researcher, Ankara, 06500, Turkey.

Assoc. Prof. Aleksandar Ivanov, PhD
Faculty of Security-Skopje, University of Bitola, Macedonia.

Full prof. Sergey Alekseevich Kachanov, PhD
Deputy Director of the Russian-Serbian Humanitarian Center, Honored Scientist of the Russian Federation, laureate of the Russian Government Prize in Science, Academician of the Russian Academy of Natural Sciences.

Full Professor Cezar Morar
University of Oradea, Romania

Full Prof. Harald Raupenstrauch
Safety and Disaster Studies, Department of Environmental and Energy Process Engineering, Montanuniversität of Leoben, Franz Josef-Straße 18, 8700 Leoben, Austria

Dr. Renate Renner
Safety and Disaster Studies, Department of Environmental and Energy Process Engineering, Montanuniversität of Leoben, Franz Josef-Straße 18, 8700 Leoben, Austria

Juel Rana Kutub
Faujdarhat Cadet College Faujdarhat, Sitakundu, Chittagong 4616, Bangladesh.

Full Prof. Slavoljub Dragićević, PhD
University of Belgrade Faculty of Geography, Studentski Trg 3/III, 11000 Belgrade, Serbia.

Assoc. Prof. Ivan Novković, PhD
University of Belgrade Faculty of Geography, Studentski Trg 3/III, 11000 Belgrade, Serbia.

Full Prof. Želimir Kešetović, PhD
Faculty of Security Studies, University of Belgrade, Gospodara Vucica 50, 11040 Belgrade, Serbia.

Assoc. Prof. Ivica Đorđević
Faculty of Security Studies, University of Belgrade, Gospodara Vucica 50, 11040 Belgrade, Serbia.

Full Prof. Srđan Milašinović, PhD
University of Criminal Investigation and Police Studies, Belgrade, Cara Dušana 196, Belgrade, Serbia.

Full Prof. Velibor Spalević
Biotechnical Faculty, University of Montenegro, Mihaila Lalića 15, 81000 Podgorica, Montenegro

Assoc. Prof. Bojan Janković, PhD
University of Criminal Investigation and Police Studies, Belgrade, Cara Dušana 196, Belgrade, Serbia.

Assoc. Prof. Tin Lukić
Department of Geography, Tourism and Hotel Management, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia

Full. Prof. Slobodan Marković
Serbian Academy of Sciences and Arts, Kneza Mihaila 35, 11000 Belgrade, Serbia

Editorial secretary
Vanja D. Cvetković
Bojana Aleksova
Scientific-Professional Society for Disaster Risk Management, Belgrade

English Language Editor and Proof-Reader
Petar Marković

Printed by
Scientific-Professional Society for Disaster Risk Management, Belgrade

Ordering:
Scientific-Professional Society for Disaster Risk Management Belgrade (https://upravljanje-rizicima.com/), Dimitrija Tucovića 121, Belgrade, Serbia
Fax/faks: +381 61 5723120
E-mail: ijodrm@gmail.com

PDF version of the journal
https://internationaljournalofdisasterriskmanagement.com
Published twice times a year

Abstracting and Indexing
J-gate; ICI Journals Master List database; ERIH PLUS; CEOOL (Central and Eastern European Online Library); Dimensions; National Library of Serbia; Crossref; ROAD – Directory of Open Access Scholarly Resources; Fatcat; Google Scholar Citations.

Publisher: Scientific-Professional Society for Disaster Risk Management, Belgrade, Serbia.

Scientific-Professional Society for DRM is a Serbian (Belgrade) non-governmental organization that seeks to improve the existing supply of theoretical and empirical knowledge in the field of disaster risk management. Conducts quantitative-qualitative research, develops knowledge base, promotes science and evidence-based policy, organizes national and international conferences, publishes journals (International Journal of DRM), and conducts training and other academic activities in disaster risk management, national security, and disaster risk management fields in Serbia and other Balkan countries. SPS-DRM has in-depth knowledge of civil protection and disaster management structures and organizations within the Balkan countries and their integration within the European Union Civil Protection.

BASIC DATA AND HISTORICAL DEVELOPMENT

On June 15, 2018, the founding assembly was held and at the proposal of the founder, prof. dr Vladimira M. Cvetković, professors from the Faculty of Security, the Criminalistics and Police University, the Faculty of Geography and Forestry unanimously adopted the Statute and formed the Scientific-Professional Society for Disaster Risk Management. In order to improve the scientific activity within the Society, 21.12.2020. year, the Statute was adopted and the International Institute for Disaster Research was established. The Scientific-Professional Society for Risk Management in Emergency Situations (NSDR-URVS) is a non-governmental, non-profit association, established for an indefinite period, for the purpose of improving the existing fund of theoretical knowledge in the field of risk management in emergency situations, conducting quantitative and qualitative research, organizing national and international conferences, launching and managing journals, conducting trainings and risk assessments, as well as other academic activities in the aforementioned field.



CONTACT INFORMATION

Scientific-professional society for disaster risk management
Belgrade, Dimitrija Tucovića 121 ID number: 28259727
PIB: 110885182 President - prof. Dr. Vladimir M. Cvetkovic
Secretary - Sofija Radojković

Website - www.upravljanje-rizicima.com.



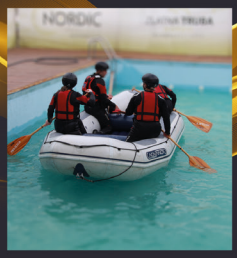
+381 61 572 31 20

Belgrade, Dimitrija Tucovića 121

www.upravljanje-rizicima.com
upravljanje.rizicima.vs@gmail.com

SCIENTIFIC-PROFESSIONAL SOCIETY FOR DISASTER RISK MANAGEMENT







MEMBERS AND ASSOCIATES

It has more than 1,000 members made up of professors from state and private Universities and Colleges in Serbia, scientific researchers, practitioners (members of the police, fire and rescue units, emergency medical services, the army, NGO organizations in the field of security, etc.), students and young people who are directly or indirectly engaged in research and specific activities in the field of emergency situations. Within NSD-URVS, a general-purpose civil protection unit was formed with the aim of providing assistance to vulnerable citizens in emergency situations.



Become a member by filling out the application form on the website and sending it via email to NSD-URVS užvalje.rizicima.vs@gmail.com



OBJECTIVES

Objectives of NSDR-URVS: a) conducting research in the field of disaster studies; b) establishment and management of an international journal - International Journal of Disaster Risk Management; v) preparation, application and implementation of national and international projects on various aspects of risk management in emergency situations; g) promoting, designing, implementing and improving preventive measures against disasters; d) designing and implementing campaigns, programs, plans to strengthen citizens' awareness of the necessity of improving their preparedness for disasters; f) organizing national and international scientific conferences on risk management in emergency situations; e) implementation of expert risk assessments and preparation of protection and rescue plans in emergency situations; h) organizing and implementing various types of training, courses, seminars and other training for citizens, students and employees in interested institutions; z) performing other tasks in accordance with the law and its Statute.





HELD TRAININGS, COURSES AND LECTURES



In the organization of the Scientific-Professional Society for Risk Management in Emergency Situations, a large number of trainings and other activities aimed at education in the field of emergency situations were realized: the first, second, third, fourth and fifth basic safety training in the field emergency situations.

SCIENTIFIC RESEARCH AND PUBLISHING ACTIVITY

Over 15 textbooks, monographs and collections of works were published within the scientific and publishing activities of the Society. Associates of the society have written more than 10 projects in the field of emergency situations and more than 150 scientific papers.





INTERNATIONAL JOURNAL (IJDRM) AND INSTITUTE (IDR)

At the founding assembly, held on 21.12.2020. year, the Statute was adopted and the International Institute for Disaster Research was established as an organizational unit of the Society. In 2019, the first international journal in the field of risk management in emergency situations was founded in Serbia - Journal of Disaster Risk Management.

The journal cover all aspects of disaster risk management from a global and national perspectives



Editor-in-Chief
Prof. dr Vladimir M. Cvetković

CONTENT

SANTANU BARUAH, CHANDAN DEY, NANDITA DUTTA, MANOJ KUMAR PHUKAN
Dima Hasao, Assam (India) landslides' 2022: A lesson Learnt.....1-12

MOHAMMED M. A. EL MOUGHER, SABAH A. M. ABU SHAREKH, MR. RAMZY F. ABU ALI, AYED A. M. ZUHUD
Risk Management of Gas Stations that Urban Expansion Crept into in the Gaza Strip.....13-26

FAICEL TOUT
Flood policy in Algeria.....27-38

BOJAN JANKOVIĆ, ALEKSANDAR SAKAČ, IGOR IRIČANIN
Students' perception of police readiness to respond to disasters caused by a COVID-19 pandemic.....39-50

MST. RAJANI AKTER, TUHIN ROY, RINA AKTAR
Challenges of Women in Post-disaster Health Management: A Study in Khulna District.....51-66

VLADIMIR M. CVETKOVIĆ, SAŠA ROMANIĆ, HATIDŽA BERIŠA
Religion Influence on Disaster Risk Reduction: A case study of Serbia.....67-82

AYESHA IFTIKHAR, JAWED IQBAL
Factors Responsible for Urban Flooding in Karachi: A Case Study Of DHA.....83-104

Editor-in-Chief
Assoc. Prof. Vladimir M. Cvetković, PhD
University of Belgrade, Faculty of Security Studies
International Institute for Disaster Research
Scientific-Professional Society for Disaster Risk Management

ISSN 2620-2662

INTERNATIONAL JOURNAL OF DISASTER RISK MANAGEMENT (IJDRM)

About journal (IDRM)

International Journal of Disaster Risk Management (IJDRM) is a double-blind peer-reviewed (twice a year), open-access journal that serves all aspects of disaster studies, policy, and management. It provides a platform for academics, policymakers, and practitioners to publish high-quality research and practice concerning natural disasters, anthropogenic disasters, complex political emergencies, and crises around the world. This is an open-access journal which means that all content is freely available without charge to the user or his/her institution.

Publisher

Scientific-Professional Society for Disaster Risk Management, Belgrade, Serbia

www.upravljanje-rizicima.com

Supported by

International Institute for Disaster Research (IDR), Belgrade, Serbia

Printed edition - ISSN 2620-2662

Electronic edition - ISSN 2620-2786

CC BY NC ND

SCIENTIFIC-PROFESSIONAL SOCIETY FOR DISASTER RISK MANAGEMENT, BELGRADE, THE REPUBLIC OF SERBIA

INTERNATIONAL JOURNAL OF DISASTER RISK MANAGEMENT (IJDRM) Vol. 5 • № 1

INTERNATIONAL JOURNAL OF DISASTER RISK MANAGEMENT (IJDRM)

Vol. 5 • № 1

INTERNATIONAL JOURNAL OF DISASTER RISK MANAGEMENT

Abstracting and Indexing Information

- Sherpa Romeo
- ERIH PLUS (European Reference Index for the Humanities or ERIH)
- CEOOL (Central and Eastern European Online Library)
- National Library of Serbia - COBISS.SR-ID - 275644172
- Crossref
- ROAD – Directory of Open Access Scholarly Resources
- Fatcat
- Google scholar citations

Journal Abbreviation

Int. J. Disaster Risk Manag. (IJDRM)



Aims and Scope

Journal will cover all aspects of disaster risk management from a global perspective, including but not limited to:

- Disaster and crisis management theory and practice
- Risk awareness and assessment
- Hazard and vulnerability analysis
- Knowledge development including education, training, research, and information on disasters
- Public commitment and institutional frameworks, including organizational, policy, legislation, and community action
- Disaster prevention, mitigation, response, recovery planning, policies, and implementation
- Promotes the interchange of ideas between practitioners, policymakers, and academics

Contact Information

+381 61 572 31 20

Dimitrija Tucovića 121. Beograd

disaster.risk.management.serbia@gmail.com

Keywords

Disasters, disaster risk management, natural disaster, technological disaster, emergency situations, crisis management, theory and practice, mitigation, preparedness, hazards, policy, natural, complex, emergencies, political, aid, relief, developing, humanitarian, field, reports, refugee, journal, research, analysis, review.

Submission Process

Authors are kindly invited to submit their formatted full papers. All paper submissions will be blind peer-reviewed and evaluated based on originality, research content, correctness, relevance to the conference, and readability (reviewer form). Submission of the articles doesn't involve article processing charges (APCs) or submission charges.

ABOUT US

The Scientific-Professional Society for Disaster Risk Management (SPS-DRM) took the initiative to establish the International Institute for Disaster Research (IDR) in 2020. The primary mission of the IDR is to engage in scientific research within the domain of disaster studies. This important research work is conducted from the Institute's headquarters situated at the mentioned address.

The scientific endeavours of the Institute align with the framework established by the Law on Scientific and Research Activity of Serbia. Furthermore, these activities adhere to the predefined and formally adopted program orientation that guides the Institute's work.

The Institute's research activities span a wide spectrum, encompassing basic, applied, and developmental scientific research within the field of disaster risk management. Through these research initiatives, the Institute seeks to advance the scientific understanding of disaster-related issues and contribute to the development of effective strategies, policies, and practices that enhance disaster resilience and mitigate the impact of natural and man-made disasters.





ACTIVITIES

- Organizes and conducts field research to collect primary data necessary for the realization of scientific research activities in the field of disasters;
- Establishes scientific databases based on the collection of primary and secondary data (analysis of domestic and world literature, as well as research);
- Publishes scientific monographs, proceedings from national and international conferences, collections of regulations, journals and other publications in the field of disaster risk management;
- Establishes cooperation with all relevant subjects and organizations (held bodies, faculties, legal entities) that deal with disaster risk management in the country and abroad;
- Gathers the interested scientific and professional public to improve theoretical thinking in the field of disaster risk management, as well as improving the actions of competent entities and the forces of the protection and rescue system;
- Organizes campaigns aimed at promoting a culture of reducing disaster risk;
- Conducts education of citizens, students and pupils by the adopted education programs;
- Influences decision-makers in the country to base their decisions regarding emergency risk reduction on the results of the latest research and recommendations of relevant international organizations in the field of emergency risk management.
- Prepares Acts on risk assessment in the field of disasters and private security, as well as plans for the protection and rescue of people and their property.

TESTIMONIAL



PROF. DR VLADIMIR M. CVETKOVIĆ

President of Scientific-Professional for Disaster Risk Management (SPS-DRM)
Director of International Institue for Disaster Research (IDR)

"Natural and man-made hazards that lead to disasters will become increasingly complex and severe in the future. People should not be passive but actively engage in proactive mitigation, which means mitigating the potential consequences of future disasters. The path we choose and the consequences of our decisions in the future depend on us. God has granted us the freedom of choice, and it is our responsibility to make the right decisions. We must not remain idle; instead, we should proactively prepare for worst-case scenarios involving threats to people's safety, whether caused by natural or man-made disasters."



CONNECT WITH US TODAY!

+381 61 572 31 20

institute.disaster.research@gmail.com

www.idr.edu.rs

121 Dimitrija Tucovića, Belgrade

RESEARCH DEPARTMENTS

It comprises multiple research departments, each specializing in distinct research areas:

- **DEPARTMENT FOR PHENOMENOLOGY, ENDANGERMENT, AND DISASTER RESILIENCE RESEARCH**
- **DEPARTMENT FOR DISASTER PREPAREDNESS AND MITIGATION RESEARCH**
- **DEPARTMENT FOR DISASTER PROTECTION AND RESCUE RESEARCH**
- **DEPARTMENT FOR DISASTER RECOVERY RESEARCH**
- **DEPARTMENT FOR DISASTER RISK MANAGEMENT**
- **DEPARTMENT FOR INTERNATIONAL COOPERATION IN DISASTER RISK REDUCTION AND LEGAL FRAMEWORK RESEARCH**



SCIENTIFIC-PROFESSIONAL SOCIETY FOR DISASTER RISK MANAGEMENT

INTERNATIONAL INSTITUTE FOR DISASTER RESEARCH

The core mission of the International Institute for Disaster Research (IDR) primarily revolves around conducting rigorous scientific research in the field of disaster studies. This extensive research work is systematically carried out within the Institute, which serves as the hub for these endeavours. The Institute's headquarters, where all these research activities are coordinated, are located at the specified address.

THE MISSION

Admitting researchers is a deliberate endeavour aimed at assembling and nurturing a dynamic team of young, dedicated, and ambitious research associates. This team is envisioned to actively engage in a wide spectrum of activities, including the authorship of both national and international projects, their meticulous execution, rigorous scientific research, and the publication of scholarly papers and monographs within the realm of disaster studies.



PUBLICATIONS AND PROJECTS

Disaster Research (IDR) has been dedicated to fulfilling its mission through a dual approach, focusing on publishing activities and the enrichment of the theoretical knowledge base within the field of disaster risk management.

This commitment to publishing encompasses a diverse range of activities, including the production of research papers, comprehensive reports, informative articles, and scholarly books. Through these publications, the IDR aims to share insights, findings, and best practices that can contribute to a more informed and prepared global community.



INTERNATIONAL JOURNAL OF DISASTER RISK MANAGEMENT

Scientific-Professional society for
disaster risk management
Belgrade, Serbia

Editor-in-Chief
prof. dr Vladimir M. Cvetković
University of Belgrade, Faculty of Security Studies

disaster.risk.management.serbia@gmail.com





BECOME A MEMBER!

SCIENTIFIC-PROFESSIONAL SOCIETY FOR DISASTER RISK MANAGEMENT





- Field training
- Seminars
- Courses
- Workshops

- Training
- Publications
- Journals
- Conferences













+381 61 572 31 20

naucno_drustvo

www.upravljanje-rizicima.com

upravljanje.rizicima.vs@gmail.com

SCIENTIFIC-PROFESSIONAL SOCIETY FOR DISASTER RISK MANAGEMENT

2018.



CONTACT
+381 61 572 31 20

ACTIVITIES

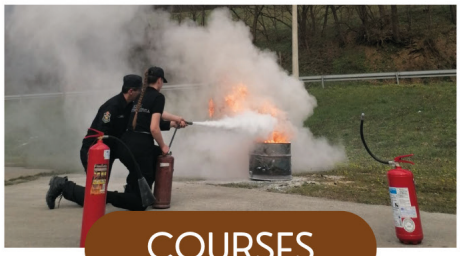
- Field training
- Seminars
- Courses
- Workshops
- Trainings
- Publications
- Newspapers
- Proceedings



TRAINING



WORKSHOPS



COURSES



SEMINARS

Information

If you work or are interested in training in the field of emergency situations, you want to train or become a member of the civil protection unit and provide help to vulnerable people - APPLY via email - upravljanje.rizicima.vs@gmail.com

"Be prepared for emergency situations and protect others"

naucno_drustvo | upravljanje.rizicima.vs@gmail.com | wwww.upravljanje-rizicima.com

TABLE OF CONTENS

Dragisa Jurisic, Žarko Marčeta
Collaborative Gaps: Investigating the Role of Civilian-Religious Authority Disconnection in Psychosocial Support Provision during the 2014 Floods 1

Mosekama Osia Mokhele
Centres or Units: Making Sense of Decentralisation of Disaster Management in South African Municipalities 19

Faicel Tout, Nouh Rebouh, Haythem Dinar, Yacine Benzi, Zakaria Zouak
The Contribution of Roads to Forest Fire Protection in Tamza Municipality, Northeast Algeria 39

Yudhistra A. Kumar
Business Continuity Planning for the Hazardous Chemical Handling Industry: A New Conceptual Approach 51

Fikret Emre Öcal, Salih Torun
An Inevitable Technological Disaster Type: Space Debris 61

Dalibor Milenković, Vladimir M. Cvetković, Renate Renner
A Systematic Literary Review on Community Resilience Indicators: Adaptation and Application of the BRIC Method for Measuring Disasters Resilience 79

Sukhdeep Kaur, Kashmir Singh
Private sectors' interventions in Disaster Risk Management 105

Henderson K. Balanggoy
Implementation of Disaster Risk Reduction and Management 119

Manindra Singh Hanspal, Bijayananda Behera
Role of Emerging Technology in Disaster Management in India: An Overview 133

Vladimir M. Cvetković, Renate Renner, Vladimir Jakovljević
Industrial Disasters and Hazards: From Causes to Consequences— A Holistic Approach to Resilience 149

Goran Milošević, Cvjetana Cvjetković – Ivetić, Luka Baturan
State Aid in Reconstruction of Natural and Other Disasters' Consequences Using the Budget Funds of the Republic of Serbia 169

Nikola Vidović, Hatidža Beriša, Vladimir M. Cvetković
Optimising Disaster Resilience Through Advanced Risk Management and Financial Analysis of Critical Infrastructure in the Serbian Defence Industry 183

Aleksandar Ivanov
Disaster Risk Reduction and Disaster Risk Management: State of Play in North Macedonia 201

Oluwayemisi Ireti Ogunleye, Segun Joseph Arohunsoro
An Assessment of Socio-Economic Impacts of Rainstorm Disaster on the Livelihood of the Residents of Ikole Local Government Area in Ekiti State, Nigeria 213

Ivica Đorđević, Jasmina Gačić
Sustainable Recovery: the Link Between Development and Response to Disasters 223

Nouh Rebouh, Faicel Tout, Haythem Dinar, Yacine Benzid, Zakaria Zouak
Integrating Multi-Source Geospatial Data and AHP for Flood Susceptibility Mapping in Ain Smara, Constantine, Algeria 245

Rajagopal, Parameswaran Kunjukrishnan, Sreekala Krishnakumariamma
Understanding Crowd Dynamics and Disaster Risks in Kerala Temple Festivals: Strategies for Effective Management 265

Hatidža Beriša, Vanja Cvetković, Aleksandar Pavić
Implications of Artificial Intelligence and Cyberspace on Risk Management Capabilities 279

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research article

Collaborative Gaps: Investigating the Role of Civilian-Religious Authority Disconnection in Psychosocial Support Provision during the 2014 Floods

Dragisa Jurisic[1*], **Žarko Marčeta**[1]

1 Security Research Center, Banja Luka, Bosnia and Herzegovina; bicbl@yahoo.com (D.J.); marcetazarko@gmail.com (Z.M.)

* *Correspondence*: bicbl@yahoo.com

Received: 13 August 2024; Revised: 20 October 2024; Accepted 18 November 2024; Published: 25 December 2024

ABSTRACT

This study examines the collaborative dynamics between civilian and religious authorities in providing psychosocial support following the 2014 floods in the Sava, Vrbas, and Vrbanja River Basins in the Republic of Srpska / Bosnia and Herzegovina. Through surveys with 275 residents and interviews with civil and religious authorities, a notable pattern emerged: while both groups expressed a mutual desire to work together, a reluctance to initiate collaboration hindered progress. Interviews revealed that each group awaited an invitation from the other, resulting in a standstill despite shared interests in cooperation. The study identifies several underlying reasons for this hesitation. Uncertainties about roles, responsibilities, and communication channels contributed to the impasse, perpetuating a cycle of inaction. Despite recognizing the importance of supporting disaster-affected communities, the absence of proactive outreach from either side sustained the disconnect. This research underscores the significance of addressing these collaborative barriers. It emphasizes the need for clear communication, mutual understanding, and proactive engagement to foster effective collaboration between civilian and religious authorities. By creating an environment conducive to openness and initiative-taking, stakeholders can overcome hurdles and enhance disaster response and resilience efforts. The findings have implications for policymakers, practitioners, and community leaders involved in disaster management. By acknowledging and addressing the challenges inhibiting collaboration, stakeholders can unlock the potential of civilian-religious partnerships to strengthen psychosocial support provision and build more resilient communities in the face of future disasters.

KEYWORDS

Collaboration, civilian, religious authorities, psychosocial support, disaster management

1. Introduction

In May 2014, the Western Balkans, comprising Bosnia and Herzegovina, Croatia, and Serbia, encountered catastrophic floods triggered by intense cyclonic activity and heavy rainfall. The Sava River Basin, which spans these countries, was severely affected, particularly impacting urban and

rural areas along tributaries like the Vrbas River in Banja Luka (Rajcevic et al., 2016). The floods caused extensive damage across the region, with Bosnia and Herzegovina bearing a significant brunt. Approximately 81 municipalities in Bosnia and Herzegovina were affected, leading to the displacement of 90.000 people, including 60.000 vulnerable children. Tragically, the event claimed 25 lives and caused economic losses amounting to billions of dollars, equivalent to 15% of Bosnia and Herzegovina's GDP (European Commission, 2014; CERF, 2015). Environmental factors such as deforestation and riverbed erosion exacerbated the floods' impact, intensifying vulnerabilities in both urban and rural settings (ICPDR, 2015). Humanitarian operations were quickly deployed in response to the tragedy, with physical healthcare, psychosocial support, livelihood recovery, temporary housing, WASH facilities, protection services for vulnerable people, concerns related to land and house ownership, psychosocial support, and mine action given top priority. Temporary housing, WASH facilities, protection services, and mine action were among the priority areas (European Commission, 2014; CERF, 2015).

The health and social protection sector in the Republic of Srpska responded to natural disasters in 2010 and 2014 by providing psychosocial support to the affected population (Latinović, 2013; 2014). The Ministry of Health and Social Protection responded to floods by reducing illnesses and injuries, and minimizing negative social and economic consequences. In May 2014, the Ministry of Health and Social Protection formed the Team for Coordination of Psychosocial Aid and Support, involving experts from various ministries and non-governmental organizations in the Republic of Srpska (МЗиСЗ РС, 2014). The Team consisted of members from the Ministry of Health and Social Welfare, Ministry of Family, Youth, and Sports, Ministry of Education and Culture, Institute of Public Health, Coordination Center for Mental Health, Association of Psychiatrists, Psychological Society and Association of Professional Workers in Social Activities. The Republic of Srpska declared a state of emergency on May 17, 2014, due to an immediate danger of flooding. The Team for Coordination of Psychosocial Aid and Support was formed on May 21, 2014. The formation of this Team on May 21, 2014, indicates a delayed response in organizing preventive actions during the initial phase of disaster management (Марчета, 2021). It was only after this date that an Action Plan with specific measures, activities, and timelines was formulated and executed between May 21, 2014, and May 26, 2014 (МЗиСЗ РС и ДПРС, 2015). The first activities were to support Primary Health Care teams in affected municipalities. Psychologists, psychiatrists, and family medicine practitioners were dispatched to various cities, facilitating communication with crisis headquarters, reception centers, hospitals, Primary Health Care centers, Social Welfare Centers, and the Red Cross of the Republic of Srpska. The psychological needs of the affected population were identified, and initial assistance was provided to normalize situations. The events of May 2014 indicate that the system of protection and rescue in the field of psychosocial assistance missed preventive activities for protection and rescue and most of the operational activities (Марчета, 2021). It acted at the time of the risk of danger and carried out operational activities for protection and rescue, that is, activities that are undertaken to eliminate the consequences during the danger and after the end of the danger. Namely, after the disaster, key recovery activities are carried out, i.e. reconstruction and rehabilitation through quick action and recovery measures. The most difficult period for victims occurs after a disaster (Rao, 2006). In this stage of disaster management, the organization of subjects and the mobilization of the forces of the psychosocial assistance system of the Republic of Srpska responded to the requirements (Марчета, 2021).

Natural disasters, such as the catastrophic floods that struck the Sava, Vrbas, and Vrbanja River Basins in 2014 in the Republic of Srpska / Bosnia and Herzegovina, often result in critical psychosocial challenges for affected individuals and communities (Gray et al., 2020; Haroz et al., 2020; ELRHA, 2021; Bangpan et al., 2024). The provision of effective psychosocial support during such crises requires collaboration among various stakeholders, including governmental agencies, non-governmental organizations (NGOs), and religious institutions (IASC, 2007; World Health Organization, War Trauma Foundation, & World Vision International, 2011, 2013; Sphere Association, 2018). However, gaps in collaboration and coordination between these entities can hinder the delivery of timely and adequate assistance to those in need (Gray et al., 2020; Haroz et al., 2020; ELRHA, 2021; Bangpan et al., 2024).

While representatives of governmental agencies and non-governmental organizations were actively involved in disaster response efforts as members of the Team for Coordination of Psychosocial Aid and Support in the Republic of Srpska, religious authorities were notably absent from the coordination team (Марчета, 2021). This study aims to investigate the collaborative gaps between civilian and religious authorities in psychosocial support provision during the 2014 floods. By examining the perspectives and experiences of residents and representatives from religious communities, governmental agencies, and non-governmental organizations, the research seeks to identify challenges and opportunities for improving collaboration in disaster response efforts.

This study employs a mixed-methods approach to investigate the role of religious institutions in flood disaster management, focusing on the 2014 floods in the Sava, Vrbas, and Vrbanja River Basins in the Republic of Srpska / Bosnia and Herzegovina. By employing a mixed-methods approach, this research aims to provide in-depth insights into the contributions of religious institutions to disaster resilience and recovery, informing more effective and inclusive approaches to disaster management in the future. The research methodology involves conducting surveys with 275 residents from the affected areas and interviews with representatives from governmental and non-governmental organizations, as well as religious institutions. Survey data and interview responses were analyzed to explore the role of civilian-religious authority disconnection in psychosocial support provision during the 2014 floods. This study employs a mixed-methods approach to investigate the role of religious institutions in flood disaster management, focusing on the 2014 floods in the Sava, Vrbas, and Vrbanja River Basins in the Republic of Srpska / Bosnia and Herzegovina. By employing a mixed-methods approach, this research aims to provide in-depth insights into the contributions of religious institutions to disaster resilience and recovery, informing more effective and inclusive approaches to disaster management in the future. The research methodology involves conducting surveys with 275 residents from the affected areas and interviews with representatives from governmental and non-governmental organizations, as well as religious institutions. Survey data and interview responses were analyzed to explore the role of civilian-religious authority disconnection in psychosocial support provision during the 2014 floods.

This paper is structured and consists of five parts. Part one is an introduction. In the second part, methods are presented. The third part contains the findings of research conducted in the period August-December 2020. The fourth part refers to the discussion of the research results, while the conclusion is given at the end.

1.1. Literary review

Natural disasters pose significant challenges to affected communities, not only in terms of physical infrastructure but also regarding the psychological and social well-being of individuals. Effective psychosocial support provision is essential in mitigating the adverse impacts of disasters and promoting resilience among survivors. In times of crisis, individuals often turn to religious institutions for psycho-logical solace and communal support, fostering a positive psychological response that bolsters societal resilience (Cvetković, Romanić, & Beriša, 2023). While existing literature acknowledges the importance of collaboration between civilian and religious authorities in disaster management, there remains a gap in understanding the dynamics of these partnerships and their impact on psychosocial support provision. However, according to the research in Serbia religious rituals strengthen collective identity, and research suggests the need for a stronger focus by religious institutions on disaster preparedness (Cvetković, Šišović; 2024). Moreover, research in Croatia showed that in the context of a clinical approach, psychospiritual treatments could serve as valuable help for persons who need an integrated type of help (Ruter, 2023.)

Civilian authorities, including governmental agencies and non-governmental organizations, play a vital role in coordinating and implementing psychosocial support programs during disasters. They are responsible for providing crisis intervention, counseling services, and community outreach initiatives to address the psychological and social needs of affected populations (World Health Organization, War Trauma Foundation, & World Vision International, 2011, 2013; Sphere Association,

2018). Conversely, religious authorities, such as churches, mosques, temples, and synagogues, serve as central hubs within communities, offering spiritual and emotional support to disaster survivors (Dein et al., 2010; Koenig, 2012; Baidhawy, 2015; JLI, 2022). Religious organizations play a significant role in the recovery phase by offering essential material aid and psychological care to affected populations. Moreover, their messaging during disasters holds critical significance, influencing public perceptions and disaster risk communication strategies (Cvetković, Romanić, & Beriša, 2023). However, the collaboration between these stakeholders is often overlooked in disaster management literature. Collaborative partnerships between civilian and religious authorities are essential for ensuring effective and comprehensive psychosocial support provision during disasters. Studies have shown that coordinated efforts between multiple stakeholders lead to better mental health outcomes for affected populations (Baidhawy, 2015). Religious institutions possess unique strengths, such as deep-rooted community connections and cultural competence, which complement the resources and expertise of civilian authorities (Rahmani et al., 2022). Therefore, leveraging these strengths through collaborative partnerships can maximize the impact of psychosocial support interventions. Despite the potential benefits of collaboration, several challenges exist in establishing and maintaining partnerships between civilian and religious authorities. These challenges include differences in organizational structures, communication barriers, and varying priorities (Dein et al., 2010; Rahmani et al., 2022).

In disaster settings, religious authorities and institutions often serve as pillars of support for affected communities, offering spiritual guidance, comfort, and hope during times of crisis. Religious leaders play a significant role in providing psychosocial support by addressing the emotional and spiritual needs of disaster survivors (Baidhawy, 2015; Cvetković, Romanić, & Beriša, 2023). The involvement of religious authorities in disaster management varies across contexts and is influenced by factors such as cultural norms, religious beliefs, and government policies (Dein et al., 2010; Rahmani et al., 2022). Studies have highlighted the importance of collaboration between civilian and religious authorities in disaster response and recovery efforts. Religious institutions often have extensive networks within their communities, allowing them to reach vulnerable populations and provide essential services (Pargament et al., 2011). Additionally, religious leaders are often viewed as trusted figures, making them valuable partners in delivering psychosocial support programs (Fitchett et al., 2004; Koenig et al., 2012). However, challenges exist in fostering collaboration between civilian and religious authorities. Differences in organizational structures, priorities, and approaches to disaster management can hinder effective partnerships. Moreover, concerns regarding the separation of church and state may influence the extent to which religious institutions are involved in government-led initiatives. Despite these challenges, studies have shown that successful collaboration between civilian and religious authorities can enhance the resilience and well-being of disaster-affected communities (Pargament et al., 2011; Koenig et al., 2012).

Faith-based organizations (FBOs) and religious denominations are crucial in disaster response efforts due to their networks, resources, and commitment to serving communities in need (FEMA, 2013). FBOs provide material assistance, spiritual and emotional support, and mobilize volunteers, donations, and expertise to address community needs (Martin, 2008; Clarke, 2008; Baidhawy, 2015; Borpujari, 2021). They collaborate with secular organizations, government agencies, and other FBOs to maximize their impact. The events that took place in Serbia provide tools for understanding the disaster response capacity of FBOs and produce lessons relevant to the regional contexts. Serbia experienced destructive floods in May 2014 and was also affected, which ruined households, physical systems, and social enterprises. It also, however, laid bare several weaknesses of the disaster response and frustrated the government's efforts to deal with the challenges in certain rural localities (Catholic Relief Services, 2016). In particular, Catholic Relief Services (CRS) and Philanthropy (in Serbian: Човекољубље), a charity controlled by the Serbian Orthodox Church, were among the quickest organizations to respond to immediate needs. While CRS's interventions were cash-based, targeted for both immediate assistance and recovery efforts, Philanthropy used its established presence within the Orthodox Christian Church in Serbia to assist target groups well (Catholic Relief Services, 2016). This ensured that aid was allocated in a manner that reflected actual needs thereby closing the divide between government provisions and community expectations.

The inclusion of FBOs in disaster management frameworks is important to enhance community resilience by leveraging regional expertise, customs, and spiritual support networks (Borpujari, 2021). The American disaster relief system is primarily top-down, leading to disaster relief fatigue and requiring local communities to play a larger role. FBOs can include various religious affiliations like Christianity, Islam, Judaism, Hinduism, and Buddhism (Goldberg, 2015). Religious denominations often have their own disaster relief agencies or networks, mobilizing resources and volunteers for disaster response and recovery (FEMA, 2013). They use their congregations, clergy, and re-sources to provide immediate and long-term assistance to affected communities. Religious institutions have historically provided immediate relief and long-term support in disaster-affected communities, often acting as community hubs. However, they face challenges such as limited resources, capacity gaps in disaster management expertise, and exclusionary practices towards religious minorities or differing belief systems (Borpujari, 2021). Kyoo-Man Ha's study on Korean disaster management (2015) emphasizes the importance of religious beliefs and institutions, particularly Christianity, Buddhism, and Confucianism. It emphasizes the need for cultural adaptations and comprehensive disaster management understanding. The study advocates for collaboration among different religions and effective dissemination of disaster management information. It also warns against competition and conflict among religious groups during disaster recovery. Collaboration between religious denominations, FBOs, and secular organizations is vital for comprehensive aid delivery. Some researches show synergistic benefits from partnerships between these entities, utilizing resources, expertise, and networks to better meet diverse populations' needs (Clarke, 2008; FEMA, 2013; Baidhawy, 2015; Goldberg, 2015; Borpujari, 2021).

Understanding the multifaceted role of religious beliefs in disaster contexts is essential for developing inclusive and effective disaster management strategies that cater to diverse societal needs (Cvetković, Romanić, & Beriša, 2023). Political initiatives that combine theoretical perspectives, advocate for interreligious cooperation, and effectively disseminate disaster management information to local religious institutions need to be encouraged (Ha, 2015). The Circle of Serbian Sisters, Merhamet, and Caritas are a few organizations in Bosnia and Herzegovina that are committed to humanitarian and charitable work; each has a unique mission and cultural context (Савић, 2009; Gavrić, Banović, & Barreiro, 2013; Caritas, 2024). Usually connected to Serbian Orthodox communities and churches is the Circle of Serbian Sisters organization (Савић, 2009). Its main objectives are to support and assist the underprivileged members of the Serbian community through humanitarian endeavors, cultural preservation, and financial assistance for church-related events. Based in Bosnia and Herzegovina, but with operations also in other areas, Merhamet acts as an Islamic humanitarian organization (Gavrić, Banović, & Barreiro, 2013). Its main objective is to offer assistance and support to marginalized populations, such as refugees, internally displaced people, and those impacted by violence. Merhamet's operations include social services, cultural preservation, and humanitarian aid. An international alliance of Catholic groups dedicated to social assistance, development, and relief is called Caritas It serves those in need, irrespective of their religious or cultural background, by offering development support, disaster relief, and humanitarian help in more than 200 nations and territories worldwide. Caritas concentrates on problems like disaster relief, healthcare, education, and poverty alleviation (Caritas, 2024).

To effectively address the psychosocial needs of disaster survivors, it is necessary to strengthen collaborative partnerships between civilian and religious authorities in disaster management. This can be achieved by formalizing agreements, incorporating religious leaders into decision-making, establishing joint training programs, scheduling meetings, and monitoring partnership effectiveness (Sendai Framework for Disaster Risk Reduction 2015-2030, 2015; IFRC, 2009, 2018; World Health Organization, War Trauma Foundation, & World Vision International, 2011, 2013). By following these guidelines and taking proactive steps, governments and disaster management agencies can enhance their capacity to provide effective psychosocial support during natural disasters. Effective collaboration between religious institutions, humanitarian organizations, and governmental bodies is crucial for developing comprehensive disaster preparedness, response, and recovery strategies. Religious institutions can also play a vital role in long-term recovery and rebuilding processes, facilitating emotional healing and social cohesion (Borpujari, 2021).

2. Methods

This paper presents findings from a larger research project (Марчета, 2021) to assess the preparedness of institutions in the Republic of Srpska for providing psychosocial assistance during natural disasters. The research method involved both semi-structured interviews and surveys to gather data from three distinct groups of respondents.

Semi-Structured Interviews: Two intentional samples, groups G1 and G2, were selected for semi-structured interviews. Group G1 comprised experts from various governmental and non-governmental organizations involved in psychosocial assistance and support during the 2014 floods as members of the Team for Coordination of Psychosocial Aid and Support in the Republic of Srpska. The group G2 consisted of representatives of three traditional religious communities operating in the affected areas (the cities of Banja Luka and Gradiška and the municipalities of Čelinac, Laktaši and Kozarska Dubica). Semi-structured interviews were conducted with purposive and deliberate samples of six respondents from group G1 and eight respondents from group G2, respectively. Interview protocols were developed specifically for each group of respondents to guide the conversation and ensure comprehensive data collection.

Surveys: A convenient sample, group G3 was selected for the survey component of the research. The group G3 consisted of a total of 275 residents living in the affected regions during the 2014 floods. The residents of the cities of Banja Luka and Gradiška and the municipalities of Čelinac, Laktaši, and Kozarska Dubica were surveyed using survey questionnaires with combined questions.

2.1. Data Analysis

Qualitative data from semi-structured interviews were analyzed thematically to identify key themes and patterns related to the roles of religious institutions in disaster management and resilience. Quantitative data from surveys were analyzed using statistical techniques to examine residents' perceptions and experiences. Comparative analysis was conducted to triangulate findings from both qualitative and quantitative data sources, providing a comprehensive understanding of the research topic.

3. Results

The first group of respondents (G1) consisted of experts from the relevant field, the Ministry of Health and Social Welfare, the Ministry of Family, Youth, and Sports, the Ministry of Education and Culture, the Institute of Public Health, the Coordination Center for Mental Health, the Association of Psychiatrists, the Psychological Society, the Association of Professional Workers in Social Services, who were members of the Team for Coordination of Psychosocial Aid and Support in the Republic of Srpska during the 2014 floods. The Ministry of Health and Social Welfare of the Republic of Srpska issued a Decision on the Appointment of the Team for Coordination of Psychosocial Aid and Support in the Republic of Srpska on May 21, 2014 (МЗиСЗ РС, 2014). According to the mentioned document, 10 representatives were appointed. It was planned to conduct research with all 10 representatives. However, one respondent was no longer employed, and another was on sick leave at the time of the survey, while two respondents refused to participate in the interview. The research was conducted on an intentional sample of six respondents in September 2020.

The second group of respondents (G2) consisted of representatives of three traditional religious communities operating in the affected areas (the cities of Banja Luka and Gradiška and the municipalities of Čelinac, Laktaši and Kozarska Dubica): the Serbian Orthodox Church, the Eparchy of Banja Luka, the Roman Catholic Church, the Diocese of Banja Luka and the Islamic Community in Bosnia and Herzegovina, Majlis of the Islamic Community of Banja Luka. The research was conducted on an intentional sample of eight respondents, during the period from October to December 2020.

The third group of respondents (G3) consisted of residents of Republic of Srpska living in the cities of Banja Luka and Gradiška, as well as in the municipalities of Čelinac, Laktaši, and Kozarska Dubica. A convenient sample of a total of 275 residents was formed, with 55 participants from each of the two cities and three municipalities. The research was conducted between August and October 2020.

3.1 Group G1

Based on the responses gathered from experts involved in the Team for Coordination of Psycho-social Aid and Support in the Republic of Srpska during the 2014 floods, here are the summarized findings regarding the inclusion of a representative of the religious community in the psychosocial support system during natural disasters.

All experts interviewed agreed that a representative of the religious community should be part of the psychosocial support system during natural disasters. They emphasized the authority and influence that religious leaders hold within their communities, which can be instrumental in mobilizing support and care for affected individuals. The involvement of religious communities was seen as indispensable not only for spiritual and moral support but also for accessing material resources through affiliated charitable organizations like the Circle of Serbian Sisters, Merhamet, or Caritas.

Religious representatives were perceived, by experts, as capable of reaching and mobilizing their followers effectively, thereby enhancing community resilience and response. Their inclusion was viewed as essential for fostering solidarity and compassion within communities, which are vital for psychosocial recovery after a disaster.

Moreover, experts advocated for a holistic approach that integrates various stakeholders, including religious leaders, to maximize the effectiveness of psychosocial support initiatives. This approach recognizes the diverse needs of disaster-affected populations and leverages community networks and re-sources for comprehensive support.

The research highlighted a unanimous agreement among experts that integrating a representative of the religious community into the psychosocial support system during natural disasters is beneficial. Their role in providing spiritual guidance, mobilizing resources, and fostering community solidarity was recognized as pivotal for effective disaster response and recovery. This perspective underscores the importance of inclusive and collaborative approaches that leverage community strengths and support mechanisms in times of crisis.

3.2 Group G2

When it comes to the group G2 there were some questions that were analyzed. The first question for a group G2 was: *What is the role of your religious community in reducing the psychological and social effects of natural disasters on individuals and communities in the circumstances of a natural disaster?*

According to the answers, the role of religious communities in reducing the psychological and social effects of natural disasters in the Republic of Srpska is multifaceted and necessary, as highlighted by representatives of traditional religious communities in the region.

Moreover, religious communities are deeply embedded in the daily lives of individuals and com-munities. They provide both material assistance (such as basic necessities) and advisory support during natural disasters. The familiarity with community members allows religious leaders to address specific needs effectively, offering comfort and reassurance in times of crisis.

However, representatives of three traditional religious groups agreed that during critical times like floods, religious symbols and rituals play a significant role. For instance, the ringing of church bells during floods in 2014 provided emotional support and a sense of solidarity among parishioners. Religious gatherings and joint prayers serve to strengthen the spiritual and emotional resilience of believers, helping them cope with the trauma and uncertainty caused by natural disasters.

Also, religious leaders inform affected individuals about available resources and direct them to relevant public institutions or organizations for assistance. They play a role in educating the community about coping mechanisms and resilience-building strategies in the face of disaster.

At the end, all religious communities collaborate closely with humanitarian and non-governmental organizations to expand support networks and resources. They emphasize the importance of community cohesion and strengthen family ties and relationships to foster a supportive environment for recovery.

Answers showed that specific initiatives, such as psychosocial support teams organized by entities like Caritas of the Banja Luka Diocese, focus on vulnerable groups like the elderly, women, and children, took a place. These teams provide essential psychosocial support aimed at empowering the affected community and promoting long-term well-being through individual and group interventions.

Religious communities in Republic of Srpska play a pivotal role not only in meeting immediate physical needs but also in addressing the profound psychological and social impacts of natural disasters. Their activities are deeply integrated into community life, providing vital support systems during times of crisis. Activities were directed in two directions to material assistance and to advisory support.

The second question for group G2 was: *What were the experiences of your religious community regarding the mentioned role during natural disasters – floods in 2010 and 2014?*

Taking under considerations answers of the religious experts, during the 2010 and 2014 floods in Bosnia and Herzegovina, religious communities played a critical role in disaster response efforts. Despite extensive damage to infrastructure and residential areas, they provided aid and support to those affected.

It is important to notice that the floods highlighted the vulnerability of society but also showcased its resilience and capacity to unite in times of crisis. Religious communities mobilized believers and volunteers to collectively respond to the disasters. These community organizations were the key in mitigating the immediate and long-term consequences of the floods.

However, religious communities actively procured and distributed substantial material aid to those affected by the floods. This aid included essentials such as food, clothing, and other necessities. They managed to reach a significant portion of the affected population, demonstrating their reach and organizational capabilities.

Also, in rural areas particularly, religious communities played a crucial role in organizing assistance for livestock, ensuring that even agricultural needs were addressed amidst the disaster.

All those efforts were largely supported by volunteers from within the religious communities, showing a strong commitment to humanitarian action and community service during crises.

At the end, the response of religious communities during the 2010 and 2014 floods in Bosnia and Herzegovina was characterized by effective mobilization, coordination, and tangible assistance to those in needs. Their positive experiences underscore the importance of community solidarity and the significant role that religious institutions can play in disaster response and relief efforts, complementing the efforts of governmental and non-governmental organizations.

The third question for religious leaders was: *Was the role of your religious community in the circumstances of a natural disaster recognized by relevant authorities (the Team for Coordination of Psychosocial Aid and Support - at the republic level, crisis staff - at the local level)?*

The religious community in Bosnia and Herzegovina has been largely overlooked or disregarded by authorities responsible for coordinating psychosocial support or crisis management. This lack of recognition is attributed to several factors, including the lack of recognition of their efforts and initiatives by the Team for Coordination of Psychosocial Aid and Support at the republic level and crisis staff at the local level. Reasons for that can be found in several factors.

One of the first factors is related to secular nature of the state. Respondents believed that Bosnia and Herzegovina's secular state structure played a significant role. Authorities may have been hesitant to involve religious communities due to concerns about maintaining the separation of religion and state, fearing criticism or condemnation for perceived violations of this principle.

Moreover, the complex political environment in Bosnia and Herzegovina was also cited as a barrier. It was easier for authorities to avoid joint action with religious communities rather than navigate potential political sensitivities and justifications.

Also, there were significant communication challenges between religious communities and governmental authorities. Respondents noted weak communication and loose coordination, which hindered effective collaboration in disaster response efforts.

Despite their contributions, religious communities reported rare expressions of gratitude or acknowledgment from authorities. This lack of recognition further underscored the marginalization of their role in disaster response.

While religious communities actively engaged in disaster response through their own initiatives and efforts, their contributions were generally not integrated or recognized by governmental authorities in Bosnia and Herzegovina. This disconnect highlights significant challenges in fostering effective collaboration between religious and state institutions during crises.

The fourth question for group G2 was: *Should a representative of the religious community be part of the psychosocial support system (the Team for Coordination of Psychosocial Aid and Support in the Republic of Srpska in the circumstances of a natural disaster)?*

The argument bellow strongly supports the inclusion of a religious community representative in the psychosocial support system's Coordination Team during natural disasters in the Republic of Srpska, as it provides essential support and coordination for the community's well-being and recovery.

The natural disasters often trigger religious needs among affected individuals. Regardless of their specific religious affiliation, people may turn to their faith for comfort and support during crises.

Moreover, religious communities have an inherent obligation to assist those in need, including during natural disasters. Their involvement ensures that spiritual and emotional support aligns with the cultural and religious backgrounds of the affected population.

Also, representatives from religious communities are often local residents who understand the community dynamics, cultural norms, and specific needs of the affected population. This local knowledge enhances the effectiveness of psychosocial support efforts.

The answers suggest that the role of the religious community representative should be advisory within the Coordination Team. This implies that their expertise in understanding community needs and providing culturally sensitive support would inform decision-making and implementation strategies.

However, the overarching goal is to provide comprehensive assistance that respects the diversity of religious beliefs and nationalities among the affected population. Including a religious community representative helps ensure that support efforts are inclusive and responsive to all individuals' needs.

The answers argue convincingly that having a representative of the religious community in the psychosocial support system's Coordination Team is beneficial. Their inclusion supports the provision of effective, culturally sensitive, and inclusive assistance during natural disasters.

The last fifth question for group G2 was: *In your opinion, how can, the way your religious community provides psychosocial support in the circumstances of natural disasters, be improved?*

Based on the responses gathered regarding how religious communities can improve their psychosocial support during natural disasters, several key themes emerge.

At the beginning is important to notice that there is a unanimous agreement among respondents on the importance of preventive measures. This includes proactive coordination and cooperation with government mechanisms and local crisis teams. Preventive action is seen as essential not just in mitigating disaster impact but also in enhancing overall preparedness.

Respondents suggest that religious community representatives could play an advisory role within local crisis teams and organizations. Their intimate knowledge of the community and its needs can con-tribute significantly to effective disaster response strategies.

Also, the strength of religious communities lies in their deep local roots and personal familiarity with community members. Leveraging this knowledge can tailor psychosocial support more effectively to meet individual and community needs during disasters.

However, the emphasis is placed on non-profit activities that directly benefit the community. This contrasts with purely project-based initiatives that may not always address immediate community needs during crises.

Volunteers are highlighted as paramount resources in disaster prevention and response efforts. Mobilizing retired professionals with relevant skills (psychologists, educators, military officers, etc.) is seen as particularly valuable due to their expertise and local knowledge.

Moreover, education is cited as a central preventive measure. By educating the population on disaster preparedness and response, communities can better protect themselves and mitigate the destructive consequences of natural disasters.

These insights underline the potential for religious communities to enhance their psychosocial support capabilities through proactive measures, local engagement, volunteer mobilization, and educational initiatives. Effective collaboration with governmental bodies and a focus on community-specific needs are also seen as critical for improving disaster resilience and response.

3.3 Group G3

The following section will present findings from a survey conducted with residents of the Republic of Srpska, specifically those living in the cities of Banja Luka and Gradiška, as well as in the municipalities of Čelinac, Laktaši, and Kozarska Dubica, during the 2014 floods.

The findings indicate that 22.18% of respondents used self-reliance as a coping mechanism for stress, while 17.45% used family support. None mentioned religion as a coping mechanism, and 0.55% used professional help. The most common combination was self-reliance and family support. The impact of natural disasters was affirmed by 18.18%, with 43.27% identifying them as significant stressors. Despite the potential role of religion in providing coping mechanisms, none mentioned using it. A significant majority (87.63%) acknowledged natural disasters as stressors, indicating a widespread recognition of their psychological impact. The findings highlight the prevalence of individual and familial coping mechanisms in dealing with stress, with a notable absence of religious coping mechanisms.

The results suggest that despite the recognition of the need for diverse forms of psychosocial support during natural disasters, including basic life needs, material aid, healthcare, and psychological support, there is a notable lack of acknowledgment of the role of religious communities in satisfying spiritual needs. The majority of respondents (73.09%) acknowledged a combination of these forms, indicating a holistic approach that considers multiple dimensions of support beyond basic necessities like food and shelter. However, only 2.64% mentioned satisfying spiritual needs, suggesting a potential oversight or underestimation of this component in disaster support systems. The outcomes underscore the need for a comprehensive approach to psychosocial support in the context of natural disasters.

The results reveal that 68.00% of respondents believe that multiple institutions and organizations have an obligation to provide psychosocial support during natural disasters. Crisis management teams and medical institutions are the most prominent in providing this support, with 37.55% of

individual responses and 13.82% of respondents overall believing this is their obligation. Medical institutions have a similar obligation, with 39.06% and 8.00% of respondents recognizing this. Religious communities are acknowledged by 10.52%, but only 0.73% of respondents see them as having an obligation. NGOs are not mentioned as having an obligation. The majority of respondents believe multiple institutions should provide psychosocial support during natural disasters, with crisis management teams and medical institutions being the most prominent.

The findings reveal that religious communities provide psychosocial support to disaster-affected and endangered populations, with 14.91% of respondents stating they always provide such support. However, the majority of respondents are uncertain about whether religious communities provide such support. The role of religious communities in mitigating stress consequences is perceived as very important by 19.27%, while 45.09% consider it important. Despite differing opinions, a majority of respondents believe the role of religious communities is significant, with nearly two-thirds (64.36%) finding it either very important or important.

The outcomes reveals that religious communities are not the primary source of expert assistance in alleviating psychological issues caused by natural disasters, such as the floods of 2010 and 2014. The majority of respondents sought help from family and friends (23.88%), emphasizing the importance of social networks in providing psychosocial support. Other sources of assistance included crisis management teams, family doctors, non-governmental organizations, psychiatrists, and psychologists. While religious communities have a share of 7.79% in requests for expert assistance, this share is relatively small compared to other sources like crisis management teams and family doctors.

4. Discussion

Interviewed members of the Team for Coordination of Psychosocial Aid and Support in the Republic of Srpska have unanimously agreed that involving religious community representatives in psychosocial support systems during natural disasters is essential. They believe that religious leaders possess significant authority and influence within their communities, which can be vital in mobilizing support and care for affected individuals. This aligns with research conducted by Florine De Wolf (2018), which indicated that religion and spirituality play a significant role in psychosocial support activities for individuals affected by humanitarian crises, as a positive relationship exists between religion, spirituality, and psychological well-being. Religious organizations often have established networks and resources, such as charitable organizations like the Circle of Serbian Sisters, Merhamet, or Caritas, which can provide material support during crises. Religious leaders are perceived as effective mobilizers, fostering solidarity and compassion, and contributing significantly to the psychosocial recovery of communities affected by disasters. A holistic approach to support, integrating various stakeholders, including religious leaders, is emphasized, recognizing that different segments of society have distinct needs and strengths. This inclusive approach ensures that the diverse needs of disaster-affected populations are met comprehensively, utilizing existing community networks and support mechanisms effectively.

While three traditional religious organizations differ in their origins, affiliations, and specific areas of focus, they all share a common commitment to humanitarian principles and the alleviation of suffering among vulnerable populations. Each plays an indispensable role in their respective communities and beyond, contributing to global efforts for social justice and humanitarian relief.

Religious communities in Republic of Srpska play an important role in reducing the psychological and social effects of natural disasters. They provide immediate assistance and support, offering material necessities and advisory support. Religious symbols and rituals, such as the ringing of church bells during floods, provide emotional support and a sense of solidarity among parishioners. Religious leaders also provide information and guidance, directing affected individuals to relevant public institutions or organizations for assistance. They educate the community about coping mechanisms and resilience-building strategies during disasters. Similar findings were reported in De Wolff's research (2018), that the best way to implement psychosocial support activities with a religious or spiritual component is to work closely with local religious and spiritual leaders and

communities because these leaders possess a deeper understanding of the context and needs of affected individuals.

Religious communities collaborate with humanitarian and non-governmental organizations to expand support networks and resources, emphasizing community cohesion and strengthening family ties. Psychosocial support teams, organized by entities like Caritas of the Banja Luka Diocese, focus on vulnerable groups like the elderly, women, and children, providing essential psycho-social support to empower the affected community and promote long-term well-being. Their activities are deeply integrated into community life, providing essential support systems during times of crisis.

During the 2010 and 2014 floods in Bosnia and Herzegovina, religious communities played a crucial role in disaster response efforts. They mobilized believers and volunteers to collectively respond to the disasters, mitigating the immediate and long-term consequences. Religious communities distributed substantial material aid, including essentials like food and clothing, to those affected. They also provided support in rural areas, organizing assistance for livestock and addressing agricultural needs. Volunteer efforts from religious communities largely supported these efforts, demonstrating a strong commitment to humanitarian action and community service during crises. The response of religious communities during these disasters was characterized by effective mobilization, coordination, and tangible assistance to those in need. These experiences highlight the importance of community solidarity and the significant role religious institutions can play in disaster response and relief efforts, complementing the efforts of governmental and non-governmental organizations.

The role of religious communities in Bosnia and Herzegovina during natural disasters is generally not recognized by authorities at the republic and local levels. Factors contributing to this lack of recognition include the secular nature of the state, political dynamics, communication and coordination issues, and the lack of recognition of their efforts. The secular state structure in Bosnia and Herzegovina may have prompted authorities to avoid involving religious communities due to concerns about maintaining the separation of religion and state. Communication and coordination issues between religious communities and governmental authorities were also noted as significant barriers. Despite their efforts, religious communities reported receiving little gratitude from authorities. Their active involvement often went unrecognized, and their contributions were not integrated into government responses, underscoring the challenges of fostering effective collaboration between religious institutions and state authorities during crises. These findings may confirm earlier research by Hirono and Blake (2017), who concluded that clergy should collaborate among themselves and with other professionals in natural disaster relief efforts, and that collaborative efforts between mental health professionals may also be needed health and clergy.

The inclusion of a religious community representative in the psychosocial support system's Coordination Team during natural disasters is highly beneficial. This is because it recognizes religious needs, ensures community assistance, and enhances the effectiveness of psychosocial support efforts. Religious community representatives are often local residents who understand community dynamics and cultural norms, which enhance the effectiveness of psychosocial support efforts. Their advisory role informs decision-making and implementation strategies, and their expertise in understanding community needs and providing culturally sensitive support informs decision-making and implementation strategies. Additionally, their inclusion ensures comprehensive assistance that respects the diversity of religious beliefs and nationalities among the affected population, ensuring that support efforts are inclusive and responsive to all individuals' needs.

The findings reveal that religious communities can improve their psychosocial support during natural disasters through several key themes. Preventive action is critical, including proactive coordination with government and local crisis teams. The current initiative titled "Strengthening Resilience to Natural Disasters and Improving Preparedness Strategies" (PREPS) also attests to the involvement of FBOs in regional disaster response. It was initiated in 2014 in Bosnia and Herzegovina by CRS, in cooperation with Caritas Serbia and Philanthropy in Serbia, with the goal of strengthening community resilience against the impact of natural hazards. With support from the U.S. Agency for International Development (USAID), this project's emphasis lies in local government capacity building, civil protection unit creation, trainings, and preparation of regulatory acts (Caritas Srbije, 2024). It also responds to the local conditions, especially in those areas, which were pinpointed to be

especially fragile to the impact of natural disasters, where improving the protective measures posed considerable advancement. The project started in 2014 and was able to implement its first phase recently. The objective of the second phase of the PREPS project, which is presently underway, is the enhancement of the capacities of 16 municipalities, including 10 in Serbia and 6 in Bosnia and Herzegovina, for the management of disaster risk reduction (Caritas Srbije, 2024).

Religious community representatives can play an advisory role, leveraging their deep local roots and personal familiarity with community members. Additionally, other research shows that psycho-spiritual support and care services are crucial for diminishing long-term adverse psychological impacts following a disaster (Saidon et al., 2020). Non-profit activities that directly benefit the community are preferred, as they address immediate community needs. Volunteerism is emphasized as a valuable resource in disaster prevention and response efforts, especially for retired professionals with relevant skills. Education is also a central preventive measure, as it educates the population on disaster preparedness and response. These insights suggest that religious communities can enhance their psychosocial support capabilities through proactive measures, local engagement, volunteer mobilization, and educational initiatives. Collaboration with governmental bodies and focusing on community-specific needs is also essential for improving disaster resilience and response.

The outcomes highlight the prevalence of individual and familial coping mechanisms in natural disasters, but a significant lack of religious coping mechanisms among respondents. Despite their potential benefits, religious coping mechanisms are underutilized in disaster response strategies. The results suggest that integrating religious support more effectively into disaster response strategies could lead to more comprehensive and inclusive approaches to psychosocial support. While crisis management teams and medical institutions are recognized for their obligation to provide psychosocial support during natural disasters, there is room for broader recognition and integration of other stakeholders, particularly religious communities, in disaster response frameworks. The findings suggest a dual narrative: while religious communities recognize the potential impact and importance of psychosocial support, there is a need for clearer understanding and visibility of their contributions. Increased engagement and integration of religious communities into disaster response structures could maximize their potential benefits in providing psychosocial support to affected populations.

Strengthening collaboration between civilian and religious authorities in disaster management is essential for addressing the psychosocial needs of disaster survivors. This can be achieved through formal agreements, religious leaders' involvement, joint training programs, and monitoring effectiveness. De Wolf (2018) also suggests the need for training local religious and spiritual communities and leaders to respond to the psychosocial needs of individuals in prevision of a humanitarian crisis, while respecting humanitarian ethics. The partnership between CRS and Philanthropy demonstrates the important function of FBOs involvement in regional relief work. The last ten years have shown both the benefits and challenges of working towards a common goal of collaboration among government entities, local authorities and FBOs in disaster response. There are still issues around recognition and inter-agency working, but initiatives like PREPS, however, show the positive side of such collaborations.

5. Conclusions

The research reveals unexpected support from religious organizations in disaster recovery after the 2014 floods in the Sava, Vrbas, and Vrbanja River Basins in Republic of Srpska / Bosnia and Herzegovina. The study emphasizes the vital role of religious organizations in disaster management, especially when local and national authorities did not involve them. The research findings highlight the significant involvement of traditional religious communities in mitigating the psychological and social impacts of natural disasters. They show a dedication to helping others in need, motivated by conviction rather than self-interest, via their proactive activities and extensive support. Nevertheless, there is a need for more institutional acknowledgment and incorporation into official disaster response frameworks, as this involvement is frequently disregarded. By fostering closer collaboration between religious organizations and disaster management structures, communities can benefit

from a more effective approach to disaster resilience and recovery. Clarifying roles, improving coordination, and increasing awareness are essential steps toward leveraging the capabilities of religious institutions in disaster management.

The support systems appear fragmented, lacking clear coordination and delineation of responsibilities. While religious communities are recognized as potential providers of psychosocial support, there's ambiguity regarding their roles and obligations, hindering effective collaboration. Despite recognition, religious support services are underutilized compared to other sources of assistance, indicating potential barriers to access during crises. Collaboration among stakeholders, including religious institutions, is crucial to enhancing the effectiveness of psychosocial support systems in disaster management. While governmental and non-governmental entities undoubtedly play indispensable roles in disaster response and recovery, the inclusion of religious representatives is essential. By acknowledging and leveraging the strengths of religious organizations and leaders, disaster response frameworks can better meet the di-verse needs of affected populations and promote sustainable recovery and resilience.

Addressing collaborative gaps between civilian and religious authorities requires proactive measures to bridge differences, establish formal partnerships, and leverage religious resources effectively. By doing so, disaster management efforts can become more inclusive, culturally sensitive, and ultimately more resilient in the face of future challenges.

Author Contributions: The following actions were undertaken by the research team members: project conceptualization and execution, questionnaire dissemination and data collection Ž.M.; data analyze and interpretation and theory development, Ž.M. and D.J.; writing – original draft preparation, Ž.M.; writing – review and editing, Ž.M. and D.J.; while D.J. critically reviewed the data analysis and contributed to the content for revising and finalizing the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgments: The authors express their gratitude to the anonymous reviewers for their comments, as well as to the participants of this study, whose willingness to share their experiences added depth and richness to this research.

Conflicts of Interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Baidhawy, Z. (2015). The role of faith-based organization in coping with disaster management and mitigation: Muhammadiyah's experience. *Journal of Indonesian Islam, 9*(2), 167-194. https://doi.org/10.15642/JIIS.2015.9.2.167-194 , *Accessed: 2024-06-10.*
2. Bangpan, M.,, Felix, L., Soliman, F., D'Souza, P., Jieman, A.T. & Dickson, K. (2024). The impact of mental health and psychosocial support programmes on children and young people's mental health in the context of humanitarian emergencies in low- and middle-income countries: A systematic review and meta-analysis. *Cambridge Prisms: Global Mental Health, 11,* e21. https://doi: 10.1017/gmh.2024.17 , *Accessed: 2024-06-10.*
3. Borpujari, P. (2021). Religious institutions and disasters: Scope for DRR and long-term recovery. Humanitarian Affairs. https://blogs.icrc.org/religion-humanitarianprinciples/religious-institutions-and-disasters-scope-for-drr-and-long-term-recovery/ , *Accessed: 2024-06-10.*
4. Caritas. (2024). *Bosnia and Herzegovina*. Caritas Internationalis. https://www.caritas.org/where-caritas-work/europe/bosnia-and-herzegovina/ , *Accessed: 2024-06-10.*
5. Caritas Srbije. *(2024). Projekat za povećanje otpornosti na prirodne katastrofe i unapređenje strategija pripravnosti (PREPS). https://caritas.rs/madad-2/ , Accessed: 2024-10-22.*

6. CERF (2015). *Resident / Humanitarian Coordinator report on the use of CERF funds: Bosnia and Herzegovina rapid response floods*. Central Emergency Response Fund. https://cerf.un.org/sites/default/files/resources/Bosnia%20Herzegovina%20RCHC%20Report%2014-RR-BOS-001.pdf , *Accessed: 2024-06-10.*
7. Catholic Relief Services. (2016). *Using cash for shelter: Flood emergency response in Serbia.* https://www.calpnetwork.org/publication/using-cash-for-shelter-flood-emergency-response-in-serbia/ , *Accessed: 2024-10-23.*
8. Clarke, G. (2008). Faith-Based Organizations and International Development: An Overview. In G. Clarke & M. Jennings (Eds.), *Development, Civil Society and Faith-Based Organizations* (17-45). International Political Economy Series. Palgrave Macmillan. https://doi.org/10.1057/9780230371262_2 , *Accessed: 2024-06-10.*
9. Cvetković, V.M., Romanić, S., & Beriša, H. (2023). Religion Influence on Disaster Risk Reduction: A Case Study of Serbia. *International Journal of Disaster Risk Management, 5*(1), 67-81. https://doi.org/10.18485/ijdrm.2023.5.1.6 , *Accessed: 2024-06-10.*
10. Cvetković, V.M. & Šišović, V. (2024). Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. *Sustainability* 16(7), 2620. https://doi: 10.3390/su16072620 , *Accessed: 2024-10-23.*
11. Dein S., Cook C.C.H., Powell A., & Eagger S. (2010). Religion, spirituality and mental health. *The Psychiatrist, 34*(2), 63-64. https://doi:10.1192/pb.bp.109.025924 , *Accessed: 2024-06-10.*
12. De Wolf, F. (2018). *Religion, spirituality and psychosocial support activities to people affected by a humanitarian crisis: The role of faith-based organizations* (Master's thesis, University of Groningen, Faculty of Theology and Religious Studies). https://rcs.studenttheses.ub.rug.nl/402/ , *Accessed: 2024-23-10.*
13. ELRHA. (2021). *Review and assessment of mental health and psychosocial support intervention research in humanitarian settings.* Research for Health in Humanitarian Crises (R2HC). https://www.elrha.org/wp-content/uploads/2021/02/MHPSS-research-review-2021.pdf , *Accessed: 2024-06-10.*
14. European Commission. (2014). *Floods in Bosnia and Herzegovina: ECHO joint assessment report* (Status Request for Assistance). https://ec.europa.eu/echo/files/news/bosnia_herzegovina_floods_joint_report_en.pdf , *Accessed: 2024-06-10.*
15. FEMA. (2013). Engaging Faith-Based and Community Organizations: Planning Considerations for Emergency Managers. Federal Emergency Management Agency https://www.fema.gov/media-library-data/1416855001826-4f2c599df0b9f3d708f7fa6d2f7216fa/FBO_Guide_FINAL_10_29_14.pdf , *Accessed: 2024-06-10.*
16. Fitchett, G., Murphy, P. E., Kim, J., Gibbons, J. L., Cameron, J. R., & Davis, J. A. (2004). Religious struggle: Prevalence, correlates and mental health risks in diabetic, congestive heart failure, and oncology patients. International *Journal of Psychiatry in Medicine, 34*(2), 179-196. https://doi:10.2190/UCJ9-DP4M-9C0X-835M , *Accessed: 2024-06-10.*
17. Gavrić, S., Banović, D., & Barreiro, M. (Eds.). (2013). *The Political System of Bosnia and Herzegovina: Institutions – Actors – Processes* (Edition BH politika/BH politics). Sarajevski otvoreni centar/Sarajevo Open Centre. https://sarajevoopen-centre.ba/wp-content/uploads/2020/05/BH_politika_political_system_of_bosnia_and_herzegovina_2020.pdf , *Accessed: 2024-06-10.*
18. Goldberg, Z. (2015). *Faith-Based Organizations in Disaster Relief: Locally-Based Strategies for a Higher Demand Future* (Honors Capstone Project). Renée Crown University Honors Program, Syracuse University. https://surface.syr.edu/cgi/viewcontent.cgi?article=1832&context=honors_capstone , *Accessed : 2024-06-10.*
19. Gray, B. L., Hanna, F., & Reifels, L. (2020). The integration of mental health and psychosocial support and disaster risk reduction: A mapping and review. *International Journal of Environmental Research and Public Health, 17*(6), Article 1900. https://doi.org/10.3390/ijerph17061900 , *Accessed : 2024-06-10.*
20. Ha, K.-M. (2015). The role of religious beliefs and institutions in disaster management: A case study. *Religions, 6*(4), 1314-1329. https://doi.org/10.3390/rel6041314 , *Accessed : 2024-06-10.*

21. Haroz, E. E., Nguyen, A. J., Lee, C. I., Tol, W. A., Fine, S. L., & Bolton, P. (2020). What works in psychosocial programming in humanitarian contexts in low- and middle-income countries: A systematic review of the evidence. *Intervention, 18*(1), 3-17. https://doi.org/10.4103/INTV.INTV_43_20 , *Accessed : 2024-06-10.*
22. Hirono, T., & Blake, M. E. (2017). The role of religious leaders in the restoration of hope following natural disasters. *SAGE Open*, *7*(2). https://doi.org/10.1177/2158244017707003 , *Accessed : 2024-10-23.*
23. IASC. (2007). IASC Guidelines on Mental Health and Psychosocial Support in Emergency Settings. Geneva: IASC. https://interagencystandingcommittee.org/system/files/iasc_guidelines_on_mental_health_and_psychosocial_support_in_emergency_settings.pdf , *Accessed: 2024-06-10.*
24. ICPDR. (2015). *Floods in May 2014 in the Sava River Basin: Brief overview of key events and lessons learned*. Vienna, Austria: International Commission for the Protection of the Danube River & International Sava River Basin Commission. https://www.icpdr.org/sites/default/files/nodes/documents/sava_floods_report.pdf , *Accessed: 2024-06-10.*
25. IFRC. (2009). *Psychosocial interventions: A handbook*. Copenhagen: International Federation Reference Centre for Psychosocial Support. Reference Centre for Psychosocial Support. https://pscentre.org/wp-content/uploads/2018/02/PSI-Handbook_EN_July10.pdf , *Accessed: 2024-06-10.*
26. IFRC. (2014). *IFRC Framework for Community Resilience*. Geneva. International Federation of Red Cross and Red Crescent Societies. https://www.ifrc.org/sites/default/files/IFRC-Framework-for-Community-Resilience-EN-LR.pdf , *Accessed: 2024-06-10.*
27. JLI. (2022). The State of the Evidence in Religions and Development. Washington, DC: Joint Learning Initiative on Faith and Local Communities. https://jliflc.com/wp-content/uploads/2022/07/FINAL-State-of-the-Evidence_30062022_highres.pdf , *Accessed: 2024-06-10.*
28. Koenig, H.G. (2012). Religion, spirituality, and health: the research and clinical implications. *ISRN Psychiatry, 2012*, 278730. https://doi: 10.5402/2012/278730 , *Accessed: 2024-06-10.*
29. Koenig, H.G., King, D.E. & Carson, V.B. (2012). *Handbook of Religion and Health*. 2nd edition. New York, NY, USA: Oxford University Press.
30. Martin, F. (2008). Psychology, Religion and Development: A Literature Review. Religions and Development Working Paper 25. https://www.researchgate.net/publication/242460686_Psychology_Religion_and_Development_A_Literature_Review , *Accessed: 2024-06-10.*
31. Pargament, K. I., Feuille, M., & Burdzy, D. (2011). The Brief RCOPE: Current psychometric status of a short measure of religious coping. *Religions*, *2*(1), 51-76. https://doi.org/10.3390/rel2010051 , *Accessed: 2024-06-10.*
32. Rahmani, M., Muzwagi, A. & Pumariega, A.J. (2022). Cultural Factors in Disaster Response Among Diverse Children and Youth Around the World. *Curr Psychiatry Rep. 24*(10), 481-491. https://doi: 10.1007/s11920-022-01356-x , *Accessed: 2024-06-10.*
33. Rajcevic, V., Crnogorac, C., Trbic, G. & Popov, T. (2016) Floods in the Vrbas River Basin and Climate Changes. *International Journal of Environmental Science*, ***1***, 244-249 https://www.iaras.org/iaras/filedownloads/ijes/2016/008-0038.pdf , *Accessed: 2024-06-10.*
34. Rao, K. (2006). Psychosocial support in disaster-affected communities. *International Review of Psychiatry, 18*(6), 501–505. https://doi.org/10.1080/09540260601038472 , *Accessed: 2024-06-10.*
35. Ruter, K. (2023). The Relationship between Religious Coping and Mental Health – What Do We Know? In. M. Knežević (Ed.), *Coping with Crisis – Pathways towards Resilience. Selected Proceedings of the 3rd International Scientific Conference of the Department of Psychology at the Catholic University of Croatia* (39-52). Zagreb, Croatia: Catholic University of Croatia. ISBN 978-953-8014-75-8 (e-book).
36. Sendai Framework for Disaster Risk Reduction 2015-2030. (2015). *World Conference on Disaster Risk Reduction, Sendai, Japan*. https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf , *Accessed: 2024-06-10.*
37. Saidon, R., Ab Manan, S. K., Sueb, R., Abd Rahman, F. N., Sahari, N. H., & Aziz, N. S. (2020). Religious Psycho-spiritual Care Services for Disaster Victims. *Malaysian Journal Of Consumer And*

Family Economics Vol 24 (S2). https://majcafe.com/wp-content/uploads/2022/11/ Vol-24-S2-2020-Paper-12.pdf, *Accessed: 2024-10-23.*

38. Sphere Association. (2018). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response* (4th edition). Geneva: Sphere Association.
39. World Health Organization, War Trauma Foundation, & World Vision International. (2011). *Psychological first aid: Guide for field workers.* Geneva: World Health Organization.
40. World Health Organization, War Trauma Foundation, & World Vision International. (2013). *Psychological first aid: Guide for field workers.* Geneva, World Health Organization.
41. Latinović, M. (2013). *Uloga zdravstvenog sistema u smanjenju rizika od katastrofa u vanrednim situacijama.* Banja Luka: Ministarstvo zdravlja i socijalne zaštite Republike Srpske.
42. Latinović, M. (2014). Mentalno zdravlje u katastrofama – Psihosocijalna podrška i pomoć. *Medici. com – Mozaik medicinskih komunikacija, XI*(63), 37-47.
43. Marčeta, Ž. (2021). *Psihosocijalna pomoć u okolnostima prirodnih katastrofa* [Psychosocial assistance in the context of natural disasters] (Master rad, Univerzitet u Banjoj Luci, Fakultet bezbjednosnih nauka) [Master's thesis, University of Banja Luka, Faculty of Security Sciences].
44. MZiSZ RS i DPRS. (2015). Akcioni plan za pružanje psihološke pomoći i podrške stanovništvu u situacijama prirodnih katastrofa. Ministarstvo zdravlja i socijalne zaštite i Društvo psihologa Republike Srpske. U zborniku: *Psihosocijalna podrška djeci i porodici nakon prirodnih katastrofa*, 117-119. Banja Luka: Društvo psihologa Republike Srpske.
45. MZiSZ RS. (2014). *Rješenje o imenovanju Tima za koordinaciju psihosocijalne pomoći i podrške u Republici Srpskoj*. Banja Luka: Ministarstvo zdravlja i socijalne zaštite Republike Srpske.
46. Savić, J. (2009). Kolo srpskih sestara – odgovor elite na žensko pitanje (*Pregledni rad). Glasnik Etnografskog muzeja u Beogradu = Bulletin of the Ethnographic Museum in Belgrade = Bulletin du Musée Ethnographique de Belgrade. 73,* 115-132. Beograd : Etnografski muzej. http://www.anthroserbia.org/Content/PDF/Articles/5_GEM_73_Savić_115-132.pdf , Accessed: 2024-06-10.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research Article

Centres or Units: Making Sense of Decentralisation of Disaster Management in South African Municipalities

Mosekama Osia Mokhele[1]*

[1] Nelson Mandela University, Department of Public Management and Leadership, Faculty of Humanities, Summerstrand, Port Elizabeth, 6001; mokhele@mandela.ac.za

*Correspondence: mokhele@mandela.ac.za; Tel.: +27-812-561-733

Received: 9 July 2024; Revised: 29 September 2024; Accepted 24 October; Published: 25 December

Abstract

Disasters can shake institutions and their adaptive strategies temporarily and often in the aftermath of a disaster. Disaster events, such as floods and epidemics, unceasingly demonstrate that disasters provide an avenue for a "litmus test" for institutional effectiveness, efficiency, and accountability. Therefore, this study examines municipalities' receptivity to their role in an integrated disaster management system. Based on the literature and 25 interviews in three research areas: (1) legislative understanding and legislative implementation, (2) the establishment of disaster management centres as units and (3) relevance of institutional capacity [decision-making powers of the head of centres]. This study established that the disaster management centres are established in various municipalities as units supported by Disaster Management Act 57 of 2002 as amended by Act 16 of 2015. This is very solid legislative support, but practical implementation problems persist, especially concerning coordinating disaster management activities and financial accountability at the municipal level. Whereas the framework has sought to ensure a standardised method of governance, the decentralisation process has ensured disparities in municipalities' resource base and procedural practices. Deep-rooted power differences and tightly embedded hierarchies can restrict collaboration and slow decision-making. Given these findings, it is recommended that attention be directed at the following areas: i) developing more effective mechanisms for compliance with standardised disaster management guidelines; ii) planning and operationalising policies to ensure equitable resource distribution; and iii) introducing reforms into existing systems to make disaster management structures more transparent and equitable. Furthermore, the head of the centre should be fully delegated with disaster management power and authority as enshrined in Section 44(3) of the Disaster Management Act 2002, as amended in 2015, to strengthen various stakeholders' internal and external collaboration.

Keywords

Decentralisation, Disaster management, disaster management centres, units, South African municipalities.

1. Introduction

South Africa's disaster management has been characterised by fragmentation and confusion among various institutions and policies, leading to inefficient and disjointed preparedness and disaster response. This disorganisation highlights the need for a decentralised authority to streamline and coordinate disaster management efforts effectively. Recent studies show that there have been significant shifts from this traditional top-down approach to a technocratic and institutionally focused approach, emphasising multilevel, multi-sectoral, and multi-stakeholder involvement, including the participation of communities at risk (Van Niekerk & Visser, 2010; Mokhele, Ncube, & Kunguma, 2024; Cabane, 2023). Moving the whole of government (WoG) closer to communities (Pietersen, 2020), the South African government adopted the decentralisation agenda on disaster management with a strategic focus on curbing the unintended consequences of hazards on local communities (Scott & Tarazona, 2011). A centralised disaster management approach in the military unit proved inadequate, as demonstrated by various disasters, among others, the Lainsburg floods in 1981 and the severe Cape Flats floods in Cape Town, Western Cape, in June 1994, leaving many individuals devastated and vulnerable (Voggel, 1998; Reid & Van Niekerk, 2008; Zuma et al., 2012; Mwera, 2013).

This unfortunate event highlighted the need to reassess the old disaster management legislation, Civil Protection Act 67 of 1977, on disaster management capacity. This was followed, among others, by developing the Green Paper on Disaster Management in 1998, the White Paper on Disaster Management in 1999, and ultimately, the promulgation of Disaster Management Act 57 of 2002 in 2023, as amended by Act 16 of 2015. Therefore, this legislative transformation informed the development of the 2005 National Disaster Management Framework. This critical achievement has allowed the South African disaster management law to be recognised internationally as meeting the global benchmark for embedding disaster management in development plans. Disaster management in South Africa has been established as a public sector function within each sphere of government (Van Niekerk & Visser, 2010; Kunguma, 2020). For the effectiveness of the function as stipulated in Sections 20, 33, and 47 of the DMA, Chapters 3, 4, and 5 of the DMA, sections 8, 29, and 43, respectively, mandate the establishment of the national disaster management centre (NDMC), provincial disaster management centres (PDMCs) in each province, district disaster management centres (DDMCs) and metropolitan disaster management centres (MDMCs) (Republic of South Africa, 2002).

Furthermore, Section 43(4) of the amended DMA of 2015 provides that municipalities may establish disaster management centres within a municipality (Republic of South Africa, 2015). Disaster management is an "*integrated multisectoral and multidisciplinary administrative, organisational and operational planning processes and capacities aimed at lessening the impacts of natural hazards and related environmental, technological and biological disasters*" (Republic of South Africa, 2005:2). This definition highlights the critical need for disaster management to be deeply embedded within every municipality's Integrated Development Planning (IDP) process to ensure its effectiveness. From the above definition, disaster management should involve various stakeholders and be incorporated into development planning processes in every municipality. In other words, every municipality should ensure that disaster management becomes the primary function to be implemented collaboratively with various actors, such as sector departments, private sector, research institutions, NGOs, CSOs, CBOs, and the population at risk [community]) to succeed (Botha et al., 2011; Cabane, 2023). It is worth noting that the existence of the DMA and the NDMF has contributed to the transformation of local governance in handling decentralised disaster-related issues (Coetzee et al., 2013; Mamabolo & Sebola, 2021).

However, in practice, various disaster incidents demonstrate that disaster efforts in South Africa still need to be managed promptly, following a reactive approach and leaving at-risk populations vulnerable. (Kunguma, 2020). The COVID-19 pandemic and flooding disasters have highlighted the shortcomings of South Africa's decentralised disaster management framework. Although the DMA and NDMF are theoretically well-crafted, the pandemic has exposed egregious weaknesses in their practical application, as evidenced by Van Niekerk and Du Plessis (2020), Kunguma et al. (2021), Ngcamu (2022), and Van Zyl (2022). Such fragmentation within government spheres often

demonstrated a lack of clarity regarding direction and coordination, coupled with inefficiencies and inconsistent actions. However, despite the generally sound principles of the DMA, the pandemic highlighted how well-deserved and effectively drawn policy contrasted with practical implementation. Scholars have asserted that effective legislation cannot always be assumed to represent effective implementation (Ngcamu, 2011; Sithole, 2014; Sibanda, 2017; Oosthuizen, 2018; Kunguma, 2020). Given the practical nature of handling disasters, the available literature shows that coordination should be at the highest level for rapid decision-making (Kunguma, 2020).

Most disaster management activities, especially responses, have mainly been handled at the national or provincial level, making the role of municipalities as implementing agencies invisible or insignificant (Coetzee et al., 2013; Van Niekerk, 2014). This aligns with the United Nations Development Programme (UNDP) Report (2015), which stated that South African municipalities are detached from their legislative roles and responsibilities (UNDP, 2015). This paper argues that decentralised disaster management still needs to fulfil the expectations of moving the state closer to at-risk populations due to numerous governance challenges identified by various scholars in disaster management (Wentink & Van Niekerk, 2017; Munzhedzi, 2021). Decentralisation of disaster management is a global challenge, as Malalgoda et al. (2010). These scholars argued that the problem of decentralising disaster management requires more clarity on what should be managed nationally and locally, as discussed in the disaster management literature (Malalgoda et al., 2010). These global governance challenges could be more exceptional for the South African disaster management fraternity. Recent studies show that the difficulties are linked to the practical sense that disaster management functions and responsibilities are subject to municipalities' coordination and response (Oosthuizen, 2018; Van Niekerk & Du Plessis, 2020).

This challenge agrees with Koelble and Siddle (2014:610) that implementing the decentralisation model in South Africa is no different from the "*Rolls Royce model of local decentralisation in theory – a Ford Pinto in Praxis*." Despite the progress made by the South African government in decentralising disaster management functions across spheres of government, the critical role of municipalities as implementing agencies has not been fully realised, especially in local municipalities that are the worst (Wood et al., 2021). On the other hand, there is a rising recognition of the significance of providing municipalities with the capacity to undertake disaster management functions efficiently. To improve disaster pre-disaster phase efforts, such as prevention, mitigation, and preparedness activities at the local level, the movement towards increased capacity building represents a significant step in the right direction. These efforts are being made to improve the coordination between the spheres of government to guarantee an improved integrated and unified command approach to disaster management in South Africa. The remainder of this paper is structured as follows. After the introduction, the paper discusses the links between decentralisation and governance through a theoretical lens, followed by a legislative framework guiding the decentralisation of disaster management in South Africa.

Moreover, this paper discusses the interconnectivity between municipal disaster management centres and sector departments, followed by the challenges faced by the decentralisation set-up of disaster management in South Africa, explains the methodology approach this paper followed and presents the data sources of our study. The results are divided into five sections that detail the feasibility of decentralising disaster management functions for municipalities, their engagement and motivation, uniformity, power dynamics, and placement of disaster management functions in municipalities, centres, and sector departments. Lastly, this paper concludes by discussing possible ways forward regarding decentralising disaster management in South African municipalities, especially on the placement of the function to retain the legitimacy of the function in centres or units.

2. Literature Review

2.1. Governance and Decentralisation: Concepts and frameworks

Governance concerns the system, process, and institution through which authority is exercised, and decisions are prepared and implemented in each society or organisation (Van Niekerk, 2015).

This includes accountability and transparency mechanisms and ways stakeholder inputs are elicited to lead and guide various aspects of public and private operations. Decentralisation involves shifting decision-making powers and administrative duties from the centre to the lower tiers of government, such as regional (provinces) or local governments, and sometimes even lower than that, like municipalities (Mantzaris & Ngcamu, 2020). It does so to attain responsiveness at the grassroots level, efficient delivery of services, and community participation. For disaster management, decentralisation can be framed as administrative decentralisation that involves the distribution of functions. On the political front, it empowers municipalities and communities through elected representation and local autonomy (Gumede et al., 2019). The statutory guidelines include Disaster Management Act (DMA) 57 of 2002 and the National Disaster Management Framework (NDMF) of 2005. The latter ensures that processes through which roles and responsibilities across different spheres of government govern disasters are defined (Cabane, 2023).

Section 40(1) of the Constitution of 1996 provides that South Africa has a three-tier governance system: national, provincial, and local spheres of government which are "distinctive, interrelated, interdependent" and "interlocked" with other spheres (Republic of South Africa, 1996; Siddle, 2011; Sithole, 2014; Feinstein, 2015; Koelble & Siddle, 2018). The interlocking suggests independence and equality between a three-sphere of governments, as opposed to the more overt hierarchical concept brought about by "levels" of government, as may be the case in a unitary state like South Africa (Ngcamu, 2011, p. 55). Each of these spheres enjoys, to some level, executive, legislative, and judicial powers (Feinstein, 2015). This structure is intended to ensure that powers and functions are divided in a manner that caters to the myriad needs of the population (Gumede et al., 2019). The national government sets overall policies and frameworks, such as the NDMF, which articulate critical key performance areas (KPAs) and enablers of disaster management (Mantzaris & Ngcamu, 2020). Provincial governments implement such policies at the provincial level, while municipalities account for frontline service delivery through direct community engagement. The Disaster Management Act (DMA) 57 of 2002 provides disaster management centres in spheres of government as a committee to guide disaster response and recovery.

However, some challenges arise from overlapping responsibilities and varied administrative capacities regarding the requirements for coordination across disaster management centres, including sector departments (Van Niekerk, 2014; Duze & Reddy, 2020). Moreover, this set of challenges created loose boundaries between sectors and state institutions and served a few individuals rather than collaborative efforts (Cabane, 2023). Decentralisation, while intended to enhance good governance by bringing the means of decisions closer to the people, can produce the countervailing tendencies of fragmentation and inconsistency in policy implementation. As Van Niekerk (2014) indicated, these issues might arise from decentralisation. Decentralising disaster management functions in South Africa has led to some identified issues (Pietersen, 2021). This is often found at the municipal level in resource allocation, expertise, and coordination (Mamabolo & Sebola, 2021). Although municipalities are delegated with disaster management functions, they usually need more political and administrative support capacity. While the DMA focuses on creating disaster management centres throughout the spheres of government, resource constraints and the need for intergovernmental cooperation must be adequately addressed (Sithole, 2014; Van Niekerk &Du Plessis, 2020).

2.2. Statutory and Framework of Decentralised Disaster Management in South Africa

Disaster management in South Africa began to take shape in June 1994, culminating in the enactment of Disaster Management Act 57 of 2002 (DMA) and the National Disaster Management Policy Framework (NDMF) in 2005. The Policy Framework (NDMF) provides guidelines on how the objectives of the DMA through Key Performance Areas (KPAs) and Enablers can be achieved in each sphere of government. The Act and the policy framework further emphasise the need to establish institutional arrangements for disaster management across government spheres (Botha et al., 2013; Sithole, 2014). South Africa's enactment of the DMA positioned it as one of the first African countries to adopt comprehensive disaster management legislation that integrates disaster management efforts into development planning (Vermaak & Van Niekerk, 2004; Botha et al., 2011). The South

African decentralisation structures are even complicated: the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) and the Municipal Structures Act 117 of 1998 (MSA) with the Municipal Systems Act 32 of 2000 (MSA) outline what municipalities can do and their powers (Republic of South Africa, 1996, 1998, 2000). The 1998 MSA categorises municipalities into three categories: Category A, which consists of 8 metropolitan municipalities; Category B, comprising 205 municipalities; and Category C, comprising 44 district municipalities and encompasses areas under Category B.

Category B municipalities have full authority in their areas but share responsibilities with district municipalities, especially in disaster management as delegated by the DMA. Existing studies have identified the authority responsible for coordinating and responding to disasters within South Africa (Van Niekerk, 2014; Kunguma et al., 2021). While the DMA and the NDMF are moving from the traditional approach of responding to disasters to a more risk-reduction approach, this often works in practice against the letter of the legislature for crisis or emergency management, usually referred to as a reactive approach. Municipalities (Category B) are understood as first responders and are granted significant rhetorical authority within their jurisdictions. In this sense, rhetorical authority may be conceptualised as the influence or power given to an actor due to perceptions or claims of that actor's capacity to speak authoritatively or provide guidance rather than through any actual, substantive authority or control (Van Niekerk & Du Plessis, 2020). While the amendments to the DMA indicate coordination and implementation roles assigned to metropolitan and district municipalities, disaster management is still very often a line function of departments such as the Department of Cooperative Governance and Traditional Affairs (CoGTA), thus indicating a misalignment between where the highest decision-making authority and operational placement of the disaster management function are situated in various centres or units (van Niekerk & Du Plessis, 2020).

Figure 1.1 summarises the categories of municipalities in South Africa, further divided into three categories under Municipal Structures Act 177 of 1998 (Republic of South Africa, 1998). Category A includes metropolitan municipalities representing significant cities with high population density and heavy economic load. Category B municipalities are smaller than those falling under Category A and can be seen as rural or semi-urban areas. Category C consists of district municipalities that take responsibility for several municipalities within a particular region and give them assistance and coordination if a specific service needs to cross local boundaries. This categorisation allows detailed responsibilities and administrative functions in different municipalities for orderly governance and delivery of services.

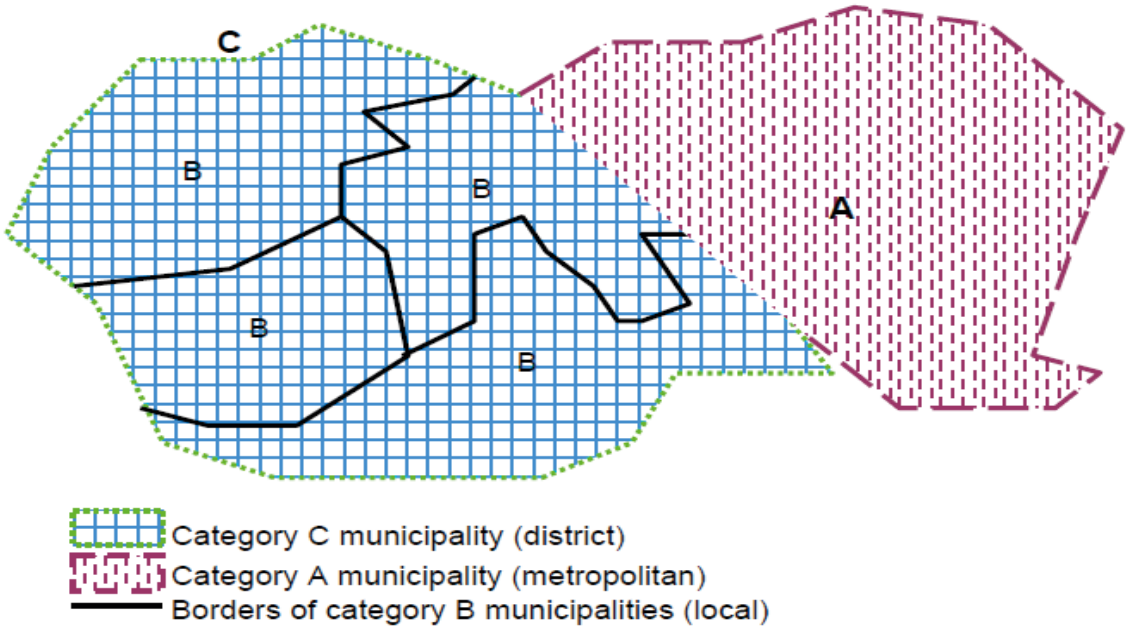


Figure 1.1: Categories of South African municipalities. Source: (Van Niekerk and Visser, 2010:2).

2.3. Inter-Connectivity Between Municipal Disaster Management Centres and Sector Departments.

Disaster management is a responsibility shared among spheres of government in a decentralised manner, as stated in Chapter 4, Schedule 4, Part A and Section 156(4) of South Africa's constitution (Republic of South Africa, 1996). Consequently, national, provincial, and local spheres of government concurrently perform these roles and responsibilities in disaster management. Thus, the National Disaster Management Centre (NDMC) is responsible for leading the national coordination within South Africa during large-scale or multi-provincial disasters. On the other hand, all Provincial Disaster Management Centres (PDMCs) are charged with coordinating disaster management activities at the provincial level. While disaster management is among the issues jointly held by the three spheres of government, with municipalities operating in immediate response, the NDMC and PDMCs have vital functions in terms of strategic oversight and coordination (Sithole, 2014; Kunguma, 2020). Disaster management involves a proactive approach, and national and provincial governments play vital roles in ensuring a comprehensive response to disasters and risk reduction. Interconnectivity in municipal disaster management centres and sector departments ensures efficient disaster response (Sithole, 2014; Kunguma, 2020). Municipal disaster management centres are the central points of disaster management at the grassroots level and are responsible for local emergency planning and immediate response. These central hubs can do much better if they can establish good communication and coordination with relevant sector departments in putting forth an agenda since each brings significant expertise and resources.

For example, healthcare needs to be provided for, and the healthcare department becomes indispensable for this task; similarly, repairing and maintaining infrastructure calls for a public works department. In this way, harmony among participants is ensured, and thus, an all-inclusive approach to disaster prevention and mitigation is adopted. Although South Africa has ample legislation for disaster management, more than legal provisions, institutional systems, and political will are needed to achieve success (Van Niekerk, 2014). It is argued in the literature that decentralised disaster management will only be able to implement with participatory decision-making involving various stakeholders (Sithole, 2014; Kunguma, 2020). What is now needed is critical policy leadership, credibility, and legitimacy; it will be successful if resource allocation is made for the most vulnerable people and households (Cabane, 2023). The literature has indicated how the top-down approach to managing disasters and risks has expressed various shortcomings, especially regarding local capacity (Mokhele, Fana, & Ramolobe, 2024). This means more than national and provincial government efforts are needed because local strategies lack alignment, are embedded in the local context, or are integrated into national policies and planning (Khambule, 2021).

This gap provided an opportunity, as the observed situations proved that disasters manifest locally occasionally, and municipalities and communities are the first responders to such disasters. Thus, disaster management is a shared responsibility that should be developed through collaboration between various stakeholders from inside and outside government domains. Sithole (2014) noted that disaster management requires an intergovernmental approach in which each government domain plays a role and a distinct set of obligations to fulfil. Scholars such as Tau, Van Niekerk, and Becker (2016) asserted that cooperation is required to facilitate resource sharing, critical for reducing disaster risk and all aspects of response and recovery. As a result, any weakness or ineffectiveness in one domain can collapse the entire system, as occurs in various municipalities (Sithole, 2014). To further improve the collaboration between different spheres of government and other stakeholders, mechanisms for sharing expertise should be established at the provincial and local levels (Duze & Reddy, 2020). These two spheres may also consider Organising disaster assistance response teams and other specialist teams composed of professional and technical experts to support one another during disaster response and recovery, thus including local communities and all other relevant stakeholders (Botha et al., 2011; Kunguma, 2020; Kunguma et al., 2021). Thus, exploring methods and data collection, as discussed in the next section, is essential for understanding how these collaborative mechanisms can be effectively implemented.

2.4. Challenges in Disaster Management to South African Municipalities

South Africa's disaster management landscape suffers from a fragmented institutional framework that complicates coordination and response efforts (Cabane, 2023). The Disaster Management Act (DMA) 57 of 2002 and the National Disaster Management Framework (NDMF) 2005 establish a multi-tiered disaster management approach, with responsibilities divided among national, provincial, and municipal governments (Sithole, 2014). The reality is that such an overlap and lack of clarity about roles and responsibilities often promote inefficiencies and confusion. For example, while the DMA tasked municipalities with fundamental disaster management roles, municipalities usually have limited resources and institutional capacity to manage such tasks well (Wentink & Van Niekerk, 2017). This often leads to higher spheres of government, including the National Disaster Management Centre (NDMC) and Provincial Disaster Management Centres (PDMCs), having to intervene, hence creating a non-proactive but rather reactive approach to disaster management (Van Niekerk, 2014). This fragmentation weakens the efficiency of disaster preparedness and recovery operations.

Furthermore, Sithole (2014) cited resource constraints and municipal capacity issues as significant problems within the disaster management system of South Africa. Municipal disaster management centres set up through DMA and NDMF legal mandates have substantially inadequate funding and understaffing; some centres receive national financial support (Category C), while others depend on their revenues (Category A and Category B). This impacts their effectiveness in implementing disaster preparedness measures and responding quickly during emergencies. Studies have observed that disaster management funds are diverted to less critical but more politically significant issues, decreasing the actual financial allocation for disaster management (Sibanda, 2016; Mamabolo & Sebola, 2021; Mokhele et al., 2024). On the other hand, some challenges facing municipalities in managing disaster risks comprehensively include a need for more technical expertise and training opportunities (Wentink & Van Niekerk, 2017; Munsamy, 2018). The impact of this is that it negatively affects or adversely affects the operational effectiveness of municipal disaster management centres and units. This means that municipal disaster management centres/units do not execute their mandates in preparing and responding to disasters as anticipated (Kunguma et al., 2021).

Effective disaster management requires coordination and cooperation between and among stakeholders, including government agencies, non-governmental organisations (NGOs), and community-based organisations (CBOs). In South Africa, these actors need to be integrated. Thus, disaster management functions are perceived as a platform for the selected few. While the NDMF focuses on integrated efforts across spheres of government and sectors, its actual application needs to meet these requirements. High-quality, well-established Community Task Teams outside of weak collaboration frameworks result in fragmented responses in resource utilisation in response to disasters (Kunguma et al., 2021). This is further worsened by the overreliance on reactive measures instead of proactive ones in disaster management; when disasters occur, stakeholders are largely mobilised instead of engaging them in all phases of disaster management, particularly the pre-disaster phase (Sithole, 2014; Mokhele et al., 2024). Each of these challenges calls for a more integrated approach to coordination and collaboration in disaster management and hence requires the involvement of all relevant actors in such processes.

3. Methods

Primary and secondary sources gave this research a precise and scientifically sound theoretical and empirical foundation. This investigation, in which the findings were assessed and placed into perspective, was guided by the DMA and the NDMF to support the primary data. In terms of research methodologies, this article used a qualitative method to direct the analysis. The selection of participants was carried out using a non-probabilistic sampling strategy that was further followed by purposive sampling (Berg & Lune, 2012; Sekaran & Bougie, 2013). The participants were selected due to their inherent knowledge of decentralisation, disaster management, disaster management legislation and the policy framework for its significance.

In other words, a purposive sampling strategy was used to select participants with knowledge about the subject matter, research interests, and characteristics. Thus, the selection of the participants in this research, including the development of research interviews, was influenced by a systematic review of the relevant literature. Acknowledging the sample size, Dworkin (2012) argued that qualitative research in the data collection method adopts semi-structured or in-depth interviews if the sample ranges from 5 to 50 or 25 to 30 participants to reach saturation and redundancy (Fusch & Ness, 2015). Similarly, Vasileiou et al. (2018) contended that to manage or control the complexity of qualitative data analysis, researchers should not conduct more than 50 interviews. According to these scholars' suggestions, only 27 participants from the NDMC, three PDMCs, and metropolitan municipalities were interviewed.

4. Results

This section presents the qualitative data analysis collected through the participants' interviews. The participants interviewed in this study have been employed in a municipality that performs disaster management functions for more than five years. The main research question was designed to examine how the decentralisation of disaster management in South Africa affects the role of municipalities as implementing centres and the policy implications thereof. The analysis used a few verbatim that corresponded with the emerging themes and indicated where the views were elicited; thus, only some of the verbatim were used in the study, regardless of their concurrence. The section below presents the findings from the interviews.

4.1. Feasibility of disaster management decentralisation in South Africa

When participants were asked about the feasibility of decentralisation in municipalities, they provided different responses. Some participants in the NDMC viewed decentralisation from the perspective that disaster management functions exist in every sphere of government in South Africa. One participant from the NDMC attested that the feasibility of decentralisation is inherently supported by the legislative framework, stating, *"That is a legislative point and foundation of the Disaster Management Act and Intergovernmental Relations Act 13 of 2005 (IGR), which also allocates responsibilities and expectations to other state bodies.' From that point onwards, even the feasibility is natural for me. It is only a matter of checking the feasibility and functionality of the decentralisation exercise."* This highlights the participant's belief that decentralisation is fundamentally sound within existing legislation, with the primary concern being the evaluation of its practical implementation and effectiveness.

Results at the PDMCs reveal significant challenges in the decentralisation process, particularly in coordinating with municipalities. One participant noted, *"As I indicated, as a PDMC, we are struggling with local municipalities regarding issues related to the municipal Disaster Relief Grant and the submission of expenditure reports."* This highlights the difficulty of ensuring consistent and effective disaster management practices at the municipal level, where administrative and financial reporting obligations are not adequately met or complied with. Olaniyan et al. (2020) noted that local governments in Ibadan cannot implement practical disaster risk reduction (DRR) actions despite formal commitments to empower them, reflecting similar challenges in the South African context. The incomplete political, fiscal, and administrative decentralisation limits the effectiveness of decentralisation reforms, making disaster management more challenging at the local level (Olaniyan et al., 2020). Understanding local knowledge and community-specific contexts in disaster management is important, emphasising the necessity for more transparent communication and community engagement in decentralised frameworks, particularly when local disparities hinder coordination and practical implementation (Sukhwani et al., 2019).

On the other hand, results from the MDMCs reflect a more optimistic view of decentralisation. A participant from the MDMC stated, *"In my context, this feasibility is based on disaster management functions in every sphere of government in South Africa. Hence, I would say, for now, decentralisation in South Africa makes sense based on the essential functions of disaster management being delegated from national to*

provinces and municipalities." It is evident from this quote that at the municipal level, the benefits of decentralisation are recognised, particularly regarding the precise allocation of disaster management responsibilities across different levels of government, although practical challenges persist. Goyal (2019) noted that disaster policies in India often overlook decentralised institutions as crucial actors, highlighting that those practical issues still need to be addressed due to ineffective local-level structures. Additionally, Otwori and Nyandiko (2024) indicated that the limited decentralisation of disaster risk reduction initiatives poses significant challenges to effective implementation, which resonates with the concerns raised by participants regarding coordination challenges and the effectiveness of local structures in disaster management.

The need for functional decentralisation processes to address localised disaster management challenges is paramount (Otwori & Nyandiko, 2024). The focus on multi-stakeholder, polycentric and multi-sectoral disaster risk governance strategies further reinforces the importance of decentralisation (Koivisto, 2020). Rumbach (2016) noted that although decentralisation has potential, it has yet to significantly improve urban disaster risk management in small cities, indicating that legislative support is insufficient without the practical capacity to implement effective governance.

4.2. Uniformity discrepancies

Regarding the issue of uniformity in the decentralisation of disaster management across government spheres, the participants' results provide a complementary perspective across these spheres. The results of the NDMC reveal that uniformity is a significant concern. One participant highlighted, *"Looking at the compliance assessment we do at the NDMC every quarter, you identify the gaps because the Act clearly states what they are and their PDMCs' responsibilities." Their activities are constrained in other PDMCs because their budgets limit them. For example, the Northern Cape is not well-resourced in terms of budget. So, it has constraints and cannot deliver, as in other provinces such as Western Cape."* This indicates that discrepancies in resource allocation and budgetary constraints across provinces lead to inconsistent implementation of disaster management functions, undermining the uniformity the decentralisation framework aims to achieve. Olaniyan et al. (2020) noted that in Nigeria, uneven fiscal transfers and the lack of proper enforcement mechanisms create resource distribution imbalances across local governments, reflecting similar uniformity discrepancies observed in South African municipalities.

For those in the PDMCs, the results show a pronounced need for uniformity in disaster management practices. One participant remarked, *"It is a lack of uniformity, and every time there is a significant incident, the whole classification declaration process changes. It always changes. There is no uniformity, and there is no one with that concern. When it suits them, it is the premier or MEC. However, again, the Act clearly states that the Premier should declare a disaster in consultation with other MECs."* This highlights a recurring issue where inconsistencies in declaration, classification, and procedural responses during significant incidents lead to operational challenges and inefficiencies, further exacerbating the difficulties of implementing a cohesive disaster management strategy across different regions. Sukhwani et al. (2019) emphasised that institutional barriers, such as unclear organisational arrangements and a top-down approach, can exacerbate discrepancies in disaster response systems, supporting the findings on uneven implementation across provinces.

However, the results from the MDMC show that while there have been efforts to establish uniformity, challenges still need to be addressed in terms of enforcement and adherence. One participant noted, *"Hence, I am talking about uniformity that we have in the MDMC; they [NDMC] will develop the guidelines, but there is no enforcement to say that all the heads of centres should be at the senior management level. We have been fighting to say that maybe, for a start, we should start with the basics and ensure we have disaster management centres that are at the operational level like municipalities such as those in Western Cape, KwaZulu-Natal, Gauteng, especially the City of Joburg."* This highlights the gap between establishing uniform guidelines and their practical implementation, particularly ensuring that all provinces meet standardised levels of leadership and organisational structure. Goyal (2019) noted that non-compliance with safety regulations and the lack of enforcement powers within disaster

management institutions have contributed to inconsistent outcomes, further complicating efforts to ensure uniformity across provinces and municipalities.

The findings highlight significant challenges in decentralising disaster management in South Africa. The NDMC points to budget constraints affecting capabilities, while PDMCs emphasise practice inconsistencies during major incidents (Kunguma, 2020; Van Niekerk & Du Plessis, 2020). MDMCs recognise efforts to establish uniform guidelines but stress enforcement difficulties, particularly regarding provincial leadership. Van Zyl (2022) argued for more robust enforcement mechanisms. Additionally, Otwori and Nyandiko (2024) noted that inadequate budgets hinder disaster risk reduction, while Ng (2016) highlighted poor citizen engagement as contributing to uneven implementation.

4.3. Managing power dynamics and hierarchy structures

The participants were asked to manage power dynamics and hierarchy structures, eliciting varying responses, with a central point causing severe challenges. Participants noted that entrenched power dynamics often hinder collaborative efforts and decision-making processes, whereas rigid hierarchical systems create bottlenecks and slow response times. The results from the PDMCs show that power dynamics significantly hinder disaster response measures within provinces. One participant remarked, *"I just indicated that power dynamics hamper disaster response measures in the province. It should not happen like that in public service. Being the head of the centre at the Deputy Director level is only based on relationships; now, because the HoD of the Department of Agriculture knows me, he will have an audience."* This highlights how personal relationships and hierarchical positions impact access to resources and decision-making, illustrating the need for more equitable and transparent systems to enhance disaster management effectiveness. Olaniyan et al. (2020) noted similar issues in Ibadan, where entrenched power dynamics hinder local governance effectiveness.

The results of the NDMC revealed that power dynamics across the NDMC, PDMCs, and MDMCs pose a primary constraint to effectively decentralising disaster management to municipalities. One participant from the MDMC noted, *"Power dynamics across the spheres of government will be the primary constraint in decentralising disaster management to municipalities. Budget: distributing sufficient budget across all spheres of government. Increased human capacity: more employees will be needed to execute duties in additional satellite offices."* The results of the NDMC revealed that power dynamics across the NDMC, PDMCs, and MDMCs pose a primary constraint to effectively decentralising disaster management to municipalities. One participant from the MDMC noted, *"Power dynamics across the spheres of government will be the primary constraint in decentralising disaster management to municipalities. Budget: distributing sufficient budget across all spheres of government. Increased human capacity: more employees will be needed to execute duties in additional satellite offices."*

This underscores the necessity of managing power imbalances alongside equitable budget distribution and increased staff for effective decentralised disaster management (Goyal, 2019). These findings concur with Munzhedzi (2021) that managing power dynamics and hierarchical structures presents a significant challenge to decentralising disaster management across municipalities. However, participants' varied responses highlight that entrenched power imbalances and rigid hierarchies can impede effective collaboration and decision-making (Van Niekerk& Du Plessis, 2020; Wood et al., 2021). The results of the PDMCs emphasise how personal relationships and hierarchical positioning impact resource allocation and response efficiency. At the same time, the findings of the NDMC stress that these power dynamics and budgetary and staffing issues are critical constraints in the decentralisation process.

4.4. Placement of Disaster Management Centre in Municipalities

Regarding the impact of the disaster management centre function's placement in municipalities, the participants' responses concurred that the primary thrust of integrating these functions into

municipal structures is intended to enhance local responsiveness and coordination during disasters. However, such placement's impact hampers disaster management centres' effectiveness. The results of the PDMC indicated that the placement of disaster management functions within municipal structures significantly impacts the effectiveness of such activities. One participant pointed out, *"The issue of placement and its impact of making our activities challenging to implement, the issue of making decisions is complicated because the disaster management centre is a section reporting to a division, which is business operations."* This illustrates how the organisational placement of disaster management centres can complicate decision-making processes and hinder the effective implementation of disaster response activities, particularly when these centres are embedded within broader business operations divisions (Ng, 2016).

Results from NDMC revealed that improper placement of disaster management functions significantly hampers disaster practitioners' daily operations. One participant elaborated, *"The wrong placement just makes our daily disaster management activities as disaster practitioners difficult because you will not have the proper budget, will not have the right personnel with high disaster management expertise, or credentials would come and go because they would see that no disaster management practises are happening here. It is just a matter of maintaining the status quo."* This indicates how inadequate placement can lead to insufficient funding, a lack of specialised personnel, and a tendency to maintain existing, ineffective practices, ultimately undermining the effectiveness of disaster management efforts (Otwori & Nyandiko, 2024). MDMC results show that the placement of disaster management functions in municipalities can significantly affect their efficacy. This was articulated by one participant who stated, *"It does have an impact on the placement of disaster management function in any local or district municipality because if you are placed in the wrong place, then your voice would not be heard, and now and then, you would have to go through red tape for your voice to be heard, and therefore the people that actually on top might not even understand what you are meant to do in the local or district municipality."*

This highlights that improper placement can lead to difficulties in communication and decision-making and a lack of understanding of the disaster management role among higher-level officials, which can hinder effective disaster response and management at the local level (Koivisto, 2020). Overall, the improper placement of disaster management roles within municipal structures in Nigeria complicates coordination and decision-making, underscoring the critical need for appropriate disaster management functions in municipalities for effective response (Olaniyan et al., 2020). Institutional barriers, such as improper organisational placement, often lead to inefficient disaster response, reinforcing the need for proper alignment within local structures to ensure smoother communication and resource flow (Sukhwani et al., 2019). Ultimately, inadequate engagement of local communities and leaders in disaster planning and mitigation has resulted in inefficiencies in disaster response and preparedness (Goyal, 2019).

4.5. Disaster management centres and sector department collaboration

When asked about the disaster management centres and sector department collaboration, the participants highlighted the critical role that inter-agency cooperation should play in effective disaster management. One participant from the PDMCs asserted, *"Still, in terms of risk assessment, our project development in terms of prevention, awareness, campaign, and preparedness designation of early warning systems, I think the decentralisation is working because, for instance, if there are issues of risk, just meant is we are all away that our municipalities and provinces are not the same."* This statement highlights that decentralisation has facilitated a more nuanced approach to risk assessment and project development by acknowledging the diverse needs and conditions across municipalities and provinces. This aligns with Rumbach (2016), who discussed how decentralisation can enhance responsiveness by bringing decision-making closer to local communities and addressing their risks. However, similar to Nyandiko (2020) and Koivisto (2020), challenges with coordination and communication among sectors persist, leading to delays in effective policy implementation. The results of the NDMCs showed that effective collaboration with sector departments significantly enhances disaster management efforts. One participant stated, *"We have very sound institutional arrangements with our sector departments.*

We usually go to disaster management incidents because we know about them. Especially when drawing up risk reduction and preparedness plans; that is where you build that relationship."

This reflects institutional solid ties, essential for successful disaster management, as highlighted by Ocal (2019), who observed that national-level collaboration and stakeholder participation are critical for effective disaster planning and education. Similarly, Fujita and Shaw (2019) emphasised the importance of institutional cooperation in flood risk reduction, supporting findings from South Africa that well-established networks between disaster management centres and sector departments facilitate better planning, response, and collaboration. The MDMC results showed that structured collaboration between disaster management centres enhances effectiveness. One participant remarked, *"Collaboration amongst the disaster management centres occurs through the offices of different Head of Centres and Head of Centre Forums, which meet monthly. Many disaster management activities, such as public awareness, have been successfully conducted by municipalities in collaboration with the Provincial Disaster Management Centre and other relevant stakeholders within the municipalities."* This structured approach resonates with Olaniyan et al. (2020), who noted that in Ibadan, grassroots collaboration and community-led initiatives often complement formal disaster risk reduction (DRR) strategies, reflecting the importance of both institutional and community involvement.

Furthermore, Rico (2019) supported this by highlighting that knowledge sharing between local institutions, such as schools and the community, plays a vital role in building preparedness, which echoes the value of the public awareness campaigns mentioned by the MDMC participants. These findings demonstrate that effective collaboration between disaster management centres and sector departments is essential for optimising disaster management practices. However, as Cvetkovic and Martinović (2020) point out, innovative solutions in inter-sectoral collaboration, particularly in communication and civil protection, remain untapped, which could further enhance disaster response efforts. Moreover, Otwori and Nyandiko (2024) stressed that integrating disaster risk reduction strategies across multiple sectors, such as planning, finance, and agriculture, is necessary for ensuring sustainable resource access—another aspect underscored by participants who noted the importance of inter-agency cooperation for effective disaster planning and management.

Responses regarding disaster management centres and sector department collaboration emphasise the importance of inter-agency cooperation in effective disaster management. The participants from the PDMCs highlighted that decentralisation has improved the ability of municipalities to address diverse risks and develop targeted prevention and preparedness strategies by recognising the varied needs of different municipalities and provinces. This localised approach has enhanced overall effectiveness (Duze & Reddy, 2020; Cabane, 2023). The results of the NDMC emphasised that robust institutional arrangements and established relationships with sector departments are crucial for effective disaster response and planning because they facilitate the development of comprehensive risk reduction and preparedness plans. Furthermore, the MDMC results demonstrated that structured collaboration through regular forums and meetings has led to successful disaster management activities, such as public awareness campaigns, illustrating the significant benefits of coordinated efforts across various levels of disaster management centres, as was the case during the COVID-19 crisis. The findings resonate with Kunguma et al. (2021) and Mokhele et al. (2024) that effective collaboration and well-established communication channels are essential for optimising disaster management practices and improving readiness across different levels of government and sectors.

5. Discussion

Results from this study depict the complex interplay between legislative frameworks and practical challenges in disaster management implementation in South African municipalities. This, of course, relates to the receptiveness at the municipality level to their roles within an integrated disaster management system, of which the engagement of key stakeholders by local government officials and community leaders is part. This highlights the critical role of local government officials in implementing the will of the legislature and engaging communities in critical principles of disaster

management (Baudoin et al., 2017). Knowledge of the Disaster Management Act (DMA) and the Intergovernmental Relations Act regarding these relationships is essential for local implementation of these frameworks. Another vital function community leaders perform is reinforcing municipalities' disaster management. Community leaders interface with municipalities and communities to ensure that local needs and vulnerabilities are acknowledged in disaster planning and response efforts (Zamisa & Mutereko, 2019). This cooperation is vital for municipalities to enhance their responsiveness to disasters by ensuring their strategies meet the community's expectations and requirements.

Although the DMA has legislative support, just like the Intergovernmental Relations Act, practical problems still lie regarding coordination and financial reporting at the municipal level (Mamabolo & Sebola, 2021). Although there is a semblance of a desire to create standard uniformity in practices related to disaster management, the decentralisation process has resulted in differences in significant resources and procedure practices between different municipalities. This study revealed that budgetary issues limit the practical implementation of disaster management functions across participating cities, consistent with the literature by Olaniyan et al. (2020) on fiscal imbalances in local governance. Creating regulatory resource benchmarks may further stabilise municipalities in terms of resource input into eventuated equal disaster management capabilities. Inter-municipality agreements on resource sharing can be another strategy for balancing resource availability across municipalities and enabling support for one another during the disaster. Targeted financial models, such as a tiered support system in which funding is proportional to different types of risk, will ensure funding to areas where it is most needed (Üster & Dalal, 2017). In this way, adequate funding can be increased in higher-risk areas while ensuring that all municipalities receive satisfactory resources for disaster preparedness.

On the other hand, public-private partnerships could also be sought to finance disaster management plans that require resources and technical skills from the private sector to increase municipal capacity for disaster response. Entrenched power dynamics and rigid hierarchical structures are significant barriers to collaboration and decision-making. Resource distribution also goes down the line of personal relationships and hierarchical positioning, again raising the issue of the need to address the balance of power. Munzhedzi (2021) stated that if appropriately handled, power dynamics allow for an equal distribution of resources and responsibilities, which is required to optimise disaster management outcomes. Transparencies in implementing systems and collaboration across stakeholders are critical to realising this development and overcoming challenges (Van Niekerk & Du Plessis, 2020; Wood et al., 2021). Where disaster management centres fall in municipal structures determines how efficiently they operate. Placing such a unit at a broader business operation division level complicates decision-making. This slows down response activities, as stated by the respondents. This is related to Koivisto (2020), who argued that the organisational placement of disaster management roles is necessary for effective communication and the flow of resources. Disaster management, therefore, needs to be strategically positioned within municipal frameworks to garner maximum prominence and visibility and influence better coordination during disasters.

In addition, cooperation with disaster management centres and departments in the respective sectors should be practical for optimising optimal disaster management practices. Participants, for instance, explained that cooperation among agencies enabled nuanced risk assessments and targeted prevention strategies that met local needs more precisely. However, it also creates persistent policy implementation delays because of challenges in coordination and communication among sectors. Improvement in coordination could be attained if municipalities adopted specific technological tools, such as Geographic Information Systems (GIS), to track resources to identify allocation and actual impacts in real time (Kurwakumire et al., 2019). Moreover, mobile-based communication platforms facilitate information-sharing and decision-making among stakeholders involved in disaster cases (Handayani et al., 2023). Although the legislative framework supports decentralisation, this practice in coordination, power dynamics, resource allocation and organisational placement remains a significant test for efficient disaster management. This will require a multi-faceted approach that includes community involvement and equitable distribution of resources through closer cooperation among stakeholders. Municipalities should have robust mechanisms to comply with standard disaster management guidelines and design means of equitably distributing resources. Reforms must also be begun towards more transparent and equal disaster management framework systems.

Additionally, all municipalities should be supported in developing a transparent and efficient disaster management system with clearly articulated strategies and finance models that achieve specific outcomes and embrace technological innovations.

6. Long-Term Strategies for Sustaining Decentralisation Efforts

Decentralisation, if effective at all in disaster management, must be multi-faceted. Tselios and Tompkins (2017) emphasise that the devolution of authority to local self-governments may minimise the consequences of natural hazards. However, persistent challenges exist in developing further local capacity and improving coordination. Formal resource benchmarks in keeping with municipalities should be established as a guideline for the tools and infrastructure municipalities require to respond effectively. This has been an essential area of concern because, as Rumbach (2016) noted, most smaller municipalities need more adequate resources. Learning to share resources between municipalities can help build trust and hasten the process of aid when needed urgently. Disaster management units should be created in each municipality. The case of South Korea highlights how a unified management system helped coordinate efforts between different levels of governance. This will involve investment in regular capacity-building programmes, enabling local officials to understand better and manage disaster risks. Putra and Matsuyuki (2019) confirmed that ongoing training is necessary to counter the challenges related to funding shortages and lack of expertise.

Municipal disaster units should also be regularly appraised to identify performance gaps and congruence with national policies. Garschagen (2016) called for constant evaluations when contesting governance agendas (Bae et al., 2015). Finally, integrating technological equipment in disaster management, such as Geographic Information Systems (GIS), in resource tracking and communication platforms through mobile devices for improved coordination might significantly enhance the efficiency of disaster management (Hermansson, 2019). With the assistance of such technologies, timely decision-making during disasters can be achieved. To summarise, all requirements for decentralisation at all levels ensure that clear indications of resource availability are flashed, coordination is enhanced, proper structures and institutions in those structures are trained, and new technologies and methodologies are adopted to address emerging risks and vulnerabilities.

7. Conclusions

Underpinned by the Disaster Management Act (DMA) and supported by the National Disaster Management Framework (NDMF), decentralisation of disaster management in South Africa ensures that an intricate dance between legislative intent and systemic weakness, on the one hand, and practical challenges dampen any hope for effective municipal disaster responses. While the DMA and NDMF are intended to structure and support disaster management at different governmental levels, the effectiveness of their intent is compromised by a significant understanding and implementation gap existing at the municipal level. Several participants from MDMCs and PDMCs needed to gain developed knowledge of such legislative tools; thus, there is an urgent need for education and training. This gap affects how municipalities effectively implement disaster management strategies, highlighting the need for dedicated capacity-building programmes to enhance local disaster management capacity. Another study finding is that decentralised disaster management usually results in reactive rather than proactive responses due to practical realities. The DMA and the NDMF have set out an appropriate framework, but conflicts and the need for alignment with national and provincial policies remain essential challenges municipalities face.

This misalignment, along with the centralisation of crucial disaster management functions, undermines the effectiveness of municipal contributions and exposes a pivotal barrier to effective decentralisation. It is such that political commitment needs to be improved at higher levels of government, leaving municipalities with little resourcing and thus side-lined in disaster risk reduction efforts. This analysis also reveals profound discontinuities and fragmentation in disaster management practices in various government spheres. These differences in the understanding and application

of disaster management policies at the municipal level translate into ineffective local risk reduction strategies, which constitute a fundamental weakness of the disaster management system in South Africa. Fragments and inconsistent policy application work to decrease the overall effectiveness of disaster response mechanisms; thus, unity and cohesion of the disaster management framework are necessary.

Ethics statement: No ethical approval was required in this study as no sensitive research data was used.

Funding: This research received no specific grant from public, commercial, or not-for-profit funding agencies.

Author Contributions: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

Acknowledgements: The author thanks the selected South African municipal disaster management centre participants for their support and the information given.

Conflicts of Interest: The authors declare no conflict of interest.

Data availability: Data will be made available on request.

References

1. Bae, Y., Joo, Y., & Won, S. (2015). Decentralization and collaborative disaster governance: Evidence from South Korea. *Habitat International, 52*, 50–56. https://doi.org/10.1016/j.habitatint.2015.08.027
2. Baudoin, M. A., Vogel, C., Nortje, K., & Naik, M. (2017). Living with drought in South Africa: lessons learnt from the recent El Niño drought period. *International Journal of Disaster Risk Reduction, 23*, 128–137.
3. Berg, B.L. and Lune, H. (2012). Qualitative Research Methods for the Social Sciences. 8th Edition, Pearson, Upper Saddle River, NJ.
4. Botha, D, Van Niekerk, D, Wentink, G, Coetzee, C, Forbes, K, Maartens, Y, Annandale, E, Tshona, T, and Raju, E. (2011). Disaster risk management: Status assessment at municipalities in South Africa. The African Centre for Disaster Studies, North-West University.
5. Botha, D., and Van Niekerk, D. (2013). Views from the Frontline: A critical assessment of local risk governance in South Africa. Jàmbá: Journal of Disaster Risk Studies, 5(2), 1–10. https://doi.org/10.4102/jamba.v5i2.82.
6. Cabane, L. (2023). The Government of Disasters: State Formation and Disaster Management in South Africa. Springer Nature Switzerland AG: Palgrave Macmillan
7. Coetzee, C., Van Niekerk, D., Murphree, M., Shoroma, B., et al. (2013). Feasibility study on the decentralisation and institutional capacity development for the Department of Agriculture, Forestry and Fisheries: Directorate Agricultural Disaster Risk Management. https://www.researchgate.net/publication/265587768.
8. Cvetkovic, V. M., & Martinović, J. (2020). Innovative solutions for flood risk management. *International Journal of Disaster Risk Management, 2*(2), 71–100.
9. Cvetković, V. M., Tanasić, J., Ocal, A., Kešetović, Ž., Nikolić, N., & Dragašević, A. (2021). Capacity Development of Local Self-Governments for Disaster Risk Management. International Journal of Environmental Research and Public Health, 18(19). doi:10.3390/ijerph181910406
10. Duze, M., and Reddy, P. S. (2020). Disaster Risk Management at the Local Level: The Case of Ethekwini City Council in South Africa. Advances in African Economic, Social, and Political Development, in Purshottama Sivanarain Reddy & Henry Wissink (ed.), Reflections on African Cities in Transition, chapter 12, 247-271, Springer. http://doi.org/10.1007/978-3-030-46115-7_12.
11. Dworkin, S. L. (2012). Sample size policy for qualitative studies using in-depth interviews. Archives of Sexual Behavior, 41(6), 1319–1320., 41(6), 1319–1320. https://doi.org/10.1007/s10508-012-0016-6.

12. Feinstein, A. (2015). Decentralisation: The South African experience. 1st ed.). Global Partners Governance.
13. Fujita, K., & Shaw, R. (2019). Preparing international joint projects: Use of Japanese flood hazard map in Bangladesh. *International Journal of Disaster Risk Management, 1*(1), 62–80.
14. Fusch, P., & Ness, L. (2015). Are we there yet? Data saturation in qualitative research. The Qualitative Report, 20, 1408–1416. Retrieved from http://tqr.nova.edu/wp-content/uploads/2015/09/fusch.
15. Garschagen, M. (2016). Decentralizing urban disaster risk management in a centralized system? Agendas, actors, and contentions in Vietnam. *Habitat International, 52*, 43–49. https://doi.org/10.1016/j.habitatint.2015.08.030
16. Goyal, N. (2019). Disaster governance and community resilience: The law and the role of SDMAs. *International Journal of Disaster Risk Management, 1*(2), 61–75.
17. Gumede, N., Byamukama, J. and Dakora, E. (2019). Contemporary perspectives on fiscal decentralisation and new local government in South Africa. Ghana Journal of Development Studies, 16(2), pp.52-69.
18. Handayani, A., Hopipah, N., & Fadhli, M. (2023). The implementation of mobile technology in the process of reporting disasters and events. *IJCCS (Indonesian Journal of Computing and Cybernetics Systems*. https://doi.org/10.22146/ijccs.8766
19. Hermansson, H. (2019). Challenges to decentralization of disaster management in Turkey: The role of political-administrative context. *International Journal of Public Administration, 42*, 417–431. https://doi.org/10.1080/01900692.2018.1466898
20. Khambule, I. (2021). Decentralisation or deconcentration: The case of regional and local economic development in South Africa. Local Economy, 36(1), 22–41.
21. Koelble, T.A. (2011). Decentralisation in South African local government: A critical evaluation. Doctoral thesis. Cape Town, South Africa: University of Cape Town
22. Koelble, T.A. and Siddle, A. (2014). Decentralisation in Post-Apartheid South Africa Decentralization in Post-Apartheid South Africa. Regional and Federal Studies, 24(5), 607–623. https://doi.org/10.1080/13597566.2014.971773.
23. Koelble, T.A. and Siddle, A., 2018. Decentralisation in post-apartheid South Africa. In Federalism and Decentralization in Sub-Saharan Africa (pp. 72-88). Routledge.
24. Koivisto, J. (2020). Navigating in the midst of uncertainties: Challenges in disaster risk governance in Mozambique. *Expertgruppen för biståndsanalys (EBA).*
25. Kunguma, O. (2020). South African disaster management framework: Assessing the status and dynamics of establishing information management and communication systems in Provinces. Unpublished Doctoral Dissertation. University of the Free State, South Africa: Bloemfontein.
26. Kunguma, O., Ncube, A., and Mokhele, M. (2021). COVID-19 disaster response: South African disaster managers' faith in mandating legislation tested? Jamba: Journal of Disaster Risk Studies, 13(1), a1099. https://doi.org/doi.org/10.4102/jamba.v13i1.1099.
27. Kurwakumire, E., Muchechetere, P., Kuzhazha, S., & Ikokou, G. B. (2019, July). Geographic information and geo-visualisation in support of disaster resilience. In *Proceedings of the ICA (Vol. 2, p. 68)*. Göttingen, Germany: Copernicus Publications.
28. Malalgoda, C.I., Amaratunga, R.D.G., and Pathige, C. (2010). Role of local government in disaster risk reduction. The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors (COBRA), 2nd-3rd September 2010.
29. Mamabolo, M.A. and Sebola, M. P. (2021). The role and adequacy of disaster management unit within the South African Municipalities. The Business & Management Review, 12(2), 126–131.
30. Mantzaris, E. A. and Ngcamu, B. S. (2020). Dissecting Disaster Responses during COVID-19: An eThekwini Municipality Experience. Alternation Special Edition, 32, 117–144.
31. Mokhele, M. O., Ncube, A., and Kunguma, O. (2024). Disaster Risk Management Challenges Towards Integrated Disaster Risk Management at the South African Municipalities: What Is Left

Untouched? In Z. Mbandlwa (Ed.), Challenges, Strategies, and Resiliency in Disaster and Risk Management (pp. 242-276). IGI Global. https://doi.org/10.4018/979-8-3693-2721-0.ch011.

32. Mokhele, M.O., Fana, T.E., and Ramolobe, K.S. 2024. To explore the effectiveness of capacity development strategies for disaster management in the Sol Plaatjie Local Municipality, South Africa. In BK Sebake and P. Hlongwane (Ed), Development and public issues in Sub-Saharan Africa: The 21st-century imperatives (42-64). Batalea Publishers (PTY).
33. Munsamy, L. (2018). Development of an integrated disaster risk management model for the municipalities in the Free State Province. Unpublished doctoral dissertation, Bloemfontein: Central University of Technology, Free State).
34. Munzhedzi, P.H., 2021. An evaluation of the application of the new public management principles in the South African municipalities. Journal of Public Affairs, 21(1), p.e2132.
35. Mwera, T. S. (2013). Community awareness and participation in disaster risk management: The case of Khayelitsha TR-Section. Master's thesis: University of Western Cape.
36. Ng, S. (2016). Governance beyond the government: Responding to a reactionary flood governance regime in Ayutthaya, Thailand. *Habitat International, 52*, 11–19.
37. Ngcamu, S.B. (2011). Disaster risk management in local government: A case study of Foreman and Kennedy Road informal settlements, eThekwini Municipality, KwaZulu-Natal. Doctoral thesis. Durban, South Africa: Durban University of Technology.
38. Nyandiko, N. O. (2020). Devolution and disaster risk reduction in Kenya: Progress, challenges, and opportunities. *International Journal of Disaster Risk Reduction, 51*, 101832.
39. Olaniyan, F. A., Adelekan, I. O., & Nwokocha, E. E. (2020). The role of local governments in reducing disaster losses and vulnerabilities in Ibadan City, Nigeria.
40. Oosthuizen, R. C. (2018). A critical analysis of disaster risk management in local governance with reference to Sarah Baartman District Municipality. Doctoral thesis. Port Elizabeth, South Africa: Nelson Mandela University.
41. Otwori, D., & Nyandiko, N. (2024). Challenges against the achievement of disaster risk reduction strategies in African states. *Journal of the Kenya National Commission for UNESCO.*
42. Pietersen, J. M. M. (2020). The nexus between public administration and disaster management: a case of Covid-19 in South Africa. Africa Journal of Public Sector Development and Governance, 3(1), 40–60.
43. Putra, D., & Matsuyuki, M. (2019). Disaster management following decentralization in Indonesia: Regulation, institutional establishment, planning, and budgeting. *Journal of Disaster Research.* https://doi.org/10.20965/jdr.2019.p0173
44. Reid, P. and Van Niekerk, D. (2008). A model for a multi-agency response management system (MARMS) for South Africa. An International Journal of Disaster Prevention and Management, 17(2), 244–255. https://doi.org/10.1108/09653560810872541.
45. Republic of South Africa. (1996). *Constitution of the Republic of South Africa, 1996 (Act 108 of 1996)*. Pretoria, South Africa: Government Printers.
46. Republic of South Africa. (1998). *Municipal Structures Act 117 of 1998*. Pretoria, South Africa: Government Printers.
47. Republic of South Africa. (2000). *Municipal System Act, 2000 (Act 32 of 2000)*. Pretoria, South Africa: Government Printers.
48. Republic of South Africa. (2002). *Disaster Management Act, 2002 (Act 57 of 2002)*. Pretoria, South Africa: Government Printers.
49. Republic of South Africa. (2005). *Intergovernmental Relations Act, 2005 (Act 13 of 2005)*. Pretoria, South Africa: Government Printers.
50. Republic of South Africa. (2005). *National Disaster Management Framework of 2005*. Pretoria, South Africa: Government Printers.
51. Republic of South Africa. (2015). *Disaster Management Act - Amendment Bill 16 of 2015*. Pretoria, South Africa: Government Printers.

52. Rico, G. C. S. (2019). School-community collaboration: Disaster preparedness towards building resilient communities. *International Journal of Disaster Risk Management, 1*(2), 45–61.

53. Rumbach, A. (2016). Decentralization and small cities: Towards more effective urban disaster governance? *Habitat International, 52*, 35–42. https://doi.org/10.1016/j.habitatint.2015.08.026

54. Scott, Z., & Tarazona, M. (2011). Study on disaster risk reduction, decentralisation, and political economy. Background Paper for the Global Assessment Report on Disaster Risk Reduction.

55. Sekaran, U. and Bougie, R. (2013). *Research Methods for Business: A Skill-Buiding Approach*. John Wiley & Sons Ltd.

56. Sibanda, M. (2016). *Towards a total disaster risk management framework for implementation of disaster risk reduction programmes: The case of Nelson Mandela Bay Metropolitan Municipality*. Doctoral Thesis. KwaZulu-Natal, South Africa: University of KwaZulu-Natal.

57. Sithole, B. (2014). Municipal Disaster Management in South Africa: Intergovernmental Relations as a Planning Instrument. Doctoral Degree. Central University of Technology, Free State.

58. Sukhwani, V., Gyamfi, B. A., Zhang, R., AlHinai, A. M., & Shaw, R. (2019). Understanding the barriers restraining effective operation of flood early warning systems. *International Journal of Disaster Risk Management, 1*(2), 1–19.

59. Tau, M., Van Niekerk, D., Becker, P., Niekerk, D. Van, & Becker, P. (2016). An Institutional Model for Collaborative Disaster Risk Management in the Southern African Development Community (SADC) Region. International Journal of Disaster Risk Science, 7(4), 343–352. https://doi.org/10.1007/s13753-016-0110-9.

60. Tselios, V., & Tompkins, E. (2017). Local government, political decentralization, and resilience to natural hazard-associated disasters. *Environmental Hazards, 16*, 228–252. https://doi.org/10.1080/17477891.2016.1277967

61. United Nations Development Program (UNDP). (2015). Strengthening disaster risk governance. https://www.undp.org/sites/g/files/zskgke326/files/publications/Strengthening%20Disaster%20Risk%20Governance-Full-Report.pdf

62. Üster, H., & Dalal, J. (2017). Strategic emergency preparedness network design integrating supply and demand sides in a multi-objective approach. *IISE Transactions, 49*, 395–413. https://doi.org/10.1080/0740817X.2016.1234731

63. Van Niekerk, D and Visser, R. (2010). Experience on decentralised mechanism and funding for Disaster Risk Reduction in South Africa. Second Ministerial Conference on Disaster Risk Reduction in Africa, Nairobi: Towards a Funding Mechanism for Disaster Risk Reduction in Africa, 14-16 May 2010, September 1–15.

64. Van Niekerk, D. (2014). A critical analysis of the South African Disaster Management Act and Policy Framework. Disasters, 38(4), 858–877. https://doi.org/10.1111/disa.12081.

65. Van Niekerk, D. (2015). Disaster risk governance in Africa: A retrospective assessment of progress in against the Hyogo Framework for Action (2000-2012). Disaster Prevention and Management, 24(3), 397–416. https://doi.org/10.1108/DPM-08-2014-0168.

66. Van Niekerk, D. and Du Plessis, E. (2020). Understanding the Disaster Management Act and its implementation. News24. http://www.news24.com/news24/columnist/guestcolumn/opinion-understanding-thedisaster-management-act-and-its-implementation.

67. Van Niekerk, D. and Wisner, B. (2014). Integrating disaster risk management and development planning: Experiences from Africa. In R. Lopez-Carresi, A., Fordham, M., Wisner, B., Kelman, I. and Gaillard, J.C. (Eds), Disaster Management: International Lessons in Risk Reduction (ed.); 1st ed.). Routledge./

68. Van Niekerk, D., & Wentink, G. J. (2017). The capacity of personnel in disaster risk management in South African municipalities. The Journal for Transdisciplinary Research in Southern Africa, 13(1), 1-10.

69. Van Zyl, B. (2022). Implementation of Disaster Management Act 57 of 2002. HR Future, 2022(2), 48-51.

70. Vasileiou, K., Barnett, J., Thorpe, S. & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over a 15-year period. BMC Medical Research Methodology, 18(1), 148. https://doi.org/https://doi.org/10.1186/s12874-018-0594-7.

71. Vermaak, J. and Van Niekerk, D. (2004). Disaster risk reduction initiatives in South Africa. Development Southern Africa, 21(3), 555-574.

72. Wood, D. J., Mitchell, R. K., Agle, B. R., & Bryan, L. M. (2021). Stakeholder identification and salience after 20 years: Progress, problems, and prospects. Business & Society, 60(1), 196-245.

73. Zamisa, N., & Mutereko, S. (2019). The role of traditional leadership in disaster management and disaster risk governance: A case of Ugu District Municipality by-laws. *Jàmbá: Journal of Disaster Risk Studies, 11.* https://doi.org/10.4102/jamba.v11i1.802

74. Zuma, B.M., Luyt, C.D., Chirenda, T., and Tandlich, R. (2012). Flood Disaster Management in South Africa: Legislative Framework and Current Challenges. International Conference on Applied Life Sciences (ICALS2012) Turkey, September 10-12, 2012, 127–132.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research Article

The Contribution of Roads to Forest Fire Protection in Tamza Municipality, Northeast Algeria

Faicel Tout[1,*], **Nouh Rebouh**[2], **Haythem Dinar**[3], **Yacine Benzid**[4] and **Zakaria Zouak**[5]

[1] Territory Planning Research Center, Zouaghi Slimane Campus, Ain el Bey Road, 25000 Constantine, Algeria; faicel.tout@crat.dz (F.T.); nouh.rebouh@crat.dz (N.R.); haythem.dinar@crat.dz (H.D.); yacine.benzid@crat.dz (Y.B.); zakaria.zouak@crat.dz (Z.Z.).

** Correspondence: faicel.tout@crat.dz; tel.: (+213)044956961*

Received: 6 August 2024; Revised: 15 November 2024; Accepted 5 October; Published: 25 December

Abstract

With rising forest fire frequency due to climate change, countries are advancing measures for prevention and faster emergency response. In Algeria, efforts centre on improving access to at-risk forests by expanding forest roads and paths. This study focuses on Ain Mimoun, Tamza in Khenchela Province, examining the role of these routes in forest protection. Using Geographic Information Systems (Google Earth Engine and ArcGIS) alongside field surveys, it identifies areas impacted by the 2021 fires through the difference normalised burn ratio (dNBR) and assesses road proximity to affected zones. Using a cartographic approach, this study highlights road density in fire-hit areas, revealing several constraints limiting the roads' effectiveness as fire barriers. Factors such as tree types and terrain influence fire spread, while fires near forest entrances impede firefighting vehicles due to risks from visibility and respiratory hazards. Maintenance issues further limit the utility of forest paths, and outdated forest road maps complicate firefighting efforts. Proposed solutions include upgrading the firefighting fleet with advanced tools like aircraft for isolated areas, intensifying forest road maintenance, and increasing forest monitors. Additionally, the study suggests exploring fire-resistant plant species, adopting strategic afforestation, and using Geographic Information Systems alongside advanced technologies like drones. These drones, which can provide real-time monitoring of fire and road conditions, support timely decision-making for rescue, evacuation and emergency response.

Keywords

Disasters; forest fires; roads; protection; Tamza; Algeria.

1. Introduction

With the impacts of climate change, human activities, and land use changes, the risk of forest fires has become a significant concern in various regions around the world (Delcourt et al., 2021; Eker et al., 2024; Gupta et al., 2024; Peña-Molina et al., 2024). This type of fire, which can be considered the most damaging, remains a critical challenge despite advancements in prevention, prediction, and response strategies in many countries. It appears that we still do not fully control this hazard, and many areas continue to experience substantial losses on various fronts (Belgherbi et al., 2018). Given the ongoing risk due to numerous factors that can trigger or contribute to fires whether naturally

or through human intervention—countries are developing and seeking better methods to intervene and prevent the spread of fires to mitigate the potential losses (Tout, 2023).

In Algeria, following recent fires that severely damaged forest cover (Zahira & Hadj, 2017), especially over the past decade, the government has focused on improving and modernizing its equipment. This includes increasing the number of firefighting vehicles, employing additional personnel, and imposing regulations on forest access, particularly during the summer season, to reduce the risk of both accidental and deliberate fires (Tout, 2023). Additionally, there is a growing emphasis on improving access to remote areas to facilitate firefighting operations and meet the needs of residents and investors.

Accessibility remains a crucial need for residents, land users, and those involved in forest management or protection. It is fundamental for emergency responses, and the development of roads and forest paths can offer better opportunities for detecting and controlling fires (Tout, 2023). Furthermore, it can improve conditions for evacuating and rescuing people (Wu et al., 2023). Accordingly, many current studies are working to find more efficient planning methods to provide optimal geographic coverage. This represents a significant shift in research in this context, as most studies focuses more on the role of roads as contributing factors to fire occurrence (Ganteaume & Jappiot, 2013). However, roads are now increasingly valued for their role as firebreaks and as central elements in managing wildfire risk and controlling associated hazards (Zhu et al., 2024). This shift has motivated authorities to include the expansion of road networks in their agendas to improve accessibility.

In the Tamza municipality of Khenchela Province, the Ain Mimoun area has experienced several forest fires, the most recent of which occurred in 2021(figure.1). This fire resulted in significant damage to large forested areas and affected many agricultural investments, along with numerous other losses on various levels (Guehaz & Sivakumar, 2023).



Figure 1. A part of the fires that affected the Ain Mimoun area in 2021.

As a result, many official bodies and research efforts have sought to understand the underlying causes of forest fires, as well as the reasons behind the challenges in controlling and containing them (Meddour-Sahar et al., 2013; Tout, 2023). This has led to public and private entities pointing fingers at the perceived neglect by authorities, with many residents and stakeholders expressing frustration over the lack of control over these fires, attributing it to insufficient road infrastructure for effective intervention.

This assumption implies an inverse relationship between road density and fire spread (Lu et al., 2022). The prevailing hypothesis is that roads not only facilitate easier access for firefighting vehicles

and personnel to wildfire sites but also serve as barriers within forests, potentially preventing the spread of fires from one area to another (Suárez-Fernández et al., 2024).

In this research, we aim to validate this hypothesis by evaluating the role and contribution of roads in fire protection. This study represents an attempt to understand the actual needs of the region to address shortcomings in wildfire intervention and preparedness.

1.1. Study Area

The municipality of Tamza, located in northeastern Algeria (Figure 2), belongs to Khenchela Province and is characterized by dense forest cover in several areas (Guehaz & Sivakumar, 2023). It has experienced numerous forest fires in recent years, especially in 2014 and 2021, which caused significant damage. The municipality is administratively part of the al Hamma District and has an elongated administrative boundary with a semi-arid climate. Despite its distinctive features, this extensive administrative boundary poses challenges in terms of population distribution across settlements, service provision, and achieving stability. The municipality, with its limited financial resources, faces difficulties in ensuring adequate living conditions in the south, where the municipal headquarters are located, as well as in the north, which also requires attention to stability factors such as water, electricity, and roads. These issues continue to be a concern for many residents, particularly in rural and forested areas.

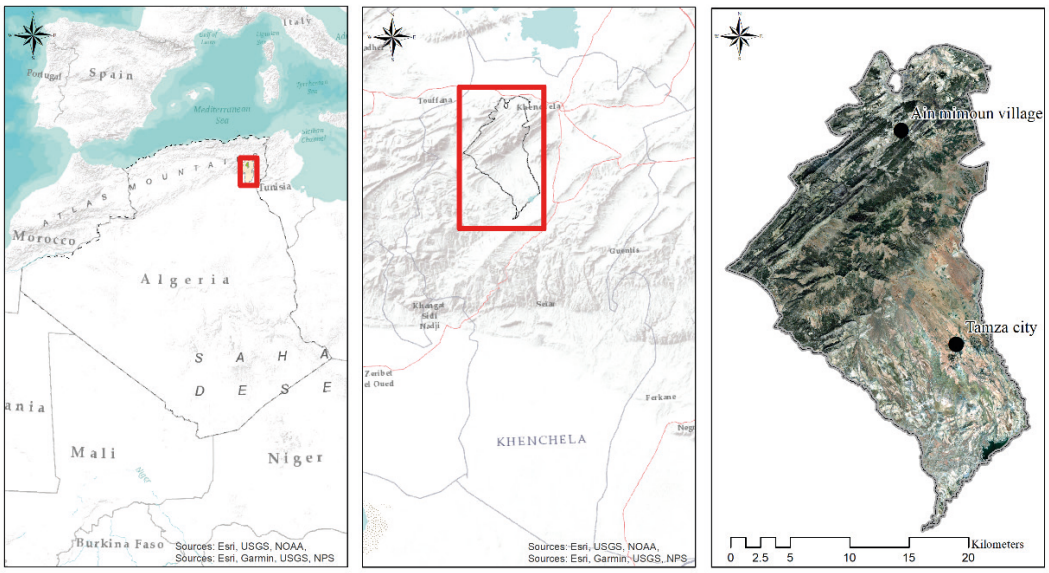


Figure 2. The location of the study area.

2. Methods

Using Geographic Information Systems (GIS), which are crucial for analyzing and evaluating geographical issues (He et al., 2024; Ibrahim et al., 2024; Mitsopoulos et al., 2019; Singha et al., 2024), we aim to assess the role of roads in forest protection in the Tamza municipality. The study began with mapping the road network of significance, including national, provincial, and municipal roads with substantial traffic, as well as some rural and forest paths that are crucial for accessing certain population centers and agricultural investments. We also excluded newly constructed roads established after the fires based on our knowledge of the study area. These new roads were specifically created for transporting timber and other activities managed by the forest administration following the fires.

The study took into account the area affected by fires during 2021, where Landsat 8 images before and after the fires were used on the Google Earth Engine platform to calculate the dNBR index to identify the most affected areas. The Burn Severity Index, dNBR (Differenced Normalized Burn Ratio), is a commonly used indicator (R. Guo et al., 2024; Llorens et al., 2021; Mohammad et al., 2023;

Sobrino et al., 2019) for assessing burn severity and damage (Llorens et al., 2021). It is calculated using the formula:

$$dNBR = NBR_PreFire - NBR_PostFire$$

NBR is derived from Landsat 8 data using the formula:

$$NBR = Band\ 5 - Band\ 7 / Band\ 5 + Band\ 7$$

where:
Band 5: Near Infrared (NIR)
Band 7: Shortwave Infrared (SWIR)

In the maps from (Figure 3), negative values indicate areas with sparse or less dense vegetation or non-vegetative conditions, while positive values indicate significant and healthy vegetation cover. It is evident in map 2 of the same (Figure 3) that there is a significant change in values before and after the fires in some areas of the northern and northwestern regions, particularly in the areas that experienced the fires (Guehaz & Sivakumar, 2023).

As for the dNBR index, positive values usually indicate a high burn severity, decreasing as we approach zero, while negative values indicate either no damage or an improvement in the vegetation cover in the area. After classification.

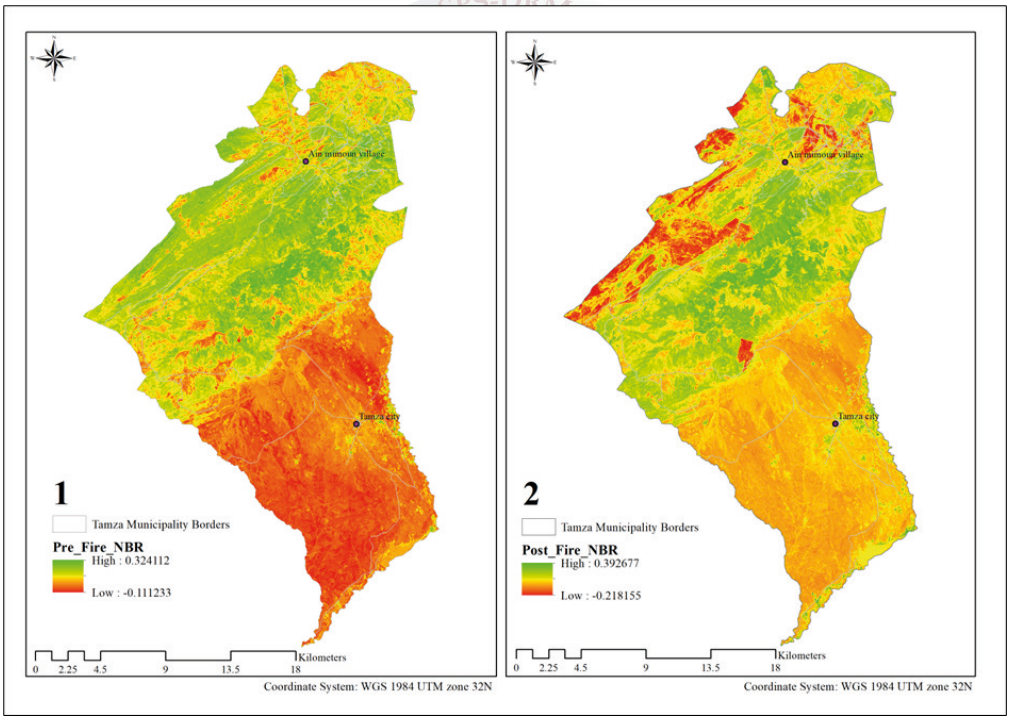


Figure 3. The Normalized Burn Ratio (NBR) values for the study area before and after the fires.

Table 1 refers to the classification of the normalized burn ratio (dNBR) as proposed by the United States Geological Survey (USGS) (Sobrino et al., 2019):

Table 1. dNBR classification

Severity Level	Pixel Values
High Regrowth	-0.5 ≤ dNBR < -0.25
Low Regrowth	-0.25 ≤ dNBR < -0.1
Unburned	-0.1 ≤ dNBR < 0.1
Low	0.1 ≤ dNBR < 0.27
Moderate-Low	0.27 ≤ dNBR < 0.44
Moderate-High	0.44 ≤ dNBR < 0.66
High	0.66 ≤ dNBR < 1.33

Although accurate assessment of areas affected by fires using remote sensing techniques requires precise data, some free data provided by relevant agencies like USGS allow for generally acceptable results that can be relied upon in many fields (Delcourt et al., 2021; Erzurumlu & Yıldız, 2024; Marra et al., 2024). This study also required numerous field visits to assess the actual condition of roads and areas directly impacted by the fires. Despite the extensive spatial reach of the fires, the research aims to integrate remote sensing systems with actual field visits to provide a better reality analysis and reliable study results

The map in (Figure 4) indicates the most severely affected areas after the 2021 fires according to the adopted classification.

According to the map, the northern and northwestern regions were significantly affected by the fires, which are generally areas with dense vegetation cover. Additionally, part of these regions can be considered areas that were previously affected by fires in 2014 (Guehaz & Sivakumar, 2023). These past fires may have made the region more vulnerable, creating conditions more prone to ignition (Fernández-García et al., 2019).

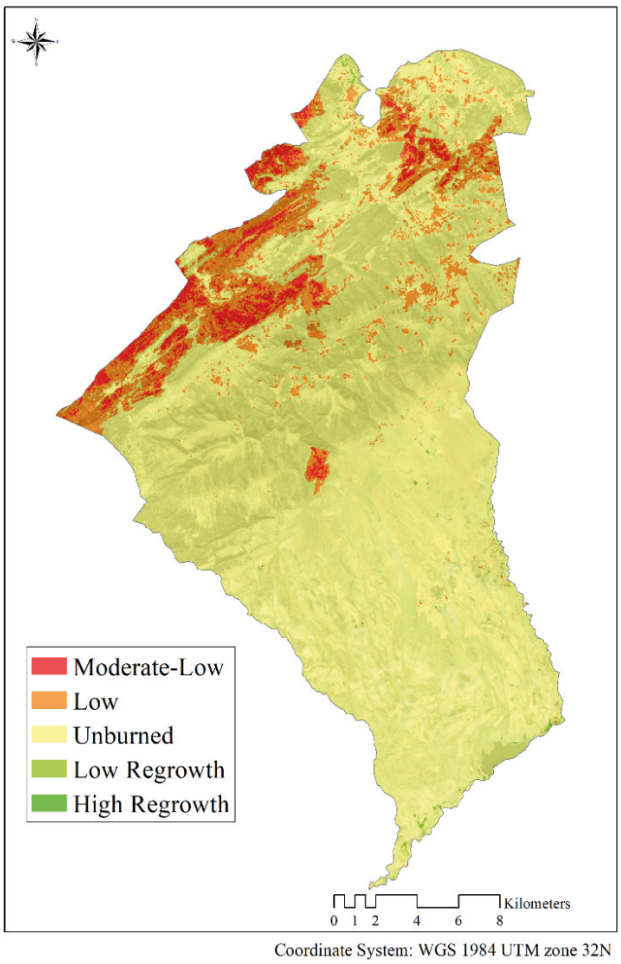


Figure 4. The fire severity for the study area is according to the adopted classification.

3. Results and Discussion

It is commonly recognized that roads significantly contribute to halting the spread of fires by facilitating the access of firefighting teams to the locations where these fires break out, allowing them to extinguish the fires and prevent their spread. Additionally, roads act as buffer zones, separating forested areas and preventing the fire from spreading on the ground or between trees and shrubs (Lourenço et al., 2023; Lu et al., 2022; Suárez-Fernández et al., 2024).

In the map from (Figure 5) which indicates the overlay of roads and areas affected by fires in the study area, there is a relative density of roads, especially in the Ain Mimoun area in the northern part of the municipality. This suggests that the roads did not contribute as expected to stop the spread of the fire, even for the major roads in the area, such as the paved road connecting the village of Ain Mimoun to National Road No. 88 (Figure 6).

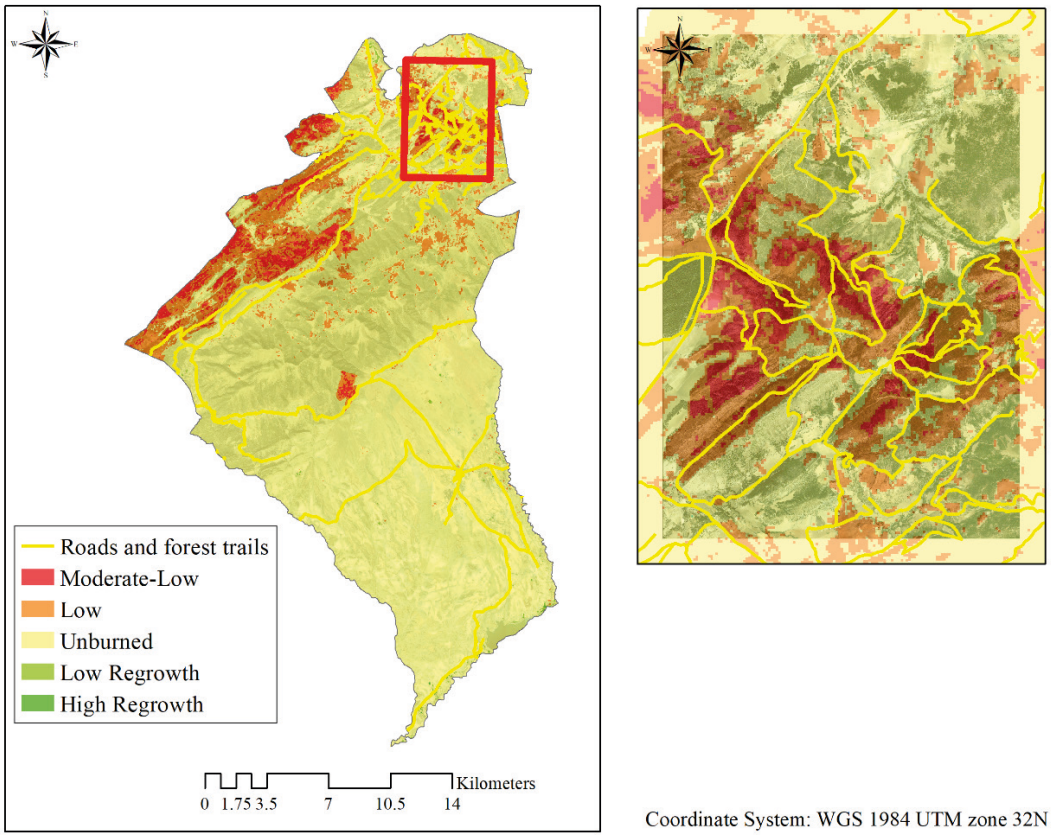


Figure 5. Road density in the burned areas.

After both sides of road number 88 were exposed to fire, it not only isolated the forested area but also isolated the village during the fires, particularly since the alternative roads were in extremely poor condition. They require long distances to reach populated areas and neighbouring cities, and reaching hospitals involves travelling even greater distances. Moreover, some of these roads have been affected or are at risk of being affected by fires or dense smoke, including the road connecting the village to the city of Kais, the southern road linking the village to the city of Tamza, and the road that connects it to the city of Khenchela via the Ras Serdoun mountains. These routes cannot be considered actual alternatives, especially given the paths they take through forests or the challenging terrain they traverse (Lu et al., 2022; Suárez-Fernández et al., 2024).

The extensive spread of some areas affected by the fire in regions with a high density of roads and forest paths also confirms that factors are limiting the role of roads as protective measures. In the Ras Al-Assa area, which provides multiple entrances to some agricultural investments located within forested areas, large fires occurred, causing harm to the residents who were isolated by these fires. The resulting smoke led to cases of suffocation among some of them, especially since the fires did not give them enough time to leave the area.

Our investigation into the factors that limited the role of roads indicates that even with the isolation provided by the road (Suárez-Fernández et al., 2024), fires still spread across the sides of the road due to several other factors. For instance, pine cones, one of the most common and possibly the most widespread trees in the area, can jump several meters, as well as embers are carried by the wind, which can transfer the fire to neighbouring areas.



Figure 6. The spread of fires between both sides of the road connecting the village of Ain Mimoun to National Road No. 88.

It is also worth noting that the mere occurrence of a fire on both sides of the road prevents the passage of vehicles due to dense smoke, reduced visibility, the risk of suffocation (Li et al., 2023), and the potential for vehicles to catch fire, especially those running on gasoline. This includes firefighting vehicles or private cars, which automatically nullifies the road's role, This is what happened on the road that leads to some of the farms in the Farkanfath area (Figure 7). Moreover, this interruption of roads hinders efforts to evacuate residents, significantly increasing the danger of the situation (Wu et al., 2023).

The lack of necessary maintenance for roads and forest paths has eliminated the possibility of relying on many of them (Akay et al., 2021), significantly limiting the options for firefighting vehicles, complicating operations, and increasing the risk for firefighting crews. Some of these paths were used only temporarily and were not rehabilitated, while others did not meet actual technical standards and only allowed the passage of light firefighting vehicles (Figure 8).

The failure to update road maps by civil defence agencies, which is one of the most important measures to facilitate effective fire response (Lourenço et al., 2023), was a key factor that limited their ability to act quickly in evacuating residents and preventing the spread of fires on time. This left them with only one option: consulting local shepherds to find paths that would allow passage.



Figure 7. The only accessible entrance to one of the agricultural investments, which has been blocked by smoke and fires, preventing the evacuation of residents and leading to the destruction of large areas of the forest.



Figure 8. The deteriorating condition of one of the forest trails in the study area.

The terrain of the area has significantly facilitated the spread of fires between the sides of roads, especially on slopes. The falling of trees, shrubs, or their fruits contributes to the transfer of fires from areas higher up the road to lower ones. Numerous studies have highlighted the role that elevations and slopes, in general, play in facilitating and intensifying the spread of fires (L. Guo et al., 2022, 2024; Ibrahim et al., 2024; Tout, 2023).

The aforementioned factors significantly impact the feasibility of relying on roads for firefighting interventions or as barriers between fire-vulnerable areas. Several exceptional conditions often accompany these fires, partially or entirely negating the reliance on certain roads and forest pathways. From another perspective, some researchers argue that roads themselves may contribute to the ignition of forest fires, especially when combined with visitors' lack of awareness. Various studies have shown that many fires have started near roads and inhabited areas (Guehaz & Sivakumar, 2023; L. Guo et al., 2022; Tout, 2023).

This difference in viewpoints underscores that roads should be part of a comprehensive strategy for protecting against forest fire hazards (Meddour-Sahar et al., 2013). Roads must also meet specific conditions and standards to enhance their reliability during emergencies. Additionally, the consideration of increasing road density in forested areas should take into account various spatial criteria, primarily providing multiple access points to potential fire zones and ensuring proximity to water sources. Roads must also be appropriately located with respect to the terrain and be cost-effective and existing ones must be maintained. In addition, alternative fire extinguishing measures should be adopted. For example, trenches could be created specifically for this purpose, and reforestation planning should utilize strategic spacing between forested areas. Special plant species that do not support the spread of fire could also be used, although this would require further research and development.

This study also highlights the need for more effective and reliable emergency response tools that can improve access to remote areas, such as firefighting aircraft and helicopters, especially given the difficulties and challenges associated with using rural and forest roads for this purpose. There is also a significant need to increase the number of surveillance and warning units to enable early detection of fires.

In addition, risk prevention requires the use of advanced technologies to predict areas at risk of wildfire, such as geographic information systems (GIS) that apply appropriate criteria. These systems can also be used in disaster management to plan rescue, evacuation and urgent preventive measures, together with the use of appropriate monitoring tools, such as drones, which provide real-time updates on the status of roads, routes and fires to support timely decision-making.

4. Conclusions

Despite the important role that roads play in providing access to fire-affected areas and aiding firefighting efforts, several factors limit their use during wildfires. In the study area, the fires created exceptional and complex conditions that automatically rendered some of these roads unusable. For example, the fire that affected the side of National Road 88, considered the main entrance to the village of Ain Maimoun and its forests, prevented access to contain the spread to other areas and isolated the village.

The study also highlights the role of other factors that contribute to the spread of fires along roadsides, such as wind, slope, and tree species, and emphasizes that roads cannot be relied upon as firebreaks between forests. The study calls for the maintenance and upgrading of roads and trails with new technical specifications to support the passage of heavy firefighting vehicles and reduce the potential for fire to spread along roadsides. It also suggests updating road maps for civil defense authorities and increasing road inspection activities.

The study recommends the adoption of an appropriate reforestation strategy using plant species that do not promote fire spread, and the use of more advanced technologies, such as drones, to provide real-time updates on road, trail, and fire conditions for informed decision-making and effective risk management during emergencies. The study also highlights the need to establish new forest guard and civil protection units in the village and surrounding rural areas, and to strengthen the civil protection fleet with helicopters and firefighting aircraft, especially in densely vegetated areas. Given the continued risk of wildfire outbreaks, additional forest guards should be deployed and residents should be more actively involved in fire prevention and forest fire risk management.

Author Contributions: The research required the use of different tools to analyze the data, find and verify the results, and it required cooperation in many stages between the researchers, but some of them contributed to specific aspects in particular, Tout Faicel, the author of the research idea and its director, did the bibliographic research and determined the research methodology and is the owner of the results related to Google Earth Engine, Nouh Rebouh contributed to the analysis and interpretation of the different results and helped in the preparation of maps, an aspect in which Yacine Benzid and Haythem Dinar also contributed, in addition to verifying the results and following up the research. Zakaria Zouak also contributed to this, especially in field investigations, translation, and finalizing the text of the article.

Funding: There was no funding for this research

Acknowledgments: We want to thank the residents of the village of Ain Mimoun in the municipality of Tamza, especially the residents of Ras al-Assa, who helped us understand the realities of the forest fires in the area.

Conflicts of Interest: "The authors declare no conflict of interest."

References

1. Akay, A. E., Podolskaia, E. S., & Uçar, Z. (2021). Effects of Improving Forest Road Standards on Shortening the Arrival Time of Ground-based Firefighting Teams Accessing to the Forest Fires. European Journal of Forest Engineering, 7(1), 32–38. https://doi.org/10.33904/ejfe.952174
2. Cvetković, V. (2019). Risk Perception of Building Fires in Belgrade. International Journal of Disaster Risk Management, 1(1), 81-91.
3. Guo, L., Wu, Z., Li, S., & Xie, G. (2024). The relative impacts of vegetation, topography and weather on landscape patterns of burn severity in subtropical forests of southern China. Journal of Environmental Management, 351(November 2023), 119733. https://doi.org/10.1016/j.jenvman.2023.119733

4. Guo, R., Yan, J., Zheng, H., & Wu, B. (2024). Assessment of the Analytic Burned Area Index for Forest Fire Severity Detection Using Sentinel and Landsat Data. Fire, 7(1). https://doi.org/10.3390/fire7010019
5. Gupta, P., Shukla, A. K., & Shukla, D. P. (2024). Sentinel 2 based burn severity mapping and assessing post-fire impacts on forests and buildings in the Mizoram, a north-eastern Himalayan region. Remote Sensing Applications: Society and Environment, 36(June), 101279. https://doi.org/10.1016/j.rsase.2024.101279
6. He, K., Shen, X., & Anagnostou, E. N. (2024). A global forest burn severity dataset from Landsat imagery (2003-2016). Earth System Science Data, 16(6), 3061–3081. https://doi.org/10.5194/essd-16-3061-2024
7. Ibrahim, S., Kose, M., Adamu, B., & Jega, I. M. (2024). Remote sensing for assessing the impact of forest fire severity on ecological and socio-economic activities in Kozan District, Turkey. Journal of Environmental Studies and Sciences. https://doi.org/10.1007/s13412-024-00951-z
8. Li, X., Zhang, G., Tan, S., Yang, Z., & Wu, X. (2023). Forest Fire Smoke Detection Research Based on the Random Forest Algorithm and Sub-Pixel Mapping Method. Forests, 14(3). https://doi.org/10.3390/f14030485
9. Llorens, R., Sobrino, J. A., Fernández, C., Fernández-Alonso, J. M., & Vega, J. A. (2021). A methodology to estimate forest fires burned areas and burn severity degrees using Sentinel-2 data. Application to the October 2017 fires in the Iberian Peninsula. International Journal of Applied Earth Observation and Geoinformation, 95 (January 2020). https://doi.org/10.1016/j.jag.2020.102243
10. Lourenço, M., Estima, D., Oliveira, H., Oliveira, L., & Mora, A. (2023). Automatic Rural Road Centerline Detection and Extraction from Aerial Images for a Forest Fire Decision Support System. Remote Sensing, 15(1). https://doi.org/10.3390/rs15010271
11. Lu, Z., Sun, S., Yuan, M., Yang, F., & Yin, H. (2022). Fire Path Fighting in Forest Off-Road Using Improved ACA—An Example of The Northern Primitive Forest Region of The Great Xing'an Range in Inner Mongolia, China. Forests, 13(10). https://doi.org/10.3390/f13101717
12. Belgherbi, B., Benabdeli, K., & Mostefai, K. (2018). Mapping the Risk of Forest Fires in Algeria : Application of the Forest of Guetarnia in Western Algeria. Sciendo, 37(3), 289–300. https://doi.org/10.2478/eko-2018-0022
13. Marra, A. B., Galo, M. de L. B. T., & Sano, E. E. (2024). Contribution of SAR/Sentinel-1 images in the detection of burnt areas in the natural vegetation of the Brazilian Pantanal biome. Boletim de Ciencias Geodesicas, 30, 0–1. https://doi.org/10.1590/s1982-21702024000100005
14. Meddour-Sahar, O., González-Cabán, A., Meddour, R., & Derridj, A. (2013). Wildfire management policies in Algeria: present and future needs. International Symposium on Fire Economics, Planning, and Policy: Climate Change and Wildfires, 92507, 382.
15. Mitsopoulos, I., Chrysafi, I., Bountis, D., & Mallinis, G. (2019). Assessment of factors driving high fire severity potential and classification in a Mediterranean pine ecosystem. Journal of Environmental Management, 235(May 2018), 266–275. https://doi.org/10.1016/j.jenvman.2019.01.056
16. Mohammad, L., Bandyopadhyay, J., Sk, R., Mondal, I., Nguyen, T. T., Lama, G. F. C., & Anh, D. T. (2023). Estimation of agricultural burned affected area using NDVI and dNBR satellite-based empirical models. Journal of Environmental Management, 343(April), 118226. https://doi.org/10.1016/j.jenvman.2023.118226.
17. Molnár, A. (2024). A Systematic Collaboration of Volunteer and Professional Fire Units in Hungary. International Journal of Disaster Risk Management, 6(1), 1–13.
18. Peña-Molina, E., Moya, D., Marino, E., Tomé, J. L., Fajardo-Cantos, Á., González-Romero, J., Lucas-Borja, M. E., & de las Heras, J. (2024). Fire Vulnerability, Resilience, and Recovery Rates of Mediterranean Pine Forests Using a 33-Year Time Series of Satellite Imagery. Remote Sensing, 16(10), 1–21. https://doi.org/10.3390/rs16101718
19. Singha, C., Swain, K. C., Moghimi, A., Foroughnia, F., & Swain, S. K. (2024). Integrating geospatial, remote sensing, and machine learning for climate-induced forest fire susceptibility mapping in Similipal Tiger Reserve, India. Forest Ecology and Management, 555(January), 121729. https://doi.org/10.1016/j.foreco.2024.121729

20. Sobrino, J. A., Llorens, R., Fernández, C., Fernández-Alonso, J. M., & Vega, J. A. (2019). Relationship between forest fire severity measured in situ and through remotely sensed spectral indices. Forests, 10(5), 1–13. https://doi.org/10.3390/f10050457
21. Suárez-Fernández, G. E., Martínez-Sánchez, J., Arias, P., & Lorenzo, H. (2024). Characterizing Forest Fires Risks Using Free Multi-Source Data: Identifying High-Risk Road Sections. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 48(4/W11-2024), 121–128. https://doi.org/10.5194/isprs-archives-XLVIII-4-W11-2024-121-2024
22. Tout, F. (2023). MODEL NA PREDPOVEDAN IE OBLASTÍ VÝSKYTU A MODEL TO PREDICT THE OUTBREAK. Geografická Revue, 19(1). https://doi.org/10.24040/GR.2023.19.1.62-75
23. Wu, Y., Lin, K., Li, W. H., Xiang, T., Zhang, Y., Yang, Y., Chen, Y., & Zhou, R. (2023). Forest fire emergency rescue and evacuation path planning based on improved APF. EM-GIS 2023 - Proceedings of the 8th ACM SIGSPATIAL International Workshop on Security Response Using GIS 2023, 1–6. https://doi.org/10.1145/3615884.3629421
24. Delcourt, C. J. F., Combee, A., Izbicki, B., Mack, M. C., Maximov, T., Petrov, R., Rogers, B. M., Scholten, R. C., Shestakova, T. A., van Wees, D., & Veraverbeke, S. (2021). Evaluating the differenced normalized burn ratio for assessing fire severity using sentinel-2 imagery in northeast siberian larch forests. Remote Sensing, 13(12), 1–20. https://doi.org/10.3390/rs13122311
25. 30. Zahira, S., & Hadj, B. (2017). L'algerie: Une Region Mediterraneene Tres Sensible Aux Incendies De Foret. Territorium, 24(I), 177–186.
26. Zhu, Y., Zhang, G., Chu, R., Xiao, H., Yang, Y., & Wu, X. (2024). Research on escape route planning analysis in forest fire scenes based on the improved A* algorithm. Ecological Indicators, 166(July), 112355. https://doi.org/10.1016/j.ecolind.2024.112355.
27. Eker, R., Çınar, T., Baysal, İ., & Aydın, A. (2024). Remote sensing and GIS-based inventory and analysis of the unprecedented 2021 forest fires in Türkiye's history. Natural Hazards, 0123456789. https://doi.org/10.1007/s11069-024-06622-0
28. Erzurumlu, G. S., & Yıldız, N. E. (2024). Determination of fire intensity after forest fire by remote sensing: marmaris case study. BIO Web of Conferences, 85, 0–5. https://doi.org/10.1051/bioconf/20248501041
29. Fernández-García, V., Fulé, P. Z., Marcos, E., & Calvo, L. (2019). The role of fire frequency and severity on the regeneration of Mediterranean serotinous pines under different environmental conditions. Forest Ecology and Management, 444(March), 59–68. https://doi.org/10.1016/j.foreco.2019.04.040
30. Ganteaume, A., & Jappiot, M. (2013). What Causes Large Fires in Southern France. Forest Ecology and Management, 294, 76–85. https://doi.org/10.1016/j.foreco.2012.06.055
31. Guehaz, R., & Sivakumar, V. (2023). A case study about the forest fire occurred on 05 July 2021 over Khenchela province, Algeria, using space-borne remote sensing. December, 1–14. https://doi.org/10.3389/frsen.2023.1289963
32. Guo, L., Li, S., Wu, Z., Parsons, R. A., Lin, S., Wu, B., & Sun, L. (2022). Assessing spatial patterns and drivers of burn severity in subtropical forests in Southern China based on Landsat 8. Forest Ecology and Management, 524(September). https://doi.org/10.1016/j.foreco.2022.120515

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Short Communication

Business Continuity Planning for the Hazardous Chemical Handling Industry: A New Conceptual Approach

Yudhistra A. Kumar[1]

[1] Novopor (Former Porus Labs Private Limited), Visakhapatnam, India.

Correspondence: yudhistrakumar@gmail.com; Mobile - +91-7904876071

Received: 10 September 2024; Revised: 17 November 2024; Accepted 8 October; Published: 25 December

Abstract

The conceptual approach of handling an on-site emergency and continuity of the business in difficult circumstances has been presented. The framework defines the various teams, which are involved in handling an emergency like an explosion of one of our chemical manufacturing units, which has caused due to the uncontrolled reaction of the 4-Nitro-N-Methyl phthalimide reaction. The firefighting team along with the state emergency rescue team have been involved in controlling the emergency. The various steps which are taken in handling the emergency have been informed to the management team through the management representative. After ascertaining the situation, the management team permits activating the business continuity plan and shifting the men, materials, and machinery to one of the new units located at Atchutapuram, Visakhapatnam, India, to continue the business. There were some delays during the transition stage. After erecting the process equipment, pre-start-up safety reviews have been conducted and resumed production, thus meeting the production goals leading to sustainable business in difficult circumstances.

Keywords

On-site emergency, Business continuity planning, Emergency Response Team, Management representative, Management team, Sustainable business.

1. Introduction

Hazardous chemical industries are prone to frequent incidents/accidents and injuries (Tahmid et al., 2020), as there are chances that this chemical reaction may go out of control in the occupational environment, which may result in an explosion causing a devastating effect (Gong et al., 2024), so safety is given the highest priority in chemical handling industry (Bhusnure et al., 2018, Wang et al., 2018). It is always better to have a clear-cut ideology to see that in case of any such eventuality, we continue the business without hindrance and we have a dedicated plan to run the business during the difficult times so that we can protect the moral and ethical values of the business and meet the client requirement as per the terms and conditions (Boatright 2020, Carroll 2000), which have been accepted mutually before manufacturing of the product. The business continuity planning (BCP) is prepared in a standardized way (Tucker 2014, Sawalha 2021) so that we can meet the requirements of the production planning. Emergency planning requirement, which includes business impact anal-

ysis, plays a crucial role in assessing the damage of the accidents (Epstein and Khan 2014, Păunescu et al., 2018), which are linked to the production plan. Such a type of analysis will help us to plan the requirements for the production activities and fulfil the demand of the customers (Bakar et al., 2015, Faertes 2015, Baldwin 2019).

The deceleration of an emergency, using high-end technology for risk management (Jovičić et al., 2024) and its combination of the onsite emergency plan (OSEP) with BCP plays a vital role in the form of a new approach. Handling an emergency in a critical industry will be difficult as it requires proper scientific planning and trained people who can handle the disastrous situation. However, the criticality depends up on the type of disaster and handling of the onsite emergency. The different ways of safety training, which are provided during mock drills (Soman & Sundararaj, 2015), help in handling critical situations, where we practise the various scenarios in handling emergencies in the hazardous chemical handling industry. The combination of the roles of the individual team members of the OSEP, not only saves the property of the company but also restricts the spread of the disaster from becoming an off-site emergency (Sorensen et al., 2013). Further proper planning during the onsite emergency helps in saving the lives of the employees and contractors who are working in the hazardous chemical handling industry.

The new approach, pays a way to support the goals of environmental health and safety (EHS) policy for handling the critical circumstances of the organisation (Khair et al., 2018). The combination of the OSEP and BCP, which acts a dual purpose, is we can save the life and the property of the company by implementing the OSEP further the BCP, which helps in continuing the business without any hindrances and fulfilling the needs of the global customers. We have presented a broader view in this paper, where we have handled a disastrous situation in our chemical manufacturing industry. Proper planning has helped us in saving the life, although we lost some people during the incident we have saved the lives of our many employees by activating the OCEP and continuing the business despite the odd circumstances, we have faced in difficult circumstances, as we have shifted our business from unit 4 to Unit 5, where we have started manufacturing the same product. Nolan (2014) reported the criticality of the product has been understood by performing the risk assessment in the form of hazard repeatability (HAZOP), further, we have carried out the pre-start-up safety review (PSSR) for our critical reaction, we have improved our safety aspects in our organisation for the safer production and achieving the targeted goals of the production has neem presented.

2. Methodology

The new scientific approach, to handling the emergency during the difficult circumstances in the chemical handling industry has been presented, various steps were taken after the blast of the reactor, which happened while carrying out the 4-Nitro-N-Methyl phthalimide reaction on 13th April 2022 in one of the unit 4, which has led to the activating the onsite emergency plan, we have presented the various ways of activating BCP, which has helped in the continuing of the business during the difficult times. It has resulted in the continuity of the business and satisfying the needs of the global customers, where we have applied the combination of emergencies and business continuity, which is in the form of OSEP and BCP. Various steps have been presented in the form of an overview of handling critical situations by the various ways of forming the different teams for the various activities.

3. Results and discussion

The preparation of the BCP, which includes the activation of the response of handling the eventuality like fire, explosion and disaster due to natural calamity in coordination with the Emergency response team (ERT) (Reilly, 2015), which is part of the on-site emergency plan (OSEP) in the hazardous chemical handling industry. Such type of teams will remain active during the emergency, which saves human lives (Dimitriou et al., 2018, Spellman 2023), machinery and involve in stopping the escalation of the fire in the hazardous chemicals storage area (Madrzykowski 2016, Zhang et

al., 2019), so it is necessary to conduct an informed and uninformed mock drill every three and six months once to tackle the emergency in different scenarios such as explosion, fire, gas leak and natural disaster in the hazardous chemical handling industries (Soman and Sundararaj 2015, LeBoeuf 2020, Petridou et al., 2023). In case of any such eventuality, the site controller will discuss it with the management team after the emergency comes to normality for crisis management (Khairilmizal 2020). The site controller will activate the recovery plan, and check the damage of the men, material and machinery (3M concept). After gathering the post-disaster information, the site controller will make a road map to shift the required materials such as equipment, chemicals and people sent to other units, so that the production plan will not be affected, which leads to the sustainability of the business during the difficult circumstances, which is known as BCP (Corrales-Estrada 2021). During the process, many of the internal departmental teams are involved in the successful shifting of 3M to the new unit to fulfil the demands of production planning leading to the continuity of the business, which is the form of emergency planning responsibility team (EPRT) matrix, which are given in the Table. 1, which helps in the recovery of the business in difficult circumstances, all the financial aspects concerning the shifting of the equipment, manpower and other resources will be coordinated with management representatives in consultation with the finance head, which are approved by the top management.

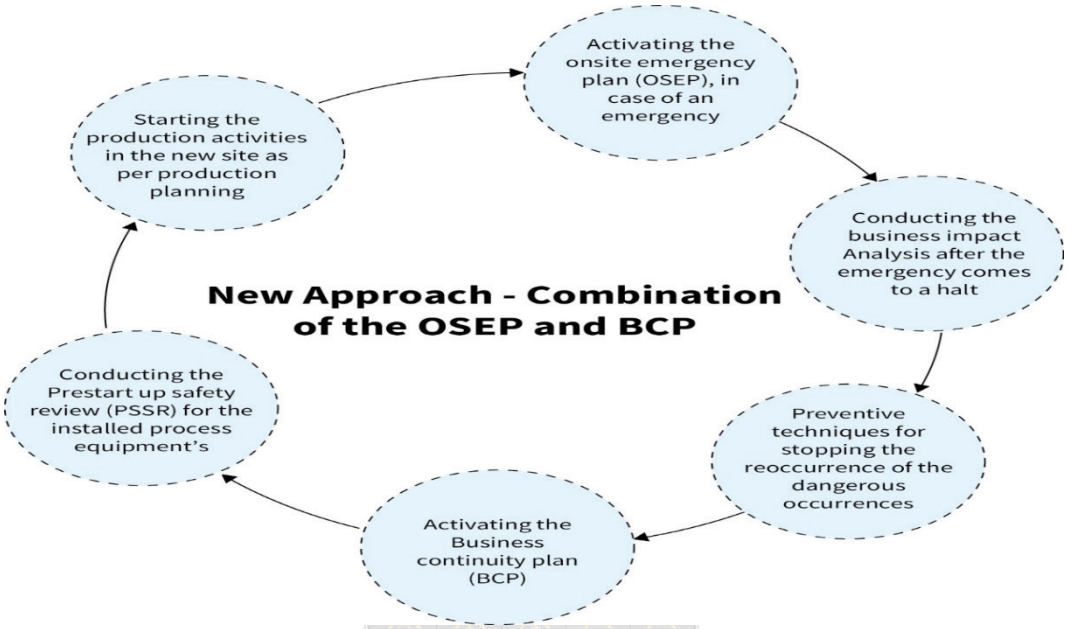


Figure 1. An overview of the new Approach – Combination of the OSEP and BCP

Table 1. Emergency planning responsibility team (EPRT), which is involved in the shifting of the business from one unit to another.

S.No.	Category Teams	Responsible Department(s)
1	Legal	Finance
2	Regulatory	EHS, Site In-charge
3	Environmental, Health & Safety	EHS
4	Economic and Financial	Finance
5	Personnel	Human resource (HR) & Admin
6	Supply Chain	Commercial/ Supply Chain
7	Market	Sales
8	Geo-political unrest in servicing markets	Sales, Commercial/ Supply Chain
9	Government Policy changes	Relevant dept. as per issue
10	Natural disaster events	HR & Admin, Site In-charge

Combining the On-Site emergency planning and the BCP will help us not only save the 3 M but also it helps in activating the sustainability of production without delay (Steen et al. 2024), which is one of the new approaches that has been introduced in Figure. 1, which we initiated during one of the disasters which has happened in the recent past in our chemical manufacturing unit. We have presented an outline of a case study of an uncontrolled reaction, which resulted in a disaster in the chemical manufacturing unit, where we have activated OSEP, which is followed by BCP, which has resulted in the successful continuity of the business in difficult circumstances.

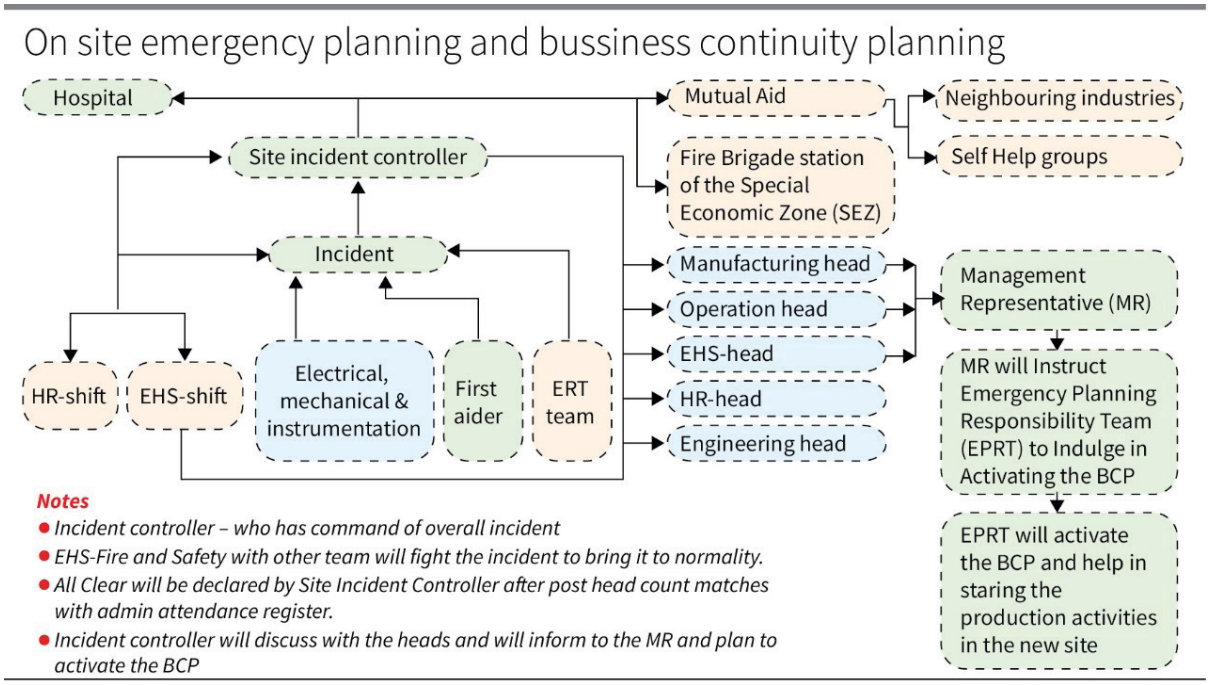


Figure 2. On-site emergency planning and activating the business continuity planning (BCP)

3.1. On-site Emergency, which has a direct relationship with the risk matrix in ascertaining the emergency.

The on-site emergency plan plays a key role in acting up on the emergency and there is a proto call for reporting an onsite emergency (Bernabei 2021, Wang et al. 2024) so that the emergency can be tackled systematically (Figure 2). The risk handling mainly depends up on the risk matrix, which is categorized based on Low, medium and high / very high, which is given in Figure 3, such type of matrix will help us to ascertain the onsite emergency and the category of risk to be handled before the eventuality (Duruel & Çelebi 2023) so that the on-site emergency plan team member pre-prepared to any kind of disastrous situation (Figure. 2), which may occur due to fire, explosion, toxic / gas leak and the natural calamities in the hazardous chemical handling industry (Hou 2021). We have classified the handling of risky situations, which are classified based on likelihood and consequences (Figure. 3).

Consequence	Likelihood			
	Low	Medium	High	Very high
Low	Low	Low	Medium	Medium
Medium	Low	Medium	Medium	High
High	Medium	High	High	Very high
Very high	High	High	Very high	Very high

Figure 3. Likelihood and consequence matrix for handling the risky situation using the onsite emergency plan

3.2. Avoiding the risk – Giving the highest priority by installing the safety critical equipment in the hazardous chemical storage area and the processing equipment of the various blocks, where these hazardous chemicals are used in the process for achieving the desired results as per batch management process (BMR).

3.3. Reducing or mitigating the risk – Taking measures to reduce the likelihood or impact of the risk depends on the handling of risky situations, an example is handling the toxic spillage of chemicals. This mainly depends on how well you are prepared to avoid the risk.

3.4. Sharing the risk – Sharing the risk depends on the handling of the emergency, which is in the form of mutual aid, where neighbouring industries, self-help groups and state fire emergency and rescue operational services are involved in handling the emergency.

3.5. Retain or accept the risk – Taking an action due to a cost/benefit analysis, which comes into action after the emergency comes to an end, which results in an all-clear signal from the incident controller, the incident controller and all the team members will discuss with the management representative (MR). The teams which are involved in the OSEP for tackling the emergency are listed in Figure. 2, where the incident controller will have command of the whole of the situation, he is an officially authorized person on the site to declare the emergency, after tackling the emergency, when the situation becomes normal, he will give all-clear signal, so that it indicates that the emergency has come to a halt. Goyal (2019) has reported that mutual aid plays an important role in disaster governance and community resilience. During the emergency, the mutual aid members in and around the factory premises will be involved in tackling the emergency, by providing additional self-contained breathing apparatus (SCBA), fire-resistant suits and boots. The site incident controller will inform the nearby police station, district collectorate, pollution control board (PCB), electricity board, and factory inspector and send a report of the incident and the suitable measures taken to all the concerned departments. The MR will discuss with the incident controller and with all the heads of the departments (HODs), same will be explained to the management for the various root causes of the incident/accident, various ways, which are involved in tackling the emergency, overall view of the business impact analyses, which includes 3M and various preventive measures, which are taken to stop the reoccurrence of such type of incident/accident. The management, after assessing the whole situation, will work on the cost-benefit analysis for running the business by applying the business sustainability concept and keeping market demand into consideration. They will activate the BCP by instructing the MR. The MR will direct the Business Continuity Coordinator (BCC) in coordination with EPRT and will organize the required 3M for the sustainability of the business. The main functions of the BCC are as follows:

1. To start the Disaster Recovery/Business Continuation process to recover the business functions through an alternate site.
2. They will inform various steps to the MR, which will lead to the sustainability of the business.
3. Only the MR after obtaining permission from the management will disclose the various developments to the public, by making an official public statement concerning the post-disaster plans for sustaining the business. Monitor the progress of all Business Continuity and Disaster Recovery teams daily.
4. MR will report the steps taken in the BCP status to the management team daily so that they can know the status for resuming the production activities.
5. Communicate directions received from senior management to the emergency teams such as EPRT and BCC for the successful starting of the production activities.
6. Provide ongoing support and guidance to the business continuity teams and personnel.
7. Review staff availability and recruit the staff based on the present requirement and need for sustaining the business based on the production plan
8. It will be ensured that all the records of all business continuity and disaster recovery activity and expenses incurred are being maintained properly and the same will be shared with the management.

3.6. Handling the difficult circumstances in the organization during the major accidents and its continuation of the business – An overview of the case study, which has resulted in activating the BCP

On 13th April 2022 in one of unit 4, all the occupants were working in the various production blocks, in one of the D blocks, where were carrying out 4-Nitro-N-Methyl phthalimide reaction in a 10 KL reactor with a standard temperature of 90 to 110-degree centigrade as per batch processing record (BPR), which is an exothermic reaction. The reaction has gone out of control due to the failure of chilling in the reactor jacket, which has resulted in the uncontrolled reaction, and it has resulted in leakage of the Monomethylamine gas leak due to pressure build-up in the reactor, which has resulted in explosion of the reactor vessel, resulting in fatality and the injury of the workers working in the occupational environment. Similarly, Furlong et al. 2024 have reported that gas explosions has been caused in the chemical industry due to the improper lopping of the system in a United States laboratory, Abbasi et al. 2010 have classified the various chemical explosions, which occurred in chemical processing industries and several authors have reported the explosion causes and the prevention techniques (Fukuoka et al. 2022) but very little information is published combining the causes of the accidents and the sustainability and application of the BCP after post disaster management plan. The site controller, on hearing about the accident, informed the emergency team members to raise the siren and the headcount of the operators was counted at the emergency assembling point and saw that it matched with the headcount of the digital display board, which is near to the entrance of the security gate of the company, such type of digital boards helps us to the exact number people available during the emergency. Kuligowski & Wakeman (2017) stressed the importance of the sound mechanism as a tool, which has been used for alerting the occupants working in the factory premises so that the people working in the occupational environment can reach the safe assembly point and the public at large, which includes the neighbouring industry can also be alerted in the occurrence of an emergency. By hearing the siren, the ERT team members reached the accident site, where the incident had taken place.

The ERT team members were involved in the firefighting, first aiders were involved in treating the injured person and they were given primary treatment, further occupants were rushed to the hospital for further treatment. Hamilton et al. 2022 have stressed the importance of treating the injured person during difficult times as the emergency teams are highly active not only giving the primary treatment but also saving the life in time. It is also important that mutual communication between the incident controller, rescue team, first aiders and other team members who are involved in the emergency operation should be in line way to tackle the disastrous situation so that the emergency can be fought time a bound manner (Brown et al. 2021).

During the disaster situation fighting phase, the emergency lasted for more than three hours and in the fourth hour all clear signals were given by the site controller. The site controller has presented the in-depth incident report to the MR and the MR has presented the same report to the management. Further, we have also ascertained that damage of around fifty Croes has been estimated for the process equipment of the D block. After one week of the incident, the management team instructed MR to activate the BCP to continue the business. Păunescu et al. 2018 have reported that the business impact analysis in Romanian enterprises has played a vital role in ascertaining the impact after the post-disastrous situation, the critical role is to capture the market and enhance the sustainability of the business in difficult circumstances.

The BCP team members of EPRT and BCC were involved in shifting the 3m from one unit to another unit, which is located at the Atchutapuram, Vizag, where around 10 reactors, 5 centrifuges and other process equipment were shifted to the new site and started manufacturing after installation and conducting the pre-startup safety review (PSSR) for the newly installed process equipment's. Abu Bakar and Abdul Aziz (2024) have reported that developing the PSSR technique has played a vital role in the safer operation in the hazardous chemical handling industries. The EPRT members, which were involved after the post-disaster in shifting of the business, which includes legal, regulatory, environmental health and safety, finance, personal & human resource and supply chain were 3, 2, 4, 2, 4 and 2 people are involved in shifting of the 3M. The BCC, includes the production team members, quality control, quality assurance, mechanical and maintenance, projects, utility and electrical department. Adapting to the changes in the location and continuity of the production with resilience to change played a vital role in meeting the goals of the production planning (Whyte et al. 2022). Steen & Pollock, 2022 reported that handling uncertainty is a challenging task, the resilience of the team members should be having a good knowledge of the projects and operational activity, it should lead to oper-

ational excellence resulting in achieving the production goals. Many of the other authors stated that the complex problems of restarting the business and continuing the operations, required dedicated vision of team members and the support of the top management (Hollnagel, 2015, Heger et al., 2017, Groenendaal & Helsloot, 2020). The visionary approach to planning with the help of BCP is in the Figure. 4.

Although there were many issues and delays during the transmission stage, the highest priority has been given by the management to see that production continued despite the delay due to the dangerous occurrence of the incident. In this way, the BCP has not only helped us to continue the business, but it has also helped in reaching the targets of the production there were a few delays, which occurred in getting the final product and achieving the targets, and this has been conveyed to the customer. In this way, the BCP has helped in customer retention and satisfying the global demand during difficult circumstances. The Ethical and moral values of the client and customers have been maintained and we have become the largest producing chemicals in the special economic zone at the Atchutapuram, Vizag, India within one and a half years. In this way the BCP not only helps is sustainability of the business but also helps satisfying the demand of the customers.



Figure 4. Visionary approach for tackling the emergency and activating the BCP.

4. Conclusion:

The new conceptual methodology, where the onsite emergency plan and the business continuity plan can be combined so that we can fight an emergency and sustain the business in difficult circumstances. In case of deceleration of the emergency, the emergency response team and other team members are involved in fighting an emergency like fire, explosion, emission and natural calamities. The ERT members are well-trained in handling challenging situations in the hazardous chemical manufacturing industry. Overall, the site controller is responsible for handling the emergency, he reports to the management representative. The management representative conveys the various steps which are taken in fighting an on-site emergency to the management. After the emergency comes to a halt, the MR will discuss with the management team, and plan to activate the business continuity plan to continue the business in difficult times, the emergency planning responsibility team is responsible for shifting the 3M in consultation with the MR and after shifting to new site, the PSSR has been conducted for all the process equipment before starting of the equipment, although we have

found few delays in starting of the production, same has been explained to the clients and we have streamlined the production to achieve the targets, which has resulted in sustainability of business in the difficult times.

5. End notes

1. Handling on-site emergencies requires highly trained people for handling dangerous occurrences.
2. Practicing mock drills will help us in the successful implementation of the OSEP during the occurrence of an emergency in the chemical handling industry.
3. The new approach will have a broader view for the chemical handling industries to sustain the business in difficult times by successful implementation of the BCP
4. Management support and the vision of the company business play a vital role in activating the BCP in difficult circumstances
5. Fighting an emergency with the least impact on 3M, which plays a vital role so that less impact on the invested capital for running the business.
6. Saving the life of the occupants plays a crucial role in handling an emergency.
7. Team coordination is important while activating the OSEP and successful implementation of the BCP for sustaining the business in difficult circumstances.

Funding: There is no funding involved, as this is a practical approach, which has resulted in the implementation of OSEP and BCP.

Acknowledgement: I thank all my team members in the safety department and other members of the organization for handling the emergency and helping to continue the business in difficult circumstances.

Conflict of interest: The author has no conflict of interest.

References

1. Abbasi, T., Pasman, H. J., & Abbasi, S. A. (2010). A scheme for the classification of explosions in the chemical process industry. *Journal of hazardous materials*, *174*(1-3), 270-280.
2. Abu Bakar, A., & Abdul Aziz, H. (2024). Development of pre-startup safety review implementation tool for safe operation in process plant. *Process Safety Progress*, *43*, S71-S77.
3. Bakar, Z. A., Yaacob, N. A., & Udin, Z. M. (2015). The effect of business continuity management factors on organizational performance: A conceptual framework. *International Journal of Economics and Financial Issues*, *5*(1), 128-134.
4. Baldwin, S. (2019). Business continuity management as an operational risk service provider: An approach to organisational resilience. *Journal of business continuity & emergency planning*, *13*(2), 102-110.
5. Bernabei, L., Mochi, G., Bernardini, G., & Quagliarini, E. (2021). Seismic risk of Open Spaces in Historic Built Environments: A matrix-based approach for emergency management and disaster response. *International Journal of Disaster Risk Reduction*, *65*, 102552.
6. Bhusnure, O. G., Dongare, R. B., Gholve, S. B., & Giram, P. S. (2018). Chemical hazards and safety management in the pharmaceutical industry. *Journal of Pharmacy Research*, *12*(3), 357-369.
7. Boatright, J. R. (2000). *Ethics and the Conduct of Business, 6/e*. Pearson Education India.
8. Brown, O., Power, N., & Conchie, S. M. (2021). Communication and coordination across event phases: A multi-team system emergency response. *Journal of Occupational and Organizational Psychology*, *94*(3), 591-615.

9. Carroll, A. B. (2000). Ethical challenges for business in the new millennium: Corporate social responsibility and models of management morality. *Business Ethics Quarterly*, *10*(1), 33-42.
10. Corrales-Estrada, A. M., Gómez-Santos, L. L., Bernal-Torres, C. A., & Rodriguez-López, J. E. (2021). Sustainability and resilience organizational capabilities to enhance business continuity management: A literature review. *Sustainability*, *13*(15), 8196.
11. Dimitriou, L., Efthymiou, D., & Antoniou, C. (2018). Saving lives through faster emergency unit response times: Role of accessibility and environmental factors. *Journal of Transportation Engineering, Part A: Systems*, *144*(9), 04018053.
12. Duruel, M. C., & Çelebi, A. (2023). Workplace Disaster and Emergency Plans, Risk Analysis and Implementation. *Resilience*, *7*(2), 357-373.
13. Epstein, B., & Khan, D. C. (2014). Application impact analysis: A risk-based approach to business continuity and disaster recovery. *Journal of business continuity & emergency planning*, *7*(3), 230-237.
14. Faertes, D. (2015). Reliability of supply chains and business continuity management. *Procedia Computer Science*, *55*, 1400-1409.
15. Fukuoka, K., & Furusho, M. (2022). A new approach for explosion accident prevention in chemical research laboratories at universities. *Scientific reports*, *12*(1), 3185.
16. Furlong, A. J., Bond, N. K., Pegg, M. J., & Hughes, R. W. (2024). Evaluation of dust and gas explosion potential in chemical looping processes. *Journal of Loss Prevention in the Process Industries*, *89*, 105277.
17. Gong, L., Yu, G., Li, J., Chen, J., Chen, R., Huang, J., ... & Duh, Y. S. (2023). Explosion incidents associated with comprehensive studies on methyl ethyl ketone peroxide under thermal decomposition: A review. *Process Safety Progress*.
18. Goyal, N. (2019). Disaster governance and community resilience: The law and the role of SDMAs. *International Journal of Disaster Risk Management*, *1*(2), 61-75.
19. Groenendaal, J., & Helsloot, I. (2020). Organisational resilience: Shifting from planning-driven business continuity management to anticipated improvisation. Journal of Business Continuity & Emergency Planning, 14(2), 102–109.
20. Hamilton, A. R. L., Södergård, B., & Liverani, M. (2022). The role of emergency medical teams in disaster response: a summary of the literature. *Natural hazards*, 1-10.
21. Heger, C., van Hoorn, A., Mann, M., & Okanović, D. (2017). Application performance management: State of the art and challenges for the future. Paper presented at the 8th ACM/SPEC International Conference on Performance Engineering.
22. Hollnagel, E. (2015). Disaster management, control, and resilience. In A. J. Masys (Ed.), Disaster management: Enabling resilience. Springer International Publishing.
23. Hou, J., Gai, W. M., Cheng, W. Y., & Deng, Y. F. (2021). Hazardous chemical leakage accidents and emergency evacuation response from 2009 to 2018 in China: A review. *Safety Science*, *135*, 105101.
24. Jovičić, R., Gostimirović, L., & Milašinović, S. (2024). Use of New Technologies in the Field of Protection and Rescue During Disasters. *International Journal of Disaster Risk Management*, *6*(1), 111–122. https://doi.org/10.18485/ijdrm.2024.6.1.8
25. Khair, N. K. M., Lee, K. E., Mokhtar, M., & Goh, C. T. (2018). Integrating responsible care into quality, environmental, health and safety management system: A strategy for Malaysian chemical industries. *Journal of Chemical Health and Safety*, *25*(5), 10-18.
26. Khairilmizal, S., Hussin, M. F., Husna, K. A., Kasri, H., Hussain, A. R., & Yassin, A. M. (2020). Effective emergency management: The roles of knowledge and practice of command structure for lead responding agencies. *Global Business and Management Research*, *12*(1), 33-41.
27. Kuligowski, E. D., & Wakeman, K. (2017). *Outdoor siren systems: A review of technology, usage, and public response during emergencies*. Department of Commerce. National Institute of Standards and Technology. Fire Research Division. Engineering Laboratory.
28. LeBoeuf, J. (2020). Mock drills: Implementation for emergency scenarios in the outpatient setting. *Number 1/February 2020*, *24*(1), E7-E12.

29. Lengyel, D. M., Mazzuchi, T. A., & Vesely, W. E. (2023). Establishing risk matrix standard criteria for use in the continuous risk management process. *Journal of Space Safety Engineering*, *10*(3), 276-283.
30. Madrzykowski, D. (2016). Fire Dynamics: The Science of Fire Fighting. *International Fire Service Journal of Leadership & Management*, *10*.
31. Nolan, D. P. (2014). *Safety and security review for the process industries: Application of HAZOP, PHA, what-if and SVA reviews*. Elsevier.
32. Păunescu, C., Popescu, M. C., & Blid, L. (2018). Business impact analysis for business continuity: Evidence from Romanian enterprises on critical functions. *Management & Marketing*, *13*(3), 1035-1050.
33. Petridou, E., Sparf, J., Hemmingsson, O., & Pihl, K. (2023). Immersive simulation and experimental design in risk and crisis management: Implications for learning. *Journal of Contingencies and Crisis Management*, *31*(4), 1009-1017.
34. Reilly, D. (2015). Business continuity, emergency planning and special needs: How to protect the vulnerable. *Journal of Business Continuity & Emergency Planning*, *9*(1), 41-51.
35. Sawalha, I. H. (2021). Views on business continuity and disaster recovery. *International Journal of Emergency Services*, *10*(3), 351-365.
36. Soman, A. R., & Sundararaj, G. (2015). Accidental Release of Chlorine from a Storage Facility and an On-Site Emergency Mock Drill: A Case Study. *The scientific world journal*, *2015*(1), 483216.
37. Sorensen, J. L., Van der Vleuten, C., Lindschou, J., Gluud, C., Ostergaard, D., LeBlanc, V., ... & Ottesen, B. (2013). 'In situ simulation'versus' off site simulation'in obstetric emergencies and their effect on knowledge, safety attitudes, team performance, stress, and motivation: study protocol for a randomized controlled trial. *Trials*, *14*, 1-11.
38. Spellman, F. R. (2023). *Physical hazard control: preventing injuries in the workplace*. Bernan Press.
39. Steen, R., & Pollock, K. (2022). Effect of stress on safety-critical behaviour: An examination of combined resilience engineering and naturalistic decision-making approaches. Journal of Contingencies and Crisis Management, 30(3), 339–351. Steen, R., Haug, O. J., & Patriarca, R. (2024). Business continuity and resilience management: A conceptual framework. *Journal of Contingencies and Crisis Management*, *32*(1), e12501.
40. Tahmid, M., Dey, S., & Syeda, S. R. (2020). Mapping human vulnerability and risk due to chemical accidents. *Journal of Loss Prevention in the Process Industries*, *68*, 104289.
41. Tucker, E. (2014). *Business continuity from preparedness to recovery: A standards-based approach*. Butterworth-Heinemann.
42. Wang, B., Wu, C., Reniers, G., Huang, L., Kang, L., & Zhang, L. (2018). The future of hazardous chemical safety in China: Opportunities, problems, challenges and tasks. *Science of the total environment*, *643*, 1-11.
43. Wang, H., Wei, L., Wang, K., Wang, R., Duo, Y., & Yang, G. (2024). Current status, challenges, and future pathways of chemical industrial park safety in China. *Journal of Loss Prevention in the Process Industries*, *87*, 105233.
44. Whyte, J., Naderpajouh, N., Clegg, S., Matous, P., Pollack, J., & Crawford, L. (2022). Project leadership: A research agenda for a changing world. *Project Leadership and Society*, *3*, 100044.
45. Zhang, G., Li, C., & Lu, S. (2019, October). Analysis of Professional Team Formation for Chemical Firefighting Based on Petrochemical Fire Treatment in A Certain City. In *IOP Conference Series: Earth and Environmental Science* (Vol. 332, No. 2, p. 022064).

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Review Article

An Inevitable Technological Disaster Type: Space Debris

Fikret Emre Öcal[1*], **Salih Torun**[2]

[1] École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland; fikret.ocal@epfl.ch

[2] Ankara Hacı Bayram Veli University, Ankara, Turkey; salih.torun@hbv.edu.tr

** Correspondence: fikret.ocal@epfl.ch*

Received: 8 July 2024; Revised: 10 October 2024; Accepted 5 November; Published: 25 December

Abstract

The rapid accumulation of space debris has emerged as a critical threat to global satellite infrastructure, jeopardizing essential services such as communications, navigation and real-time weather forecasting, which are fundamental to effective disaster management. This paper provides a comprehensive review of the multifaceted challenges posed by space debris, focusing on collision risks, Kessler Syndrome and the inherent vulnerabilities of satellite networks. It highlights significant gaps in existing international regulatory frameworks, underscoring the urgent need for stronger global coordination. While technological interventions such as Active Debris Removal (ADR) and enhanced Space Situational Awareness (SSA) show promise, they fall short when applied alone. A sustainable solution requires an integrated approach that combines innovative technologies such as on-orbit manufacturing and self-destruction systems with policy reforms that enforce stricter debris management protocols and encourage compliance with economic measures such as debris removal credits and orbital parking fees. China, European Union, the United States and some other countries have already begun the work needed to coordinate space activities, but the breadth of these efforts and rules varies from country to country, and the lack of ownership or control of space is a problem. Given the important role of satellites in disaster response, the protection of space assets is essential to sustaining global resilience. Ensuring long-term sustainability will depend on international cooperation, binding agreements and a collective commitment to preserve the orbital environment for future generations.

Keywords

Space Debris, Active Debris Removal (ADR), Space Situational Awareness (SSA), Kessler Syndrome, Technological Disaster.

1. Introduction

In the era of rapid technological advancement, space activities have become integral to modern civilization, supporting essential services such as communication, navigation, weather forecasting, and defence. There is however a paradox that exists with the increased use of space infrastructure systems, the increasing problem of space debris. This debris typically includes spent satellites, rocket stages, and fragments from objects that have collided or exploded. This represents a significant

hazard for both operational satellites and crewed space missions. The threat extends beyond outer space, affecting critical disaster-mitigation activities like emergency communication, weather services, and satellite navigation systems.

As of 2024, there are an estimated 130 million mini debris objects (less than 1 cm), 1.1 million objects (between 1 cm and 10 cm) and 40,500 objects (greater than 10 cm) in polar orbit around the earth in low earth orbit (European Space Agency [ESA], 2024). Even small objects travel at speeds of up to 28 km/h, hence even a small piece can turn into a destructive instrument that can cause major damage and even obliterate satellites (Swope et al., 2024). Also, the situation in LEO is worsened by the launching of mega constellations such as Starlink and OneWeb that plan to place thousands of satellites to ensure the availability of worldwide internet coverage. These constellations, while being of great economic and technological advantages, create a serious threat of impact collision which may destabilize the environment and, in effect, cause the Kessler Syndrome – a system of debris (Buchs, 2021). Based on 'Orbiting Now' (NanoAvionics, 2024), more than 7,000 Starlink satellites have been launched into orbit, while an estimated 9,900 operational satellites exist. Although these projects have many advantages, the risk factors from their 'end-of-life' phase heighten worries of the how these will perform in space.

The implications of space debris are profound, not only for spacefaring nations but for global disaster management capabilities. In the event of a possible disaster, activities to return life to normal are addressed in four stages: disaster response, rescue, recovery, mitigation and disaster preparedness (Öcal, 2019; 2021). Satellites play a crucial role in providing real-time data for monitoring natural disasters such as hurricanes, earthquakes, floods, and wildfires (Ryan et al., 2022). For instance, in the case of a disaster and especially within a vast area, the satellites help maintain critical telecommunication systems and help in locating the injured using satellite-based systems (ESA, 2016; Dukiya&Banji Adeleye, 2022). Unfortunately, if these services are disrupted by a collision with debris, efforts to respond to and manage the effects of a disaster will be greatly hampered in terms of saving lives and properties.

Despite these well-documented risks, global efforts to mitigate space debris remain inadequate. The existing mechanisms like the guidelines of the Inter-Agency Space Debris Coordination Committee (IADC) and the recommendations of the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) constitute soft law provisions on debris mitigation (Lambach& Wesel, 2021). These guidelines include principles like the 25-year rule, which requires that satellites be deorbited or moved to a disposal orbit within 25 years after mission completion (Virgili et al., 2016). However, several challenges hinder adherence to these recommendations, particularly among commercial satellite network providers, where economic factors and rising operational costs often take precedence over environmental concerns (Maclay& McKnight, 2021). Furthermore, the existing SSA Space Situational Awareness systems only keep track of a very small percentage of debris, primarily those objects that are over ten centimetres in size, while a few million even more hazardous pieces of debris remain untracked and unmeasured (ESA, 2024).

The obligation to maintain cleanliness and order in the orbits of the Earth is shared by every nation and commercial enterprise that launches and operates in space. Those who do not participate in such activities but depend on the services provided by satellites are not immune to the potential consequences of their inaction (OECD, 2026). This is yet another example of the tragedy of the commons; here, the actors involved are rationally self—interested and act in their own short—term — in fact, the less each of them cares about the resources, the more degraded they are (Lambach & Wesel, 2021). In the absence of adequate measures to reduce space debris, the increase in space activities, which is uncontrollable at this point, has already resulted in serious incidents such as that of Iridium and Cosmos in 2009, which destroyed over 2000 pieces of defined debris (Buchs, 2021).

To tackle the problem of space junk, a wide range of interventions including technology, regulations, and financial motivations is necessary. One such development relates to the creation of Active Debris Removal (ADR) systems which has technological promise. Companies such as Astroscale as well as regional players like the European Space Agency (ESA) are already experimenting with ways to incorporate nets, robotic arms, and even harpoons in a bid to capture and remove large objects of debris from the earth's orbit (Degrange, 2019). Widespread fragmentation of such larger

debris, however, commendable as it may be, will not address the raise many problems financial and technical that ADR face today, bringing into a need for cooperation among the countries of the earth (ESA, 2016). Along with these technologies however, there is a great realization that there is need for stricter international laws to make such measures effective. The persistent lack of effective, legally enforceable treaties that address the issue of space debris removal still impedes progress, and the establishment of such a system is imperative due to the lack of regulations governing Outer Space Operations, including a Space Traffic Management (STM), which would be regulated by an organization to ensure compliance (Maclay & McKnight, 2021). Or, alternatively, economic tools, for example, the credits for the removal of debris, or the fees for orbital parking, could motivate the private sector to consider more seriously their commitments to protecting the orbits (Carroll, 2019).

This review aims to provide a comprehensive analysis of what is the space debris problem, what can be its possible dangers focusing on its implications for disaster management, the current challenges in debris mitigation, and the potential solutions that could lead to a sustainable space environment.

2. Challenges of Space Debris

One of the most important hurdles in maintaining the viability of space activities as well as services performed on Earth is the increasing amount of space debris orbiting the planet. This is due to the fact that many active satellites have been launched particularly the launching of large constellations of satellites in low earth orbit. The number of such incidences has drastically increased due to the increase in a number of objects within the space. The problems created by these phenomena in turn cause other problems by creating more debris which in turn can lead to the destruction of the entire orbital ecosystem and the systems that go with it such as when there is a catastrophe. Given that there is a rapid increase in spatial capabilities of both individual countries and commercial entities, there is no need to re-emphasize the importance of solving the problem of space debris.

2.1. Collision Risks and Orbital Congestion

With over 130 million debris objects currently in orbit, ranging from fragments smaller than 1 cm to larger defunct satellites and rocket stages, the risk of collisions in LEO has increased significantly (European Space Agency [ESA], 2024). Even small debris fragments, traveling at velocities of 28,000 km/h, can cause catastrophic damage to operational satellites, rendering them useless and generating even more debris. Mega-constellations like SpaceX's Starlink and OneWeb have increased congestion in low Earth orbit (LEO), raising the risk of accidental collisions between satellites and debris. (Virgili et al., 2016). With SpaceX alone planning to deploy over 12,000 satellites, the task of collision avoidance has become far more complex, and as of 2024 it reached the target of 7,000. (Maclay& McKnight, 2021). Also, sending satellite to the space and space business is not just dependent on SpaceX, which is also funded by many venture capitals and small companies. The logic of business model is "renting slots". One company is producing satellite, and it allocate some slots to rent very small companies to fund itself for the satellite project. This makes to funding new space projects easier.

The threat of collisions is ever-present. A good illustration is the 2009 incident involving the collision of Iridium 33 satellite with an old Russian satellite, Cosmos 2251, which resulted in more than 2000 trackable pieces of debris. Evidence that one episode may greatly worsen the issue of space debris. (Buchs, 2021). Moreover, this example serves to demonstrate the risk that such legacy orbital debris that is not tracked presents to functioning spacecraft, even in a state of inaction. The continued expansion of satellite constellations into densely packed orbital regimes will lead to more incidents of on-orbit collision unless the issues of tracking and mitigation are addressed. Not only active satellites but also spent upper stages of rockets and other big space objects which are no longer in use add to the space debris. Such enormous space debris can break up due to collisions and form numerous small debris pieces that are still dangerous. Satellites located in geostationary orbit (GEO)

are also at risk of this kind of events, as they perform critical functions including those for weather monitoring and telecommunication services. Disruption of such geostationary satellites might bring about serious effects to the systems on earth especially for systems responsible for disaster management and crisis communication (Ryan et al., 2022).

2.2. The Kessler Syndrome: A Self-Perpetuating Cascade

The Kessler Syndrome remains one of the most significant long-term threats posed by space debris. First proposed by NASA scientist Donald Kessler, this scenario suggests that as the density of objects in orbit increases, the likelihood of collisions will rise exponentially. Each collision will generate more debris, leading to a self-sustaining cascade that could render entire regions of LEO unusable for future operations (Buchs, 2021). The threat of the Kessler Syndrome is particularly concerning in the context of mega-constellations, where thousands of satellites occupy the same orbital region. The 775 km, 850 km, and 975 km altitudes of LEO are already hotspots for debris, and any major collision in these areas could trigger a cascading effect. This would have devastating consequences as means of technological disaster, as the loss of key satellites could cripple communication networks and disrupt navigation services that are essential for coordinating relief efforts during natural disasters (ESA, 2024).

2.3. Disaster Management and Space Debris

A collision between satellites in outer space can be defined as a crisis not only in the spatial context but also in terms of the earthly systems which are satellite-dependent. Satellites are vital elements in the prediction and mitigation of hazards. Key satellites that are primed in geosynchronous earth orbits (GEO) or those that are low tend to provide services such as weather forecasting, communication and navigation which are needed on the ground for the healthcare systems in the event of a probable disaster. A major impact could render critical satellite resources unusable when quick response actions are needed hence hampering communication and satellite-based forecasting of the disaster. For instance, when a debris crash causes damage to a weather satellite, such a weather forecast would be done after the scheduled time, which pushes the estimation of the potential flood seasonal hurricane casualties to a later and more treacherous time. Hence, in this way, the collision of space objects can escalate a natural calamity into a worldwide disaster. In addition, meteorological satellites furnish timely notice of the development of hurricanes, typhoons and floods; extending governments and people the chance to take appropriate measures to reduce the impact of the monster. Again, such satellites, which provide video images, are necessary to assist rescue activities after a disaster strikes, particularly in areas where land phone services have been disrupted (ESA, 2016). Therefore, the greatest risk to the operation of such satellites is space debris. In 2020, the incident of the OneWeb and Starlink satellite constellation demonstrated how active avoidance activity also shows the downside of satellite operation, where such nearness leads to service disruption and also raises issues on the safety of space (Buchs, 2021). As satellite constellations become larger and more complex, the risk of losing key satellite capabilities due to debris-induced collisions becomes a serious concern for disaster preparedness and response strategies. Each day this threat is increasing because of an increasing number of satellites. During disaster relief efforts, rescue crews depend on navigation satellites, including those in the Global Navigation Satellite System (GNSS), for guidance. The capacity of relief workers to get to affected areas promptly and effectively could be significantly impacted by any disruption in GNSS services brought on by debris collisions. Therefore, the issue of space debris is a worldwide concern that has a direct impact on the welfare of people on Earth and is not limited to spacefaring states (Maclay & McKnight, 2021).

2.4. Lack of Global Coordination and Regulatory Gaps

The lack of international coordination and enforcement systems that guarantee compliance with debris reduction guidelines makes managing space debris more difficult. Although non-binding guidelines, such as the widely recognized 25-year rule for satellite deorbiting, have been developed by international organizations like the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) and the Inter-Agency Space Debris Coordination Committee (IADC), these frameworks lack the teeth required to enforce compliance (Lambach & Wesel, 2021). The 25-year rule recommends that defunct satellites be moved to a graveyard orbit or deorbited within 25 years of the end of their mission, but adherence to this guideline is inconsistent, particularly among private operators of large satellite constellations (Virgili et al., 2016). This lack of enforcement creates a scenario where private companies may prioritize short-term economic gains over long-term environmental stewardship. Without global regulatory bodies capable of holding operators accountable for debris mitigation failures, space actors are often left to self-regulate. As a result, the pace of debris generation outstrips mitigation efforts, particularly as the space industry becomes more privatized and competitive. The deployment of mega-constellations in LEO further complicates matters, as commercial operators may launch thousands of satellites without sufficient planning for end-of-life disposal (Maclay& McKnight, 2021).

Compounding this problem is the lack of a comprehensive Space Traffic Management (STM) system. Unlike air traffic control, which coordinates the movement of aircraft to prevent collisions, STM systems are still in their infancy and largely operate on an ad-hoc basis. Satellite operators rely on tracking data from independent Space Situational Awareness (SSA) systems to predict potential collisions, but these systems can only track larger debris objects (those greater than 10 cm), leaving millions of smaller, yet still dangerous, debris fragments unmonitored (ESA, 2024). The absence of a unified STM system increases the likelihood of accidental collisions, as operators must independently decide when to maneuver their satellites based on limited and sometimes conflicting data. The 2020 near-collision between OneWeb and Starlink satellites underscores the urgent need for better coordination and shared SSA data to prevent future accidents (Buchs, 2021).

2.5. Economic Impacts of Space Debris

Space debris isn't just a problem for the space industry; it affects many other sectors that rely heavily on satellite technology. With the cost of launching satellites dropping and companies racing to put up massive constellations, the number of objects in orbit is growing fast, which raises the risk of collisions and orbital traffic jams. This makes it essential to balance economic growth with efforts to manage space debris, as doing so can prevent potentially huge financial losses, whereas ignoring it could stall the entire space economy.

Collisions in space are costly, not just for the space industry but for industries that depend on services like GPS, Earth observation, and telecommunications. Research shows that interruptions in satellite communication can disrupt everything from financial transactions to aviation and disaster response. (Nozawa et al., 2023). Several economic models have been put out to alleviate the financial strain. Insurance models that could reduce the financial risks connected to satellite crashes are one strategy. According to these models, satellite operators must have insurance that covers possible debris-related damages. This creates a safety net that covers the financial effects of crashes and incentivizes businesses to adopt safer practices by offering lower-risk operators lower rates. By putting this approach into practice, operators may be encouraged to incorporate collision avoidance and end-of-life disposal systems into their satellites, which would promote a more responsible operational culture (Buchs, 2021). Other proposed ideas include Pigouvian taxes or tradable permits that would set limits on satellite numbers and make operators pay fees based on their potential to generate debris. These concepts are similar to tools already used in environmental protection, like carbon credits, designed to build sustainability into the economic equation (Rao et al., 2020).

Another approach focuses on Active Debris Removal (ADR), which means actually capturing and deorbiting large, defunct objects. Right now, ADR tech is still emerging and expensive, but government partnerships with private companies could help make it more accessible. For instance, the European Space Agency and ClearSpace are working together on a mission to remove debris, and both Japan and the U.S. are exploring national programs for similar goals. With governments covering part of the cost and sharing the risk, these projects become more feasible. Expanding this effort, international bodies like the United Nations could establish a global fund to provide subsidies for ADR, ensuring that both established and emerging space nations participate in keeping orbits safe and clean. Governments could support the commercialization of ADR through public-private partnerships (PPPs), co-financing projects with private companies to lower the initial financial barrier and accelerate technological development. By co-financing debris removal missions, governments can not only encourage private sector participation but also help distribute the economic burden of debris management across multiple stakeholders. Such partnerships could be further enhanced by international bodies like the United Nations establishing a global fund dedicated to debris removal, which would provide subsidies to operators engaging in clean-up activities. This would also encourage participation from emerging space-faring nations, ensuring that all countries contribute to and benefit from a cleaner orbital environment (Nozawa et al., 2023).

The economic impact of unregulated space debris could be substantial. A study by Nozawa et al. (2023) estimates that the global GDP could decline by up to 1.95% over the next two centuries if no active remediation measures are implemented. This loss is attributed to reduced satellite operations, disruptions in services, and increased costs for collision avoidance and risk mitigation. The study also highlights that the implementation of debris remediation measures, such as ADR, can significantly mitigate these losses. By maintaining the functionality of critical satellite networks, global economic stability can be preserved, demonstrating the long-term economic benefits of investing in space sustainability.

3. Some Solutions to Space Debris

As the threat of space debris continues to grow, a multi-faceted approach that combines technological innovations, regulatory reforms, and international cooperation is necessary to prevent further degradation of the orbital environment. Current mitigation efforts, while crucial, are insufficient to fully address the escalating risk posed by debris, particularly in Low Earth Orbit (LEO) where a majority of the world's satellites operate. The path forward includes both preventive measures to stop the generation of new debris and active interventions to remove existing debris from space. This section explores the key solutions being implemented, focusing on debris mitigation, Active Debris Removal (ADR), and the critical role of global collaboration.

3.1. Mitigation and Passivation Techniques for Preventing Future Debris

The first line of defense against space debris is mitigation, which involves designing and operating satellites and space missions in a way that minimizes the creation of new debris. One of the most widely adopted mitigation strategies is the 25-year rule, which requires that satellites and other space objects deorbit or move to graveyard orbits within 25 years of the end of their mission (Virgili et al., 2016). While the rule is a step forward, its implementation has been inconsistent, particularly among commercial satellite operators. Many private companies face economic pressures that discourage adherence to best practices in debris mitigation, further complicating global efforts to address the issue (Maclay& McKnight, 2021). ESA's Zero Debris Approach by 2030 outlines a broader strategy for both mitigation and removal, incorporating technologies to reduce new debris creation, enhance tracking, and ensure that space objects are safely deorbited or relocated to graveyard orbits after their mission's end (European Space Agency, n.d.).

Passivation techniques, which involve removing residual energy sources such as fuel or charged batteries from defunct satellites, are another critical mitigation method. Passivation prevents ex-

plosions that can generate new debris fragments, reducing one of the main sources of additional debris. The European Space Agency (ESA) has pioneered the use of passivation valves in its satellite designs, allowing fuel to be safely vented at the end of a satellite's mission (ESA, 2016). However, like the 25-year rule, the widespread adoption of passivation techniques remains uneven across the global space industry.

A key advancement in debris mitigation is the development of self-disposal technologies, which allow satellites to autonomously deorbit at the end of their operational lives. SpaceX's Starlink satellites, for example, are equipped with autonomous propulsion systems that enable them to perform controlled re-entries, reducing the risk of becoming long-term debris (Maclay& McKnight, 2021). As more companies adopt such technologies, the overall risk of generating new debris will decrease. Additionally, innovations in satellite design for demise, which involve using materials that disintegrate completely upon atmospheric re-entry, offer a promising way to ensure that defunct satellites do not contribute to the debris population (ESA, 2024).

3.2. Active Debris Removal (ADR)

While mitigation techniques focus on preventing the creation of new debris, Active Debris Removal (ADR) technologies aim to reduce the number of existing debris in orbit. ADR is particularly important for addressing large debris objects, such as defunct satellites and rocket stages, which pose the greatest risk for catastrophic collisions. By removing these larger objects, ADR can prevent them from fragmenting into smaller debris, which is harder to track and avoid. Several ADR systems are currently in development, with Astroscale's ELSA-d mission standing out as one of the most promising. ELSA-d uses a magnetic docking mechanism to capture and deorbit defunct satellites, reducing the risk of further debris generation (Degrange, 2019). The success of this technology demonstrates the feasibility of ADR systems and has paved the way for future missions capable of removing multiple debris objects per mission.

The European Space Agency (ESA) is at the forefront of efforts to develop Active Debris Removal (ADR) technologies, recognizing that the long-term sustainability of space depends on actively removing existing debris. According to ESA, even if all space launches were stopped today, the amount of space debris would still increase due to collisions between existing objects, leading to a "cascade" effect. This highlights the necessity of ADR for stabilizing the orbital environment. One of ESA's key initiatives is the ClearSpace-1 mission, set to launch in 2025, which will be the world's first commercial debris removal mission. ClearSpace-1 aims to capture and deorbit a defunct ESA object in Low Earth Orbit (LEO). The mission involves the use of robotic arms to capture debris and safely guide it back into Earth's atmosphere, where it will burn up. This is a crucial step toward establishing a regular market for in-orbit servicing, including refueling and repair of satellites, and more importantly, preventing future collisions by removing large, high-risk objects from key orbits. Moreover, ESA emphasizes the importance of removing 5-10 large debris objects per year to stabilize debris levels in critical orbits. The removal of large, intact objects like defunct satellites and rocket stages is seen as the most effective way to prevent further fragmentation, which could exacerbate the debris problem.

Other ADR technologies include nets, robotic arms, and harpoons designed to capture and deorbit large debris objects. The RemoveDEBRIS mission, led by the Surrey Space Centre, successfully tested these techniques in 2018, demonstrating that they can be effective at capturing debris in orbit (Degrange, 2019). Another innovative approach is the use of laser systems to nudge small debris into lower orbits, where it will burn up upon re-entry. While still in the experimental phase, laser-based debris removal offers the potential to deal with debris fragments that are too small to be captured using traditional ADR methods (Maclay& McKnight, 2021). To give an example to the companies that has been working on ADR method, "ClearSpace" is a well-known startup, originally a spin-off from EPFL (École Polytechnique Fédérale de Lausanne), focused on solving the space debris problem. ClearSpace is pioneering efforts in Active Debris Removal (ADR) with a mission to capture and deorbit defunct satellites and large debris objects from orbit. Their innovative approach involves

using a robotic arm to "grasp" and safely deorbit debris, reducing the risk of collisions in space. ClearSpace is contracted by ESA (European Space Agency**)** for its first mission.

ADR still faces several obstacles in spite of these encouraging developments. ADR is a complicated and costly solution because of the high cost of debris removal missions and the technological challenge of catching and deorbiting items in orbit. Furthermore, issues of accountability and liability have not been settled. For instance, it is unclear who should pay for the removal of outdated satellites from now-dissolved agencies or debris left behind by closed businesses (Ryan et al., 2022). Concerns regarding the possible militarization of space are also raised by the possibility that some ADR technologies, especially those that use robotic arms or lasers, could be modified for use as anti-satellite (ASAT) weapons (Carroll, 2019).

3.3. Strengthening Global Cooperation

"Effective communication and collaboration among the government, non-governmental organizations, community leaders, and the public are essential for reducing the risk of natural disasters and promoting sustainable development in landslide-prone regions" (Baruah et al., 2023).

Although these words are mentioned for the Dima Hasao region in India, it's a general approach for natural disasters and a critical aspect of solving the space debris problem is the need for stronger international cooperation. Space is a shared global resource, and the actions of one country or private company can have far-reaching consequences for others. Currently, there is no binding international treaty that mandates space debris mitigation or active debris removal (ADR). The lack of enforceable regulations leaves room for inconsistent practices across the globe, with some spacefaring nations and private operators taking minimal responsibility for their space activities. While voluntary guidelines such as those from the IADC and UN COPUOS provide a starting point, they are not sufficient to address the scale of the problem (Lambach& Wesel, 2021).

One potential solution to enhance global cooperation is the establishment of an international Space Traffic Management (STM) system. STM would serve as the space equivalent of air traffic control, ensuring that satellites and debris are closely monitored and that operators are informed of potential collisions in real time. The development of a global STM system would require significant investment and collaboration between governments and private industry, but it is essential to reducing the risk of debris-related collisions. Some initiatives toward STM are already underway, with agencies such as NASA and ESA working on improving Space Situational Awareness (SSA) systems. However, for STM to be truly effective, it will need to be embraced and integrated by all spacefaring nations (Maclay& McKnight, 2021). Sharing SSA data on a global scale would be a significant step toward improving collision avoidance. Currently, SSA systems are operated independently by different countries and private companies, leading to fragmented data and inefficiencies in tracking debris. A unified global SSA network, where all space actors share tracking data, would greatly improve the safety of space operations by ensuring that operators have access to the most accurate and up-to-date information on debris movements (ESA, 2024). This would also enable better coordination for satellite maneuvers to avoid potential collisions.

Additionally, developing nations and emerging spacefaring countries must be brought into the fold of international space debris mitigation efforts. Many of these nations are eager to enter the space economy but may lack the resources to fully implement debris mitigation technologies or adhere to SSA standards. International bodies such as the United Nations Office for Outer Space Affairs (UNOOSA) can play a key role in facilitating technical assistance and funding to help these nations comply with best practices for space debris management (Lambach& Wesel, 2021).

3.4. Regulatory Reforms and Policy Recommendations

A comprehensive strategy that incorporates targeted measures and regulatory reforms across several stakeholders, including national space agencies, commercial satellite operators, and interna-

tional regulatory bodies, is required to address the ongoing problem of space debris. These parties must work together and implement transparent, doable regulations to lower the danger of collision and the current debris population to guarantee the long-term viability of space activities.

At the international level, there is an urgent need for a unified framework to address space debris. Current efforts are fragmented, with many nations adhering to non-binding guidelines that lack enforcement mechanisms. The United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) should lead efforts to create a binding global framework for standardizing debris mitigation and cleanup. This framework could provide clear directives on post-mission disposal (PMD), the integration of Active Debris Removal (ADR) technologies, and protocols for space traffic management (IRGC, 2021. An international agreement, akin to the Zero Debris Charter promoted by the European Space Agency (ESA), could encourage collaboration between space-faring nations, fostering a unified approach to debris management that emphasizes both prevention and active cleanup efforts. Moreover, economic incentives can play a pivotal role in encouraging compliance. Financial tools, such as subsidies or tax benefits, could be introduced to reward nations and companies that invest in advanced debris removal technologies or demonstrate consistent adherence to international mitigation standards (Buchs, 2021)(IRGC, 2021). Such incentives would not only encourage broader adoption of sustainable practices but also stimulate technological innovation, making space operations safer and more efficient. Similar to how environmental funds have been used to address pollution on Earth, an international fund could be created to finance large-scale debris removal projects, especially benefiting emerging space nations that may lack the resources to tackle this issue independently (IRGC, 2021).

National space agencies have a crucial role in reinforcing these international guidelines through domestic regulations. For example, agencies should enforce stringent end-of-life disposal requirements, mandating that all future satellites include autonomous deorbiting mechanisms. This would ensure that defunct satellites are removed from critical orbits, thereby reducing the risk of collisions and further debris generation (IRGC, 2021). In addition to enforcing compliance, governments can strengthen their Space Situational Awareness (SSA) capabilities by investing in infrastructure that enables more accurate tracking of space objects, including smaller, currently untracked debris. Enhanced SSA networks can provide precise data that is vital for collision avoidance, helping operators make informed decisions to prevent potential accidents. Some countries, like the United States and Japan, have already initiated national programs focused on debris removal, exploring technologies that can capture and deorbit large, defunct satellites. These programs can serve as models for other nations, illustrating how national initiatives can contribute to a broader, global effort. Furthermore, international bodies could provide funding mechanisms to support such projects in other countries, ensuring that space sustainability is a collaborative, inclusive effort (Buchs, 2021)(IRGC, 2021).

It is also important to note that commercial satellite operators are part of this ecosystem, and their collaboration is necessary for efficient management of space debris. They need to follow these practices regarding collision avoidance: they need to be capable of sharing relevant trajectory data in real time and operate under collision avoidance guidelines which minimize the chances of inadvertent collision. Enhanced coordination between commercial operators, especially those with many satellites in the same orbits, can also reduce the likelihood of disastrous consequences owing to orbital overcrowding. Furthermore, regulatory measures should encourage new satellite designs to include means of deorbiting the satellites. This enabled satellite systems at the end of their services lifetime to avoid remaining in orbit and become a threat later on. The high costs associated with debris removal can be an impediment to action, but working together can help counter this issue. This Collaborative way of working will reduce the economic restraints regarding active debris removal, thus enhancing the autonomy of operators in keeping the outer space safe for every user. For example, the ClearSpace-1 technology that is designed to retrieve and deorbit the space debris that poses high risk is an innovation that demonstrates how creativity to solve the challenges of sustainability of space can be achieved through harnessing the resources of both the public and private sector. The repealed statute needs to provide for tougher obligations on satellite users, such as being required to provide for self-disposal apparatus and postmortem measures against debris creation (ESA, 2016). The treaty could also introduce penalties for non-compliance, such as restrictions on future launches for operators who fail to deorbit their satellites or contribute to debris generation. Additionally,

the establishment of debris removal quotas, where countries and private companies are required to remove a certain number of debris from orbit each year, could incentivize proactive participation in debris removal efforts (Carroll, 2019).

3.4.1. Ethical and Liability Issue

Liability is another highly controversial topic in the management of space debris. Although governments are held accountable for the harm caused by their space objects under the Liability Convention, it is unclear who is responsible for clearing debris and covering related expenses (Degrange, 2019). Because of this, there isn't a clear legal precedent that holds operators responsible for debris left by abandoned rocket stages or satellites. To guarantee that all parties contribute to the sustainability of space, a redesigned liability structure might place accountability for debris cleanup on the original operator or launch state. The problem of orphaned debris—debris left behind by entities that are no longer in existence or are not functioning in space—would likewise be resolved by this. And, in the annual report of the 2023 United Nations Office for Outer Space Affairs, the same issues were reported, and the same technological solutions were repeated.

Current international law, particularly the Liability Convention of 1972, holds states responsible for damage caused by their space objects, but it does not sufficiently address the complexities of debris removal or the costs associated with it. Accountability gaps have resulted from this, especially in the management of defunct satellites and abandoned rocket stages that still endanger orbital safety (Degrange, 2019). The idea of space stewardship is one of the main ethical issues. It is the ethical duty of all space-faring organizations, whether they are commercial businesses, national space agencies, or developing space nations, to make sure that their activities do not jeopardize the orbital environment. This involves not only adhering to current debris mitigation guidelines but also proactively taking steps to prevent the creation of new debris. However, this sense of shared responsibility is not always reflected in the actions of operators, especially when the cost of implementing debris mitigation measures is perceived as too high. Ethical stewardship demands that entities prioritize long-term sustainability over short-term gains, recognizing that space is a shared resource that must be preserved for future generations.

The responsibility for "Orphaned" Another particularly controversial topic is debris. Orphaned debris is the term used to describe satellites and other space objects that have been abandoned in orbit by companies that have ceased operations or are no longer in existence. Since there is currently no clear legal framework for determining who is responsible for these objects, it is difficult to enforce cleanup activities. Thousands of discarded items exist in orbit around the earth because of carelessness, and they all run the risk of colliding with operational satellites. Without a revised responsibility framework, operators might keep acting irresponsibly since they won't be held accountable for any debris that is left behind. To address these challenges, a revised liability framework could assign responsibility for debris cleanup to the original operator or launch state, ensuring that all actors contribute to the sustainability of space. This could involve mechanisms such as "polluter pays" principles, where operators are financially responsible for the removal of debris they generate. For instance, if a satellite becomes non-operational and poses a risk to other objects, the original operator or the state that authorized the launch would be obligated to finance its removal. This would not only incentivize better design and operational practices but also ensure that companies factor in end-of-life disposal when planning their missions.

Additionally, the United Nations Office for Outer Space Affairs (UNOOSA) has highlighted the need for improved legal frameworks in its 2023 annual report, reiterating that current technological solutions, such as Active Debris Removal (ADR), are only effective if supported by clear regulatory measures. The report stresses the importance of international cooperation in establishing guidelines that go beyond mitigation, urging countries to adopt practices that facilitate the removal of existing debris. This includes creating incentives for companies to develop and deploy ADR technologies, as well as establishing shared funds that can be used to address the issue of orphaned debris. By having a centralized fund, managed by an international body, resources can be allocated more efficiently,

ensuring that even debris left by defunct or inactive entities can be addressed without a disproportionate financial burden on any single nation (United Nations, 2023).

3.4.2. Business Impact and Responsibility in Space Debris Mitigation

Due to their growing reliance on satellite-based services, many businesses indirectly contribute to the buildup of space debris even if they are not directly participating in space activities. Businesses put pressure on service providers to extend satellite constellations in order to accommodate the growing demand for high-speed internet and smooth international communication. As a result of this expansion, more satellites are frequently launched, which adds to orbital congestion and, eventually, the debris issue when the satellite reaches the end of its useful life. For instance, the need for fast internet around the world has prompted internet service providers to set up massive constellations of satellites, which, although advantageous from a technological standpoint, increase the possibility of orbital debris when the satellites eventually cease to exist. To address these indirect contributions, businesses could adopt the concept of a provision fund, modeled after principles found in International Accounting Standards (IAS) 37 on environmental provisions, which guides companies in setting aside funds for anticipated future liabilities (Deloitte, 2024.). Similar to environmental liabilities on Earth, these provision funds would let businesses to set aside monies expressly for managing space debris, acknowledging its indirect influence on orbital sustainability. Businesses could guarantee they have set aside funds to address future expenses, like those related to debris removal or satellite deorbiting, by implementing a provision for space debris mitigation. As suggested by IAS 37, regular evaluations and modifications of these funds would maintain their alignment with the true costs of debris reduction, allowing them to adjust to shifting space operations and technical developments.

Drawing inspiration from Canadian practices, a collective industry fund could also be introduced. In Canada, various sectors, particularly those involving resource extraction, pool resources to manage the environmental impact of their operations collectively. As an example to those funds from Canada are Environmental Damages Fund (Environment and Climate Change Canada, 2024) and Canadian Mining Association's TSM initiative (Mining Association of Canada, 2024). Applying a similar approach to space sustainability, satellite-dependent industries could establish an industry-wide fund, distributing the financial responsibility for debris management across multiple stakeholders. This model could provide a scalable, sustainable funding source for Active Debris Removal (ADR) initiatives, enhancing the ability to address debris generated by inactive satellites effectively. Moreover, Governments could also offer tax breaks to businesses that make contributions to these provision funds. Businesses would find it financially advantageous to take part in space sustainability programs thanks to such incentives, which would also allow their contributions to be seamlessly integrated into regular accounting and financial frameworks. Businesses would have a real incentive to integrate sustainable practices into their satellite operations if tax breaks were provided for money spent on space debris mitigation. This supports proactive investment in sustainability by supporting the notion that provisions can be recognized as expected liabilities, as described in IAS 37.

Through these proactive financial and operational measures, businesses can play a significant role in fostering a sustainable orbital environment. By acknowledging their indirect role in space debris accumulation, businesses not only contribute to the resilience of the space sector but also ensure the longevity and reliability of the satellite services on which they depend.

3.5. Global Approaches to Space Debris Management

The science of risk management is considered one of the modern sciences that government institutions and international bodies are interested in; through developing guidelines, regulations, and legislation that strengthen the safety system, prevent risks, and reduce their effects (El Mougher, Abu Sharekh, Abu Ali, & Zuhud, 2023). The challenge of space debris has led to varied responses across the globe, with countries and regions implementing unique strategies based on their technological capabilities and regulatory frameworks. In the United States, the approach is guided by the

U.S. Space Policy Directive-3, which emphasizes Space Situational Awareness (SSA) and the development of a Space Traffic Management (STM) system. This policy outlines measures to improve debris tracking, encourage data sharing among international partners, and promote practices that minimize the creation of new debris. Additionally, the U.S. has partnered with private companies like Astroscale to advance Active Debris Removal (ADR) technologies, aiming to develop practical methods to deorbit defunct satellites and large debris objects (Maclay & McKnight, 2021). The Federal Communications Commission (FCC) also plays a regulatory role by setting guidelines that require satellite operators to deorbit their satellites within a specific timeframe, reducing the risk of long-term debris generation (Swope et al., 2024).

The European Union has adopted a similarly proactive stance, with the European Space Agency (ESA) spearheading efforts through its Zero Debris Charter. This initiative commits ESA and its partners to ensure that no debris-producing object remains in orbit beyond 2030, setting a clear framework for sustainability in space operations. Europe's approach also involves the development of ClearSpace-1, the world's first dedicated mission to actively remove debris, which will use robotic arms to capture and deorbit large, high-risk objects. Additionally, the European Commission has introduced the EU Space Regulation, which requires satellite operators to comply with strict end-of-life disposal guidelines and encourages innovation in debris mitigation technologies (Degrange, 2019; ESA, 2024). This regulatory environment underscores Europe's commitment to maintaining a sustainable orbital environment and advancing the global discourse on space sustainability.

In China, space debris management is integrated into the country's broader space development strategy. China regularly engages in international forums, such as the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), to coordinate debris reduction activities and has created its own orbital debris mitigation guidelines that comply with international norms. In recognition of the dangers associated with an increase in satellite launches, the China National Space Administration (CNSA) has also entered into collaborations to test technology for debris removal and monitoring (Ryan et al., 2022). The quick growth of Chinese satellite constellations, however, has sparked worries despite these initiatives. If mitigation measures are not strictly enforced, this could lead to orbital congestion (Carroll, 2019).

The efforts of emerging spacefaring states to address space sustainability are also increasing. Debris mitigation and space traffic management are two topics covered in national space plans created by nations like the Philippines, Nigeria, and Rwanda. These countries are eager to implement sustainable practices right away, even if they are still developing their space infrastructure. For example, the Artemis Accords, an international agreement that encourages ethical activity in space, including debris control, have been signed by Rwanda and Nigeria (OECD, 2024). The Asia-Pacific Space Cooperation Organization (APSCO) and the Asia-Pacific Regional Space Agency Forum (APRSAF) encourage member nations to collaborate on space sustainability by exchanging best practices and creating cooperative projects. These platforms have enabled emerging nations to align their space activities with international standards and contribute to global sustainability efforts (Lambach & Wesel, 2021).

The African Union has established the Africa Space Agency, which aims to coordinate space activities across the continent and develop a cohesive strategy for addressing space sustainability. This includes initiatives to enhance Space Situational Awareness (SSA) and support the implementation of national space policies that prioritize debris mitigation. Similarly, the European Space Agency and Japan have partnered on joint missions, such as testing laser-based technologies for nudging small debris into lower orbits, where it can burn up upon re-entry (Degrange, 2019). These collaborative efforts underscore the importance of shared responsibility and international cooperation in managing the risks associated with space debris.

Despite these efforts, challenges in international coordination persist. Established space nations like the United States, Europe, and Japan have well-developed regulatory frameworks. Under these frameworks they coordinate "How satellite operators should handle their satellites at the end of their operational life" and restrictions such as "Measures to minimize the creation of new debris", and "Tracking and managing existing debris through SSA and STM systems". However, there remains a need for more robust enforcement and greater alignment of national policies. Emerging space

nations are actively building their capabilities, but resource limitations can hinder their ability to implement comprehensive debris mitigation strategies. A more integrated global approach, which draws from these diverse regional strategies, is essential to effectively address the growing threat of space debris and ensure the sustainability of space operations (ESA, 2024; Maclay & McKnight, 2021).

3.6. Enhancing Space Situational Awareness (SSA)

One of the critical aspects of managing space debris is improving Space Situational Awareness (SSA) systems. SSA refers to the ability to detect, track, and predict the movement of objects in space, including active satellites and debris. Current SSA systems, such as those operated by the United States Space Surveillance Network (SSN), focus on tracking objects larger than 10 cm in diameter (ESA, 2024). However, this leaves millions of smaller debris fragments, many of which are still large enough to cause significant damage to satellites, untracked. Enhancing SSA capabilities to detect smaller debris is crucial for improving collision avoidance and minimizing the risk posed by Lethal Non-Trackable (LNT) debris.

Recent advancements in radar and optical tracking systems have made it possible to detect smaller objects with higher accuracy. Companies like LeoLabs, for instance, are developing commercial tracking systems that can monitor objects as small as 2 cm in Low Earth Orbit (LEO) (Maclay& McKnight, 2021). These improved tracking capabilities allow satellite operators to better predict potential collisions and take evasive actions. Furthermore, the integration of artificial intelligence (AI) into SSA systems can help process large amounts of tracking data more efficiently, enabling quicker and more accurate predictions of debris paths.

International cooperation in sharing SSA data is also essential for creating a comprehensive global debris tracking network. Currently, many SSA systems operate independently, with national space agencies and private companies maintaining separate databases of debris tracking information. A more unified approach, where SSA data is shared among all space actors, would significantly improve the safety of space operations by ensuring that all operators have access to real-time data on potential collision threats (OECD, 2024). The development of a global Space Traffic Management (STM) system, overseen by an international body, could help facilitate this level of cooperation, preventing collisions and improving the overall management of space traffic. This would not only improve the safety of space operations but also reduce the likelihood of future debris-generating collisions (Maclay& McKnight, 2021). International bodies such as the United Nations Office for Outer Space Affairs (UNOOSA) could play a key role in overseeing the development and implementation of a global STM system, ensuring that space remains accessible and sustainable for all actors.

4. The Path Forward

One of the most promising avenues for the future of space debris management lies in emerging technologies. While Active Debris Removal (ADR) systems are already being tested, future technologies will need to focus on making ADR more scalable and cost-effective. Current ADR systems, such as Astroscale's ELSA-d mission, have demonstrated the potential to capture and remove defunct satellites, but these systems need to evolve to handle multiple objects in a single mission to make debris removal more economically viable (Degrange, 2019). The development of autonomous robotic systems, which can identify, capture, and deorbit debris without human intervention, is a critical next step (Jovičić, 2024). These systems could significantly reduce operational costs and increase the efficiency of ADR missions.

Looking further into the future, on-orbit manufacturing could revolutionize how we approach debris management. By recycling debris into raw materials that can be used to construct new satellites or space infrastructure, on-orbit manufacturing addresses both the debris problem and the logistical challenges of launching materials from Earth (Carroll, 2019). This technology is still in its

infancy, but research and development in this area could open up new possibilities for long-term sustainability in space operations. For example, defunct satellites and spent rocket stages could be repurposed into building blocks for space stations or other large-scale structures, reducing waste and optimizing the use of existing resources. Although in the literature on-orbit manufacturing seems as a "future method", the last review board report for the On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1) project of NASA says that "IRB recommends the OSAM-1 project be discontinued." The reason seems to be the high cost of operation (National Aeronautics and Space Administration, 2024).

In addition to debris recycling, advancements in self-disposal technologies will play a crucial role in preventing future debris generation. Satellites equipped with autonomous propulsion systems or other end-of-life disposal mechanisms can ensure that they safely deorbit or move to graveyard orbits once their missions are complete (Maclay & McKnight, 2021). Combined with design for demise—the use of materials that completely burn up upon re-entry—these innovations will help reduce the number of defunct satellites left in orbit, lowering the risk of collisions and further debris creation (ESA, 2024).

4.1. Sustainability in Space Operations

Future space operations must be centred on sustainability. Sustainable methods that put the long-term health of the orbital environment first must be adopted by commercial businesses and spacefaring nations. This involves using materials that disintegrate upon re-entry and implementing autonomous deorbiting capabilities, two examples of best practices in satellite design. Operators must also make sure they adhere to current debris mitigation regulations, such the 25-year rule, and make investments in technology that allow them to prolong the operating lifespans of their satellites through repairs and on-orbit servicing (IOS) (Virgili et al., 2016).

The growing commercial interest in space also presents an opportunity to incentivize sustainable practices through economic mechanisms. Governments could introduce debris removal credits, similar to carbon credits, which reward operators for actively participating in debris mitigation efforts. These credits could be traded or sold, providing a financial incentive for companies to invest in Active Debris Removal (ADR) technologies (Carroll, 2019). Additionally, orbital parking fees could be implemented to charge satellite operators for occupying valuable space in Low Earth Orbit (LEO), encouraging them to adopt more responsible end-of-life disposal practices (Maclay& McKnight, 2021).

4.2. Policy Recommendations for Long-Term Space Sustainability

The future of space sustainability hinges on the implementation of robust policy frameworks that enforce debris mitigation and removal practices. While technological innovations like Active Debris Removal (ADR) and self-disposal technologies offer promising solutions, without strong regulatory backing, the space industry may continue to face challenges in preventing the proliferation of debris. One critical policy recommendation is the establishment of a binding international treaty that obligates all spacefaring nations and private operators to adhere to strict debris mitigation practices, such as the mandatory use of deorbiting mechanisms at the end of a satellite's life (Maclay& McKnight, 2021).

A convention of this kind might include establish sanctions for noncompliance, such as fines or prohibitions on operators' ability to deploy satellites in the future if they disregard debris mitigation procedures. Policymakers might encourage more responsible conduct by shifting the financial cost of debris management onto operators by establishing financial disincentives for leaving defunct satellites in space. Governments could also enact tax breaks or subsidies for businesses who make investments in ADR technology or create creative approaches to waste removal (Carroll, 2019).

Another important policy recommendation is the creation of a global debris removal fund, which would be financed by contributions from spacefaring nations and private companies. This fund could be used to support large-scale debris removal projects, particularly in areas of Low Earth Orbit (LEO) and Geostationary Orbit (GEO) that are densely populated with defunct satellites and spent rocket stages (Degrange, 2019). By pooling resources, the international community can tackle the most pressing debris hotspots and prevent further collisions that could lead to a Kessler Syndrome-like cascade of debris events (Buchs, 2021).

4.3. The Role of Emerging Spacefaring Nations

As the space industry grows, more nations are entering the space arena, launching their own satellites, and taking part in multilateral missions. Although these new spacefaring countries are becoming more and more significant to the global space ecosystem, many of them lack the means or know-how to properly execute debris mitigation plans. The long-term viability of space operations depends on these countries being able to take part in international debris management initiatives. International agencies like the United Nations Office for Outer Space Affairs (UNOOSA) should increase the scope of their technical assistance programs to support these new actors. They should offer training and resources to assist these countries in creating their own debris mitigation policies and space situational awareness (SSA) systems (Lambach & Wesel, 2021).

4.4. Long-Term Sustainability Through Public-Private Partnerships

Public-private partnerships (PPPs) will play a crucial role in ensuring the long-term sustainability of space operations. Governments, space agencies, and private companies must work together to develop new technologies and regulatory frameworks that prioritize debris mitigation. For example, governments could provide funding or tax incentives to companies that develop on-orbit servicing (IOS) technologies or other solutions aimed at extending the lifespan of satellites (ESA, 2024). These partnerships could also accelerate the development of next-generation SSA systems, which are essential for tracking smaller debris and providing more accurate collision avoidance data. Private companies, which increasingly dominate the space industry, have a vested interest in maintaining a clean and sustainable orbital environment. As mega-constellations such as SpaceX's Starlink and Amazon's Project Kuiper continue to expand, these companies must lead the way in adopting sustainable practices, such as using autonomous deorbiting systems or participating in Active Debris Removal (ADR) efforts (Maclay& McKnight, 2021). Public-private partnerships can help bridge the gap between government-led initiatives and private sector innovation, ensuring that both sectors contribute to solving the space debris crisis. One promising area for PPPs is the development of debris capture technologies, such as the robotic systems being tested by companies like Astroscale and government agencies like the European Space Agency (ESA) (Degrange, 2019). These technologies are critical for removing large debris objects that pose a significant risk to operational satellites. By combining government funding with private sector expertise, PPPs can help scale these technologies and bring them to market more quickly, addressing the growing debris problem more efficiently.

4.5. Education and Awareness Campaigns

One big piece of solving the space debris problem is simply raising awareness. Although it's a hot topic among space professionals, most people—and even many policymakers—are not as familiar with the issue, especially compared to other global challenges like climate change or pollution. Governments and space agencies could really benefit from investing in outreach efforts to explain why managing space debris is so important. They must invest in education and outreach campaigns to highlight the importance of debris mitigation and the risks associated with inaction (OECD, 2024).

These campaigns could cover the essential roles satellites play in our lives, from global communication to disaster response. For instance, weather satellites help predict storms, giving governments

crucial information to prepare for natural disasters, while communication satellites keep emergency responders connected when they're needed most. By showing how a clean, safe orbit directly benefits our daily lives, these efforts could make the importance of space sustainability a bit more real, helping to ensure that both the public and policymakers are motivated to take action.

5. Recommendations and Conclusions

This review study shows that as the threat posed by space debris continues to grow, current mitigation and removal strategies, are not enough to ensure the long-term sustainability of space operations. Several satellites and space operations continue to increase, and many national - international institutions and private companies are working to safeguard the orbital environment. The focus must shift from reactive measures to proactive, preventive strategies that will ensure the continued use of space for the benefit of humanity. For this, total collaboration and social awareness are the key essential methods, because when the satellites disappear into space or have reached their end of life, they become space debris. An increasing number of space debris negatively affects disaster management systems and GPS systems. The recovery of these garbage costs (such as the Active Debris Removal program) more than the cost of the satellite itself.

The solution strategy to new disaster type can be "solution in the source and general control mechanism." Although cleaning space with ADR and similar methods seems interesting, space logic works differently than what we know before from the perspective of cost and time. That is why project durations are extended, and the budget of the projects exceeds the financial plans. This leads to "underperformed" projects, and less willingness to space cleaning. NASA's last committee review report is a good example of this as it states the discontinuation of OSAM-1 project. Cost-effective solutions are required for better space-cleaning applications. That is why, a solution at source is an essential way to deal with this inevitable new generation disaster with the support of educational improvements such as SSA.

Funding: There is no financial fund in this study.

Conflicts of Interest: The authors declare no conflict of interest.

6. References

1. Baruah, S., Dey, C., Dutta, N., & Phukan, M. K. (2023). Dima Hasao, Assam (India) landslides' 2022: A lesson learnt. *International Journal of Disaster Risk Management*, 5(1), 1-12. Retrieved from https://doi.org/10.18485/ijdrm.2023.5.1.1
2. Buchs, T. (2021). Space sustainability and the challenge of debris mitigation in low Earth orbit. *Journal of Space Policy*, 39(3), 148-157.
3. Carla S, R. G. (2019). School-community collaboration: disaster preparedness towards building resilient communities. *International Journal of Disaster Risk Management, 1*(2), 45-59.
4. Carroll, C. (2019). Economic incentives for space debris removal: The case for orbital parking fees. *Journal of Space Law and Policy*, 153(2), 53-67.
5. Cvetković, V. M., Romanić, S., & Beriša, H. (2023). Religion Influence on Disaster Risk Reduction: A case study of Serbia. *International Journal of Disaster Risk Management, 5*(1), 66-81.
6. Degrange, A. (2019). Active Debris Removal: Opportunities and challenges for sustainable space operations. *International Journal of Space Operations*, 23(4), 162-175.
7. Deloitte. (n.d.). *IAS 37 — Provisions, contingent liabilities and contingent assets.* IAS Plus. Retrieved from https://www.iasplus.com/en/standards/ias/ias37
8. Dukiya, J. J., & Banji Adeleye, A. B. (2022). Remote Sensing and GIS Assessment of Domestic Fuel Energy Supply: A Threat to Global DRR Crusade in South-western Nigeria. *International Journal of Disaster Risk Management, 4*(2), 45-59.

9. El Mougher, M. M. A., Abu Sharekh, S. A. M., Abu Ali, R. F., & Zuhud, A. A. M. (2023). *Risk management of gas stations that urban expansion crept into in the Gaza Strip*. International Journal of Disaster Risk Management, 5(1), 13-25. https://doi.org/10.18485/ijdrm.2023.5.1.2ntegrate
10. Environment and Climate Change Canada. (2024). *Environmental Damages Fund*. Government of Canada. Retrieved from https://www.canada.ca/en/environment-climate-change/services/environmental-funding/programs/environmental-damages-fund.html
11. European Space Agency (ESA). (2016). Orbital debris and its impacts on space operations. *ESA Space Debris Report*. *Retrieved from* https://www.esa.int
12. European Space Agency (ESA). (2024). Space environment report: An overview of space debris and its risks. *ESA Annual Debris Review*, 183-200.
13. European Space Agency. (n.d.). *Active debris removal*. ESA. https://www.esa.int/Space_Safety/Space_Debris/Active_debris_removal
14. IRGC. (2021a). *Policy options to address collision risk from space debris: Standard presentation*. Lausanne: EPFL International Risk Governance Center. Retrieved from https://doi.org/10.5075/epfl-irgc-290017
15. IRGC. (2021b). *Collision risk from space debris: Current status, challenges, and response strategies*. Lausanne: EPFL International Risk Governance Center. Retrieved from https://doi.org/10.5075/epfl-irgc-285976
16. Jovičić, R., Gostimirović, L., & Milašinović, S. (2024). Use of New Technologies in the Field of Protection and Rescue During Disasters. *International Journal of Disaster Risk Management*, *6*(1), 111–122.
17. Lambach, D., & Wesel, R. (2021). The tragedy of the commons in space: Space debris and the need for stronger international regulation. *International Journal of Global Commons*, 35(2), 163-177.
18. Maclay, S., & McKnight, D. (2021). Addressing space debris: Tracking, mitigation, and removal efforts. *Space Debris Journal*, 195(5), 101-120.
19. Mining Association of Canada. (2024). *Towards Sustainable Mining*. Retrieved from https://mining.ca/towards-sustainable-mining/
20. NanoAvionics. (2024, April 15). *How many satellites are in space?*https://nanoavionics.com/blog/how-many-satellites-are-in-space/
21. National Aeronautics and Space Administration. (2024). Final Report of the Osam-1 Independent Review Board). https://www.nasa.gov/mission/on-orbit-servicing-assembly-and-manufacturing-1/
22. Nozawa, W., Kurita, K., Tamaki, T., & Managi, S. (2023). *To What Extent Will Space Debris Impact the Economy?* Space Policy, 66, 101580. https://doi.org/10.1016/j.spacepol.2023.101580
23. Ocal, A. (2019). Natural disasters in Turkey: Social and economic perspective. International Journal of Disaster Risk Management, 1(1), 51-61.
24. Ocal, A. (2021). Disaster management in Turkey: a spatial approach. International Journal of Disaster Risk Management, 3(1), 15-22.
25. OECD. (2024). Space sustainability and economic development: The growing challenge of orbital debris. *OECD Space Economy Report*, 200-218.
26. Ryan, G., Johnson, K., & Turner, P. (2022). Space debris and its implications for disaster management: Ensuring continuity in communication and navigation systems. *Earth's Future*, 10(2), 202-215.
27. Swope, C., Valdez, P., & Greene, J. (2024). Mitigating space debris: A case study of satellite mega-constellations and the risk of collisions. *Space Policy Quarterly*, 188-204.
28. United Nations Office for Outer Space Affairs. (2023). *Annual report 2023*. *Retrieved from* https://www.unoosa.org/documents/pdf/annualreport/UNOOSA_Annual_Report_2023.pdf
29. Virgili, B., Anselmo, L., Pardini, C., &Jehn, R. (2016). Mitigation of space debris in low Earth orbit: Policies and guidelines for sustainable space activities. *Acta Astronautica*, 128, 158-169.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Review Article

A Systematic Literary Review on Community Resilience Indicators: Adaptation and Application of the BRIC Method for Measuring Disasters Resilience

Dalibor Milenković[1,3], **Vladimir M. Cvetković** [1,2,3,4*], **Renate Renner** [4,1]

[1] Scientific-Professional Society for Disaster Risk Management, Dimitrija Tucovića 121, 11040 Belgrade, Serbia; milenkovic.dalibor82@gmail.com;

[2] Department of Disaster Management and Environmental Security, Faculty of Security Studies, University of Belgrade, Gospodara Vučića 50, 11040 Belgrade, Serbia;

[3] International Institute for Disaster Research, Dimitrija Tucovića 121, 11040 Belgrade, Serbia;

[4] Safety and Disaster Studies, Department of Environmental and Energy Process Engineering, Montanuniversität of Leoben, Franz Josef-Straße 18, 8700 Leoben, Austria; renate.renner@unileoben.ac.at

** Correspondence: vladimir.cvetkovic@unileoben.ac.at*

Received: 17 August 2024; Revised: 9 November 2024; Accepted 5 December; Published: 25 December

Abstract

Community resilience represents an important concept in the comprehensive approach to disaster management. It is assumed that optimal community resilience can mitigate negative impacts and enable adaptation, thereby reducing the negative consequences of future disasters. The measurement of community resilience to disasters has advanced over the past two decades, primarily through the use of indicators that measure community resilience indices. The Baseline Resilience Indicators for Communities (BRIC) represent an increasingly popular and frequently used quantitative method for measuring community resilience indices to disasters. This literature review was conducted to examine and assess the use and adaptation of the BRIC method in measuring community resilience. The review comprehensively analyzes relevant scientific papers, extracting and synthesizing the most important findings from the studies, which provided the necessary data to meet the objectives of the literature review. A total of 37 relevant studies were identified for analysis in the review. The indicators used were examined, including their selection, grouping, and evaluation procedures, as well as the calculation of the appropriate index. The review also covered the method of data collection needed to measure the impact of indicators on resilience, as well as the shortcomings of this process. The measurement of community resilience to disasters is a contemporary issue, with several detected shortcomings in the process itself. The need to adapt the BRIC method to the local context has been established. Improving the process of determining indicators and measuring indices would lead to broader use of the method in efforts to reduce disaster risk and enhance resilience to disasters.

Keywords

Community resilience; disaster resilience indicators; natural disasters; resilience index; BRIC; DROP.

1. Introduction

Community resilience is conceptually defined as the ability to resist the impact of hazards and reduce the likelihood of disaster occurrence (Aleksandrina et al, 2019; Goyal, 2019; Jaiye & Benjamine, 2021; Kabir et al, 2022; Olawuni et al., 2020). The first definition was used to describe the resilience of a system to absorb changes and disruptions while maintaining the same relationships between population and the state of variables (Holling, 1973, p. 14). The Sendai Framework for the period from 2015 to 2030 set an ambitious goal for preventing and reducing disaster risk by reducing exposure to risks and hazards, increasing preparedness, and strengthening resilience (*Sendai Framework for Disaster Risk Reduction 2015-2030*, 2015). Multidimensionality as one of the main characteristics of resilience encompasses the ability to withstand the circumstances that cause disasters, the ability to recover from them and, in the best case, to grow from the experience. Thus, resilience consists of the ability of society to adapt to the circumstances created by a disaster and minimize its impact (Alexander, 2013).

According to the United Nations and their International Strategy for Disaster Risk Reduction, resilience is defined as the ability of a system, community, or society exposed to hazards to resist, absorb, timely and effectively respond to, and recover from the consequences of hazards, including the preservation and restoration of essential basic structures and functions (*Terminology on Disaster Risk Reduction*, 2009). Considering that, according to UN data, 55% of the world's population today lives in urban areas, often densely populated (74% in Europe), and that by 2050, 68% of the global population will live in these areas, the multidisciplinary consideration of community resilience takes on special significance ("Department of Economic and Social Affairs," 2024). Special attention must be paid to the data on climate change caused by global warming and the fact that it will significantly accelerate the occurrence of more extreme events that will cause disasters (IPCC, 2023, p. 5). Exceeding a warming of two degrees would lead to irreversible processes with severe consequences for human life, caused by disaster impacts (Masson-Delmotte et al., 2018).

Traditional approaches to disaster management focus on damage prevention, effective response, and recovery, rather than mitigating consequences and building capacity. As a result, many studies related to disaster resilience are oriented toward outcomes, focusing on the ability and speed of recovery or minimizing the damage caused (Cimellaro, Reinhorn, & Bruneau, 2010). However, in contrast to this technical approach, a growing body of literature focuses on the human side of disaster resilience, on the individual and collective capacities that are essential for coping and adapting in times of crisis (Siambabala 2006).

Numerous studies support the idea that during periods of hardship, i.e., when facing immediate danger and physical injury, resilience is first manifested at the local level (Cvetković & Šišović, 2024; Cvetković & Šišović, 2024). Specifically, the affected people, their functioning, connectivity, and capacities, both individually and as a group, determine the level of resilience of local communities (Aldrich, 2012). Although the concept of resilience is considered a new foundation in disaster management, it has remained flexible without a specific set of indicators. The term resilience is not only multidimensional but also a multi-level construct that could refer to individuals, groups and communities (Cvetković et al., 2024; Cvetković, Rikanović, Knežević, 2022; Cvetković & Ivković, 2022; Cvetković, Grozdanić et al., 2024; Cvetković, 2023; 2024; Grozdanić & Cvetković, 2024). Consequently, for each specific case or community, there must be a clear definition of the entity (individuals, city, municipality, etc.), what they should be resilient to, the intensity they can endure, and the degree or speed of recovery after a disaster.

Disaster resilience indicators have evolved over time, progressing through phases in which the indicators were more precisely defined (Cai et al., 2018; Jülich, 2017). In addition to theoretical formulation, they have been concretized in terms of quantitative indicators that allow for more precise measurement and assessment of community resilience (Asadzadeh, Kötter, Salehi, & Birkmann, 2017; Chang & Shinozuka, 2004).

Baseline Resilience Indicators for Communities (BRIC) were developed by grouping various dimensions of indicators that measure community resilience. Initially, over 50 indicators were considered, and 36 were ultimately used for final analysis, divided into five groups deemed relevant, as shown in Table 1 (Cutter, Burton, & Emrich, 2010). Unlike the initial studies, there are now a total of

49 indicators grouped into six dimensions or groups ("Baseline Resilience Indicators for Communities," 2024). These indicators, as conceptual proof of measuring basic community resilience, apply so-called "preconditions" using the theoretical framework of Disaster Resilience of Place (DROP), which describes the most critical conditions for the resilience of a place before a catastrophic event occurs (Cutter et al., 2010).

The initial study that developed the BRIC model included an analysis of indicators in 736 counties across eight southeastern U.S. states. The area considered for analysis was historically prone to disasters but also characterized by intensive urbanization that brought numerous inequalities affecting disaster resilience (racial, health, and similar inequalities such as education, income, etc). Due to the high potential for deviation, ecology was not considered. The indicators were grouped into five categories: social, economic, institutional, infrastructure, and social capital.

Table 1. Groups of Indicators for Measuring Resilience (Cutter et al., 2010).

Group of Indicators	Indicators
Social	Educational uniformity; 2) Age distribution; 3) Access to transportation; 4) Communication capacity; 5) Language proficiency; 6) Social needs; 7) Health insurance
Economic	Property ownership; 2) Employment; 3) Income distribution; 4) Sectoral employment; 5) Women's employment; 6) Business size; 7) Access to healthcare
Institutional	Disaster response plans; 2) Flood protection; 3) Local services; 4) Population capacity to cope with disasters; 5) Political fragmentation; 6) Previous experiences; 7) Civil protection; 8) Storm protection capacity
Infrastructure	Types of living spaces; 2) Shelter capacity; 3) Medical capacities; 4) Road infrastructure; 5) Age of living spaces; 6) Service accommodation capacity; 7) Public educational institutions
Social Capital	Population residency; 2) Immigrants; 3) Voter turnout; 4) Number of religious people; 5) Number of civil organizations; 6) Number of social organizations; 7) Share of employment in the innovative sector

The results of the first research, which served as the foundation for subsequent studies and method adaptations, were presented as a spatial assessment of the analyzed territories. Statistically, counties were analyzed, and results were provided based on the lowest and highest resilience indicators (results). The general conclusion of the research was that resilience was highest in urban areas, with the highest parameters found in the social, economic, and institutional groups. The "culprits" for the detected low resilience in rural regions were the groups of institutional and infrastructure indicators. The BRIC method is conducted through a recursive process in which complex sets of results are summarized and simplified, ultimately yielding average values. In the initial research and method development, all indicators had equal value or "weight"; they were not weighted, and values were normalized to a range from zero to one using an equation. These values were later summed to obtain a numerical resilience score (Cutter et al., 2010).

1.1. Theoretical Basis of the BRIC Method

The theoretical framework on which the BRIC method is developed is the DROP model (Disaster Resilience of Place). This theoretical model was developed in 2008 by the same researchers from the University of South Carolina who created the BRIC model. The aim was to design a theoretical model that would enhance comparative analysis and assessment of community resilience to disasters. This model combines elements of disaster prevention, adaptation to global changes, and responses

to natural hazards. It incorporates an ecological and nature-based approach alongside comprehensive planning, offering a holistic framework for enhancing disaster resilience. The model clearly distinguishes resilience from vulnerability, stating that resilience is "the ability of a social system to respond and recover from disasters, including the primary conditions that allow the social system to absorb impacts, cope with the disaster, and adapt to post-disaster processes that facilitate the organization of society to function, change, and learn how to respond to threats" (Cutter et al., 2008, p. 599).

In the DROP model, communities are defined as "all interactions of the social system within a defined geographic space such as a neighborhood, census unit, city, or county" (Cutter et al., 2008, p. 599). The model was developed to assess resilience to natural hazards but can also be applied to other "rapid onset" shocks or long-term hazards such as droughts or pandemics. The model indicates how pre-existing conditions in a given place, combined with a disaster, produce a new impact on the community. A more resilient community will be able to implement better response mechanisms to mitigate the impact of the event. The impact of a hazard is a function of pre-existing conditions, the nature of the event, and response mechanisms. A disaster occurs when the absorptive capacity in that place is exceeded. Resilience, as a process, comes to the fore again at this stage, influencing the degree of recovery and preparedness for future events.

The key assumption of the model is that the social resilience of a place depends on the interconnection of natural systems, social systems, and the built environment. The model has six dimensions of resilience with a total of 29 indicators, which are shown in Table 2. "The model presents resilience as a dynamic process that depends on pre-existing conditions, the severity of the disaster, the time between hazard events, and the influence of external factors. Although conceptually dynamic, immediately before the disaster, the recovery process leads to a static representation of pre-existing conditions"(Cutter et al., 2008, p. 604).

Table 2. Dimensions of Resilience with Their Indicators (Cutter et al., 2008).

Dimensions of Resilience	Indicators
Environmental	Wetland areas; 2) Erosion rate; 3) Percentage of impermeable surfaces; 4) Biodiversity; 5) Coastal defence structures.
Social	Demographic factors (gender, age, ethnicity, and occupation); 2) Social networks and organizations; 3) Social cohesion; 4) Religious organizations.
Economic	Employment; 2) Property value; 3) Wealth distribution; 4) Local government funding.
Institutional	Participation in risk reduction programs; 2) Hazard mitigation plans; 3) Emergency services; 4) Zoning and building regulations; 5) Emergency response plans; 6) Communication interoperability; 7) Continuity of operations plans.
Infrastructure	Critical infrastructure; 2) Transportation network; 3) Structure and character of residential buildings; 4) Commercial and industrial buildings.
Community Competence	Local risk understanding; 2) Advisory services; 3) Absence of deviant behavior; 4) Health and sports; 5) Quality of life.

Based on all of the above, the aim is to conduct an integrative literature review to collect, critically assess, and synthesize the results of a larger number of studies on the subject, contributing to a deeper understanding of the research question. To gather and systematize the literature, the following steps were applied: identifying the topic and defining the guiding questions; data selection; defining the search; searching and saving results; selecting articles based on abstracts, according to inclusion and exclusion criteria; extracting data from selected articles; evaluating data; and synthesizing and interpreting data.

The primary reason for conducting the literature review is to identify and analyze studies that cover the following: a) indicators of community resilience to natural disasters or approaches for measuring community resilience to natural disasters; b) the use and modification of the BRIC method for measuring community resilience to natural disasters.

The focus of the critical literature review is on the BRIC method, aiming to evaluate the methodological quality of resilience index development, the range of indicators used, and the geographic locations where community resilience was measured using this method. The basis for the development and improvement of the BRIC method is the OECD "checklist" for composite indicators, which defines 10 steps for constructing a composite index (*Handbook on constructing composite indicators: Methodology and user guide*, 2008). This framework was referenced in the original BRIC study (Cutter et al., 2010). This is particularly important because there are significant possibilities for variations in how the BRIC model is applied in different contexts (index development, use for different geographic locations, differently defined communities, and the types of disasters or consequences they cause).

2. Methods

An adequate research framework is a key element for conducting a systematic literature review, enabling a thorough study of extensive and diverse literature on community resilience indicators to natural disasters. In this process, the primary methodological approach is based on the methodology of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), a widely accepted and standardized method for conducting literature reviews.

The PRISMA methodology (Page et al., 2021) involves several key stages: identifying relevant literature, assessing its eligibility, and selecting and including studies that will undergo detailed analysis. This systematic approach ensures that the literature review is comprehensive and representative, covering the most significant and relevant sources that contribute to a better understanding of community resilience to natural disasters.

With the proper application of the PRISMA methodology, the research gains scientific rigour, as this approach minimizes bias and ensures transparency in the selection and analysis process of the literature. Furthermore, PRISMA allows for clear tracking of the research process, from the initial identification of relevant sources to the final analysis and synthesis of results, ultimately providing reliable and valid conclusions that can serve as a foundation for further research and decision-making in the field of natural disaster risk management.

With such a structured and well-defined framework, the systematic literature review not only identifies trends and gaps in existing research but also contributes to building theoretical and practical knowledge about the factors that affect community resilience. In this way, it provides valuable insights that can directly impact the improvement of strategies for risk mitigation and strengthening resilience to natural disasters.

2.1. Search Criteria

The literature review on the subject of community resilience indicators to natural disasters, with a focus on the BRIC method based on the theoretical foundation of the DROP model, was conducted as follows:

- The search period spans from 2010 (when the BRIC model was initially developed) to 2024.
- The search was conducted using the free and accessible tool scholar.google.com (Google Scholar).
- Only research (scientific) articles focusing on the social aspect of community resilience to disasters, specifically on indicators, approaches to the use of indicators (models), and the BRIC method of resilience index measurement, were included.

The primary characteristic of the search is that it was limited to works published from 2010 onwards. The reason for this is that the BRIC method was first formulated at that time, and the goal was to include modern, relevant scientific articles published in English.

The initial search excluded materials such as books, book chapters, reports, systematic reviews, and articles whose titles, keywords, and abstracts do not reference community resilience indicators to natural disasters or the BRIC method, which is the focus.

During the analysis of the texts of the articles that initially met the criteria, in the next phase of the selection, the following articles were excluded:

- Those that did not use a quantitative methodological approach, as the BRIC model itself represents a quantitative model for measuring community resilience to natural disasters;
- Those that were not focused on natural disasters, were related to health, researched the resilience of organizations, businesses, or institutions, or focused on food, resources, etc. Additionally, articles that did not retain or modify the BRIC model but instead developed entirely new models based on it were excluded.

The keywords used during the search were: community resilience indicators, baseline resilience indicators, community resilience assessment tool, and community resilience assessment framework.

2.2. Sources of Information and Search

The literature search was conducted in July 2024 and included articles from 2010 onward, searched through the Google Scholar search engine, following the predefined search criteria mentioned earlier. In addition to this search technique, relevant websites (organizations, institutions, etc.) and citations from relevant papers were also explored, which indicated the potential for finding appropriate academic works.

After an initial analysis of the academic articles, including reviewing titles, their topics, and their relevance to the objectives of this critical literature review, and considering the purpose, timeframe, resources, and the fact that the review is being conducted by a single researcher, titles containing specific English phrases, such as "community resilience indicators," "baseline resilience indicators," "community resilience assessment tool," and "community resilience assessment framework" were searched. The main goal was to optimize the process and exclude a large number of papers that were not aligned with the objectives of the critical literature review, arriving at a relevant number of articles for further analysis.

After selecting the papers, an additional search of the available texts was carried out. These texts were reviewed starting with the abstracts, and after confirming their relevance and validity, the full content of the papers was analyzed. The data from these articles were selected and stored in an appropriate Excel database. The database was designed to enable the collection and analysis of data under the objectives of the critical literature review.

2.3. Data Research Process

To ensure the highest quality of data systematization and result interpretation, two types of analyses were conducted. The first is a quantitative analysis, aimed at evaluating precise data, primarily concerning the following aspects: year of publication, country of origin of the first author, the nature of the study (empirical or theoretical), the approach to analysis, and the research design (qualitative, quantitative, or multimethod). It also focused on the instruments used for data collection, the indicators employed, how they were categorized, and the tools or frameworks used to measure community resilience. Special attention was given to the BRIC method and observed modifications.

The second analysis is qualitative, focusing on critically assessing the papers concerning their stated objectives, approaches to achieving those objectives, and conclusions concerning the use of the BRIC method for measuring community resilience.

2.3. Synthesis (Sublimation) of Results

By utilizing Google Scholar along with additional databases such as Web of Science, Scopus, and JSTOR and applying the specified criteria and search terms, a total of 87 papers were identified for consideration. The search returned 53 articles for the term "community resilience indicators," 11 for "baseline resilience indicators," five for "communities resilience assessment tool," and 18 for "communities resilience assessment framework." Among them, nine (n = 9) duplicates were registered, eight (n = 8) were not scientific articles, four did not contain the required search terms (n = 4), eight texts could not be retrieved (n = 8), two were not in English (n = 2), and 11 did not address the relevant subject matter according to their titles (n = 11). From the initial number of articles, 45 remained for further analysis. After reading the abstracts and, where necessary, the full articles, it was determined that a total of 28 articles were suitable for further analysis. A total of 17 articles were excluded because their content and nature did not align with the goals of the critical literature review. Out of the 28 articles, eight pertained to the BRIC method and its adaptation, while 20 focused on community resilience indicators and their application and adaptation for measuring disaster resilience. Of the eight articles related to the BRIC method, four pertained to entire countries, while the remaining four focused on specific regions.

Using the internet and searching appropriate platforms (Academia.edu, ResearchGate), as well as searching citations and analyzing them, where the same keywords as in the initial search were not used, a total of 89 papers were initially considered. Among them, 21 duplicates were registered (including the initial Google Scholar search) (n = 21), 17 were not scientific articles (n = 17), 19 texts were not available (n = 19), three were not in English (n = 3), and 11 did not address the relevant subject matter according to their titles (n = 11). From the initial number of papers, 18 remained for further analysis. After reading the abstracts and, where necessary, the full articles, a total of nine articles were deemed suitable for further processing. Nine articles were excluded because their content and nature did not align with the goals of the critical literature review. Of these, four articles pertained to the BRIC model and its adaptation, while five articles focused on community resilience indicators and their application and adaptation for measuring resilience to natural disasters. Of the four articles related to the BRIC model, two pertained to entire countries, while the remaining two generally related to its adaptation.

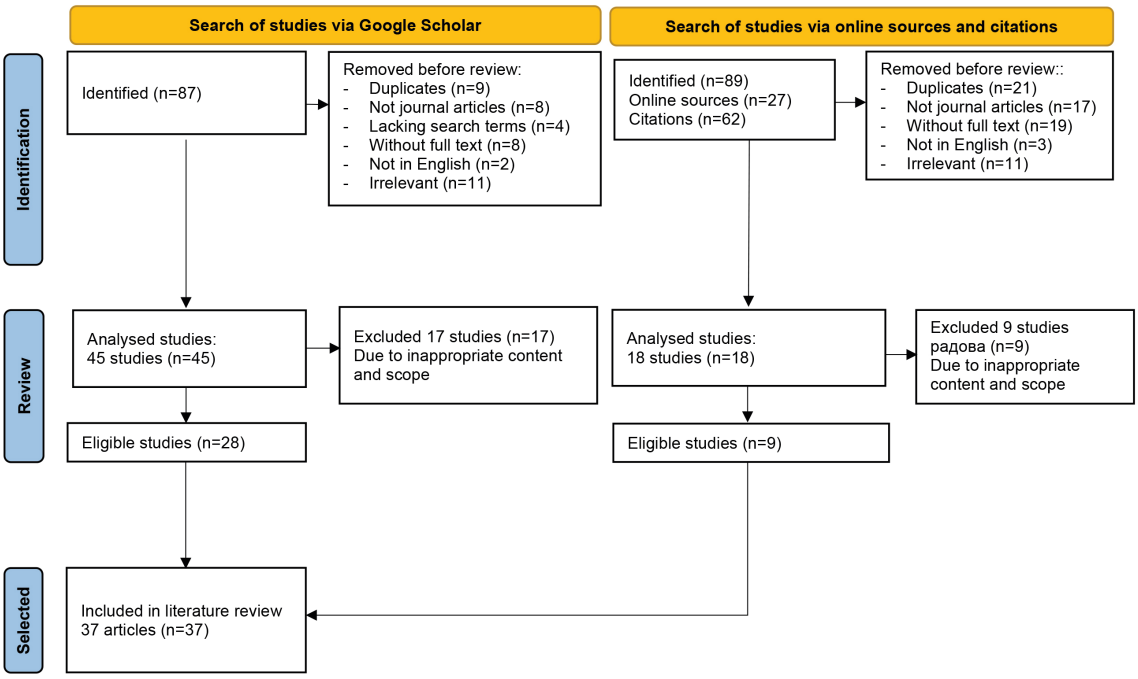


Figure 1. The article selection process is based on inclusion and exclusion criteria.

3. Results

3.1. Quantitative Characterization

A total of 37 articles were analyzed, all of which were in English. When examining the articles that specifically focus on the BRIC method and the DROP model as the theoretical foundation and operationalization of indicators, 12 articles were deemed sufficiently relevant for analysis. For the period starting from 2010, there is no dominant country from which the first authors of the articles originated. It is noteworthy that five papers deal with a specific region and the application or adaptation of the BRIC model, while seven papers either cover an entire country or address the topic in a general sense without a specific territorial application of the model. Regarding Europe, four papers are from that continent (another paper, which does not explicitly reference the BRIC method but pertains to a European country, was found but excluded from consideration).

Considering the timeline of publication and the fact that the model was created in 2010, it is evident that the number of papers has significantly increased since 2019, with a total of nine papers published since then. In terms of the type of disaster addressed in the articles, half of the papers (six) focus exclusively on natural disasters, while the other half takes a multidimensional approach, addressing all types of disasters.

When the type of research is considered, three papers are purely theoretical, while the other nine are based on practical, empirical research. Regarding research design, of the 12 articles, one uses a qualitative approach, one uses a quantitative approach, and ten apply a multimethod research design. This is due to the complexity and diversity of the data that must be collected and analyzed in the process of evaluating numerous indicators, which require an appropriate multimethod approach to provide an integrated analytical process.

Another characteristic of the papers examining the BRIC method is that publicly available data, gathered by relevant government institutions, were predominantly used, with secondary data analysis being conducted. Due to this, many of the research papers highlighted the issue of missing data in certain segments and proposed ways to address such gaps to ensure the relevance of the results.

In summary, eight of the papers used publicly available data with a segmented content analysis of existing studies in the field. Four papers employed interviews, focusing on the Delphi technique and the involvement of experts in the research. **Table 3** provides an overview of the results obtained from the analysis of papers related to the BRIC method, which also includes the consideration of the DROP theoretical model.

Table 3. Overview of Search Results and Analysis for Papers Related to the BRIC Method.

Quantitative Categories	Sample
Country of the first author	USA, Australia, Thailand, Norway, Taiwan, Brazil, Sweden, Nepal, Bangladesh, Iran, Hungary (x2).
Territory	Five papers — specific region. Seven papers — country or general territory.
Type of disaster	Six papers exclusively on natural disasters, six papers — multidimensional approach.
Year of publication	2010 — 1; 2014 — 1; 2015 — 1; 2019 — 1; 2020 — 3; 2021 — 2; 2022 — 1; 2023 — 2.
Type of Research	Theoretical — 3; Empirical— 9.
Research design	Qualitative — 1; Quantitative — 1; Multimethod — 10.
Data Collection	Access to publicly available data — 8; Interview (Delphi) — 4.

When examining articles related to resilience indicators in general, specifically their analysis, evaluation, adaptation, and overall successful application, 25 papers were analyzed. Of this number, it is noteworthy that the first author in 10 papers was from the USA during the observation period starting from 2010. Additionally, when considering the publication dates, the distribution is fairly even across the years, with two to three papers published in each observed year. Eight papers focus on specific geographic regions, while 17 papers address entire countries or the topic in a general sense without specific territorial application of the resilience index. Regarding Europe, six papers originate from that continent.

In terms of research type, it is characteristic that the majority—18 papers—take a theoretical approach, while seven papers focus on empirical research.

Regarding research design, of the 25 papers, nearly half (12) employ a qualitative approach, four use a quantitative approach, and nine apply a multimethod research design. A key characteristic of this group of papers is that the dominant approach to data collection is content analysis, which correlates with the qualitative research design and the subject matter of the papers. A total of 11 papers dealt with content analysis.

The next data collection method is the processing of publicly available data from relevant state institutions, which was used in eight papers. Four papers employed interviews and questionnaires as part of their research process. Among these, the Delphi method was used three times (in one paper, it was combined with the analysis of publicly available data). In two papers, the methodology was based on questionnaires and field research. **Table 4** provides an overview of the results obtained from the analysis of papers related to resilience indicators and their application and adaptation.

Table 4. Overview of Search Results and Analysis for Papers Related to Indicators.

Quantitative Categories	Sample
Country of the first author	The USA — 10; UK — 3; Malaysia — 2; Israel — 1; Sri Lanka — 1; Germany — 1; Japan — 1; Italy — 1; Taiwan — 1; China — 1; South Korea — 1; New Zealand — 1; Mauritius — 1.
Territory	Eight papers — specific region. Seventeen papers — country or general territory.
Year of publication	2012 — 1; 2013 — 3; 2015 — 2; 2016 — 2; 2017 — 2; 2018 — 3; 2019 — 2; 2021 — 3; 2022 — 3; 2023 — 2; 2024 — 2.
Type of Research	Theoretical — 18; Empirical — 7.
Research design	Qualitative — 12; Quantitative — 4; Multimethod — 9.
Data collection	Access of publicly available data — 8; Interview (Delphi) — 3; Questionnaire — 1.

Summarizing the quantitative characterization of the analyzed papers, within the context of the literature review, the predominant use of the Delphi technique stands out as the most significant finding. Additionally, in papers focused on practical research, data sources primarily came from secondary analysis of public institution data, supplemented in part by questionnaires and fieldwork. This is particularly evident in papers dealing with the application and adaptation of both the BRIC method and other methods or indices used to measure resilience to natural disasters.

3.2. Qualitative Characterization of Resilience Indicators

Summarizing the challenges related to the indicators used to measure community resilience to natural disasters, their application, adaptation across various models, and the implementation and

adaptation of the BRIC method derived from the theoretical DROP approach, several conclusions can be drawn.

The indicators discussed in the papers can be categorized into eight groups. Using a generalized translation from English, these are socio-demographic, community well-being, economic status, institutions, infrastructure, geographic and spatial characteristics, cooperation, and risk analysis. These groups of indicators may vary slightly in names across different studies, but essentially, they refer to the same or similar indicators within the group that are related to the context of the indicator group's name.

As the basis for the consideration, selection, and use of indicators, in most cases, the Handbook on Constructing Composite Indicators: Methodology and User Guide by the Organisation for Economic Co-operation and Development (OECD) was used (*Handbook on constructing composite indicators: Methodology and user guide*, 2008).

Among the socio-demographic indicators, those that help determine the resilience of modern urban communities are the most numerous. Together with economic characteristics, social indicators assist in assessing the long-term capabilities of a local community (Ji, Wei, Shohet, & Xiong, 2021). These indicators describe the demographic characteristics that point to the ability of the local population to cope with unwanted events and occurrences (Scherzer, Lujala, & Rød, 2019).

The most important indicators in this group include age (percentage share of a defined age range), gender, vulnerable segments of the population (those particularly at risk in the event of a disaster), the share of women in the available workforce, population density in urban communities, the average number of people per household, the demographic dependency ratio, and educational status. These indicators can be generalized and measured for each household. It is assumed that communities with a majority of employed individuals can help themselves during disasters and even assist others, compared to minors and the elderly. The awareness of the employed segment of the community regarding the resilience of the local community can significantly positively affect their behaviour and preparedness for any type of disaster (Scherzer et al., 2019).

Furthermore, as an example, acquiring knowledge mostly occurs through formal education, where skills, knowledge, and competencies are gained, influencing the population's adaptive capacity to respond adequately to disasters. Local communities with a higher percentage of individuals with limited education increase the vulnerability of such communities due to their unwillingness to take timely actions, measures, and steps. Better-educated individuals return to normal life faster after disasters because they respond adequately and have access to better social and economic resources after disasters (Muttarak & Lutz, 2014). In summary, the most important and widely used indicators and their variables for this group include: age; gender; the degree and characteristics of the so-called vulnerable population; workforce and the share of women in it; population density; the number of people per household; the percentage of the non-working population; and educational status.

Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, the difference is that indicators related to social cohesion have not been developed, religious organizations are placed in another group of indicators, while social and value indicators have developed. Concerning the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as access to transportation, language competencies, and communication capacities. Community well-being, as the next group of indicators with its variables, significantly impacts overall community resilience because it subsequently affects all other groups of indicators when it comes to disaster resilience. According to research, it has been established that local communities with adequate resources can establish and implement strategies to mitigate the effects of disasters, while impoverished communities evidently lack the resources and the ability to equip themselves before any disaster (Bergstrand, Mayer, Brumback, & Zhang, 2015).

The development of local communities contributes to a higher degree of communication among its members through existing organizations and activities. This connection facilitates easier and

better management before and during disasters, which increases community resilience (Mohamad, Jusoh, & Kassim, 2019). In this segment, the religious component is of certain importance due to its connection to the obligation to help others and to be prepared for something inevitable, such as natural disasters. The influence of religious organizations affects the preparedness of urban communities, where those with a high percentage of individuals with rooted belief systems maintain a high level of disaster resilience and promote ways to protect against destabilizing events (Kim & Marcouiller, 2018).

The most important and widely used indicators with their variables for this group include: community awareness of natural disasters; communication systems and information transmission; the ability to use previous experiences; the capacity to monitor potential risks; associations, communities, and groups formed by local authorities; religious beliefs; and prevention plans. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that, compared to the DROP model published in 2008, the difference is that no indicators related to the absence of psychopathological states were developed. Compared to the BRIC model published in 2010, it is concluded that it includes indicators not addressed in the relevant scientific papers, specifically indicators such as migration or population fluctuation and the percentage of the population engaged in creative and innovative activities. The economic condition, as the next group of indicators with its variables, is used to assess the resilience of individuals, families, and the community as a whole (Mohamad et al., 2019).

These indicators can be measured at the household level to provide a cumulative overview of the overall level of economic resilience. Indicators reflect the functioning of the economy during disasters, particularly for large and small firms. The general vitality of urban economies is reflected in employment rates, income, retail turnover, supply chains, and other aspects (Scherzer et al., 2019). The category of economic resilience encompasses both the static assessment of the current economy of the community (economic activity) and the dynamic assessment of the community's ability to continuously maintain economic growth (economic development) (Irwin, Schardong, Simonovic, & Nirupama, 2016).

The most important and widely used indicators with their variables for this group include: financial resources for disaster response, employment rates, household income levels, the percentage of the poor, and the characteristics and level of insurance coverage (from health insurance to all other types). Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, all indicators in this group have been developed. Compared to the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as the GINI coefficient, the percentage of the population employed in the food industry, and the distribution and share of companies by size. The share of women in the total employed population, unlike the BRIC model, is treated as a socio-demographic indicator. Institutions - The indicators of urban community resilience with their variables within this category reflect community and crisis management. It is widely accepted that resilience is not an isolated characteristic or feature of institutions but a product or function of comprehensive institutional performance. It arises from institutional efficiency (or the ability to achieve and improve outcomes over time). This, in turn, creates trust, legitimacy, and credibility, which themselves represent sources of resilience that further strengthen institutional capabilities. It is believed that people who work in public institutions and hold higher positions of power influence the disaster response. They attract political support and economic resources for recovery (Scherzer et al., 2019).

Furthermore, the studies show that communities located near the centres of political and economic power often benefit from resources intended for disaster mitigation (Cutter, Ash, & Emrich, 2014). The most important and widely used indicators with their variables for this group include the availability of public and emergency services; civil protection programs; cooperation between the public and private sectors; regulations and guidelines for disasters; the existence of organized disaster response units; continuous public disaster preparedness; disaster response plans; evacuation plans; community crisis operation plans; adequate spatial planning; and the percentage of the employed population in local institutions. Correlating these indicators with those listed in the

works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, all indicators in this group have been developed, and new indicators and variables have been introduced. This significantly increased the quality of institutional resilience within local communities. Compared to the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as flood risk in the community, emergency services funding, and political micro-community fragmentation. It is noticeable that more precise indicators with their variables have been developed, allowing for a more comprehensive understanding of institutional resilience in local communities than in the original BRIC model. Infrastructure, as a group of indicators with its variables, focuses on the resilience of residential units and the local infrastructure used by community members. The quality of materials used in the construction of housing and other communal infrastructure determines the community's recovery process (Scherzer et al., 2019).

Individuals with high incomes can afford quality housing units compared to those with low incomes, confirming the correlation between groups of indicators and the impact on overall resilience, according to research (Muttarak & Lutz, 2014). There is a direct correlation between the materials and construction processes adopted to make infrastructure and housing units disaster-resistant, which is necessary to achieve community resilience in infrastructure terms (Karanci, Ikize, Doğulu, & Özceylan-Aubrecht, 2016).

The most important and widely used indicators with their variables for this group include the share of areas covered by alert systems, building resilience assessments, building age, materials and construction quality, and maintenance of existing infrastructure. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, the indicators are more developed and refined, and transportation infrastructure is included under the overall infrastructure without specific segmentation. Compared to the BRIC model published in 2010, it is concluded that it includes indicators that were not addressed in the relevant scientific papers, specifically indicators such as the share of mobile homes in the total number of units, the share of vacant properties, the number of hospital beds per 10,000 people, road network density, precise building age, the number of accommodation establishments per square mile, and the number of educational institutions (for shelter) per square mile. Geographical and spatial characteristics determine the resilience of local communities to natural disasters. Geographical diversity presents an additional challenge in assessing resilience. For example, coastal communities face risks that inland communities do not, such as hurricane storm surges and tsunamis, while only communities in seismic hazard zones need to improve earthquake resilience. Preparing for a flood or hurricane requires a different approach than preparing for an earthquake or tsunami. This reveals a limitation in the scalability of resilience metrics with different hazards and communities of varying sizes, locations, and characteristics (Johansen, Horney, & Tien, 2017). Resilience considerations require accounting for the interaction between the spatial and temporal scales of a community, including how people integrate with space and how those spaces shape behaviors, thoughts, and feelings within communities, thus building their resilience over time as they inhabit a particular area (Quigley, Blair, & Davison, 2018).

The most important and widely used indicators with their variables for this group include: the geographical location of the community, the spatial composition of the community, and the use of parts of the community's location. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, this group of indices with variations is dispersed and not included as such. It is partially distributed across the environmental and institutional index groups. It is also important to note that it is not as clearly defined as it is in current studies.

Compared to the BRIC model published in 2010, it is concluded that this group of indicators does not exist. There are some indices with specific variations in infrastructure resilience and community resilience that may be similar to this group of indicators, particularly in terms of the distribution of public institutions. Collaboration involves a broad spectrum of connections between individuals, organizations, institutions, and government authorities into a unified network that allows for continuous two-way communication and mutual influence in decision-making crucial to community

resilience in the event of a disaster. "Communities have the authority to make decisions that allow for planning, financing, and implementing resilience measures, and they can act as logical intermediaries for collaboration with private property owners and utility services. Communities provide a range of services to meet social needs, supported by the built environment. The performance of these systems is integrated, though they are often designed and constructed independently of each other.

The resilience of individual buildings, facilities, and infrastructure systems should be defined in terms of the roles and functions they perform within the community. The resilience of the built environment should be evaluated as a system of systems with dependencies that can affect other systems and the entire community" (McAllister, 2015, p. 4). The most important and widely used indicators with their variables for this group include collaboration between local communities and higher authorities in decision-making and procedure implementation, comprehensive collaboration and networking at the local level, and community involvement in disaster management. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, this group of indices with variations is more developed. In that model, social networking and its rootedness in the community are mentioned under the group of social indicators.

Compared to the BRIC model published in 2010, it is concluded that this group of indicators does not exist. There is a communication capacity index in the group of social resilience indices, which only considers the proportion of the population with a telephone, a much narrower approach compared to the examined indices and their variations, which consider a much broader spectrum of communication establishment and maintenance methods. Risk analysis represents a proactive group of indicators aimed at identifying potentially vulnerable points within a community, where, in the event of a disaster, the least resilience would be mapped. The indicators of urban community resilience in this category include the availability of risk and vulnerability databases for communities, historical records of previous hazardous events, a database of the current number of people exposed to risks, a community risk assessment, the presence of disaster risk mapping associated with natural threats, and early warning response programs. Archiving data on previous disruptive events improves the learning experience for community resilience. Archived data on disruptive events represent a resilience indicator where historical data on disasters that have occurred in communities can be accumulated. This indicator represents the ability of communities to predict based on archived disaster data. Geographic Information Systems (GIS) are useful tools for governments, insurance companies, and other institutions to formulate disaster prevention strategies and implement early warning mechanisms (Macharia et al., 2020).

Advanced simulation techniques for scenario analysis can be used to identify and assess the impact of disasters. The goal of scenario analysis is to enable the generation of "surprising" threats or disruptive events that can provide valuable insights into how to make critical infrastructure resilient (Zio, 2016). The most important and widely used indicators with their variables for this group include: disaster risk databases; hazard assessments for the community; risk mapping; a database of the number of people potentially exposed to risks. Correlating these indicators with those listed in the works that established the BRIC and DROP models, it can be concluded that compared to the DROP model published in 2008, this group of indices with variations is also more developed. In the mentioned model, in the group of institutional indicators, segments can be found that represent indicators similar to those representing risk analysis. Compared to the BRIC model published in 2010, it is concluded that this group of indicators does not exist. There are several indices in the group rounding up institutional resilience, which can partially compensate for the purpose of the group of indices named risk analysis, which was actively used in the analyzed papers.

The sublimation of methodological approaches relates to the use of the previously mentioned groups of indicators and the indicators themselves with their variations. Most, or nearly all, methodological approaches have been developed after 2010 and refer to the use of indices based on the need for which they were created. Methodological approaches have been translated into specific tools or frameworks. The approaches are almost always multidisciplinary and apply to all disasters. A smaller number of tools and frameworks have been developed exclusively for natural disasters and

apply to specified areas or regions that face specific natural disaster threats. It is characteristic that fewer than ten tools developed from 2000 to 2010 are mentioned in the papers, while more than 35 tools have been registered from 2010 to 2024, excluding their adaptations, which are not considered new models, although they often significantly differ from the basic, initial model.

Several attempts have been made to measure disaster resilience by developing composite indicators, and these efforts are still in their early stages, as is what might represent a standard mechanism for measuring disaster resilience. The tools have applied various, and even opposing, approaches to fulfill the common goal of providing guidance for building resilient communities. This reflects the diverse origins of the tools, variations in the definition of community across the selected tools, and the diverse and opposing starting points that led to their development. More than half of the tools mentioned in the papers were developed for the needs of local communities in the United States. The initiators of their creation are mostly government institutions, while a certain number of tools were developed under the sponsorship of organizations concerned with environmental protection. Other tools have been developed in other developed countries. As the tools were mainly created in developed countries, there is concern about their applicability and generalizability to communities in less developed countries. Local authorities and community organizations are the main target group. There are also tools designed to inform other sectors, such as academia, aid agencies, and insurance companies.

3.3. The qualitative characterization of the use and modifications of the BRIC method

The DROP model, as the theoretical basis for the BRIC method, was designed to assess resilience to natural hazards, and the authors note that the model could also be applied to other sudden or long-term hazards. In the DROP model, communities are defined as "the totality of interactions of the social system within a defined geographic space, such as a neighbourhood, census district, town, or county" (Cutter et al., 2008, p. 599). BRIC has been applied at different levels and with various geographic units. The levels of analysis have ranged from entire countries to individual villages. Counties were the unit of analysis in the original BRIC study from 2010 and represented the most commonly used definition in subsequent research.

The original BRIC study examined 36 indicators with their variables within five groups of indicators. The number of indicators used in the analyzed studies ranged from 3 to 49. Some studies in the literature have even employed up to 57 indicators. Table 5 presents the characteristic studies used in this review, along with the specific number of indicators for each group and other relevant details for each study.

Table 5. Characteristic Studies Used in the Review.

Author and Year	Territory	Resilience	Indicator Groups	Total Indicators
(Moghadas, Asadzadeh, Vafeidis, Fekete, & Kötter, 2019)	Iran/Region	Floods	Social 7; Economic 6; Infrastructure 6; Social Capital 8; Ecological 3.	22
(Csizovszky, 2023a)	Hungary/Whole Country	Disasters	Social 7; Economic 7; Infrastructure 8; Social Capital 7; Ecological 7.	36
(Aksha & Emrich, 2020)	Nepal/Whole Country	Natural Disasters	Social 9; Economic 4; Infrastructure 3; Social Capital 3; Ecological 3.	22

(Javadpoor, Sharifi, & Roosta, 2021)	Iran/Whole Country	Disasters	Social 12; Economic 7; Institutional 2; Infrastructure 9; Social Capital 4; Ecological 4.	35
(Sung & Liaw, 2020)	Taiwan/Region	Natural Disasters	Social 2; Economic 1; Institutional 2; Infrastructure 5; Social Capital 2.	12
(Singh-Peterson, Salmon, Goode, & Gallina, 2014a)	Australia/Region	Disasters	Social 6; Economic 6; Institutional 6; Infrastructure 5; Social Capital 4.	27
(Scherzer et al., 2019)	Norway/Whole Country	Natural Disasters	Social 8; Economic 7; Institutional 4; Infrastructure 9; Social Capital 10; Ecological 9.	47
(Cutter et al., 2014)	USA/Whole Country	Disasters	Social 10; Economic 8; Institutional 10; Infrastructure 9; Social Capital 7; Ecological 5.	49
(Cutter & Derakhshan, 2019)	USA/Whole Country	Disasters	Social 10; Economic 8; Institutional 10; Infrastructure 9; Social Capital 7; Ecological 5.	49
(Mavhura, Manyangadze, & Aryal, 2021)	Zimbabwe/Whole Country	Disasters	Social 10; Economic 8; Infrastructure 4; Social Capital 2; Health 5.	26

Basic research and the establishment of the DROP and BRIC methods by a group of authors, led by Susan Cutter from the University of South Carolina (USA), represent the foundational basis for the consideration and application of these methods. In this context, their 2014 work stands out, in which the BRIC method was applied across the entire United States, and a modification of the BRIC method was carried out, which served as the foundation for further use and modifications (Cutter et al., 2014). In that study, 49 indicators were developed across six groups, instead of the initial 36, aiming to encompass all the specificities for the entire U.S. territory to effectively measure resilience indices. Initially, 61 indicators were included, but after checking and analyzing the correlations, as well as expert review, the number was reduced to the aforementioned 49. This study is important for future approaches in selecting indicators because, in subsequent studies, the selection of indicators was made by experts using various methods (most commonly Delphi), by reviewing relevant literature, applying international organization guidelines, and calculating the correlation between indicators or indicator groups.

In the studies, starting from the first one led by Susan Cutter in 2010, when the BRIC method was established, the OECD guidelines were primarily used for assessing the quality of indicator selection and application. However, although these guidelines served as a foundation, not all recommended methodological steps were applied. In Cutter's first 2010 study, five OECD guidelines were applied. The author later increased the number of guidelines used in constructing the indicators, reaching up to eight in later studies (Cutter et al., 2014). The distribution of guidelines used in other studies ranges from three to nine. Roughly divided, about 20% of the studies used five, six, or seven guidelines. The guidelines most commonly omitted include: adding missing data, analyzing the reliability and sensitivity of the indicators, revisiting the data and ensuring transparency, and studying the data structure and linking it with other indicators.

The highest number of guidelines followed was in a study where the BRIC method was adapted for Norway. Nine guidelines were applied there, excluding the addition of missing data, where indicators with missing data were removed.

It is characteristic that in only seven studies from the analysis, the Delphi technique was applied, whereby experts from relevant scientific fields for each country or community being researched

would determine appropriate indicators to measure the composite resilience index as the final result (Ciccotti, Cassia Rodrigues, Boscov, & Günther, 2020; Cohen, Leykin, Lahad, Goldberg, & Aharonson-Daniel, 2013; Pazhuhan, Moradpour, hesarakizard, & Ayyoob, 2023; Singh-Peterson, Salmon, Goode, & Gallina, 2014b; Talubo, Malenab, Morse, & Saroj, 2023; Tseng, Huang, Li, & Jiang, 2022).

Most of the studies used publicly available data, and simply, where data was not available, the OECD methodology was avoided, and such indicators were excluded without specific reasoning, and no effort was made to supplement the data with other available compatible data, as seen in studies (Aksha & Emrich, 2020; Bixler, Yang, Richter, & Coudert, 2021; Csizovszky, 2023b; Javadpoor et al., 2021; Scherzer et al., 2019; Weaver, 2016).

In some studies, indicators were excluded through the application of statistical methods if they did not provide appropriate results or were not valid indicators of resilience. A particular fact that might point to an inadequate selection of indicators in studies concerning their specific construction is the analysis of content from previously published research, synthesized through the processing of publicly available data. In these studies, by adopting the content of scientific works predominantly published in the USA and developed Western countries, the geographical, social, economic, and infrastructural differences, which are crucial for constructing optimal indicators for each country or community, were not adequately considered. The indicators obtained in this way were further shaped by the available public data, which, in poorer developing countries, are generally scarce and often of questionable value. Additionally, almost all the analyzed studies excluded fieldwork and surveys except for one study (Jepson & Colburn, 2013).

Their application, in situations where concrete publicly available data or a sufficient number of experts for the Delphi method are lacking, could lead to significant data for creating appropriate resilience indicators.

A fact that must be considered is, to a certain extent, the correct selection and use of indicators from each group, especially those related to geographical and social, but also other groups of indicators used to measure the resilience of local communities to natural disasters. The initial objectives of establishing the BRIC method and the theoretical foundation in the DROP model were designed to allow for the "localization" of indicators and their adaptation to the entity for which resilience measurement would be conducted, as done in the following studies for the DROP model (Mavhura et al., 2021; Siebeneck, Arlikatti, & Andrew, 2015).

Furthermore, after conducting a content analysis of the studies, the analysis of community resilience in Norwegian municipalities stands out as a characteristic study (Scherzer et al., 2019). The theoretical foundation was clear, and the authors explicitly stated that it was an adaptation of the BRIC model. The authors claimed that "the community resilience index for Norway should be specific to that country, and the finally selected indicators should be reasonable and justified in the context of Norway" (Scherzer et al., 2019). The starting point in the study was a list of indicators from the original BRIC study. A specificity was that indices for which complete data were not available were excluded from the analysis, unlike other studies that included indices without complete data by using the latest available or any available data (disregarding the time of data collection). Official data from institutions in Norway were used.

Of the initial 139 indicators considered, 27 were immediately excluded due to missing data. A total of 47 indicators grouped into six categories were used, which differed from the original BRIC method by emphasizing the indicator group labeled "Environment" (geographical and spatial characteristics). This number of indicators was reached by excluding indicators that did not provide relevant results or could not determine spatial differences for local communities. Some were excluded because it was assessed that they were not significant for a specific group of indicators. Unlike the original 2010 study, where the BRIC method was established, this study normalized the index values, and then they were assigned different weights based on their importance. Most studies normalized index values from 0 to 1, while a smaller number normalized them with a base value of 0 and a deviation from -1 to 1.

Only a few studies weighted the indices based on their significance, using the procedure developed by Becker as the leading author (Becker, Saisana, Paruolo, & Vandecasteele, 2017). After-

wards, a check of the comprehensiveness of the used indices and the definition of their values was performed. First-order sensitivity indices within groups were used to assess the importance of each indicator within its group. The resulting resilience index was compared with existing indices using Pearson's correlation coefficient to further exclude some indices, which was done for seven indices. The resilience index results were clearly presented on maps using standard deviation, showing the overall performance of the indices and the indicators they were based on.

Another notable and useful study is one analyzing community resilience in Hungary using the BRIC method (Csizovszky, 2023a). The theoretical foundation was clear, and the author explicitly stated that the study involved the adaptation of the BRIC model, taking into consideration previous studies that had adapted the original method, with the study on Norway serving as one example and foundation. The starting point in the study was a list of indicators from the original BRIC study.

After analyzing the literature, the author decided to use 36 indicators in five groups for Hungary. The model used for Norway and the method of excluding indicators until reaching an optimal number was not applied. Missing data were supplemented in a way that was not considered a key limitation; only the available data were used. Official data from institutions in Hungary were used. As in the study on Norway, index values were normalized from 0 to 1. Afterwards, the comprehensiveness of the used indices was checked. Throughout the process, the indices within groups were frequently adjusted to use relevant indices. All indices that had high or low values for each local community were excluded because they were not considered relevant for drawing conclusions. Unlike the study that adapted the BRIC method for Norway, the correlation was measured using Pearson's correlation coefficient, the Variance Inflation Factor (VIF), and the Kaiser-Meyer-Olkin (KMO) test, and some indices were excluded based on these tests. The resilience index results were clearly presented on maps using standard deviation, showing the overall performance of the indices and the indicators they were based on.

In addition to the mentioned studies, other useful studies that can be used as guides for research include those related to Nepal and Australia. The study on Nepal (Aksha & Emrich, 2020) due to the country's specifics, used primarily the theoretical DROP foundation and was not based on adapting the BRIC method. However, due to the quality of the approach, the research provides insight into one of the ways to use characteristic indicators and their variables for measuring community resilience indices. Regarding the research on Australia, it is notable that no modification of the indicators from the original BRIC study was made; rather, the indicator variables were simply adapted to the available statistical data, and the method's adaptation process was verified through expert interviews.

4. Discussion

The objectives of this paper relate to the analysis of scientific papers addressing the topic of indicators used for measuring the resilience of local communities and the practical application or adaptation of the BRIC method, derived from the DROP theoretical concept, in measuring community resilience to natural disasters.

After collecting and analyzing scientific papers based on established criteria, a critical review and analysis were conducted on a total of 37 papers, of which 12 specifically addressed the BRIC method and the DROP model as a theoretical basis and means of operationalizing the application of indicators. Out of this number, five papers focused on a specific region or local community. A noticeable increase in the number of papers related to the BRIC method began in 2019. The remaining 25 papers dealt with resilience indices, their analysis, and application. It is characteristic of these papers that, in 10 of them, the first author was from the USA. The distribution of papers by year of publication was consistent over the monitored period, starting from 2010. Out of the total number, eight papers focused on a specific region or local community. Furthermore, for the 37 observed papers, a multimethod approach was characteristic, used in a little over half of the papers, followed by a quantitative approach. Data were collected by processing available data from public and other

institutions or through content analysis, which is typical for papers focused on indicators and employing a theoretical approach and qualitative research design.

The main methodological shortcoming observed in the analyzed papers is that OECD guidelines were predominantly omitted where there were challenges in data collection, assessing the quality of indicators, and comparing them— in areas where the limitations of scientific papers in selecting the most suitable indicators for measuring resilience are evident.

The next observed methodological shortcoming is the insufficient application of appropriate methods to obtain results that would allow the creation of optimal resilience indicators for a geographically defined location under investigation. What stands out is the insufficient use of the Delphi method, which is based on interviewing experts in the fields for which groups of indicators are defined in the papers. Additionally, there is a lack of fieldwork and surveys where publicly available data from government and other institutions are absent. In several papers, the need for deeper and more substantial data analysis and their verification, through qualitative research approaches, is emphasized. However, it is highlighted that a qualitative research design is desirable for a deeper exploration of specific groups of indicators and the proper selection of variables for the indicators.

In a few papers, particularly those mentioned in the qualitative analysis, the development of guidelines for selecting and using indicators (constructing and validating indices) is evident. The results of multivariate analyses should guide methodological decisions, such as grouping indicators and determining weights within the index (*Handbook on constructing composite indicators: Methodology and user guide*, 2008). In addition to the aforementioned, in order to reduce the number of indices being measured, Cutter and her colleagues published a scientific paper in 2022, which, along with previously mentioned methods for correlation, applied a statistical method called Principal Component Analysis (PCA). However, PCA did not result in factors that are conceptually justified and aligned with the contemporary understanding of community resilience and its drivers (Derakhshan, Blackwood, Habets, Effgen, & Cutter, 2022, p. 5).

In other words, the approach to selecting indicators and groups of indicators used in resilience assessment should be balanced and conducted in two ways. The first is through the application of statistical indicators and correlation measurement, while the second involves the use of the Delphi method and the consideration of expert opinions on which indicators should be included for measuring resilience. This method highlights the subjective and objective approaches to constructing resilience indicators (Béné et al., 2016). Subjective indicators are the result of expert effort, while objective indicators are the product of specific quantitative methods of calculation. For this reason, objective indicators can be more easily applied in broader geographical contexts, while subjective indicators are used in narrower geographical contexts, as they are derived from a deeper understanding of the circumstances in which a particular community operates.

Summarizing the results of the qualitative analysis of indicators and their corresponding variables used for measuring resilience, and placing them in the context of their use for resilience assessment, concrete conclusions can be drawn about which indicators were not developed in Susan Cutter's BRIC method from 2010, without considering her 2014 work, which represents an adaptation of the original method. Comparing the BRIC method's indicators with those of other methodological approaches for measuring resilience, such as the Climate Disaster Resilience Index (Prashar, Shaw, & Takeuchi, 2012), the Community Disaster Resilience Index (Mayunga, 2007), the Coastal City Resilience Index (A & Simonovic, 2013), the Climate Vulnerability and Capacity Assessment Index (*Handbook of Current and Next Generation Vulnerability and Adaptation Assessment Tools* 2007), as well as other relevant methodological approaches published in earlier periods where over 80 indicators were identified, reveals certain differences. These differences relate to the indicators and corresponding variables that are not applied in the BRIC method but have an impact on optimal resilience measurement, as they take into account or could take into account the specificities of a particular country or territory in relation to economic, social, geographical, demographic, and other characteristics. A review of these indicators is provided in Table 6.

Table 6. Groups of Indicators with Indicators Not Included in the BRIC Method.

Group of Indicators	Indicators Not Covered by the BRIC Method
Socio-demographic	Community preparedness for disasters (partial); previous experiences; social connectivity; percentage of population not speaking the national language (partial); special needs of certain segments of the population; access to specialized healthcare facilities; control of infectious diseases.
Economic	Budget and household subsidies; size of business organizations; territorial distribution of trade chains; resources available for post-disaster reconstruction; degree and diversity of economic resources; food security.
Institutional	First aid training preparation; access to healthcare assistance; immunization capacity; usable biological protection systems; capacity for disease research and prevention; management and regulations in natural resource management.
Infrastructure	Residential properties and land use; community resources; electricity supply; water supply; transportation; utility infrastructure.
Community Well-being	Risk awareness and preparation (partial); risk perception; religious beliefs; religious organizations; trust in authorities.
Geographical and Spatial Characteristics	Hazard intensity; hazard frequency; number of risks; size of available land; environmental protection services; biodiversity index.
Cooperation	Effectiveness of local institutions (partial); cooperation with other levels of government; connectivity of institutions and organizations (partial); institutional cooperation and coordination (partial); integration of special population needs into crisis plans; community volunteerism.

It should be particularly emphasized that the qualitative analysis of the papers in this critical review, which dealt with resilience indicators starting from 2010, led to the conclusion that the BRIC method lacks indicators from the group of Geographical and Spatial Characteristics, Cooperation, as well as Risk Analysis. In other words, there is partial coverage of these indicators by other indicators from different groups.

Overall, although the BRIC method ranks highly in terms of resilience indicators, it lacks comprehensive and universally applicable indicators that could be used for all countries or territories where disaster resilience is measured. The use and adaptation of the BRIC method and the theoretical DROP model developed by Susan Cutter and her colleagues require adjustments (improvements) for successful use in specific local contexts. To ensure successful application, the adaptation of these methods must focus on the indicators that the BRIC method does not cover, as identified in the qualitative analysis and presented in Table 5. The incorporation of certain mentioned indicators into the BRIC method's existing groups of indicators would allow for the localization of indicators that could be measurable and meaningful in a particular territory or country. The indicators used in modifying the method will depend on available data, statistical methods, the use of the Delphi technique, and fieldwork to determine the feasibility of data collection and to optimize the use of the index through the application of these tools.

Each local community is specific due to its geographical and spatial characteristics, as well as its social structure, which influences the development of infrastructure, cooperation, risk analysis capacities, the development of institutions, and social and economic specificities. The BRIC method, to some extent, lacks defined indicators for all of the above, which need to be implemented in modifications for the successful determination of resilience indices. "There is a clear distinction in how resilience to disasters caused by natural hazards manifests in urban and rural environments. The

factors contributing to disaster resilience vary, highlighting the need for efforts to improve resilience to be adapted to the local context rather than being universally applied to all locations, including both urban and rural areas. The social, economic, and ecological processes that have transformed the nation provide the fundamental context for disaster resilience patterns: regional specificity, unique differences between urban and rural areas within and across geographical regions, and variations in factors among similarly classified areas such as rural counties (Cutter, Ash, & Emrich, 2016, p. 1251).

Due to the complexity of measuring the resilience of local communities, the multidimensional approach to selecting indicators has allowed for the inclusion of a larger and more adequate number of resilience aspects. The specificity lies in the fact that indicators are sensitive to methodological decisions in the construction of the index. BRIC was designed as a tool to support decision-making in disaster risk reduction, and as such, the authors clearly stated that some of their methodological choices were aimed at making the index transparent and intuitive for decision-makers (Cutter et al., 2010). Despite the limitations and compromises between methodological quality and ease of understanding in the selection of indicators, the improved version of the BRIC method by Susan Cutter has been incorporated into official disaster risk assessments in the USA.

The limitations of the critical literature review are based on the number of individuals who conducted it, the time frame of its preparation, and the availability of relevant scientific databases, which required subscriptions or institutional access, rather than individual access. Another limitation relates to language, as only scientific papers in English published in academic journals were included in the review. So-called gray literature, which includes a large number of papers not published in academic journals such as reports, working documents, bulletins, documents from official government institutions, and the like, was not considered. Due to the challenge of selecting keywords, as well as the limitations of the physical capacity to review the obtained results, a certain number of papers were identified through citation searches. The next limitation was the exclusive focus on the BRIC method and its adaptations. A large number of methods developed independently of this method with adaptations were excluded from the analysis. No attention was paid to the methodological quality of the papers, although significant deviations were observed during the review, which made the review more difficult to complete.

These limitations, primarily the lack of access to a certain number of papers, have contributed to the absence of a complete picture regarding the methodological approaches to selecting optimal groups of indicators, the indicators themselves, and their variations depending on the specificities of the country or region for which the BRIC method is being adapted. The data on the selection process would contribute to a higher quality approach in the selection of appropriate indices in the case of the Republic of Serbia.

5. Conclusion

Based on a detailed critical review of the literature, this paper deepens our understanding of the complexities of measuring the resilience of local communities to natural disasters, with a special emphasis on the application and adaptation of the BRIC and DROP models. The review identified a range of significant indicators that affect resilience, but it also pointed out some critical shortcomings in the existing research and models.

First, one of the fundamental shortcomings is the limited geographical and cultural scope of current research. The vast majority of the analyzed papers are focused on specific regions, such as the USA and Europe, which limits the applicability of the findings in different social and economic contexts. Future research should include more countries and regions, particularly those with different levels of development and specific socioeconomic conditions, in order to achieve a more comprehensive understanding of the applicability of the BRIC and DROP models in various contexts. Second, methodological limitations also represent a significant aspect that needs to be considered. Although the PRISMA methodology was used as the primary technique for conducting the systematic literature review, it is necessary to include other methods that can further enrich the analysis, such as

the Delphi technique and case studies. This would allow for a deeper and more precise analysis of specific local contexts and their role in defining community resilience.

Third, the analysis indicated the need for further development and adaptation of existing indicators, especially in the context of social and infrastructural resilience. Indicators such as access to transportation, language competency, and communication capacities are not sufficiently addressed in the existing literature and require additional attention. Additionally, new indicators need to be developed to better reflect the complexity and multidimensionality of local community resilience, taking into account the specificities of different geographical areas. Measuring the resilience of local communities to natural disasters using the BRIC method and adapting the indicators for measuring the resilience index represents a challenge in itself. It is a process that cannot be directly observed but is concluded based on a larger number of factors. The very meaning of the term community resilience is still a subject of discussion and relatively uneven views. The main shortcoming in existing research lies in the implementation of tools for assessing community resilience and their ability to improve outcomes, that is, to select adequate indicators. The measurement of resilience in a given community is constantly evolving as a scientific field, and there is a lack of an adequate method to determine and adapt the indicators to be measured, which may be due to the overall development of society in the modern age and the changes in the ecological aspect conditioned by this development.

The main insight provided by the critical literature review points to current literature, the one that established the foundations and the one that represented an upgrade and the establishment of adequate guidelines for measuring the resilience of local communities to natural disasters. The obtained results, in addition to fulfilling the goals set in the paper, provide insight for new research in this area, namely how to approach the adaptation of the BRIC method, the selection of appropriate indicators, and the obtaining of a resilience index for a specific community when natural disasters are involved. In the context of institutional resilience, it was concluded that institutions need to develop more precise and comprehensive indicators that would provide better insight into their ability to respond to disasters. This includes improving existing emergency intervention plans and developing new approaches to assess and enhance institutional capacities at the local level.

Overall, this paper highlights the need for further research and the development of integrated approaches to measuring disaster resilience. Future research should focus on expanding the scope of analysis to different geographical and cultural contexts, as well as on developing new methodological tools that would allow for a more comprehensive assessment of local community resilience. In addition, it is recommended that the results of this review be used as a basis for developing practical policies and strategies that will improve disaster resilience, both locally and globally.

This review points to the importance of further development and application of models such as BRIC and DROP, but at the same time emphasizes the necessity of adapting them according to specific local and regional conditions to ensure effective disaster risk management and the improvement of community resilience worldwide.

Funding: This research was funded by the Scientific–Professional Society for Disaster Risk Management, Belgrade (https://upravljanje-rizicima.com/, accessed on 12 April 2024) and the International Institute for Disaster Research (https://idr.edu.rs/, accessed on 12 April 2024), Belgrade, Serbia.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the Scientific–Professional Society for Disaster Risk Management and the International Institute for Disaster Research (protocol code 004/2024, 10 April 2024).

Acknowledgements: The authors acknowledge the use of Grammarly Premium and ChatGPT 4.0 in the process of translating and improving the clarity and quality of the English language in this manuscript. The AI tools were used to assist in language enhancement but were not involved in the development of the scientific content. The authors take full responsibility for the originality, validity, and integrity of the manuscript.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Aleksandrina, M., Budiarti, D., Yu, Z., Pasha, F., & Shaw, R. (2019). Governmental Incentivization for SMEs' Engagement in Disaster Resilience in Southeast Asia. International Journal of Disaster Risk Management, 1(1), 32-50.
2. Arooj, P., & Simonovic, S. P. (2013). Coastal cities at risk (CCaR): generic system dynamics simulation models for use with city resilience simulator. *Water Resources Research Report*.
3. Aksha, S. K., & Emrich, C. T. (2020). Benchmarking Community Disaster Resilience in Nepal. *International Journal of Environmental Research and Public Health, 17*(6).
4. Aldrich, P. D. (2012). *Building resilience: Social capital in post-disaster recovery*. Chicago: The University of Chicago Press.
5. Alexander, E. D. (2013). Resilience and disaster risk reduction: an etymological journey. *Natural Hazards and Earth System Sciences, 11*, 2707-2716.
6. Asadzadeh, A., Kötter, T., Salehi, P., & Birkmann, J. (2017). Operationalizing a concept: The systematic review of composite indicator building for measuring community disaster resilience. *International Journal of Disaster Risk Reduction, 25*, 147-162.
7. Baseline Resilience Indicators for Communities. (2024). *https://sc.edu/*. Retrieved from https://sc.edu/study/colleges_schools/artsandsciences/centers_and_institutes/hvri/data_and_resources/bric/
8. Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I. (2017). Weights and importance in composite indicators: Closing the gap. *Ecological Indicators*, 12-22.
9. Béné, C., Al-Hassan, R., Amarasinghe, O., Fong, P., Ocran, J., Onumah, E., Mills, D. J. (2016). Is resilience socially constructed? Empirical evidence from Fiji, Ghana, Sri Lanka, and Vietnam. *Global Environmental Change*, 153-170.
10. Bergstrand, K., Mayer, B., Brumback, B., & Zhang, Y. (2015). Assessing the Relationship Between Social Vulnerability and Community Resilience to Hazards. *Social indicators research*, 391–409.
11. Bixler, P., Yang, E., Richter, S. M., & Coudert, M. (2021). Boundary crossing for urban community resilience: A social vulnerability and multi-hazard approach in Austin, Texas, USA. *International Journal of Disaster Risk Reduction*.
12. Cai, H., Lam, N. S. N., Qiang, Y., Zou, L., Correll, R. M., & Mihunov, V. (2018). A synthesis of disaster resilience measurement methods and indices. *International Journal of Disaster Risk Reduction, 31*, 844-855.
13. Chang, S. E., & Shinozuka, M. (2004). Measuring improvements in the disaster resilience of communities. *Earthquake Spectra, 20*(3), 739-755.
14. Ciccotti, L., Cassia Rodrigues, A., Boscov, M. E. G., & Günther, W. M. R. (2020). Building indicators of community resilience to disasters in Brazil: A Participatory Approach. *Ambiente & Sociedade*.
15. Cimellaro, G. P., Reinhorn, A. M., & Bruneau, M. (2010). Framework for Analytical quantification of disaster resilience. *Engineering Structure, 32*(11), 3639-3649.
16. Cohen, O., Leykin, D., Lahad, M., Goldberg, A., & Aharonson-Daniel, L. (2013). The conjoint community resiliency assessment measure is a baseline for profiling and predicting community resilience for emergencies. *Technological Forecasting & Social Change*.
17. Csizovszky, A. (2023a). Analysis of community resilience in Hungary – An adaptation of the basic resilience indicators for communities (BRIC), 2020. *Regional Statistics*, 752–778.
18. Csizovszky, A. (2023b). Have Hungarian districts become more resilient? - A comparison of the 2014 and 2020 Baseline Resilience Indicators for Communities (BRICs). *European Journal of Sustainable Development*, 185-197.
19. Cutter, S. L., Ash, K. D., & Emrich, C. T. (2014). The geographies of community disaster resilience. *Global Environmental Change*, 65-77.
20. Cutter, S. L., Ash, K. D., & Emrich, C. T. (2016). Urban-Rural Differences in Disaster Resilience. *Annals of the American Association of Geographers*, 1236-1252.

21. Cutter, S. L., Barnes, L., Berry, Melissa, Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, 598–606.
22. Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. *Journal of Homeland Security and Emergency Management, 7*(1).
23. Cutter, S. L., & Derakhshan, S. (2019). Implementing Disaster Policy: Exploring Scale and Measurement Schemes for Disaster Resilience. *Journal of Homeland Security and Emergency Management*.
24. Cvetković, V., & Šišović, V. (2024). Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. *Sustainability, 16*(7), 2620.
25. Cvetković, V. M., & Šišović, V. (2024). Community Disaster Resilience in Serbia. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
26. Cvetković, V. M., Renner, R., Aleksova, B., & Lukić, T. (2024). Geospatial and Temporal Patterns of Natural and Man-Made (Technological) Disasters (1900–2024): Insights from Different Socio-Economic and Demographic Perspectives. Applied Sciences, 14(18), 8129.
27. Cvetković, V., Rikanović, S., Knežević, S. (2022). The resilience of society in disasters caused by nuclear accidents. IAI Academic Conference Proceedings, Budapest Conference, 5 May 2022.
28. Cvetković, V., Ivković, T. (2022). Social Resilience to Flood Disasters: Demographic, Socio-economic and Psychological Factors of Impact". 12th International Conference of the International Society for the Integrated Disaster Risk Management, Cluj-Napoca, Romania, 21-23 September 2022.
29. Cvetković, V., Grozdanić, G., Milanović, M., Marković, S., Lukić, T. (2024). Understanding Seismic Hazard Resilience in Montenegro: A Qualitative Analysis of Community Preparedness and Response Capabilities. *Open Geosciences*, 16 (1).
30. Cvetković, V. (2024). Disaster Resilience: Guide for Prevention, Response and Recovery. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
31. Cvetković, V. M. (2023). A Predictive Model of Community Disaster Resilience based on Social Identity Influences (MODERSI). International Journal of Disaster Risk Management, 5(2), 57-80.
32. Department of Economic and Social Affairs. (2024, јун 15). *United Nations*. Retrieved from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
33. Derakhshan, S., Blackwood, L., Habets, M., Effgen, J. F., & Cutter, S. L. (2022). Prisoners of Scale: Downscaling Community Resilience Measurements for Enhanced Use. *Sustainability*.
34. Grozdanić, G., & Cvetković, M. V. (2024). Exploring Multifaceted Factors Influencing Community Resilience to Earthquake-Induced Geohazards: Insights from Montenegro. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
35. Goyal, N. (2019). Disaster governance and community resilience: The law and the role of SDMAs. International Journal of Disaster Risk Management, 1(2), 61-75.
36. *Handbook of Current and Next Generation Vulnerability and Adaptation Assessment Tools* (2007). London: Care International.
37. *Handbook on constructing composite indicators: Methodology and user guide*. (2008). OECD.
38. Holling, S. C. (1973, September). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 1-23.
39. Irwin, S., Schardong, A., Simonovic, S. P., & Nirupama, N. (2016). A Decision Support Tool for Estimating Resilience of Urban Systems. *Water, 8*.
40. IPCC (2023): Climate Change 2023. Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Online verfügbar unter 10.59327/IPCC/AR6-9789291691647.
41. Jaiye, D. J., & Benjamine, O. (2021). Building resilience through local and international partnerships, Nigeria experiences. International Journal of Disaster Risk Management, 3(2), 11-24.

42. Javadpoor, M., Sharifi, A., & Roosta, M. (2021). An adaptation of the Baseline Resilience Indicators for Communities (BRIC) for assessing the resilience of Iranian provinces. *International Journal of Disaster Risk Reduction, 66*.
43. Jepson, M., & Colburn, L. L. (2013). Development of Social Indicators of Fishing Community Vulnerability and Resilience in the U.S. Southeast and Northeast Regions. *NOAA Technical*.
44. Ji, T., Wei, H. H., Shohet, I. M., & Xiong, F. (2021). Risk-based resilience concentration assessment of. *Natural Hazards, 108*, 1731-1751.
45. Johansen, C., Horney, J., & Tien, I. (2017). Metrics for Evaluating and Improving Community Resilience. *Journal of Infrastructure Systems, 23*(2), 04016032.
46. Jülich, S. (2017). Towards a local-level resilience composite index: introducing different degrees of indicator quantification. *International Journal of Disaster Risk Science, 8*, 91-99.
47. Karanci, N., Ikize, G., Doğulu, C., & Özceylan-Aubrecht, D. (2016). Perceptions of Individual and Community Resilience to Earthquakes. *International Journal of Disaster Risk Reduction*, 108-114.
48. Kim, H., & Marcouiller, D. W. (2018). Mitigating flood risk and enhancing community resilience to natural disasters: plan quality matters. *Environmental Hazards*, 397-417.
49. Kabir, M. H., Hossain, T., & Haque, M. W. (2022). Resilience to natural disasters: A case study on the southwestern region of coastal Bangladesh. International Journal of Disaster Risk Management, 4(2), 91-105.
50. Macharia, D., Kaijage, E., Kindberg, L., Koech, G., Ndungu, L., Wahome, A., & Mugo, R. (2020). Mapping Climate Vulnerability of River Basin Communities in Tanzania to Inform Resilience Interventions. *Sustainability, 12*(10), 4102.
51. Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., & Shukla, P. R. (2018). *Global warming of 1.5°C*. Retrieved from Geneva:
52. Mavhura, E., Manyangadze, T., & Aryal, K. R. (2021). A composite inherent resilience index for Zimbabwe: An adaptation of the disaster resilience of place model. *International Journal of Disaster Risk Reduction*.
53. Mayunga, J. S. (2007). Understanding and Applying the Concept of Community Disaster Resilience: A capital-based approach. *Summer academy for social vulnerability and resilience building*.
54. McAllister, T. P. (2015). *A Guide to Develop Community Resilience Performance Goals and Assessment Metrics for Decision Making*. Retrieved from Vancouver:
55. Moghadas, M., Asadzadeh, A., Vafeidis, A., Fekete, A., & Kötter, T. (2019). A multi-criteria approach for assessing urban flood resilience in Tehran, Iran. *International Journal of Disaster Risk Reduction*.
56. Mohamad, N., Jusoh, H., & Kassim, Z. (2019). Localizing of Community Resilience Indicators for Assessing the Urban Community Resilience in Putrajaya, Malaysia. *International Journal of Engineering and Advanced Technology*, 359-365.
57. Muttarak, R., & Lutz, W. (2014). Is education A key to reducing vulnerability to natural disasters and hence Unavoidable Climate Change? *Ecology And Society, 19*.
58. Olawuni, P., Olowoporoku, O., & Daramola, O. (2020). Determinants of Residents' Participation in Disaster Risk Management in Lagos Metropolis Nigeria. International Journal of Disaster Risk Management, 2(2), 1-18.
59. Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Brennan, S. E. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *Bmj, 372*.
60. Pazhuhan, M., Moradpour, N., hesarakizard, A., & Ayyoob, S. (2023). District-based Baseline Resilience Indicators for Communities (DBRIC) for assessment of a Global South city. *Sustainable Cities and Society*.
61. Prashar, S., Shaw, R., & Takeuchi, Y. (2012). Assessing the resilience of Delhi to climate-related disasters: a comprehensive approach. *Natural Hazards*, 1609–1624.

62. Quigley, M., Blair, N., & Davison, K. (2018). Articulating a social-ecological resilience agenda for urban design. *Journal of Urban Design*, 581-602.
63. Scherzer, S., Lujala, P., & Rød, J. K. (2019). A community resilience index for Norway: an adaptation of the baseline resilience indicators for communities (BRIC). *International Journal of Disaster Risk Reduction, 36*.
64. *Sendai Framework for Disaster Risk Reduction 2015-2030*. (2015). Retrieved from Geneva:
65. Siambabala , M. B. (2006). The concept of resilience revisited. *Disaster, 30*(4), 434-450.
66. Siebeneck, L., Arlikatti, S., & Andrew, S. A. (2015). Using provincial baseline indicators to model geographic variations of disaster resilience in Thailand. *Natural Hazards*.
67. Singh-Peterson, L., Salmon, P., Goode, N., & Gallina, J. (2014a). Translation and evaluation of the Baseline Resilience Indicators for Communities on the Sunshine Coast, Queensland Australia. *International Journal of Disaster Risk Reduction*, 116–126.
68. Singh-Peterson, L., Salmon, P., Goode, N., & Gallina, J. (2014b). Translation and evaluation of the baseline resilience Indicators for Communities on the Sunshine Coast, Queensland Australia. *International Journal of Disaster Risk Reduction*, 116–126.
69. Sung, C.H., & Liaw, S.C. (2020). A GIS Approach to Analyzing the Spatial Pattern of Baseline Resilience Indicators for Community (BRIC). *Water*.
70. Talubo, J. P., Malenab, R. A., Morse, S., & Saroj, D. (2023). Practitioners' Participatory Development of Indicators for Island Community Resilience to Disasters. *Sustainability*.
71. *Terminology on Disaster Risk Reduction*. (2009). Retrieved from Geneva:
72. Tseng, Y.P., Huang, Y.C., Li, M.-S., & Jiang, Y.Z. (2022). Selecting Key Resilience Indicators for Indigenous Community Using Fuzzy Delphi Method. *Sustainability*.
73. Weaver, R. (2016). Capacity Building and Community Resilience: A Pilot Analysis of Education and Employment Indicators Before and After an Extension Intervention. *The Journal of Extension*.
74. Zio, E. (2016). Challenges in the vulnerability and risk analysis of critical infrastructures. *Reliability Engineering and System Safety*, 137-150.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Article

Private sectors' interventions in Disaster Risk Management

Sukhdeep Kaur[1], **Kashmir Singh**[1,*]

[1] DST- Centre for Policy Research, Panjab University, India; deep.gurna.49@gmail.com (S.K.), kashmirbio@pu.ac.in (K.S.)

** Correspondence: kashmirbio@pu.ac.in; Tel.: +91 95016 84096*

Received: 1 September 2024; Revised: 28 November 2024; Accepted 20 October; Published: 25 December

Abstract

The private sector can play a pivotal role in Disaster Risk Management (DRM) by providing services to strengthen resilience such as climate-resilient infrastructure, supply chain, recovery planning, etc. It can also lead the projects to enhance preparedness by providing expertise in risk assessment, relief coordination, and financial protection. With these capabilities, the private sector can extend its cooperation to the government and public sector to reduce people's vulnerability to various disasters. Corporate Social Responsibility (CSR) is one of the prominent ways in which the private sector can contribute towards DRM. In India, private sector-led bodies like the Confederation of Indian Industry (CII) and, the Federation of Indian Chambers of Commerce and Industry (FICCI) are prominently contributing to DRM through CSR towards capacity-building programs. Private firms of varied sizes such as Mahindra, Reliance, and TATA, make varying financial and non-financial contributions toward relief operations and resilience at the individual level. However, a contribution to disaster preparedness in India by collective private bodies and industry associations has the upper edge because they push for improving the scalability and efficiency of innovative solutions and ease of community use of advanced technological tools. The present study highlights the prominent programs these private bodies such as Alliance for Disaster Resilient Societies (ARISE) India that promote the private sector's contribution to disaster risk management. Based on the best practices of these programs the recommendations are drawn that stress a strong partnership (Public Private Partnerships (PPPs)) between different stakeholders (Public and Private) to improve the accountability and feasibility of disaster preparedness.

Keywords

Disaster Risk Management (DRM); Private sector; Public Private Partnerships (PPPs); Disaster Risk Reduction Private Sector Partnership (DRR-PSP); Corporate Social Responsibility (CSR).

1. Introduction

1.1. Private Sector and Disaster Risk Management (DRM)

Disaster Risk Management (DRM) is a multidisciplinary concept (IORA, 2024) that needs a multi-directional approach (Fleming et al., 2020) to work on various aspects such as mapping of types and the sizes of disasters, financial and social perspectives as well as supply chain assurance and operational performance as per a report by Mercy Corps and R3ADY Asia- Pacific (2015). For an effec-

tive and efficient DRM and to maximize the chances of achieving the desired objectives of DRM, A proactive engagement of stakeholders is recommended (UNDP, 2024; Mojtahedi and Lan Oo, 2017; Cvetković & Janković, 2020). The key stakeholders for an effective DRM are the Government, Private partners, and Civil Society (ADB, 2024) that are needed to catalyze the actions to be taken per the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015a).

The role of each stakeholder in disaster risk reduction is emerging as an important area of attention post-Hyogo Framework to prioritize disaster risk reduction, identification, assessment through legal and policy frameworks, disaster preparedness, and use of innovation (Chatterjee and Shaw, 2015). While considering each sector's role, the World Bank (2011, 2015) emphasized the participation of the private sector in DRM by highlighting the private sector as an important supplier of knowledge, financial services, and technical know-how. Thereby, preparing for and responding to disasters to ensure an effective response to the impact of hazards that are classified as "Preparedness", "Response" and "Recovery".

The Global Facility for Disaster Reduction and Recovery (GFDRR) (Marcelo Gordillo et al., 2020) which works in partnership with the World Bank towards DRM highlights the positive role the private sector can play in disaster recovery and mitigation. It highlights the importance of Public-Private Partnerships (PPPs) by mentioning them as a way of creating new assets or managing existing mechanisms in place. The private sector can contribute at different levels of DRM at various global (Izumi and Shaw, 2015) as well as at the national level whether it is financial or non-financial contributions in the aftermath of disasters.

The United Nations (UN) explains and defines Corporate Social Responsibility (CSR) as one of the tools for the private sector that goes beyond the sector's day-to-day operation, of producing a certain range of products and services for disbursing its social responsibility, most efficiently and economically (Sattar, 2017). It is often considered an entry point for companies to engage in Disaster Risk Reduction (DRR) as in the case of Indonesia where DRM became an integral part of the Business Continuity Plans (BCPs) of large MNCs quoted by Mercy Corps and R3ADY Asia- Pacific (2015) for minimizing the negative impact of economic downpour on the environment and its resources and come forward to work with other stakeholder in terms of coordination, consultation, co-investing and collaboration. The UNDRR- UN International Strategy for Disaster Reduction (UNISDR) (2015)'s five Private Sector Visions for a Resilient Disaster Risk Reduction Private Sector Partnership (DRR-PSP) highlights the ways and means to work upon the above-mentioned 4C's i.e. coordination, consultation, co-investing and collaboration for increasing resilience, reduce loses and volatility of earnings. The major initiatives in this direction mentioned under DRR-PSP are the disaster resilience scorecard, Green Star communities, Japan's Business Continuity Management (BCM), etc.

The UNDRR's Global Assessment Report (GAR) (2024) highlights the case studies of DRR-PSP such as of Indonesia providing incentives and alternative livelihood in case of forest fires. As well as the case of Jamaica providing climate resilient infrastructure against flood risks or the case of the USA supporting state grant program to fund fire-resistant improvements to the home in case of wildfires and many more case studies like this where the private sector connects with other stakeholders for strategic planning for risk reduction. The study by Mavrodieva et. al. (2019) highlights the crucial interventions of SMEs in South Asian countries such as Indonesia Philippines and Thailand for resilience even though SMEs are the most vulnerable part of the private sector. An important initiative that highlights the leading role of the private sector in technology know-how is the recent Tunis "Call for Action" on Science and Technology for Disaster Risk Reduction in the Arab States and Africa" catalyzing the coordination for DRR and resilience (UNDRR, 2023). A study by the World Bank (Hodgson, 2024) shows the private sector's contribution to providing services such as weather and climate services through Global Weather Enterprise (GWE). All these studies highlight the good practices of the private sector in DRM globally being the case of resilience, finance, incentivization, strengthening the science, technology and Innovation (STI) or contributing to good governance for DRM.

1.2. Disaster Risk Management (DRM) in India

India is a diversified nation. It is demographically rich in the human race. It stands second in the human population (1.21 billion) at the world level with the largest number of people in need of basic amenities having a poverty rate of 37.2% (Dave, 2023). Over the years, India has contemplated its image as a disaster-prone country (UNICEF, 2024). It is ranked third by UNDRR (2020) based on the series of disaster events that took place from 2000 to 2019 leading to huge economic losses. Further, India has to face different types of disasters every year i.e. natural disasters as well as man-made disasters on an average basis (NDMA, 2023). As per the Ministry of Home Affairs (MHA), Government of India (GoI) (2022b), different actors play a part in making the country vulnerable to disasters such as socio-economic, demographic & cultural, and political-ethical in addition to geographical locations, and geological formations (Anand and Choubey, 2018).

According to Dave (2023), the high socio-economic vulnerability makes India one of the most disaster-prone countries in the world. The rate of occurring disasters is at pace every day. In 2021, India lost US$ 3.2 billion from flooding only as per the UNDRR Global Assessment Report (GAR) (2022). The impact was significant when translated into a percentage of Gross Domestic Product (GDP), i.e. 0.5 per cent of GDP. The main actors causing flooding might be heavy and inconsistent rainfalls, deforestation, and melting of Glaciers such that India is prone to such types of disasters. To curb such disasters efficient risk management is required which covers critical verticals such as disaster risk reduction, climate change adaptation, sustainable natural resource management, sustainable natural resource management, social protection, and prevention of undernutrition (Sattar, 2017). This requires international cooperation as per the National Platform for Disaster Risk Reduction (NPDRR) (2023) where India has taken a firm stand to strengthen partnerships for the effective implementation of DRM at all levels.

India is actively involved in various global platforms such as the Asian Development Bank (ADB), United Nations Development Programme (UNDP), and United Nations Office for Disaster Risk Reduction (UNDRR), United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA), United Nations Disaster Assessment and Coordination (UNDAC), Global Platform for Disaster Risk Reduction (GPDRR), and World Bank etc. (MHA, GoI, 2022a). At the national level, the National Disaster Management Authority (NDMA) (2023) is the nodal agency in India that works with different stakeholders such as with regional govt., academia, and the private sector to accelerate the efforts for DRM in line with the Disaster Management Act, 2005, National Disaster Management Plan (NDMP), 2019 and various national guidelines for the preparation of domain-specific action plan. The third session of NPDRR (2023) highlighted the need to bring all stakeholders for mainstream DRR, building local resilience, forging partnerships, and efficiently using technology. In line with the objectives of NPDRR 2023 India is strengthening its governance structure for DRM, catalyzing efforts for resilience by strengthening its regional coordination with state governments-led disaster management authorities known as State Disaster Management Authorities (SDMAs). It is actively moving towards disaster preparedness through various ways such as capacity building and developing an STI-based research ecosystem such as the National Disaster Risk Reduction (DRR) Research Facility by the National Institute of Disaster Management (NIDM) (2024).

To further strengthen disaster preparedness, India needs to engage every sector (Shah, 2011) of the nation to come out at the forefront to contribute towards DRM such that risk factors can be reduced to a greater extent. The Ministry of Home Affairs (MHA, GoI, 2022b) highlights the need for "Involvement of corporate sector in awareness generation and disaster preparedness and mitigation planning". Kanji and Agrawal (2020) also advocate the idea of mainstreaming DRM which needs to be cultivated among the private sector through CSR. In India CSR is a business strategy that works (Issar, et. al, 2005) for private sector organizations through the implementation of enterprise risk management (Bassey, 2016). Clause 135 of the Companies Act 2012 of India, throws light on the domains in which CSR can be useful (Chadda and Kundal 2022). As per the act, CSR-led activities in disaster reduction can be categorized into five types: Philanthropic/ Charitable, Contractual, Sponsorship, Collaborative, Adversarial, and Unilateral (Anand and Choubey, 2018; Twigg, 2001). As such focus on community betterment through CSR-led activities (Bhatt, 2018).

These CSR-led activities address the importance of integrating these activities as a strategic CSR activity for building a resilient society which needs further scale up to enhance the private sector's contribution in the pre-discovery of disaster. This requires effective partnerships among Government, Public, and Private sectors that can help to manage disasters efficiently. However, the challenge lies within an unbalanced contribution from all the sectors. So far in India, the Government along with the public sector have taken the lead together with community participation to some extent. The private sector in India which has a wider range with major footfall in transport, financial services, Infrastructure, etc., needs to provide its expertise for DRM in these sectors. As well as the footfall of the private sector in the Indian economy has taken a pace in recent years (Majumdar, 2023) which is an important catalytic of resilient thinking (UNISDR, 2015). The private sector in risk assessment is also required to influence disaster relief and rehabilitation activities (MHA, GoI, 2022). The frequency of disasters is increasing, and the private sector needs to re-examine its roles and contribute towards several aspects of DRM considering it its social responsibility (Eyerkaufer et. al, 2016). There is a need to push the role of CSR further and redefine the business community plan of the private sector to factor in hazards, risks, and vulnerabilities as well as to create value in innovative social investments in the community (MHA, GoI, 2022).

2. Methods

The present study aims to highlight the initiatives of the private sector in India for Disaster Risk Management (DRM). It highlights the prominent programs that have led to the acceleration of the role of the private sector through CSR for DRM such as Alliance for Disaster Resilient Societies (ARISE) India by prominent private sector-led bodies such as the Confederation of Indian Industry (CII), Federation of Indian Chambers of Commerce and Industry (FICCI), PHD Chambers of Commerce. The private bodies have been considered because they represent high penetration in DRM by the private sectors collectively.

These bodies act as prominent faces of strategic partners to effectively channel the various activities of DRM in India in partnership with other stakeholders. The programs by these industry associations and collective bodies provide a platform for decision-making and an environment of opportunities to conduct multi-directional research as well as floor-to-conduct outreach activities for disaster preparedness in alliance with international partners. Considering the upper edge of industry associations and collective bodies of the private sector in terms of resource pooling and scalability, collective experience and strategies, and contribution to national policies and guidelines; these entities can contribute more effectively than the single entity for disaster preparedness, risk assessment and structuring tailor strategies with collective expertise in STI along with sharing collective burden and responsibility with stakeholders through Disaster Risk Reduction Private Sector Partnership (DRR-PSP). Mapping the robust structure, functioning, and mechanism to develop a comprehensive approach to disaster risk management the program by these bodies can further help to strengthen community development which might not be possible individually. Thus, can further help to accelerate the work India is doing in the DRM domain.

The programs were analyzed based on the 4 C's discussed in the introduction i.e. coordination, consultation, co-investing, and collaboration. The study under context is descriptive and is based on secondary data and information available about these programs in the public domain accessed through published books, articles, and periodicals as well as annual reports and official reports made available by the private bodies and associations. Recommendations are drawn from the best practices of these programs to further strengthen the private sector-led DRM in the Indian scenario. To map the 4 C's a multi-faceted approach was adopted that involves looking for the indicators such as

- *Governance Structure* that may represent the type of committee on board, framework for decision making and resource allocation as well as mechanisms to assess effective DRM.
- *Functions* may involve establishing coordination with other stakeholders, evaluation of effective outcomes of DRR-PSP to analyze the strength of different sectors along outreach to a large population for knowledge dissemination.

- *Research contribution* to enhance disaster preparedness and developing technology know-how for resilience in line with the Sendai Framework and increasing effectiveness based on the assessment of global practices.

3. Data

Following are the few prominent industry associations and collective private bodies considered that show commitment to enhance the collective approach to DRM from the private sector and address the disaster preparedness and efforts for resilience depending upon their expertise in different sectors (IBEF, n.d.; IDRN, n.d.; IVCA, n.d.; SIAIndia, n.d.).

1. All India Management Association (AIMA)
2. Associated Chambers Of Commerce & Industry Of India (ASSOCHAM)
3. Automotive Component Manufacturers Association of India (ACMA)
4. Basel Committee on Banking Supervision (BCBS)
5. Builders Association of India (BAI)
6. Confederation of Indian Industry (CII)
7. Federation of Indian Chambers of Commerce & Industry (FICCI)
8. Healthcare Federation of India (NATHEALTH)
9. Indian Banks' Association (IBA)
10. Indian Chamber of Commerce (ICC)
11. Indian Electrical and Electronics Manufacturers' Association (IEEMA)
12. Indian Venture and Alternate Capital Association (IVCA)
13. National Association of Software and Service Companies (NASSCOM)
14. PHD Chambers of Commerce and Industry (PHDCCI)
15. SatCom Industry Association (SIA-India)
16. Small and Medium Business Development Chamber of India (SME Chamber of India)

Mapping of the above-mentioned bodies was done to look for prominent programs where they have come on board and proven the contribution of the private sector for the upliftment of the present stature of DRM in India. Numerous initiatives by these bodies contribute to DRM. However, the following are the prominent programs that were considered in this study that take the 4 C's into account i.e. coordination, consultation, co-investing, and collaboration.

1. Alliance for Disaster Resilient Societies (ARISE) India by FICCI
2. Disaster relief and rehabilitation program by CII- Foundation
3. Centre for Sustainability by PHDCCI

4. Results

The private sector contributes to developing resilient infrastructure, raising awareness, and the recovery process in India through CSR. Detailed mapping of programs is described in Table 1 based on indicators described in the Methods section to bring forward the private bodies and associations' present scenario of commitment to DRM.

Table 1. Prominent programs by private bodies and industry associations to accelerate DRM.

Name of the Programs	Governance Structure	Functions	Research contribution	Best practices in line with 4 C's for disaster preparedness
Alliance for Disaster Resilient Societies (ARISE) India (ARISE, 2024 ; UNDRR, 2015b & 2020)	Board FICCI DM committee has members from industry and private players such as TATA, and HCC India. Decision making Collaborative approach in line with Sendai Framework Resource allocation Support funding to specific country-based requirements in coordination with UNDRR to strengthen resilience. Assessment mechanisms Target based monitoring Case-based reporting Annual reporting as part of ARISE global.	Coordination with other stakeholders National Agencies such as the National Disaster Management Authority (NDMA) Evaluation of different sectors Sector-specific industry associations such as energy, and infrastructure to identify initiatives for resilience and integration of DRM in BCPs *Outreach activities* Symposiums Annual General meetings Knowledge dissemination	Enhance disaster preparedness Healthcare sector Developing technology know-how Easy-to-use online Quick Risk Estimation tool by Resilience Innovation Knowledge Academy (RIKA) Use of global practices UNDER Asia-Pacific Science, Technology and Academia Advisory Group (APSTAAG)	ARISE India cater methodology for setting up coordination between its members and alliances of UNDRR to bring forward dynamic solutions. It holds roundtable meetings and knowledge dissemination programs for raising funds for resilience infrastructure and developing strategies for investment funds. ARISE India holds consultative meetings with experts to accelerate multi-sectoral efforts for disaster preparedness. It has collaborated with different entities nationally and internationally to improve the management system for DRR and to foster opportunities for developing a technological ecosystem for effective DRM.

Disaster relief and rehabilitation program (CII, 2023; CII-Foundation, 2024)	Board Board of Trustees of CII Foundation (CIIF) Decision making Expertise team for disaster relief and rehabilitation Resource allocation Support essential aid materials such as food and medicine as well as pool-funded projects. Assessment mechanisms As a part of Annual reporting one of the areas of intervention along with publication in rehabilitation case studies.	Coordination with other stakeholders Government, civil society, corporate sector, and NGOs Evaluation of different sectors Education and Healthcare. *Outreach activities* Empower development initiatives through workshops, conferences	Enhance disaster preparedness Mechanisms for allocation of aid to support immediate disaster response Developing technology know-how Strengthen the skill-building ecosystem to support livelihood. Use of global practices Adoption of skill-based programs to provide knowledge about early warning systems, emergency drills.	CII coordinates with state disaster management authorities to strengthen the DRM at the local level. It holds expert consultative meetings to foster the initiatives for disaster resilience across healthcare and education. CIIF raises funds for resilience and post-disaster relief through CSR funding from CII members and collaborating with international agencies to support projects at the community level.
Centre for Sustainability (PHDCCI, n.d.)	Board Board of directors of PHDCCI Decision making An expertise team led by the head Resource allocation Prioritize risk assessment and provide resources for relief and recovery. Assessment mechanisms Guidelines for risk assessment and management	Coordination with other stakeholders Government and cooperate entities and NGOs Evaluation of different sectors Energy, waste management, and fire safety standards *Outreach activities* Services to impart training on potential hazards, and review the existing protection systems.	Enhance disaster preparedness Mechanisms extending recommendation in compliance with safety regulatory frameworks Developing technology know-how Strengthening the electrical and fire safety domain by critical assessment and management Use of global practices Managing GHG and resource-related risks as per global standards.	The center is mainly a service provider for electrical and fire safety risk assessment and management. It works with state governments to asses potential fire-related disasters. Promote a knowledge-based platform for capacity building Facilitates sustainability practices among fellow members.

5. Discussion

The present study drops down three prominent programs led by collective bodies and associations that address the importance of integrating activities related to disaster preparedness to enhance the role of the private sector as a strategic CSR activity for building a resilient society. These industrial and corporate organizations-led platforms such as CII, FICCI, and PHDCCI have been presented in Table 1 and are at the forefront of their social responsibility through CSR at the various levels of disaster response and recovery. Best practices of the programs i.e. ARISE India (FICCI), Disaster Relief and Rehabilitation Program (CII), and Centre for Sustainability (PHDCCI) were drawn based on the understanding of the overall stature of the activities that are essential for fulfilling the verticals of DRM where private sector's contribution in DRM can be optimized further.

5.1. ARISE India

The program led by FICCI advocates the immediate actions that needs to be taken for DRM by concentrating on the motto of being resilient. The programs foster the DRR-PSP by creating its impact through its outreach activities to bring more private players of different statures for disaster preparedness and help them establish fruitful interlinkages with the public sector under PPPs to foster opportunities for disaster-resilient societies. An initiative which works closely with international organizations such as UNDRR in alignment with Sendai Framework for Disaster Risk Reduction (SFDRR) and its associate members of ARISE global; that helps ARISE India to expand its network globally and adopting best practices of working with the public sector to bring resilience into priority. It helps its members to flourish DRM ecosystem at the individual level by doing their capacity building to leverage the opportunity available through CSR such as in the case of Small and Medium Enterprises (SMEs) (ARISE, 2024). where ARISE India provides training on risk assessment and prepares them for situations like disruptions. It collaborates with big industries to foster a research ecosystem and seeks technological support and funding for the projects that bring forward the broader impact of PPPs-led DRM. It takes part in an advocacy role to integrate disaster and climate-related risk investment into the supportive regulatory environment existing in India thereby supporting policy changes towards the allocation of CSR resources more effectively. Taking the best practices existing at the global level (UNDRR, 2023) ARISE India helps business enterprises to work with local government to support community-based initiatives through CSR by working towards data enhancement to improve resource exploration such as in the case of the insurance sector for efficient risk management.

5.2 Disaster relief and rehabilitation program

CII provides a platform to channel the industry representations for working efficiently for the upliftment of the socio-economic stature of India. Thereby contribute towards India's sustainable future. It leads industry participation in various government initiatives, one of them being Disaster Risk Management. Through its CII- Foundation (CIIF), it promotes disaster relief and rehabilitation programs in alignment with the National Disaster Management Plan (NDMP) where it contributes to various rehabilitation projects led by the public sector. CIIF through its channelized program contributes towards the India Disaster Resource Network (IDRN) (NIDM) (2021), a nationwide electronic inventory of resources providing aid for disaster preparedness and response. CIIF promotes the CSR initiatives of its members to help in the enhancement of resource mobilization and capacitate manpower for DRM such as by publishing the case studies of initiatives taken by its members for resilient health systems (CIIF, 2024). It promotes CSR activities of individual initiatives as guidance for others for resource utilization for rural and urban management. As well as coordinate with national agencies such as the National Institute of Disaster Management (NIDM) (2021) to provide education on logistics management and deployment for community resilience.

5.3 Centre for Sustainability

PHIDCCI brings forward the Indian industry initiatives for DRM to achieve resilience through the centre for Sustainability. It is an integration of activities for resilience and suitability efforts. The center provides capacity building on disaster preparedness for SMEs by mapping standards in different domains to enhance awareness and encouragement for charting strategies such as energy audits and risk assessment. It promotes CSR initiatives taken up by members for resilient infrastructure and foster the opportunities for the businesses to reduce vulnerability towards hazards of various types. It fills gaps between public sector and private sector to adopt sustainable practices by providing insights on global practices and collaborative research with national and international agencies. It helps the members to mobilize the CSR funds for technology know-how and connects with the public sector to strengthen the community's knowledge about innovation in disaster preparedness.

Based upon the programs highlighted in the present study for DRM initiatives by the private sector a need to promote such programs is felt that can immensely contribute to the government-led programs such as Coalition for Disaster Resilient Infrastructure (CDRI) (2022), a global initiative being India as one of the members. The private sector which has a direct relationship with consumers, customers, and suppliers can steer the public demand towards risk-sensitive products and services by contributing to CSR. The programs mentioned in this study can provide a collaborative approach based on the 4 C's i.e. coordination, consultation, co-investing, and collaboration to further enhance the CSR role for members of the associated organizations to foster the opportunities for disaster preparedness under DRR-PSP. Following are some suggestive points that can mushroom the collaborative approach identified from the mapping of these programs.

- Introduction of substantial changes to strengthen DRM capacity through suggestive policy and legal interventions for building a resilient society such as applying DRM standards to PPPs contracts (World Bank, 2019).
- Raising awareness in the public with the use of mass media expertise of the private sector by enhancing its role through CSR to contribute towards DRR-PSP led networks that are complex and need emergency managers for effective disaster response as the case of Federal Emergency Management Agency (FEMA) (2021).
- Joint capacity building systems in DRM-promoting technology now known for disaster preparedness should be placed along with hands-on training from private sector work will act as a catalyst. Thereby can reduce the wastage of resources and will improve the service coverage as case of Iran (Gharaee, et al., 2023)
- Private sector-led assessment of severity or magnitude of effects of any disaster, expanding pre-disaster activities for disaster management with a focus on capacity-building of district disaster management authorities by private players as the case of Japan that has made pre-disaster contracts operational to enhance disaster preparedness for natural hazards (Marcelo Gordillo et al., 2020).
- Build partnerships and Accountability mechanisms through CSR and PPPs (NDMP, 2021) with a focus on responsible financing as endorsed by Japan at the G7 summit through 'The G20 Principles on Quality Infrastructure Investment' and exploring innovative financing mechanisms such as providing low-interest loans by US Environmental Protection Agency under DRR-PSP (OECD, 2024).
- Collaboration and collective efforts to raise awareness in the public domain. One means of doing this is sharing experience in implementing PPP agreements (Torayashiki and Watanabe, 2024)

6. Conclusions

The responsive action-based initiatives (Anand and Choubey, 2018) presented in this study lit out experiences that show private sector involvement in Disaster Risk Management (DRM) in the Indian

context. The activities led by private associations and bodies through programs like ARISE India highlight the collective efforts of the private sector under Corporate Social Responsibility (CSR) are not limited to relief, and rehabilitation. However, they cherished competence at the community level by providing support and help to communities and restoring their lives and livelihoods even at the pre-disaster stage. Increasingly, these programs demonstrate private sector commitment to areas such as risk transfer to reduce the vulnerability of communities. The present discussion reveals that CSR is no longer a one-off intervention but an agent of change and development (Kanji and Agrawal, 2020) in DRM. It encourages management of risk that can be done more efficiently with minimization of the negative impact of economic downpour on the environment and its resources. It brings forward the capabilities of the private sector to efficiently help strengthen the Public Private Partnerships (PPPs) by motivating itself to contribute on priority in DRM at various verticals of government programs by working upon 4 C's i.e. coordination, consultation, co-investing, and collaboration. Recommendations provided in the present context can raise the importance of integrating DRM as a strategic CSR activity for building a resilient society using PPPs as a tool that can act as a primary base for further studies to analyze the private sector's initiatives in DRM.

Funding: This research was funded by the Department of Science and Technology, GoI.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Anand, M. N., & Choubey, D. S. (2018). Role of corporate social responsibility in disaster risk management – India's perspective. International Journal of Research, 5, 1074-1086.
2. Aleksandrina, M., Budiarti, D., Yu, Z., Pasha, F., & Shaw, R. (2019). Governmental Incentivization for SMEs' Engagement in Disaster Resilience in Southeast Asia. International Journal of Disaster Risk Management, 1(1), 32-50.
3. Alliance for Disaster Resilient Societies (ARISE) India. (2023). ARISE regional network. Retrieved February 1, 2023, from https://www.ariseglobalnetwork.org/join/network/arise-india
4. ARISE. (2024). ARISE Annual Report. Retrieved October 27, 2024, from https://www.ariseglobalnetwork.org/media/100875/download?startDownload=20241102
5. Asian Development Bank (ADB). (2024). Disaster Risk Management Action Plan (DRMAP), 2024–2030: Redoubling Action Toward Disaster Resilience [Report]. https://www.preventionweb.net/media/102149/download?startDownload=20241101
6. Port, K. J. N., & Jawahar, G. (2024). Management of COVID: The Creeping Disaster in the Indian Scenario. International Journal of Disaster Risk Management, 6(1), 103–110.
7. Bassey, C. (2016, June 30). Private Sector Engagement in Disaster Response: Opportunity and Lessons. Middle East Institute. https://www.mei.edu/publications/private-sector-engagement-disaster-response-opportunity-and-lessons
8. Bhatt, M. R. (2018). Investing in disaster risk reduction: Corporate social responsibility initiatives in India. Southasiadisasters.net, 176, 1-12.
9. Chadda, V. M., & Kundal, N. S. (2022). Corporate sector and disaster risk management: A critical analysis with reference to corporate social responsibility in India. In Challenges of Disasters in Asia: Vulnerability, Adaptation and Resilience (pp. 437-450). Springer.
10. Chatterjee, R., & Shaw, R. (2015). Public-private partnership: Emerging role of the private sector in strengthening India's disaster resilience. In Disaster Management and Private Sectors (pp. 187-212). Springer.
11. CII-Foundation. (2024). Annual Report. https://ciifoundation.in/assets/img/A-report/24/CII-Foundation-Annual-Report-2024.pdf
12. Coalition for Disaster Resilient Infrastructure (CDRI). (2022). About CDRI. Retrieved February 1, 2023, from https://www.wto.org/english/tratop_e/envir_e/session_12_final_draft_cdri_presentation_wto_ce_week.pdf

13. Confederation of Indian Industry (CII). (2023). Disaster Management. Retrieved February 1, 2023, from https://www.cii.in/sectors.aspx?enc=prvePUj2bdMtgTmvPwvisYH+5EnGjyGX-O9hLECvTuNsAsLi8AXCEZ1JIiB0wtPeN
14. Dave, R. K. (2023). A concept paper on corporate social responsibility (CSR) in disaster risk reduction (DRR). CSR world. Retrieved February 1, 2023, from http://www.csrworld.net/A-concept-Paper-on-CSR-in-Disaster-Risk-Reduction-by-Dr-R-K-Dave.asp
15. Eyerkaufer, M. L., Lima, F. S., & Gonçalves, M. B. (2016). Public and private partnership in disaster risk management. Jamba (Potchefstroom, South Africa), 8(1), 277. https://doi.org/10.4102/jamba.v8i1.277
16. Federal Emergency Management Agency (FEMA), USA. (2021). New FEMA guide helps build private-public partnerships. https://www.fema.gov/blog/new-fema-guide-helps-build-private-public-partnerships
17. Fleming, K., Abad, J., Booth, L., Schueller, L., Baills, A., Scolobig, A., Petrovic, B., Zuccaro, G., & Leone, M. F. (2020). The use of serious games in engaging stakeholders for disaster risk reduction, management, and climate change adaptation information elicitation. International Journal of Disaster Risk Reduction, 49, 101669. https://doi.org/10.1016/j.ijdrr.2020.101669
18. Gharaee, H., Dewey, R. S., Gholami, A. H., & Azami-Aghdashd, S. (2023). Developing a public-private partnership framework for managing the adverse health effects of environmental disaster (A case study of Lake Urmia – Iran). Journal of Water and Health, 21(2), 251. https://doi.org/10.2166/wh.2023.239
19. Healthcare Federation of India (NATHEALTH). (2023). Annual Report. Retrieved October 27, 2024, from https://nathealthindia.org/wp-content/uploads/2023/03/Mar-2023-NATHEALTH-Annual-Report.pdf
20. Hodgson, S. (2024). Weather, law, and public-private engagement [Report]. Washington, DC: World Bank.
21. India Brand Equity Foundation (IBEF). Authorities and associations. Retrieved October 27, 2024, from https://www.ibef.org/economy/directory/regulatory-authorities-associations-and-councils
22. Indian Disaster Resource Network (IDRN). Builder Association of India. Retrieved October 19, 2024, from https://nidm.gov.in/pdf/iec/IDRN.pdf
23. Indian Venture and Alternate Capital Association (IVCA). Retrieved October 27, 2024, from https://www.ivca.in/
24. Indian Ocean Rim Association (IORA). Disaster risk management. Retrieved October 19, 2024, from https://www.iora.int/disaster-risk-management
25. Issar, R., Mathur, N. B., Padmanabhan, G., & Karanth, A. (2005). Disaster risk management and the role of corporate sector: The Indian perspective. Ministry of Home Affairs, Government of India & Confederation of Indian Industry [Report]. https://ndmindia.mha.gov.in/images/public-awareness/DRM%20&%20The%20role%20of%20Corporate%20Sector.pdf
26. Izumi, T., & Shaw, R. (2015). Disaster management and private sectors: Challenges and potentials. In Disaster Risk Reduction: Methods, Approaches and Practices. Springer.
27. Kanji, R., & Agrawal, R. (2020). Exploring the use of corporate social responsibility in building disaster resilience through sustainable development in India: An interpretive structural modelling approach. Progress in Disaster Science, 6, 100089.
28. Majumdar, R. (2023). India economic outlook, January 2023. Deloitte Global Economist Network. Retrieved February 1, 2023, from https://www2.deloitte.com/us/en/insights/economy/asia-pacific/india-economic-outlook.html
29. Marcelo Gordillo, D., Raina, A., & Rawat, S. (2020). Private sector participation in disaster recovery and mitigation [Report]. World Bank. http://documents.worldbank.org/curated/en/589341609771914404/Private-Sector-Participation-in-Disaster-Recovery-and-Mitigation
30. Mercy Corps and R3ADY Asia-Pacific. (2024). Optimizing private sector engagement in disaster risk reduction in Indonesia [Report]. https://seepnetwork.org/files/galleries/1686_READY-Executive-Summary-Report-FINAL_MC_Indonesia_6-May-2015.pdf

31. Ministry of Corporate Affairs (MCA), Government of India (GoI). (2017). Disaster management plan 2017 [Guidelines]. https://www.mca.gov.in/Ministry/pdf/DisasterManagementPlanMCA.pdf
32. Ministry of Home Affairs (MHA), Government of India (GoI). (2022a). International cooperation in disaster management [R.S.US. Q. NO. 3900 FOR 06.04.2022]. https://www.mha.gov.in/MHA1/Par2017/pdfs/par2022-pdfs/RS06042022/3900.pdf
33. Ministry of Home Affairs (MHA), Government of India (GoI). (2022b). National Policy on Disaster Management (NPDM) - 2022 [Policy Draft]. https://www.mha.gov.in/sites/default/files/2022-08/NPDM-101209%5B1%5D.pdf
34. Mojtahedi, M., & Lan Oo, B. (2017). Critical attributes for proactive engagement of stakeholders in disaster risk management. International Journal of Disaster Risk Reduction, 21, 35-43. https://doi.org/10.1016/j.ijdrr.2016.10.017
35. National Platform for Disaster Risk Reduction (NPDRR). (2023). Third session of the National Platform for Disaster Risk Reduction. Retrieved October 19, 2024, from https://npdrr.nidm.gov.in/pdf/NPDRR_concept_note.pdf
36. National Institute of Disaster Management (NIDM). (2021). Annual report (2020-2021). https://nidm.gov.in/PDF/pubs/AR2021.pdf
37. National Institute of Disaster Management (NIDM). (2024). National Disaster Risk Reduction (DRR) Research Facility. Retrieved October 19, 2024, from https://iuin-drr.nidm.gov.in/Activities/Research
38. National Disaster Management Authority (NDMA). (2023). Annual report (2021-2022). https://ndma.gov.in/sites/default/files/PDF/Reports/NDMA_Annual_Report_2021-22.pdf
39. Organization for Economic Cooperation and Development (OECD). (2024). Global good practices for infrastructure resilience to natural disasters. In Compendium of Good Practices on Quality Infrastructure 2024. https://www.oecd-ilibrary.org/docserver/213a4274-en.pdf?expires=1730654707&id=id&accname=guest&checksum=D7FBFF0D6F09E43F0850C9420978B361
40. PHD Chambers of Commerce and Industry (PHDCCI). (n.d.). PHD rural development foundation. Retrieved February 1, 2023, from https://www.phdcci.in/about-us/phd-rural-development-foundation/
41. PHD Chambers of Commerce and Industry (PHDCCI). (n.d.). Centre for Sustainability. Retrieved October 19, 2024, from https://phdcci-centreforsustainability.com/
42. Sattar, M. A. (2017). Corporate social responsibility in disaster risk management: A study on some selected private commercial banks of Bangladesh. International Journal of Environment, Ecology, Family and Urban Studies, 7(5), 7-18.
43. SatCom Industry Association (SIA-India). (n.d.). Assessing India's space and defence preparedness. Retrieved October 27, 2024, from https://www.sia-india.com/wp-content/uploads/2024/07/IndSpace-War-Game-2024.pdf
44. Shah, A. J. (2011). An overview of disaster management in India. WIT Transactions on The Built Environment, 119, 73-83. https://doi.org/10.2495/DMAN110081
45. Torayashiki, T., & Watanabe, K. (2024). Factors contributing to the enhancement of feasibility in public–private partnership during disasters. Journal of Disaster Research, 19(3), 570-579.
46. Twigg, J. (2001). Corporate social responsibility and disaster reduction: A global overview. Benfield Greig Hazard Research Centre, University College London.
47. United Nations International Children's Emergency Fund (UNICEF). (n.d.). Disaster risk reduction. Retrieved October 19, 2024, from https://www.unicef.org/india/what-we-do/disaster-risk-reduction
48. United Nations Development Program (UNDP). (2024). Strengthening disaster risk management capacities in Albania: Stakeholder analysis [Report]. https://www.undp.org/albania/publications/strengthening-disaster-risk-management-capacities-albania-stakeholder-analysis
49. United Nations International Strategy for Disaster Reduction (UNISDR). (2015). Disaster risk reduction private sector partnership: Post-2015 framework-private sector blueprint five private

sector visions for a resilient future [Report]. https://www.unisdr.org/files/42926_090315wcdrrpspepublicationfinalonli.pdf

50. United Nations Office for Disaster Risk Reduction (UNDRR). (2015a). Sendai framework for disaster risk reduction 2015 – 2030 [Report]. https://www.undrr.org/media/16176/download?startDownload=20241101
51. United Nations Office for Disaster Risk Reduction (UNDRR). (2015b). ARISE value proposition [Report]. https://www.ariseglobalnetwork.org/sites/default/files/2020-12/arise-value-proposition.pdf
52. United Nations Office for Disaster Risk Reduction (UNDRR). (2020). ARISE India members are helping India and the world overcome COVID-19 [Report]. https://www.undrr.org/news/arise-india-members-are-helping-india-and-world-overcome-covid-19
53. United Nations Office for Disaster Risk Reduction (UNDRR). (2022). Global assessment report on disaster risk reduction 2022: Our world at risk: Transforming governance for a resilient future. https://www.undrr.org/gar/gar2022-our-world-risk-gar#container-downloads
54. United Nations Office for Disaster Risk Reduction (UNDRR). (2023). Annual report. https://www.undrr.org/media/47138/download?startDownload=20241101
55. United Nations Office for Disaster Risk Reduction (UNDRR). (2024). Global assessment report on disaster risk reduction 2024: Forensic insights for future resilience learning from past disasters [Report]. https://www.undrr.org/media/100220/download?startDownload=20241101
56. World Bank. (2011). Disaster risk management: Building a safe and resilient future for all [Report]. https://www.gfdrr.org/sites/default/files/publication/WorldBank_DRM_Brochure_Jan2012.pdf
57. World Bank. (2015). 5th disaster risk management seminar: "The role of the private sector in building resilience to disasters." Retrieved October 19, 2024, from https://www.worldbank.org/en/events/2015/01/13/the-role-of-the-private-sector-in-building-resilience-to-disasters
58. World Bank. (2019). Technical brief on resilient infrastructure PPPs – Contracts and procurement. https://documents1.worldbank.org/curated/en/925691571416771609/pdf/Technical-Brief-on-Resilient-Infrastructure-Public-Private-Partnerships-Policy-Contracting-and-Finance.pdf
59. Cvetković, V., & Janković, B. (2020). Private security preparedness for disasters caused by natural and anthropogenic hazards. International Journal of Disaster Risk Management, 2(1), 23-33.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research Article

Implementation of Disaster Risk Reduction and Management

Henderson K. Balanggoy[1]*

[1] Benguet State University, College of Nursing, La Trinidad Benguet, Philippines 2601.

* Correspondence: balanggoyhenderson@gmail.com : +639270766099

Received: 1 October 2024; Revised: 5 December 2024; Accepted 15 October; Published: 25 December

Abstract

The high mortality rates resulting from the disaster have led to significant losses. This study is of utmost importance as it aims to evaluate the implementation of the four thematic areas of disaster risk reduction and management (DRRM) in the Secondary Public Schools located in the Province of Benguet Philippines. The study also aims to identify the variations in implementing DRRM across the participating schools and the challenges and training needs related to DRRM. While the findings indicate a high level of implementation for disaster prevention and mitigation, preparedness, recovery, and rehabilitation, disaster response needs improvement in the implementation. DRRM raises various concerns among institutions, such as lack of budget, multiple tasks assigned to the school DRRM coordinator, and insufficient parental support. However, with the right interventions, these challenges can be overcome. Moreover, public school educators must receive training in the field of DRRM, such as basic life support training, first aid training, contingency training, and incident command systems, which presents an opportunity for improvement. As a result, a lack of resources, emergency supplies, communication systems, and effective response mechanisms will not be delivered, and this can turn out to be disastrous to the learners and the teachers. With this, collaboration needs to be established with other government agencies and the private sector.

Keywords

DRRM, Philippine Disaster Risk Reduction and Management, Implementation of DRRM, four thematic Areas of DRRM, Challenges in the Implementation of DRRM

1. Introduction

Dealing with resiliency towards disaster is a major concern involving education. With a huge fallback when a community is devastated by natural or human-induced hazards, class disruption and the quality of education will not be delivered. Numerous reasons aggravate the worsening of a disaster, leading to a greater impact that affects society. Save the Children (2016) asserts that disasters influence children, adolescents, and educational institutions annually. The right to a high-quality education is a fundamental entitlement for every child. However, the impact of calamities has resulted in many children in the region being unable to exercise this right. The exacerbation of educational inequities can occur due to various reasons, such as inadequate site selection, architecture, or

development resulting in damage or destruction of schools, the utilization of schools as evacuation centres, and insufficient backing of disaster risk reduction (DRR) policies by the authorities and the public at large. Additionally, if education is encouraged before, during, and following calamities, lives can be saved, children can be protected, and entire communities and nations can benefit. Schools can thereby increase the effectiveness of humanitarian efforts, lessen vulnerabilities, and enhance risk mitigation for potential risks.

Consequently, the incorporation of Disaster Risk Reduction and Management into the educational curriculum has been mandated to ensure the safety of students and equip them with knowledge of disaster management. This measure has been implemented in basic education institutions. DepEd Order 83, S. 2011, and DepEd Order 21, S. 2015 pertain to implementing disaster preparedness measures, disaster risk reduction, management coordination, and information management protocols in schools.

All agencies should discuss and execute disaster Risk Reduction and Management from the highest levels of government to the grassroots level and from preschool to the tertiary level. The students need to comprehend Disaster Risk Reduction and Management from its basics to its complexity. However, more is required to let them understand its concept; it is important to show them its application in the daily operation of an institution so that they can better incorporate the theory and application. Meanwhile, it has been observed during past calamities that when classes are suspended due to tropical cyclones or any adverse potential hazards, many of the students do not heed the warnings seriously; instead, they tend to take their time roaming around for various reasons, whether for pleasure, livelihood, or to take videos for social media, which puts their lives at risk. In addition, during multiple trainings conducted, it was noticeable that many students needed more knowledge of DRRM, particularly its policies. Some have minimal knowledge, while others are unaware of the consequences. Also, only a few know what to do before, during, and after disasters. Moreover, some students claim that they have yet to encounter DRRM as a subject or a topic during their junior and senior high school years, which makes them prone to different hazards.

1.1 Review of Literature

The comprehensive execution of Disaster Risk Reduction and Management (DRRM) across various national agencies and local government units is not just a complex undertaking but a crucial one. In different training sessions and during deployment in the different parts of the Cordillera, it is observed that many stakeholders need more knowledge of DRRM, particularly its policies and other legal bases. Some have minimal knowledge, while others are unaware of this system, highlighting the urgent need for its understanding and implementation.

The Philippines is vulnerable to multiple hazards due to its geographic location. According to Bollettino et al. (2018), the Philippines is prone to natural calamities such as earthquakes, volcanoes, floods, landslides, drought, and the transmission of illnesses like malaria and dengue. This vulnerability is due to its geographical location, where there are two major tectonic plates and it is also located in the Pacific where typhoons frequently develop. The area where these typhoons form is known as the 'typhoon belt '. In addition, the country is surrounded by active volcanoes, a region known as the 'Ring of Fire ', and is situated in the Pacific typhoon belt, rendering 60% of its total land area susceptible to natural hazards. In addition, Mina (2021) also mentions that the World Risk Index states that 74% of the country's population is affected by these calamities.

In retrospect of the history of Disaster Risk Reduction and Management (DRRM) in the Philippines, the National Disaster Coordination Council (NDCC) was established based on Presidential Decree 1566, which is also referred to as Strengthening the Philippine Disaster Control, Capability, and Establishment of the National Program on Community Disaster Preparedness. After 36 years, PD 1566 was enacted, and the country encountered numerous devastating calamities. It may be a natural hazard, a human-induced hazard, or a combination. It has been observed that during this time, disaster management concentrated on disaster relief and response, which needed to be more dressed and delivered better disaster management.

Meanwhile, the cascading of the DRRM program from the national government to the grassroots community is somewhat straggling. According to Agub (2017), Line agencies and LGUs need more resources to implement the mandates that the DRRM law requires the office to perform. Another commonly cited issue in disaster management is the need for national and local governments to carry out their duties concerning DRRM effectively. Several factors contribute to the issue, including a shortage of personnel, insufficient technical proficiency, insufficient financial funding, and technological capabilities such as multiple-hazard early warning devices.

With that, The Department of Education (DepEd) has taken a proactive step by releasing a set of regulations dubbed the Basic Education Framework for Disaster Risk Reduction and Management (DO 37, s. 2015). It is a significant move to strengthen the implementation of DRRM in the educational sectors and set a pattern to expand its efforts in schools and offices. In addition, this will also guarantee that education will continue, even during and after catastrophic events or emergencies, and that the level of quality will not be affected. Furthermore, the Disaster Risk Reduction and Management School Manual Book 1 from the Department of Education was used in this study. This comprehensive manual, formulated by the Department of Education, serves as a template for the localization, conceptualization, and adaptation of DRRM to the sub-national context. The components of this manual include the background and rationale, the basic framework of DRRM in basic education, and the three (3) Pillars of the Comprehensive Approach to Basic Education. It helps explore the scope of DRRM implementation and integration in schools, covering all three (3) pillars as a guide to its application. Safe Learning Environments, School Disaster and Risk Reduction, and Building Educational Resilience. The Department of Education (DepEd) issued a guideline entitled "Comprehensive Disaster Risk Reduction and Management (DRRM) in the Basic Education Framework" to steer the disaster risk reduction and management efforts in the basic education sector towards resilience-building in schools and offices.

2. Methods

This study utilized descriptive quantitative research to determine the Implementation of Disaster Risk Reduction and Management in Basic Education in the Province of Benguet. Descriptive research is a study that systematically describes the participants accurately. A survey-based design was used to produce the needed data.

The study was conducted at the Province of Benguet's secondary public schools, main and extension. The participants were from eighteen (18) different schools. The questionnaire, a key tool in this study, was meticulously developed by the research team and underwent a rigorous evaluation process to ensure its quality. Using Cronbach's Alpha to measure its internal consistency, the evaluation yielded a result of 0.926, interpreted as excellent.

The researcher rigorously adhered to ethical protocols while administering the questionnaire, ensuring the study's integrity. These protocols included obtaining informed consent from the participants, ensuring their anonymity and confidentiality, and respecting their right to withdraw from the study at any time. The researcher sought authorization from the superintendent of the Benguet school division to carry out the study and administer the questionnaire to the secondary public schools. Next, the researcher sought permission from the school principal to distribute the survey questionnaires to the designated school coordinators for DRRM. The study's analytical approach was robust, using descriptive statistics. Frequency count and to answer the extent of the implementation of DRRM, the four thematic weighted means were used as the statistical tool. The Kruskal-Wallis Test, a non-parametric test used to compare more than two independent groups when the dependent variable is ordinal, was utilized to determine if there was a significant difference in the implementation of DRRM regarding the municipal classification where the school is located.

3. Results

3.1 The extent of implementation of Disaster Risk Reduction and Management

Disaster Risk Reduction and Management reduces natural and man-made disaster risks. It includes identifying risks, preparing, responding, recovering, and reducing them. DRRM implementation varies widely by country and region. It is due to governance, economic capacity, public awareness, and local hazards. Some places have solid frameworks and policies thanks to technology and community involvement. DRRM is less effective in areas with insufficient money, infrastructure, and public education.

Table 1: Extent Implementation of Disaster Risk Reduction and Management

	Mean	Description
Disaster Prevention and Mitigation	3.28	Highly Implemented
Disaster Preparedness	3.36	Highly Implemented
Disaster Response	3.20	Moderately Implemented
Disaster Recovery and Rehabilitation	3.33	Highly Implemented
Extent Implementation of DRRM	3.29	Highly Implemented

Table 1 shows the extent of implementation of the four (4) themes of DRRM by the three (3) clustered schools that are highly implemented, with a mean score of 3.29; this shows that the public secondary schools in Benguet have proactive plans and activities to alleviate these threats toward the learners and the employees. It also implied that the institutions are doing their best to assure the public schools that they will actively implement DRRM in their respective schools. To emphasize the implementation of DRRM in schools, the Department of Education Regional Office requires the regional division offices to submit DRRM reports for project implementation review and review of the DRR policies and standards. The firsttwo themes, disaster preparedness, disaster prevention and mitigation, and Disaster recovery and rehabilitation have the highest mean scores of 3.36, 3.28, and 3.33, respectively, interpreted as highly implemented. This means that this institution is putting more effort into controlling, minimizing, and preparing when calamities strike.

3.2 Extent of Implementation on Disaster Prevention and Mitigation

Disaster prevention and mitigation emphasizes a strong domain to reduce or eliminate the impact of disaster. This implementation varies greatly depending on regional vulnerabilities, governance frameworks, and resource availability.

Table 2: Extent of Implementation on Disaster Prevention and Mitigation

	Mean	Description
Retrofitting of Infrastructures	2.83	Moderately Implemented
Approved localize policies on Disaster Risk Reduction and Management Implementation	3.22	Moderately Implemented
Implementation of Disaster Risk Reduction and Management in line with Climate change Adaptation and Mitigation	3.50	Highly Implemented
Established Early Warning System	3.56	Highly Implemented
Disaster Prevention and Mitigation	3.28	Highly Implemented

It can be seen from Table 2 that both prevention and mitigation are being put into practice. An early warning system can be established by the institutions, which receives a score of 3.56; the implementation of Disaster Risk Reduction and Management following climate change adaptation and mitigation receives a score of 3.50, which is the second highest score. A similar result in the study of Domingo and Ormilla (2022) is that early warning systems are in place in the institutions. On the other hand, with a score of 3.22 and 2.83, respectively, approved localized policies on disaster risk reduction and management implementation and retrofitting of facilities are moderately implemented. This contrasts with the situation where the policies are not implemented at all.

3.3 Extent of Implementation of Disaster Preparedness

A community equipped for disaster preparedness is resilient, as its members know appropriate actions during crises. Understanding how to respond enhances the likelihood of survival.

The table shows the extent of implementing Disaster Preparedness, which has a score of 3.36, interpreted as highly implemented. Of the 15 activities on disaster preparedness, 10 of which are highly implemented rank from highest to lowest and as follows: Conducts quarterly drills alongside students and Identification of evacuation areas with a score of 3.83, DRRM is incorporated in the school curriculum with a score of 3.78, Revisiting the DRRM plan annually with a score of 3.56, Strengthening of partnership to external stakeholders, Posting visible signages or markings indicating warning signs on buildings, playgrounds, and pathways and Appropriate signages are visible to all faculty, staff, students, and visitors to follow with a mean score of 3.39, School Disaster Risk mapping and upgraded on monthly or annual bases and Formulation of the disaster-controlled group with a mean score of 3.33 and the last activity Purchases of disaster equipment and first aid kits with a mean score of 3.28.

On the other hand, five of these are moderately implemented. Rank for highest to lowest, having backup or duplicate school records, and The school has identified temporary learning space and alternative mode of delivering education with a mean score of 3.17; trainings and seminars conducted to increase the level of awareness with a mean score of 3.06, Testing the plans or table tap exercises after crafting with a mean score of 3.00, and the lastly School Disaster Risk Reduction and Management quarterly meeting with a mean score of 2.83.

Table 3: Extent Implementation of Disaster Preparedness

Questions	Mean	DE
School Disaster Risk mapping and upgraded on a monthly or annual basis	3.33	Highly Implemented
Identification of evacuation area	3.83	Highly Implemented
Formulation of disaster-controlled group	3.33	Highly Implemented
Revisiting the DRRM plan annually	3.56	Highly Implemented
Posting visible signages or markings indicating warning signs on buildings, playgrounds, and pathways	3.39	Highly Implemented
School Disaster Risk Reduction and Management quarterly meeting	2.83	Moderately Implemented
Training and seminars conducted to increase the level of awareness	3.06	Moderately Implemented
Strengthening of partnerships with external stakeholders	3.39	Highly Implemented
Testing the plans or table tap exercises after crafting	3.00	Moderately Implemented
Conducts quarterly drills alongside students	3.83	Highly Implemented
DRRM is incorporated into the school curriculum	3.78	Highly Implemented
Purchases of disaster equipment and first aid kits	3.28	Highly Implemented

Having backup or duplicate school records	3.17	Moderately Implemented
Appropriate signage are visible to all faculty, staff, students, and visitors to follow	3.39	Highly Implemented
The school has identified temporary learning space and alternative modes of delivering education	3.17	Moderately Implemented
Disaster Preparedness	3.36	Highly Implemented

3.4 Extent of Implementation of Disaster Response

A disaster response effort is a quick set of actions taken after a disaster to lessen its effects on people, their property, and their ability to provide for their fundamental needs. The level of disaster response strategy varies by region and is influenced by things like infrastructure, government, and how ready the community is, among other things. For disaster response to work well, many groups must work together. These groups should include government agencies, local communities, and non-governmental organizations (NGOs).

Table 4 shows that the extent of implementation of disaster response has a mean score of 3.20, interpreted as moderately implemented. The three activities identified are systematic coordination with parents or guardians during a disaster, the composition of rapid damage and the need analysis team, and systematic response mechanisms in a controlled group. All are moderately implemented, with a mean score of 3.28, 3.22, and 3.11, respectively.

Table 4: Extent of Implementation on Disaster Response

Questions	Mean	DE
Composition of Rapid Damage and need analysis team	3.22	Moderately Implemented
Systematic response mechanism on Disaster Controlled Group	3.11	Moderately Implemented
Systematic coordination to parents or guardians during disaster	3.28	Moderately Implemented
Disaster Response	3.20	Moderately Implemented

3.5 Extent of Implementation of Disaster Recovery and Rehabilitation

Disaster recovery and rehabilitation are critical stages in disaster management, addressing the restoration of properties, livelihood, and economy. The degree of implementation in this area fluctuates significantly and is affected by factors including community resilience.

The extent of disaster recovery and rehabilitation implementation is highly implemented, with a mean score of 3.33. With six activities identified, three activities are highly implemented and as follows Bayanihan program committed by the PTA, Repair of Structural Damages, and Conducting Post-disaster Needs Assessed and proper channelling of result with a mean score of 3.78, 3.61, and 3.39, respectively. On the other hand, three activities are moderately implemented. Post-disaster psychological and mental health programs are in place; alternative temporary classrooms are identified, and alternative livelihood programs are in place with a mean score of 3.22, 3. 17, and 2.83.

Table 5: Extent of Implementation on Disaster Recovery and Rehabilitation

Questions	Mean	DE
Conducting Post-disaster Needs Assessments and proper channeling of result	3.39	Highly Implemented
Identified alternative temporary classroom	3.17	Moderately Implemented

Post-disaster psychological and mental health programs in place	3.22	Moderately Implemented
Repair of Structural Damages	3.61	Highly Implemented
Bayanihan program committed by the PTA	3.78	Highly Implemented
An alternative livelihood program is in place	2.83	Moderately Implemented
Disaster Recovery and Rehabilitation	3.33	Highly Implemented

3.6 Implementation of DRRM According to the Municipality the Schools are located

Especially in areas prone to natural disasters, it is crucial for educational institutions to implement Disaster Risk Reduction and Management (DRRM) measures to safeguard both students and staff. The success of DRRM initiatives may vary greatly depending on factors such as the community's involvement, the local resources, the municipality where the schools are situated, and the degree to which the program is adopted.

Table 6: Implementation of DRRM According to the Municipality the Schools are located

Implementation of DRRM	Municipality	Mean	DE	Kruskal-Wallis Statistic	p-value	Pairwise
Disaster Prevention and Mitigation	Buguias	3.13	MI	3.404ns	0.182	-
	Bokod	3.00	MI			-
	La Trinidad	3.53	HI			-
Disaster Preparedness	Buguias	3.33	HI	0.093ns	0.955	-
	Bokod	3.35	HI			-
	La Trinidad	3.38	HI			-
Disaster Response	Buguias	3.17	MI	2.123ns	0.346	-
	Bokod	2.92	MI			-
	La Trinidad	3.37	HI			-
Disaster Recovery and Rehabilitation	Buguias	3.25	MI	1.726ns	0.422	-
	Bokod	3.17	MI			-
	La Trinidad	3.48	HI			-
Implementation of DRRM	Buguias	3.22	MI	2.010ns	0.366	-
	Bokod	3.11	MI			-
	La Trinidad	3.44	HI			-

Overall, schools located in Buguias score between 2.13 and 3.33 across four thematic areas of DRRM, indicating moderate to high implementation. Meanwhile, in Bokod, scores range from 2.92 to 3.35, suggesting a range from mild to high implementation. On the other hand, for schools in La Trinidad, Scores range from 3.37 to 3.53, indicating a higher implementation level than the different municipalities.

P-values of Disaster Prevention and Mitigation, Preparedness, Response, and Recovery and Rehabilitation with p-values of 0.182, 0.955, 0.346, and 0.422, respectively, are not statistically significant ($p > 0.05$). It suggests that the four thematic areas have no substantial differences in all municipalities. The result indicates that schools in La Trinidad have stronger implementation than those in Buguias and Bokod. On the other hand, there is no strong support suggesting that the statistic is substantial enough to prove that there is a significant difference in the implementation of DRRM

3.7 Training and Seminars needed to be conducted

The ability to prevent, mitigate, and recover from disasters depends on people's and organizations' capacity, which is a part of disaster risk reduction and management (DRRM). Strengthening communities, making responses more efficient, and encouraging a mindset of readiness that can all be achieved through organized training programs and seminars.

Table 7: Training and Seminars needed to be conducted

Training	**Frequency**	Percentage	Rank
Incident Command System	17	7.20%	1
First Aid Training	17	7.20%	1
Community First Responder	16	6.78%	6
Basic Life Support	17	7.20%	1
Search and Rescue	16	6.78%	6
Logistics Training	16	6.78%	6
Contingency Planning	17	7.20%	1
Climate Change Action Planning	16	6.78%	6
Mental Health and Psychosocial Support	16	6.78%	6
Livelihood Training	13	5.51%	14
Community-based Disaster Risk Reduction and Management	15	6.36%	12
Public Service Continuity Plan	13	5.51%	14
Rapid Damage and Needs Analysis	17	7.20%	1
Post Disaster and Needs Analysis	16	6.78%	6
Climate and Disaster Risk Assessment (CDRA)	14	5.93%	13

Table 7 shows that out of the 15 activities enumerated, 5 activities are more prioritized disaster management to increase their capabilities by the schools with 7.20%, which are First Aid Training, Basic

Life Support, Incident Command System, Contingency Planning, and Rapid Damage and Needs Analysis are the most frequent activities. While Livelihood Training, Public Service Continuity Plan, and Climate and Disaster Risk Assessment are activities that the schools seem not to prioritize, this does not indicate that they are not a crucial part of disaster management. To conclude, the data suggests that basic life-saving skills, coordination, and rapid assessment are consistently given priority, along with emergency response and preparation. Climate issues and mental health assistance are also receiving attention, but other areas like livelihood training and public service continuity planning are not as much given attention.

3.8 Encountered in implementing the four thematic areas of Disaster Risk Reduction and Management are discussed.

The ability to prevent, mitigate, and recover from disasters depends on people and organizations having the capacity to be a part of disaster risk reduction and management (DRRM). Conducting skill enhancement increases community resilience, strengthens response productivity, and promotes a proactive environment.

The primary challenges that the schools are encountering are insufficient budgets, which are the most challenging, and the next are the additional responsibilities of DRRM coordinators and the heavy workload of these coordinators. The lack of teacher training in DRRM and weak coordination with disaster management agencies. On the other hand, a strong and positive that can impact the result of their implementation is the strong support by The Local Government Unit of the SDRRM, the parent's support of the implementation of SDRRM, and The division office's full support with the SDRRM to provide training equipment and policy.

Table 8: Encountered in implementing the four thematic areas of Disaster Risk Reduction and Management are discussed.

Challenges	Frequency	Percentage	Rank
The school DRRM coordinator is well-trained	6	5.17%	8
Being a school DRRM coordinator is an additional function	16	13.79%	2
The Local Government Unit has a full support on the SDRRM	14	12.07%	6
The division office has a full support with the SDRRM to provide trainings equipment and policy	16	13.79%	2
The parents support the implementation of SDRRM	15	12.93%	4
The DRRM coordinator has a lot of tasks to do in addition to his/her regular load	15	12.93%	4
Not enough budget for the implementation of disaster risk reduction and management	17	14.66%	1
The faculty are not supportive on the programs	4	3.45%	10
The teacher does not have trainings in disaster risk reduction and management	7	6.03%	7
Weak coordination between schools and disaster management agency such as BDRRMC and MDRRMO	6	5.17%	8

4. Discussion

The implementation of the four themes of Disaster Risk Reduction and Management is to ensure the safety of every individual in the community. It envisions having a community that is Disaster resilient, stronger, and proactive in governance as it aims to shift from being reactive to a proactive community. The 2011–2028 NDRRM Framework contemplates having "safer, adaptive, and disaster-resilient Filipino communities toward sustainable development." With this vision, it is proper to check on implementing the four themes in the education sector, as it has a community where they belong to the vulnerable group. The prevention and mitigation show high implementation and compliance with DepEd Order No. 33 Series of 2021. It is worth noting that, compared with the study of Comighud (2020), the Benguet division shows a slight difference in terms of disaster Prevention and Mitigation. This difference underscores the importance of continuous improvement and adaptation in these measures. Furthermore, Baluran's (2023) research confirms that public schools in Cotabato demonstrate high disaster preparedness implementation. It indicates that most public schools in the Philippines strive to enhance their resilience to mitigate or avert the effects of disasters. Domingo and Ormilla (2022) found that one of the best practices observed was disseminating information on emergency protocols. Early warning systems are identified as one of the most in place in all schools as this is very important to track hazards so proactive measures can be considered. This knowledge was uncovered through their research.

The outcome indicates deficiencies within the system that necessitate attention during the execution of disaster response measures. It also suggests that training or retraining in particular skills needs to be organized. As shown in Table 4, basic life support and first aid training are some of the

skills required during response. It underscores the fact that not all personnel in the institutions are well-trained or have the corresponding skills related to DCG. In the study of Balanggoy, H. K. (2024), the capacity in terms of skills of the public secondary schools is not well established. Similar results were found in the study by Rico (2019), which found that educators have inadequate knowledge and skill in basic life support and search and rescue. With this, the respondents believe that training is the key to becoming more knowledgeable and skilled in areas that need improvement. According to Harward (2017), the best way to improve performance is to be trained and practice the desired skills. Still, the problem is that it is expensive, which goes back to the agency's fund, which is insufficient to support all the programs and activities of the schools. With this, improving the specific activity in all thematic areas will benefit the school and the community more.

Moreover, it is worth noting that the implementation of disaster preparedness is significantly higher in these clusters. In contrast, the La Trinidad cluster effectively incorporates all four thematic areas. Some possibilities can contribute to and affect the findings. First, as claimed by the respondents, budget allocation is one of the major challenges for schools in implementing programs related to DRRM, as reflected in Table 8. Secondly, according to Col (2007), as cited by Domingo et al. (2018), The local government plays a crucial role before, during, and after disasters. This role provides reassurance and confidence, as the LGU has direct authority over its constituents and is expected to understand their requirements. As mandated by the Local Government Code of 1991, the local government unit will supervise disaster risk reduction and management. The LGU must have the authority to act independently and make proactive decisions based on the circumstances of its constituents, with the backing of higher levels of government.

Furthermore, the potential risks are alarming because once a hazard strikes an area, like an earthquake or typhoon, it can easily collapse or be destroyed. According to the report of Nicholls (2022), the secretary of education announced that the Department's annual budget has little funding for infrastructure.

With this, the parents are actively helping restore the school after it was devastated because, in return, it will also help protect their children from getting injured or being harmed. The success of the Bayanihan program underscores the importance of community involvement in disaster recovery efforts, a fact that we should all appreciate and support. According to the study by Pfefferbaum et al. (2010), parents play an important role in protecting their children from possible exposure that can harm or cause accidents after a disaster. However, the research conducted by Escobar (2021) presents a contrasting perspective to the research findings. Escobar's study challenges the notion that the absence of support from learners' parents in implementing DRRM programs and activities is one of the top five challenges teachers face in Marikina City. Cultural differences may influence these factors that affect an individual's social responsibilities.

Furthermore, the problems the schools encountered were also confirmed by Escobar (2021) in Marikina, which needed clarification on the funding source and the unavailability of funds to implement activities related to DRRM, confirmed the result. It only implies that it's not just the Benguet division that experiences budget shortages to implement DRRM; it's the problem of the entire DepEd system. The study of Arierto, C. et al. (2023) shows that one of the school's common problems is a need for more budget.

5. Conclusion and Recommendation

With the limited funding in the education system, schools are still striving to create a safe and resilient community for learners. The personnel of the schools are doing their best to be more proactive in ensuring the implementation of DRRM. With the challenges encountered in disaster risk reduction and management, safety is still one of their priorities.

These recommendations, drawn from the study's findings, to significantly enhance our disaster risk reduction and management efforts. We urge you to continuously coordinate with the Municipal and Provincial Disaster Risk Reduction and Management (DRRM) Council, the Office of Civil Defense CAR, and other government agencies. By doing so, you can be one of the beneficiaries of their

capacity-building programs and provide technical assistance in formulating plans and implementing projects. I encourage you to explore collaborative alliances with private entities to secure financial support for training initiatives, projects, and various undertakings. Implementing an annual or biannual skills refresher course for teachers would involve the participation of the school nurse and physician. Partner with any nursing school to provide community services and disaster nursing to teach skills in basic life support, first aid training, and other health-related topics to the teachers and learners.

Funding: This research was funded by Benguet State University

Acknowledgements: To all participants and the funding agency thank you.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. AC Nicholls, (2022) DepEd chief tells teachers: Budget not enough to address school facility woes. Retrieved from http://www.cnnphilippines.com/news/2022/10/5/DepEd-budget-not-enough-school-facility-woes.html
2. Agub, S., (2017) Examining the Philippines' Disaster Risk Reduction and Management System Retrieved from https://legacy.senate.gov.ph/publications/sepo/pb_examining%20ph%20drrm%20system_revised_27june2017.pdf
3. Arierto., C., Monte, S. and Robas, J. 2023, Extent of Disaster Risk Reduction Management in Selected Elementary Schools: Evidence from the Philippines. Retrieved from https://iiari.org/journal_article/extent-of-disaster-risk-reduction-management-in-selected-elementary-schools-evidence-from-the-philippines/
4. Balanggoy, H. K. (2024). Capacity audit on disaster risk reduction and management in basic education. *Journal of Interdisciplinary Perspectives, 2(7)*, 368-374. https://doi.org/10.69569/jip.2024.0145
5. Baluran, A. G. S. (2023). The Level Of Disaster Risk Reduction And Management (Drrm) Program Implementation Among Public Elementary Schools: Basis For A Proposed 'Our School, Our Safe Zone' Program. *European Journal of Education Studies*, *10*(6). https://doi.org/10.46827/ejes.v10i6.4859
6. Bollettino, V., Alcayna, T., Enriquez, K., and Vinck, P., (2018), Retrieved April 5, 2022 from Perceptions of Disaster Resilience and Preparedness in the Philippines, Retrieve from https://hhi.harvard.edu/publications/perceptions-disaster-resilience-and-preparedness-philippines
7. Comighud S., (2020) Implementation of the Public Schools' Disaster Risk Reduction Management Program and Level of Capabilities to Respond. Retrieved from https://www.researchgate.net/publication/340630378_Implementation_of_the_Public_Schools'_Disaster_Risk_Reduction_Management_Program_and_Level_of_Capabilities_to_Respond
8. Cvetković, V. (2020). Disaster Risk Management. Belgrade: Scientific-Professional Society for Disaster Risk Management.
9. Department of Education, School Disaster Risk Reduction and Management Manual, Retrieved from http://depedbohol.org/v2/wp-content/uploads/2012/06/DRRM-Manual_Booklet-1_Final-1.pdf
10. Department of Education, School Disaster Risk Reduction and Management Manual. Retrieved from http://depedguihulngan.ph/index.php/2015-12-02-06-14-23/other-downloads/summary/20-other-downloads/652-school-drrm-manual-booklet-2
11. Department Order 33, s. 2021 (2021) school base disaster preparedness and response measures for tropical cyclones, flooding, and other related weather disturbances and calamites, Retrieved from https://www.deped.gov.ph/2021/08/24/august-20-2021-do-033-s-2021-school-based-disaster-preparedness-and-response-measures-for-tropical-cyclones-flooding-and-other-weather-related-disturbances-and-calamities/

12. Department Order 37, s. 2015., (2015), The Comprehensive Disaster Risk Reduction and Management (DRRM) in Basic Education Framework Retrieved from https://www.deped.gov.ph/2015/08/12/do-37-s-2015-the-comprehensive-disaster-risk-reduction-and-management-drrm-in-basic-education-framework/
13. Department Order 61, s. 1990., (1990), The Creation of Calamity and Disaster Control Groups Amended, Retrieved from from https://www.deped.gov.ph/1990/06/08/do-61-s-1990-the-creation-of calamity-and-disaster-control-groups-amended-by-do-14-s-1997 amending-and-reconstituting-the-calamity-disaster-and-fire-control-group-cdfcg/
14. Department Order 83, s. 2011., (2011), Disaster Preparedness Measures for Schools., Retrieved from https://www.deped.gov.ph/2011/10/28/do-83-s-2011-disaster-preparedness-measures-for-schools/
15. Department Order do 21, s. 2015, (2015), Disaster Risk Reduction and Management Coordination and Information Management Protocol, Retrieved from https://www.deped.gov.ph/2015/06/01/do-21-s-2015-disaster-risk-reduction-and-management-coordination-and-information-management-protocol/
16. DO_s2022_037 (2022) Guidelines on the Cancellation or Suspension of Classes and Work in Schools in the Event of Natural Disasters, Power Outages/Power Interruptions, and Other Calamities. Retrieved from https://www.deped.gov.ph/2022/09/01/september-1-2022-do-037-s-2022-guidelines-on-the-cancellation-or-suspension-of-classes-and-work-in-schools-in-the-event-of-natural-disasters-power-outages-power-interruptions-and-other/
17. Domingo Dela Cruz, R. ., & Ormilla, R. C. G. (2022). Disaster Risk Reduction Management Implementation in the Public Elementary Schools of the Department of Education, Philippines. *International Journal of Disaster Risk Management*, *4*(2), 1–15. https://doi.org/10.18485/ijdrm.2022.4.2.1
18. Domingo, S., and Manejar, 2018 A., Disaster Preparedness and Local Governance in the Philippines. Retrieved from https://pidswebs.pids.gov.ph/CDN/PUBLICATIONS/pidsdps1852.pdf
19. Doug Harward (2017) Practice Makes Perfect. Retrieved from https://trainingindustry.com/magazine/issue/practice-makes-perfect/
20. Elli, M., and Ricafort J. 2020 Competencies of Grade VI Teachers in Technology and Livelihood Education (TLE). Retrieved from https://files.eric.ed.gov/fulltext/ED607222.pdf
21. Escobar, M. (2021) Disaster Risk Reduction and Management Plan of Selected Public Schools in Marikina City. Retrieved from https://papers.ssrn.com/sol3/papers. cfm?abstract_id=3792508#:~:-text=The%20top%20five%20most%20prevalent,school%20buildings%20and%20infrastructures%3B%20c)
22. Gabriela Delgado (2023) Importance of Meetings in 2023, Are Meetings Really That Important? Retrieved from https://www.agreedo.com/importance-of-meetings/
23. Kirstie Chisholm 2020, Better safe than Sorry. Retrieved from https://www.scm-safety.com/better-safe-than-sorry/#:~:text=%E2%80%9CBetter%20 safe %20than%20sorry.,'More%E2%80%9D%20circa%20about%201837.
24. Memorandum Circular 25, 2014 Guidelines in the Conduct of Rapid Damage Assessment and Needs Analysis (RDANA) National Disaster Risk Reduction and Management
25. Mina, R., (2021)., Philippines looks to improve disaster preparedness with geospatial tech Retrieved from https://news.mongabay.com/ 2021/03/philippines-looks-to-improve-disaster-preparedness-with-geospatial-tech/
26. Mohamad, H. and Parcon, M. 2022 Unfolding Stories of English Teachers with Multiple Ancillary Functions in Maguindanao-1 Division: A Phenomenological Study. Retrieved from https://hal.science/hal-03752785/document
27. Pfefferbaum, B and North, C. 2010 Children and Families in The Context of Disasters: Implications For Preparedness And Response. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2898281/#:~:text=THE%20ROLE%20OF%20PARENTS%20IN,experience%20in%20anticipation%20of%20disasters.

28. Presidential Decree no 1566 s.,1978., (1978)., Strengthening the Philippine Disaster Control, Capability and Establishing the National Program on Community Disaster Preparedness. Retrieved from Https://www.officialgazette.gov.ph/1978/06/11/presidential-decree-no-1566-s-1978/
29. Republic Act no. 10121, (2010), An Act Strengthening the Philippine Disaster Risk Reduction and Management System, providing for the National Disaster Risk Reduction and Management Framework and Institutionalizing the National Disaster Risk Reduction and Management Plan, appropriating funds therefor and for other purposes. Retrieved from Https://www.officialgazette.gov.ph/2010/05/27/republic-act-no-10121/
30. Rico, G. C. S. (2019). School-Community Collaboration: Disaster Preparedness towards Building Resilient Communities. *International Journal of Disaster Risk Management*, *1*(2), 45–61. https://doi.org/10.18485/ijdrm.2019.1.2.4
31. Save the Children (2016), Disaster Impacts on Education in the Asia Pacific Region in 2015 Retrieved from https://resourcecentre.savethechildren.net/pdf/education_disrupted_save_the_children_full_report.pdf/

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research article

Role of Emerging Technology in Disaster Management in India: An Overview

Manindra Singh Hanspal[1]*, Bijayananda Behera[2]

[1] Post Graduate Department of Law, Sambalpur University, Jyoti Vihar, Burla, Sambalpur, Odisha, India, mhanspal21@gmail.com

[2] Lajpat Rai Law College, Constituent College of Sambalpur University, Sambalpur, Odisha, India.

* *Corresponding: mhanspal21@gmail.com*

Received: 5 July 2024; Revised: 10 October 2024; Accepted 24 October; Published: 25 December

Abstract

India's diversified topography and dense population present unique challenges for disaster management. Developing technologies for disaster management plans has the potential to improve reaction times and lessen the adverse effects of natural catastrophes. This paper meticulously examines the role of various technologies, including Artificial Intelligence (AI), Geographic Information Systems (GIS), mobile communication systems and drones, in fortifying disaster management efforts across India. Through a literature review and multiple case studies, including the 2018 Kerala floods, Cyclone Fani in 2019, and the COVID-19 pandemic response, this research demonstrates how AI-driven predictive models enabled early warning and resource optimization, GIS facilities precise hazard mapping and rapid damage assessment, and drones provided critical aerial data in inaccessible areas for relief efforts and rescue operations. This research underscores the potential of technology to enhance recovery operations management, accelerate disaster prediction, and enhance response times. However, we must acknowledge technical constraints, infrastructure shortcomings, and legislative barriers to achieve full-scale application. This article argues that regulatory changes, improved training initiatives, and expanded public-private partnerships are necessary to create more resilient disaster management systems. Subsequent investigations should concentrate on creating flexible and durable technology to tolerate the intricate disaster situations encountered in India. The present study highlights the pivotal function of technology in revolutionizing disaster management methodologies in India, promoting a proactive strategy for incorporating cutting-edge technological solutions.

Keywords

Disaster Management, Geographic Information Systems (GIS), Artificial Intelligence (AI), Technologies, India.

1. Introduction

India's unique geographic and climatic features make it particularly vulnerable to various natural calamities, such as cyclones, floods, earthquakes, and droughts. Recurring natural disasters

are a widespread phenomenon in India. The nation's vast coastline, the Himalayan region, and the extensive plains are prone to hydro-meteorological and geological hazards. According to the National Disaster Management Authority (NDMA), almost 40 million hectares are at risk of flooding, and around 59% of India's landmass is susceptible to earthquakes. An essential requirement for efficient disaster management is that 68% of the cultivated land is vulnerable to droughts (Shakeri, 2022). Droughts cause significant loss of life and property and impede socio-economic growth. Over the years, India's approach to disaster management has evolved significantly, transitioning from a reactive to a proactive and policy-driven framework.

India's disaster management paradigm changed due to the 2001 Gujarat Bhuj earthquake and the 2004 Indian Ocean tsunami. Implementation of the Disaster Management Act in 2005 represented a key achievement, creating a legislative structure for a holistic, prevention-mitigation-oriented strategy for disaster management. The Disaster Management Act 2005 establishes a three-tier framework, i.e., the National Disaster Management Authority (NDMA), State Disaster Management Authority (SDMA), and District Disaster Management Authority (DDMA), to coordinate and implement disaster management efforts at various levels. Under this Act, the **National Disaster Management Authority (NDMA)** was instituted as the central agency responsible for overseeing and coordinating disaster management initiatives, ensuring a consistent and cohesive approach across the country. India implemented the National Cyclone Risk Mitigation Project (NCRMP) to strengthen resilience further, targeting cyclone-prone coastal regions. This project, executed in partnership with state governments, aims to reduce the vulnerability of communities through improved early warning systems, disaster response infrastructure, and risk mitigation measures. The **Digital India initiative** has advanced the incorporation of digital and geospatial technologies in disaster management, facilitating real-time data analysis, rapid information dissemination, and improved coordination among agencies. Through Digital India, satellite-based insights from the **Indian Space Research Organisation (ISRO)** enhance disaster predictions and response strategies, further illustrating the government's commitment to a technologically informed disaster management framework. These developments underscore India's dedication to leveraging policy frameworks and technological advancements, laying the groundwork for integrating emerging technologies like Artificial Intelligence, Geographic Information Systems (GIS), and drones into the disaster management ecosystem. Despite these institutional advancements, the scale and frequency of disasters have necessitated incorporating innovative solutions to enhance preparedness, response, and recovery mechanisms. The following schematic representation best illustrates the structure of the Legal-Institutional Framework of the Disaster Management Act (2005) in India.

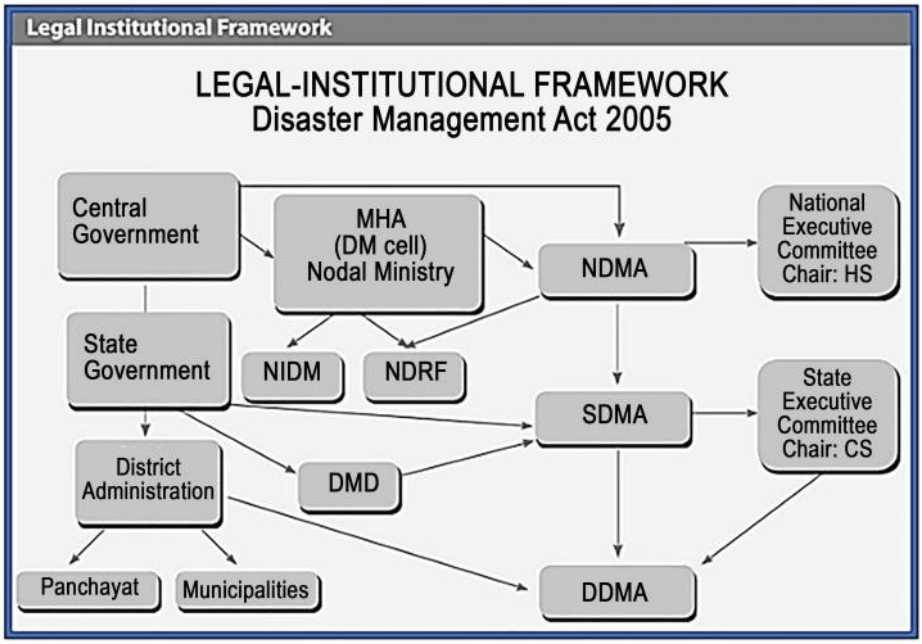


Figure 1. Legal-Institutional Framework of the Disaster Management Act (2005) in India
(Image source: https://compass.rauias.com/disaster-management/act-2005-2nd-arc-recommendations/)

In recent years, the role of emerging technology in disaster management has gained prominence, offering new avenues to tackle the challenges posed by natural and artificial disasters. Technological innovations such as Geographic Information Systems (GIS), Artificial Intelligence (AI), drones and remote sensing are transforming the landscape of disaster management by providing real-time data, enhancing predictive capabilities, and improving coordination among stakeholders. For instance, GIS and remote sensing technologies are instrumental in mapping hazard-prone areas, monitoring environmental changes, and assessing damage post-disaster. These tools enable authorities to prepare more accurate risk assessments and disaster preparedness plans (Tomaszewski, 2020). UAVs (Unmanned aerial vehicles) have emerged as a vital technology for disaster response, capable of conducting aerial surveys in inaccessible areas, delivering essential supplies, and assisting in search and rescue operations. During the 2018 Kerala floods, drones were crucial in locating stranded individuals and assessing the damage (Munawar, 2021). Artificial Intelligence (AI) and machine learning algorithms analyze vast amounts of data to predict disaster events and optimize response strategies. AI-driven models can predict the likelihood of disasters such as floods or cyclones with greater accuracy, thus providing timely warnings and enabling better preparedness (SP, 2024). Moreover, mobile technology and social media platforms have revolutionized communication during disasters, facilitating rapid dissemination of information, crowdsourced data collection, and real-time updates on the evolving situation.

India has been leveraging these emerging technologies to improve its disaster management framework. For example, the Indian Space Research Organisation (ISRO) has been at the forefront of using space-based technology for disaster management. ISRO's satellites provide critical data for early warning systems, disaster impact assessments, and recovery efforts. Integrating satellite data with GIS has enhanced the country's ability to manage disasters more effectively (Stout, 2024). Additionally, the government has initiated various programs to incorporate technology in disaster management. The National Cyclone Risk Mitigation Project (NCRMP) aims to reduce the vulnerability of coastal communities through improved early warning systems and strengthened disaster response infrastructure.

Further, the Digital India initiative seeks to harness digital technologies to enhance disaster resilience by improving information dissemination and coordination among agencies. The increasing adoption of these technologies underscores their potential to mitigate the impacts of disasters and improve resilience. However, to fully realize the benefits of technological interventions in disaster management, we must address challenges like the digital divide, lack of technical expertise, and robust policy frameworks.

2. Literature review

Research conducted worldwide has actively examined emerging technologies in disaster management, demonstrating their potential to boost disaster resilience. Studies have explored various technological interventions, such as Geographic Information Systems (GIS), remote sensing, drones, Artificial Intelligence (AI), and mobile technologies, which have proven effective in different phases of disaster management: preparedness, response, recovery, and mitigation. (Nouali-Taboudjemat, 2009), (Kaur, 2019) emphasizes the potential of information and communication technology (ICT) in enhancing crisis response and decision-making. The integration of Information and Communication Technologies (ICT) is pivotal, enabling a holistic Disaster Risk Management (DRM) framework that supports decision-making during crises (Bania, 2023). Blockchain technology is emerging as a robust solution for secure data transactions, ensuring the protection and anonymity of personal information during disaster scenarios (Hassan, 2019). Artificial Intelligence (AI) and Machine Learning (ML) are extensively applied to manage large datasets, identify critical features, and classify disaster-related data, significantly improving disaster management processes (Linardos, 2022). Geographic Information Systems (GIS) and remote sensing are pivotal in disaster management because they can map hazard-prone areas, monitor environmental changes, and assess damages post-disaster. GIS technology facilitates the visualization and analysis of spatial data, which is crucial for risk assessment and decision-making processes (Goodchild & Glennon, 2010). The utilization of geospatial

technologies, including Remote Sensing (RS) and Spatial Data Infrastructure (SDI), has enhanced data acquisition, analysis, and dissemination, facilitating effective disaster management across all phases (Ghosh, 2023). Similarly, remote sensing provides real-time data that enhances situational awareness during disasters, as evidenced by its use in monitoring wildfires, floods, and hurricanes (Joyce et al., 2009). Pre-disaster management leverages IoT, Big Data, and Machine Learning to enhance early warning systems and predictive analytics, helping to mitigate potential damages (Bouzeraa, 2022). Technologies such as robotics, drones, and mobile devices are crucial in all disaster management phases, aiding in prediction, real-time response, and post-disaster analysis (Bhandari, 2022). Mobile crowdsensing (MCS) through smart devices enables the collection of vast amounts of data, crucial for informed decision-making and efficient disaster management (Cicek, 2023). Drones have emerged as valuable tools in disaster response. They can reach inaccessible areas, conduct aerial surveys, and deliver essential supplies. A study highlighted the efficacy of drones in search and rescue operations, particularly in urban environments affected by earthquakes (Adams & Friedland, 2011). Drones equipped with thermal imaging cameras can locate survivors trapped under debris, expediting rescue efforts.

The concept of smart cities incorporates edge computing, IoT, and social media analytics to create emergency-aware systems, enhancing the ability to predict, detect, and manage disasters effectively (Aboualola, 2023). Lastly, aerial and networked technologies, such as drones and satellites, have reoriented disaster management towards a volumetric and planetary approach, impacting power dynamics between authorities and affected populations (Enns, 2022). This comprehensive integration of diverse technologies underscores the global effort to improve disaster management and mitigate the adverse effects of natural and human-induced disasters. Artificial Intelligence (AI) and machine learning have revolutionized predictive analytics in disaster management. AI models can more accurately predict the likelihood and impact of disasters, enabling better preparedness and early warning systems (Varsha, 2024). For instance, AI algorithms analyze vast datasets to forecast floods, cyclones, and landslides, allowing authorities to take pre-emptive measures (Wang & Srinivasan, 2017). Mobile technologies and social media platforms have also transformed disaster communication and information dissemination. Social media platforms like Twitter and Facebook provide real-time updates, crowdsourced information, and coordination among responders and affected communities (Houston et al., 2015). Mobile applications developed for disaster management offer features such as early warning alerts, emergency contact information, and resources for disaster preparedness (Tan, 2017).

The use of technology in disaster management in India has significantly evolved, leveraging advancements in Information and Communication Technologies (ICTs) to enhance the efficiency and effectiveness of disaster response and mitigation efforts. ICTs, including the Internet, Geographical Information Systems (GIS), Remote Sensing, and Satellite-based communication systems, play a crucial role in all stages of disaster management, from pre-disaster prevention and preparedness to post-disaster recovery and reconstruction (Mohan, 2020). Mishra et al. (2024) utilized geospatial tools to assess Cyclone Michaung's impact on Andhra and Tamil Nadu coastal zones, revealing substantial infrastructure, agricultural, and ecological damage. The study underscores the importance of vulnerability mapping for targeted disaster preparedness, though it recommends broader, long-term analyses to capture ongoing effects and socio-economic factors. Early warning systems have proven effective in large-scale evacuations, as evidenced by the successful evacuation of 1.2 million people during Cyclone FANI in Odisha in 2019 (Mohanty, 2022). Remote sensing and geospatial techniques are valuable for tracking and monitoring natural disasters like tropical cyclones, providing essential data for timely evacuations and risk assessments (Sharma, 2021). Social media platforms have emerged as vital tools for real-time information dissemination and public engagement, allowing the general public to report incidents and contribute to disaster monitoring, thereby enhancing the overall disaster management process (Ojha, 2022). Integrating robotics, drone technology, mobile phones, and artificial intelligence plays a crucial role in predicting upcoming disasters, facilitating rapid response efforts, and assessing damage in the aftermath of disasters (Abid, 2021). The Kerala floods of 2018 highlighted the importance of innovative rescue and rehabilitation models, showcasing the critical role of technology in managing large-scale disasters (Linardos, 2022). Despite these advancements, challenges remain, such as the need for more comprehensive and co-

ordinated efforts at the national and state levels to fully harness the potential of these technologies. While India faces significant disaster risks due to its geo-climatic conditions and socio-economic vulnerabilities, the strategic use of technology offers promising solutions to mitigate these risks and enhance disaster resilience.

The Indian Space Research Organisation (ISRO) has leveraged remote sensing for disaster management, providing critical data for early warning systems and damage assessments. Drones have also played a significant role in disaster response in India. In various disasters, drones were deployed for aerial surveys, helping to locate stranded individuals and assess the extent of the damage (Goyal, 2022). The operational efficiency of drones in disaster-hit areas emphasizes their ability to access remote and flooded regions that were otherwise inaccessible (Garg, 2022). Artificial intelligence (AI) is increasingly using in India for predictive disaster analytics. The AI models analyzed historical data, weather patterns, and topographical information to forecast flood-prone zones, thus aiding in disaster preparedness and resource allocation (Abid, 2021). Mobile technology and social media have revolutionized disaster communication in India as well. The Digital India initiative has seen the development of mobile applications that provide early warning alerts and resources for disaster preparedness (Ministry of Electronics and Information Technology, 2021). Social media platforms have been instrumental during disasters, enabling real-time information sharing and coordination among responders and the public. For instance, during the 2015 Chennai floods, social media was extensively used for rescue operations and relief coordination (Joseph, 2018). The existing body of research underscores the significant role of emerging technologies in disaster management globally and highlights their practical application in the Indian context. Integrating GIS, remote sensing, drones, AI, and mobile technologies has enhanced India's disaster preparedness, response, and recovery capabilities. However, challenges such as the digital divide, lack of technical expertise, and the need for robust policy frameworks remain, and stakeholders must address these to realize the full potential of these technologies.

3. Emerging technologies in disaster management

Integrating emerging technologies into disaster management practices offers substantial benefits regarding response time, risk assessment accuracy, and effective resource allocation.

3.1. The Role of Big Data in Disaster Management:

Big data plays an essential role in disaster management by allowing the collection, processing, and analysis of vast and diverse datasets, helping authorities make informed decisions during emergencies. By aggregating data from weather sensors, social media feeds, satellite images, and on-ground reports, big data analytics enables real-time monitoring of evolving disaster conditions, which is crucial for early warnings and rapid response efforts (Yin et al., 2012). For instance, predictive analytics can analyze weather patterns and historical data to forecast potential disasters, allowing communities to prepare in advance and authorities to allocate resources efficiently. A prominent example is the 2015 Chennai floods, where big data was instrumental in timely information dissemination and rescue coordination. Analysis of social media activity, combined with meteorological and geographic data, helped identify severely impacted areas, direct resources effectively, and communicate critical updates to the public (Dharmapuri, 2017). As big data technology advances, it promises to enhance disaster preparedness, response, and resilience by providing actionable insights that reduce risks and save lives.

3.2. Blockchain Technology in Disaster Management:

Blockchain technology is a secure, decentralized platform that enhances transparency and accountability in disaster management. It creates a tamper-proof ledger that records transactions, en-

suring all aid distribution activities are traceable and verifiable. It is crucial in disaster scenarios where efficient and fair allocation of resources can save lives (Kshetri, 2017). By preventing tampering, blockchain minimizes fraud, unauthorized fund diversion, and resource misallocation—challenges that often complicate relief efforts. A significant example of blockchain's impact on disaster management is the United Nations World Food Programme's (WFP) use of blockchain to improve food distribution in crisis zones. This initiative streamlined distribution, reducing the risk of fraud and enhancing operational efficiency while ensuring that aid reaches those in need accurately and transparently (Mattila, 2016). As blockchain technology evolves, it promises to further transform disaster relief by instilling trust and efficiency in aid operations, benefiting humanitarian agencies and disaster-prone communities.

3.3. GIS and Remote Sensing in Disaster Management:

Geographic Information Systems (GIS) and remote sensing are fundamental technologies in disaster management, providing detailed spatial and temporal data that aid in every disaster response phase. GIS facilitates the mapping and analysis of high-risk areas, allowing authorities to identify vulnerable zones, plan evacuation routes, and allocate resources efficiently. By overlaying data on topography, population density, and infrastructure, GIS enhances preparedness and risk assessment, making predicting potential disaster impacts easier and optimizing response strategies (Goodchild & Glennon, 2010). On the other hand, remote sensing uses satellite and aerial imagery to monitor disaster events, such as floods, cyclones, and wildfires. This technology captures critical information on environmental changes, the extent of damage, and areas requiring immediate attention. In India, GIS and remote sensing have been crucial in managing major disasters; for instance, they were instrumental in monitoring the impact and planning response efforts during the Kerala floods and Cyclone Fani (Goyal, 2024). Together, these tools allow for a faster, data-driven response, supporting recovery operations by assessing infrastructure damage and prioritizing reconstruction needs, ultimately enhancing resilience in disaster-prone regions.

3.4. The Role of Mobile Technology and Communication in Disaster Management:

Mobile technology is pivotal in disaster management by enabling quick and reliable communication between authorities, responders, and the public. During disasters, mobile networks and applications are instrumental in disseminating critical information, such as early warnings, evacuation instructions, and real-time updates, allowing people to make timely, life-saving decisions (Wang et al., 2020). Mobile devices with location-based services provide emergency managers valuable data on affected populations' whereabouts, helping effectively prioritize and target relief efforts. In India, mobile applications like the 'SACHET App' are designed to enhance disaster preparedness and response. The SACHET App, launched by the National Disaster Management Authority, delivers real-time alerts, safety guidelines, and emergency contact information to users, improving public awareness and readiness during emergencies (SACHET, 2021). Additionally, mobile platforms facilitate two-way communication, enabling affected individuals to report their status or seek assistance, enhancing response teams' situational awareness. These advancements underscore mobile technology's importance in making disaster response more efficient, coordinated, and responsive to the community's needs.

3.5. The Use of Drones and Robotics in Disaster Management:

Drones and robotics play a growing role in disaster management, helping teams conduct search and rescue operations, evaluate damage, and supply remote areas. Drones offer quick surveys of disaster-stricken areas and provide high-resolution images for assessing situations and planning relief efforts (Erdelj et al., 2017). Robotics can assist in hazardous environments, making search and

rescue missions safer and more efficient (Murphy, 2014). Drones, or Unmanned Aerial Vehicles (UAVs), operate without an onboard human pilot, typically controlled remotely or autonomously via pre-programmed routes. Equipped with cameras, sensors, and GPS technology, drones can capture high-resolution aerial images, relay real-time data, and access areas that may be dangerous or difficult for human responders. In disaster management, drones play a crucial role by providing rapid aerial assessments of disaster-stricken areas, which is invaluable for identifying damage, locating stranded individuals, and coordinating relief efforts (Papyan et al., 2024). Their ability to reach isolated regions quickly allows authorities to assess the scale of a disaster within hours, enabling faster decision-making and resource allocation. Additionally, robotics—including ground-based robots—are used in search and rescue missions to access hazardous environments, such as collapsed buildings or flooded areas, where human entry may be too risky. These robots can perform tasks like locating survivors and delivering essential supplies, enhancing the safety and efficiency of rescue operations.

3.6. The Role of Artificial Intelligence and Machine Learning in Disaster Management:

Artificial Intelligence (AI) and Machine Learning (ML) enable computers to process large amounts of data, recognize patterns, and autonomously make predictions or informed decisions. In disaster management, AI and ML are essential tools that enhance preparedness, response, and recovery. By analyzing historical and real-time data—such as weather patterns, satellite imagery, and seismic records—AI and ML algorithms can predict disasters like floods, earthquakes, and hurricanes with greater accuracy, allowing authorities to issue timely warnings and organize pre-emptive evacuations (Sun et al., 2022). During a disaster, AI can optimize response efforts by quickly assessing areas in need, prioritizing rescue missions, and managing resources effectively. Additionally, AI-powered chatbots provide real-time information and assistance to affected individuals, reducing pressure on emergency services (Wang et al., 2018). In recovery phases, AI and ML help assess damage, streamline rebuilding, and allocate resources where needed most, ultimately making disaster management more proactive, efficient, and resilient.

3.7. Internet and Social Media in Disaster Management:

The Internet and social media have become essential tools in disaster management, facilitating rapid communication, coordination, and resource mobilization. Platforms like Twitter, Facebook, and Instagram enable authorities and organizations to broadcast emergency alerts instantly, reaching large audiences with critical information on evacuation routes, shelter locations, and safety protocols (Alexander, 2014). Social media also serves as a valuable resource for situational awareness, with affected individuals sharing real-time updates, photos, and videos that help responders assess on-the-ground conditions more accurately (Houston et al., 2015). Additionally, crowdsourcing platforms allow people in disaster zones to report their status, submit damage assessments, and request assistance, enabling emergency management teams to map needs and allocate resources effectively (Gao et al., 2011). This collective information sharing accelerates response times and informs data-driven decisions. Beyond immediate response, social media supports post-disaster recovery by connecting survivors with aid organizations and volunteers, strengthening community resilience and fostering cross-sector collaboration.

Emerging technologies have significantly enhanced disaster management capabilities in India. Big data analytics, blockchain, GIS, mobile technology, drones, AI, and social media provide innovative solutions that improve the effectiveness and efficiency of disaster response. These technologies facilitate rapid decision-making and resource optimization, ultimately saving lives and mitigating the impacts of disasters.

4. Methodology: Criteria for Case Study Selection

This study selected the Kerala floods (2018) and Cyclone Fani (2019) as case studies to represent diverse disaster types and illustrate technology's role in disaster management. Selection criteria included (1) Disaster Type: varied events like floods and cyclones; (2) Severity and Impact: high-impact disasters with significant social, economic, and environmental consequences; and (3) Technology Application: cases where emerging technologies (e.g., GIS, drones, early warning systems) extensively used, highlighting modern trends in disaster response.

5. Case studies

Case Studies in Disaster Management

This section presents a series of case studies showcasing the practical application of emerging technologies in disaster management across India. These cases illustrate how GIS, drones, and mobile applications strengthen response capabilities, enable timely interventions, and significantly reduce the adverse impacts of disasters on affected communities.

5.1. Case Study 1: Kerala Floods (2018)

In 2018, Kerala experienced one of the most devastating floods in its history, affecting millions and causing significant economic losses. Technology was pivotal in managing this disaster. The state government utilized satellite imagery and Geographic Information Systems (GIS) to predict the flood's impact and coordinate rescue operations. Social media platforms served as a vital communication channel, enabling real-time information sharing among authorities and the public. Crowdsourced data from platforms like Twitter and Facebook were analyzed to effectively identify the most affected areas and direct relief efforts (Walia, 2022).

5.2. Case Study 2: Cyclone Fani (2019)

Cyclone Fani, which struck Odisha in May 2019, was a severe tropical cyclone that required extensive disaster management efforts. Early warning systems, powered by satellite technology and meteorological data, allowed for timely evacuations, significantly reducing casualties. The Indian government deployed drones to assess damage and restore connectivity by inspecting damaged infrastructure. Moreover, social media and mobile applications enabled effective communication between authorities and the public, ensuring information about shelters, relief distribution, and safety measures reached the affected populations (Jena, 2021).

5.3. Case Study 3: COVID-19 Pandemic

While not a natural disaster in the traditional sense, the COVID-19 pandemic presented unique challenges, prompting the adoption of emerging technologies in disaster management. India leveraged digital tools and technologies to manage the crisis effectively. The Indian Government created the Aarogya Setu mobile application to track the spread of the virus, provide real-time data on infection rates, and assist in contact tracing efforts (Aarogya Setu App). Telemedicine platforms facilitated remote consultations, reducing the burden on healthcare facilities and enabling continuous care for non-COVID patients (Narayane et al., 2020). Furthermore, drones were utilized for surveillance, disinfection of public areas, and delivery of medical supplies, ensuring minimal human contact. These technological interventions significantly improved the pandemic response, showcasing the critical role of technology in managing public health emergencies.

5.4. Case Study 4: Himachal Flood (2023)

In 2023, Himachal Pradesh faced severe floods, and emerging technologies, particularly drones, played a crucial role in the disaster response. Rescue teams used drones for aerial surveillance to assess the extent of the flood damage, locate stranded individuals, and deliver essential supplies to inaccessible areas. The real-time data collected by drones helped plan and execute rescue operations more effectively. Additionally, drones assisted in infrastructure inspections, ensuring that repair and restoration work could be prioritized and executed promptly (Sharma, 2024).

The case studies of the Kerala floods, Cyclone Fani, and the COVID-19 pandemic, Himachal Flood, 2023, highlight several vital improvements in disaster management due to the deployment of emerging technologies. The Kerala floods in 2018 and Cyclone Fani in 2019 highlight distinct applications of emerging technologies in disaster management across different types of natural disasters, demonstrating how tools like GIS, drones, and early warning systems enhance response capabilities, improve resource allocation, and mitigate disaster impacts effectively. Table 1 compares technology usage in flood and cyclone disaster management in India from a global perspective. It examines specific technologies deployed, their roles in response and recovery, challenges encountered, and lessons learned from each disaster.

Table 1. Comparative Analysis of Technology Usage in Flood and Cyclone Disaster Management in India with Global Perspectives.

Aspect	Kerala Floods	Cyclone Fani (2019)	Global Perspectives
Technology Used	- GIS for flood-prone mapping and real-time monitoring - Satellite imagery from ISRO - Drones for high-resolution images - Social media for crowd-sourced updates	- Early warning systems supported by IMD's satellite and meteorological data - Drones for post-cyclone damage assessment - Mobile applications for information dissemination	- In the US, the Hurricane Katrina response used GIS to map flood-affected areas and satellite imagery to monitor impact[1]. - Japan's Typhoon Hagibis response utilized drones and early warning alerts for assessment[2].
Role of Technology in Response and Recovery	- GIS and satellite imagery enabled real-time mapping, aiding in evacuation and resource allocation - Drones provided high-resolution imagery for identifying stranded individuals - Social media allowed real-time citizen reports to guide response efforts	- Early warning systems enabled timely evacuation of over a million people - Drones assessed infrastructure damage and inspected power lines post-cyclone - Mobile applications helped communicate shelter locations and safety measures	- Haiti Earthquake (2010) relief used drones for rapid assessment, though infrastructure limitations hindered data collection[3]. - Typhoon Hagibis in Japan saw coordinated efforts with drones for targeted post-disaster assessment.

Key Challenges	- Data overload and verification difficulties with unfiltered social media information. - Coordination challenges in filtering reliable data from crowdsourced updates.	- Regulatory restrictions on drone usage in populated areas. - Logistical challenges in managing mass evacuations and restoring communication infrastructure quickly.	- The US response to Hurricane Katrina faced delays due to restricted drone deployment and limited data verification. - Haiti struggled with infrastructure gaps affecting drone and satellite usage[3].
Lessons Learned	- Social media and GIS are valuable in floods for enhancing real-time responsiveness, but data verification is crucial to prevent misinformation. - Drones proved effective for surveying inaccessible flooded areas, suggesting a need for faster regulatory permissions.	- Early warning systems and pre-positioned resources are essential for cyclones, as timely evacuation can significantly reduce casualties. - Mobile applications streamline communication, improving public safety during evacuations.	- Coordinated international efforts and standardized protocols (e.g., Typhoon Haiyan and Typhoon Hagibis) demonstrate that consistent application of technology can enhance disaster response across countries.
Future Implications	- Develop frameworks for social media monitoring to ensure credible information in real time. - Policy reforms to expedite drone deployment in emergency response.	- Strengthen early warning systems and coastal evacuation plans. - Expand mobile technology infrastructure for coordinated disaster communication.	- Global disaster response systems could benefit from enhanced collaboration and standardized technology protocols, as seen in international responses to Typhoon Haiyan and Hurricane Katrina.

The table provides a comparative analysis of technology use in managing the Kerala floods and Cyclone Fani, with insights from global examples. In India, GIS, drones, and social media supported flood response, while early warning systems and mobile apps improved cyclone preparedness. Key challenges included data verification and regulatory restrictions. Lessons highlight the importance of timely evacuation, adaptable technologies, and standardized protocols, as seen in responses like Japan's Typhoon Hagibis with drones and early warnings (Kanbara et al., 2021), Hurricane Katrina's GIS usage (Garg et al., 2022), and Haiti's earthquake response, impacted by infrastructure gaps (Sheller et al., 2013).

6. Challenges and barriers

While emerging technologies offer significant advantages in disaster management, their implementation in India faces numerous challenges and barriers. This section explores these obstacles and suggests possible solutions.

6.1. Technical Challenges

- **Interoperability Challenges:** Integrating data from various platforms is difficult, complicating coordinated disaster response efforts.

- **Environmental Impact on Technology:** Rain, clouds, and strong winds can reduce the accuracy of satellite imagery and drone operations, affecting real-time assessments.
- **Data Quality for AI/ML:** AI models need large, high-quality datasets for accurate predictions, but disaster conditions often result in incomplete or inaccessible data, reducing the model.

6.2. Infrastructure and Training Requirements

- **Lack of Technological Infrastructure:** Many rural and remote areas lack reliable Internet and power supply.
- **Skill Gaps:** Disaster management personnel often lack the technical expertise to use advanced technologies. Continuous training is essential.

6.3. Policy and Regulatory Environment

- **Regulatory Barriers:** Strict regulations on drone usage and data privacy pose challenges in disaster management. India's Drone Rules 2021 limit drone operations, requiring permissions that can delay emergency response. Additionally, pending data protection laws aim to safeguard privacy, highlighting the need for policy updates to enable timely, compliant technology deployment in disaster scenarios.
- **Data Privacy Concerns:** There is a need for robust data governance to protect sensitive information while using AI/ML.
- **Insufficient Funding:** There is a lack of sustained financial support for technological infrastructure and research. Programs like Digital India are steps in the right direction but require more investment.

7. Future directions

Strategic advancements and policy reforms are necessary to further enhance disaster management in India through technology. This section outlines potential future directions that could help overcome existing barriers and leverage technology more effectively.

7.1. Technological Advancements

Continuous innovation will enable faster, more effective disaster response.

- **Enhanced AI Prediction:** Develop advanced AI algorithms with improved accuracy for disaster prediction, tailored explicitly to India's varied climate and geographic conditions. These algorithms can provide more reliable early warnings, optimize resource allocation, and reduce the impact of disasters on vulnerable populations, thereby strengthening India's resilience to natural hazards.
- **Resilient Drones:** Design drones capable of withstanding harsh weather, ensuring reliable data collection and rescue operations during extreme conditions.
- **IoT Integration:** Expand the use of IoT devices to improve real-time monitoring and early warning systems.
- **Mobile Connectivity:** Strengthen mobile network resilience to ensure uninterrupted communication in remote and disaster-prone areas.

7.2. Policy Reforms

Comprehensive policy reforms are crucial for integrating emerging technologies like AI and drones in disaster management. Key recommendations include:

- **Expedited Drone Approvals:** Implement a fast-track clearance process for deploying drones in emergencies.
- **Establishing Guidelines for AI in Emergencies:** Develop preliminary guidelines for AI's ethical and practical use in disaster response, anticipating future formal AI regulations.
- **Humanitarian Exemptions:** Allow specific exemptions for drones and AI systems to operate in restricted areas during disasters to facilitate timely response.
- **Enhanced Data Protection:** Enforce data privacy protocols in line with India's proposed Personal Data Protection Bill, ensuring secure use of sensitive data by AI and drones.
- **Cross-Agency Collaboration:** Strengthen collaboration among regulatory bodies like DGCA (Directorate General of Civil Aviation), NDMA (National Disaster Management Authority), and local authorities to streamline drone and AI technology usage.

These reforms will reduce delays, foster innovation, and uphold privacy standards, supporting effective disaster management.

7.3. Training and Capacity Building

Building human capacity is as crucial as technological innovation in disaster management. Comprehensive training programs and capacity-building initiatives empower disaster management personnel to utilize emerging technologies effectively. Establishing partnerships with academic institutions and international organizations can help develop standardized training modules, ensuring consistent knowledge transfer. These initiatives should focus on practical GIS, AI, drones, and data analytics skills, equipping responders to adapt quickly to dynamic disaster scenarios.

7.4. Public-Private Partnerships

Strengthening collaboration between government bodies, the private sector, and non-governmental organizations is essential for advancing technology integration in disaster management. Public-private partnerships bring diverse expertise, share financial burdens, and enhance resource availability, enabling faster and more cost-effective technology deployment. These partnerships can also facilitate knowledge exchange on best practices, improve data sharing, and drive innovative solutions tailored to local disaster response needs, ultimately building more resilient communities.

7.5. International Collaboration

Given the global nature of technology development, India could benefit from increased international collaboration. Engaging with global tech leaders and international disaster management agencies provides access to cutting-edge technologies and best practices the team can adopt for local needs. By addressing these future directions, India can enhance its disaster management capabilities, making them more efficient, timely, and effective. Integrating advanced technologies with well-designed policies and comprehensive training programs will pave the way for a safer and more resilient society.

8. Conclusion

This paper has examined the crucial impact of emerging technologies on improving disaster management capabilities in India, highlighting the transformative effect of satellite and remote sensing, Geographic Information Systems (GIS), drones, Artificial Intelligence (AI), Machine Learning (ML), and mobile technology. These advancements have improved the timeliness, accuracy, and coordination of disaster management efforts, reducing the impact of natural and artificial disasters. Key results include real-time data provision and imagery for monitoring and assessing disaster impacts, precise mapping and spatial analysis for risk assessment and resource allocation, enhanced accessibility and efficiency in response and recovery operations through drones and robotics, improved predictive analytics for better preparedness via AI and ML, and facilitated real-time information dissemination and community engagement through mobile technology. Despite these promising outcomes, several challenges remain, including technical issues with data interoperability and accuracy, infrastructure and training gaps, regulatory hurdles, and data privacy and security concerns. Addressing these challenges through enhanced data sharing standards, investment in infrastructure and capacity building, updated regulatory frameworks, and exploration of new technologies like blockchain and IoT is crucial. Continued collaboration between government, private sector, and academia will drive innovation and ensure effective implementation, positioning India as a global leader in leveraging technology for disaster management.

Conflicts of Interest: Declare conflicts of interest or state: The authors declare no conflict of interest.

References

1. Shakeri, E. (2022). Comparative and Systematic Analysis of Disaster Management System.
2. ISRO, Disaster Management National International. Retrieved November 9, 2024, from *https://www.isro.gov.in/DisasterManagementNationalInternational.html*
3. Tomaszewski, B. (2020). Geographic Information Systems (GIS) for Disaster Management (2nd ed.). Routledge. *https://doi.org/10.4324/9781351034869*
4. Munawar, H. S., Hammad, A. W., Waller, S. T., Thaheem, M. J., & Shrestha, A. (2021). An integrated approach for post-disaster flood management via the use of cutting-edge technologies and UAVs: A review. *Sustainability*, *13*(14), 7925.
5. SP, S. I., Sathya, D., Gokulnath, B. V., Singh, J., & Murugan, T. (2024). Deep Learning and AI-Powered Natural Catastrophes Warning Systems. In Utilizing AI and Machine Learning for Natural Disaster Management (pp. 274-292). IGI Global.
6. ISRO, Retrieved from *https://www.isro.gov.in/*
7. Stout, S. (2024). From Space to Ground Zero: The Application of Geographic Information Systems and Rocket Cargo Transportation to Disaster Management Operations.
8. NCRMP. Retrieved from *https://ncrmp.gov.in/*
9. Ministry of Electronics and Information Technology. (2021). Digital India Initiative. Retrieved from *https://digitalindia.gov.in*
10. Garg, V., Pathak, S., Rathour, J., & Eslamian, S. (2022). Flood Mapping, Monitoring, and Damage Assessment. Flood Handbook: Impacts and Management, 323.
11. Kanbara, S., & Shaw, R. (2021). Disaster risk reduction regime in Japan: An analysis in the perspective of open data, open governance. Sustainability, 14(1), 19.
12. Nouali, N., Bouchama, N., Bendjoudi, A., Babakhouya, A., Yahiaoui, S., Belhoul, Y., ... & Guellati, N. (2009). Information technology for enhancing disaster management. *Congrès National des Télécommunications et leurs Applications (CNTA'09), May*, 23-24.
13. Sheller, M. (2013). The islanding effect: post-disaster mobility systems and humanitarian logistics in Haiti. cultural geographies, 20(2), 185-204.

14. Kaur, A., & Sood, S. K. (2019). Analytical mapping of research on disaster management, types and role of ICT during 2011–2018. Environmental Hazards, 18 (3), 266–285.
15. Bania, A., Iatrellis, O., & Samaras, N. (2023). Information Communication Technologies (ICTs) and Disaster Risk Management (DRM): Systematic Literature Review. In *Conference on Sustainable Urban Mobility* (pp. 1779-1794). Springer, Cham.
16. Hassan, M. U., Rehmani, M. H., & Chen, J. (2019). Privacy preservation in blockchain-based IoT systems: Integration issues, prospects, challenges, and future research directions. Future Generation Computer Systems, 97, 512-529.
17. Linardos, V., Drakaki, M., Tzionas, P., & Karnavas, Y. L. (2022). Machine learning in disaster management: recent developments in methods and applications. Machine Learning and Knowledge Extraction, 4(2).
18. Goodchild, M. F., & Glennon, J. A. (2010). Crowdsourcing geographic information for disaster response: a research frontier. International Journal of Digital Earth, 3(3), 231-241.
19. Ghosh, C. (2023). GIS and Geospatial Studies in disaster management. In International Handbook of Disaster Research (pp. 701-708). Singapore: Springer Nature Singapore.
20. Joyce, K. E., et al. (2009). Remote sensing and the disaster management cycle. Progress in Physical Geography, 33(2), 183-198.
21. Bhandari, V. (2022). Use of Technology in Disaster Management. Unity Journal, 3(01), 292-304.
22. Cicek, D., & Kantarci, B. (2023). Use of mobile crowdsensing in disaster management: A systematic review, challenges, and open issues. Sensors, 23(3), 1699.
23. Aboualola, M., Abualsaud, K., Khattab, T., Zorba, N., & Hassanein, H. S. (2023). Edge technologies for disaster management: A survey of social media and artificial intelligence integration. IEEE Access.
24. Enns, C., Bersaglio, B., & Karmushu, R. (2022). Disaster management takes to the skies: how new technologies are reconfiguring spatialities of power in desert locust management. Political Geography, 98, 102732.
25. Varsha, V. R., Naganandini, S., & Hariharan, C. (2024). Utilizing AI and machine learning for natural disaster management: predicting natural disasters with AI and machine learning. In *Internet of Things and AI for Natural Disaster Management and Prediction* (pp. 279-304). IGI Global.
26. Wang, Z., & Srinivasan, R. S. (2017). A review of artificial intelligence based building energy use prediction: Contrasting the capabilities of single and ensemble prediction models. Renewable and Sustainable Energy Reviews, 75, 796-808.
27. Houston, J. B., Hawthorne, J., Perreault, M. F., Park, E. H., Goldstein Hode, M., Halliwell, M. R., ... & Griffith, S. A. (2015). Social media and disasters: a functional framework for social media use in disaster planning, response, and research. Disasters, 39(1), 1-22.
28. Tan, M. L., Prasanna, R., Stock, K., Hudson-Doyle, E., Leonard, G., & Johnston, D. (2017). Mobile applications in crisis informatics literature: A systematic review. International journal of disaster risk reduction, 24, 297-311.
29. Mohan, P., & Mittal, H. (2020). Review of ICT usage in disaster management. *International Journal of Information Technology*, *12*(3), 955-962.
30. Mishra, M., Bhattacharyya, D., Guria, R., Paul, S., da Silva, R. M., & Santos, C. A. G. (2024). Rapid impact assessment of severe cyclone storm Michaung along coastal zones of Andhra and Tamil Nadu, India: A geospatial analysis. Journal of Environmental Management, 370, 122369.
31. Mohanty, A., Dubey, A., & Singh, R. B. (2022). The Application of Early Warning System in India. In Cyclonic Disasters and Resilience: An Empirical Study on South Asian Coastal Regions (pp. 65-102). Singapore: Springer Nature Singapore.
32. Sharma, A., & Sivasankar, T. (2021). A Review of Tropical Cyclone Disaster Management Using Geospatial Technologies in India. Recent Technologies for Disaster Management and Risk Reduction: Sustainable Community Resilience & Responses, 159-171.
33. Ojha, M. (2022). Use of Social Media in Disaster Management: A Review.

34. Abid, S. K., Sulaiman, N., Chan, S. W., Nazir, U., Abid, M., Han, H., ... & Vega-Muñoz, A. (2021). Toward an integrated disaster management approach: how artificial intelligence can boost disaster management. Sustainability, 13(22), 12560.
35. Linardos, V., Drakaki, M., Tzionas, P., & Karnavas, Y. L. (2022). Machine learning in disaster management: recent developments in methods and applications. Machine Learning and Knowledge Extraction, 4(2).
36. Goyal, S. (2022). Deploying Unmanned Aerial Vehicle (UAV) for Disaster Relief Management. In *The Internet of Drones* (pp. 383-399). Apple Academic Press.
37. Garg, R., Srivastava, R., Rathore, V., Gautam, S. K., Gupta, A., Saha, P. K., & Kumar, J. S. (2024, February). Utilization of UAVs to Detect and Locate Safe Sites in Disaster Affected Area Using Geo-Referencing. In *2024 Second International Conference on Emerging Trends in Information Technology and Engineering (ICETITE)* (pp. 1-8). IEEE.
38. Joseph, J. K., Dev, K. A., Pradeepkumar, A. P., & Mohan, M. (2018). Big data analytics and social media in disaster management. In *Integrating disaster science and management* (pp. 287-294). Elsevier.
39. Yin, J., Lampert, A., Cameron, M., Robinson, B., & Power, R. (2012). Using social media to enhance emergency situation awareness. *IEEE intelligent systems*, *27*(06), 52-59.
40. Dharmapuri Sridhar, M. P. (2017). *Real-time flood mapping for disaster management decision support in Chennai* (Doctoral dissertation, Massachusetts Institute of Technology).
41. Kshetri, N. (2018). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, *39*, 80-89.
42. Mattila, J. (2016). The blockchain phenomenon. *Berkeley Roundtable of the International Economy*, *16*.
43. Goyal, P. K. (2024). Cyclone Disaster Mitigation and Management in India: An Overview. *Disaster Risk and Management Under Climate Change*, 121-147.
44. Wang, Y., Li, J., Zhao, X., Feng, G., & Luo, X. (2020). Using mobile phone data for emergency management: a systematic literature review. *Information Systems Frontiers*, *22*, 1539-1559.
45. SACHET, *https://sachet.ndma.gov.in/*
46. Papyan, N., Kulhandjian, M., Kulhandjian, H., & Aslanyan, L. (2024). AI-Based Drone Assisted Human Rescue in Disaster Environments: Challenges and Opportunities. *Pattern Recognition and Image Analysis, 34(1), 169-186.*
47. Murphy, R. R. (2014). *Disaster robotics*. MIT Press.
48. Sun, W., Bocchini, P., & Davison, B. D. (2020). Applications of artificial intelligence for disaster management. *Natural Hazards*, *103*(3), 2631-2689.
49. Wang, Y., Kung, L., & Byrd, T. A. (2018). Big data analytics: Understanding its capabilities and potential benefits for healthcare organizations. *Technological forecasting and social change*, *126*, 3-13.
50. Alexander, D. E. (2014). Social media in disaster risk reduction and crisis management. *Science and engineering ethics*, *20*, 717-733.
51. Gao, H., Barbier, G., & Goolsby, R. (2011). Harnessing the crowdsourcing power of social media for disaster relief. *IEEE intelligent systems*, *26*(3), 10-14.
52. Walia, A., Sharma, P., & Nusrat, N. (2022). Kerala Floods 2018: Impacts and Lessons Drawn. In *International Handbook of Disaster Research* (pp. 1-17). Singapore: Springer Nature Singapore.
53. Jena, P. K., & Kishore, J. The Fani: A case study Of Odisha disaster management. *A. and Bindal, MK (eds.)(2021) Health Adaptation and Resilience to Climate Change and Related Disasters-A Compendium of Case Studies*, 73.
54. Aarogya Setu App. Retrieved from *https://aarogyasetu.gov.in.*
55. Narayane, M., Nagrale, N., & Patond, S. (2020). Usefulness of Aarogya Setu App to Fight with Covid19. *Indian Journal of Forensic Medicine & Toxicology*, *14*(4).
56. Sharma, M., Das, S., Pain, A., Kanungo, D. P., & Sarkar, S. (2024). Preliminary assessment of the Shiv Bawdi landslide in Shimla, Himachal Pradesh, India. *Landslides*, 1-11.

57. Baruh, S., Dey, C., & Dutta, N. P. M. K. (2023). Dima Hasao, Assam (India) landslides' 2022: A lesson learnt. International Journal of Disaster Risk Management, 5(1), 1-13.
58. Kaur, B. (2020). Disasters and exemplified vulnerabilities in a cramped Public Health Infrastructure in India. International Journal of Disaster Risk Management, 2(1), 15-22.
59. Cvetković, V. (2019). Risk Perception of Building Fires in Belgrade. International Journal of Disaster Risk Management, 1(1), 81-91.
60. Adams, S. M., & Friedland, C. J. (2011, September). A survey of unmanned aerial vehicle (UAV) usage for imagery collection in disaster research and management. In *9th international workshop on remote sensing for disaster response* (Vol. 8, pp. 1-8).
61. Bouzeraa, Y., Bouchemal, N., & Zendaoui, N. (2022, December). Pre-disaster Management based Machine Learning, IoT and Big Data: Survey and future direction. In 2022 2nd International Conference on New Technologies of Information and Communication (NTIC) (pp. 1-7). IEEE.
62. NCRMP, Schemes. Retrieved November 9, 2024, from *https://ndmindia.mha.gov.in/ndmi/programs.*

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Review Article

Industrial Disasters and Hazards: From Causes to Consequences—A Holistic Approach to Resilience

Vladimir M. Cvetković[1,2,3,4]*, **Renate Renner**[2,4], **Vladimir Jakovljević**[1,2]

[1] Department of Disaster Management and Environmental Security, Faculty of Security Studies, University of Belgrade, Gospodara Vučića 50, 11040 Belgrade, Serbia; vmc@fb.bg.ac.rs; vladimir.cvetkovic@unileoben.ac.at (V.M.C.); vjakov@fb.bg.ac.rs (V.J.).

[2] Scientific-Professional Society for Disaster Risk Management, Dimitrija Tucovića 121, 11040 Belgrade, Serbia.

[3] International Institute for Disaster Research, Dimitrija Tucovića 121, 11040 Belgrade, Serbia.

[4] Safety and Disaster Studies, Chair of Thermal Processing Technology, Department of Environmental and Energy Process Engineering, Montanuniversitaet, Leoben, Austria; renate.renner@unileoben.ac.at.

* Correspondence: vmc@fb.bg.ac.rs

Received: 18 August 2024; Revised: 5 November 2024; Accepted 15 October; Published: 25 December

Abstract

Starting from accelerated industrial development, industrial disasters (chemical spills, explosions, nuclear accidents, etc.), which fall under man-made (technological) disasters, increasingly threaten human lives, the environment, and property. Their complexity and far-reaching consequences, both at the local and global levels, require effective management of industrial risks and the disasters themselves (preparedness, mitigation, response, and recovery). For these reasons, the review paper aims to provide a holistic description of the diverse causes, dynamics, and multidimensional consequences of disasters. Additionally, it highlights and explains the key factors that directly or indirectly contribute to their occurrence. Furthermore, it could be said that the paper analyzes existing strategies for managing risks from industrial disasters and systematizes recommendations for improving preventive and reactive measures in high-risk industries. On the other side, the paper utilizes a comprehensive literature review, which involves the systematic identification, review, analysis, and critical evaluation of existing scientific papers, studies, reports, and regulatory documents on industrial disasters. Besides that, it also includes a detailed analysis of well-known industrial disaster cases such as Seveso (Italy, 1976), Bhopal (India, 1984), Chernobyl (Ukraine, then USSR, 1986), and Fukushima (Japan, 2011). The paper emphasizes that industrial disasters are often the result of the combined influence and interaction of technical failures, human errors, and inadequately developed safety procedures. Moreover, it can be highlighted that the design and implementation of preventive measures, such as regular maintenance of technical systems and systematic training and education of employees, are crucial for reducing the likelihood of such catastrophic events. The implications of this review paper are multifaceted and point to the following: the need to reassess current safety practices in industries; reconsider the potential for introducing innovations in preventive technical-technological solutions; examine the thorough implementation of innovative early warning systems, safety procedures, and modern equipment in facilities; improve cooperation between engineers, safety managers, and regulatory workers; reassess the need for additional updates and tightening of regulations regarding the storage, transport, and use of hazardous materials in industry; and improve the management of risks from industrial disasters.

Keywords

Hazards; disasters; resilience; industrial; definition; classification; consequences; human health; economic; environmental impact; causes; failures; human error; lessons.

1. Introduction

The rapid technological development has greatly improved the quality and way of life of modern people, but it has also contributed to the rise of various risks to their safety. In many sectors of production, processing, distribution, and storage, devastating negative events occur that have the potential to evolve into serious disasters. The dependency on chemical products is increasing, which leads to the growth in the number and size of petrochemical plants. These industries are required to meet the needs of mass production, which necessitates the storage of larger quantities of hazardous compounds in these facilities. If chemical leaks occur, they can have serious consequences for human health and the environment (Yet-Pole & Fu, 2021) .

Industrial hazards fall under the category of man-made (technological) hazards, which refer to dangers arising from technological or industrial conditions. These include accidents, hazardous processes, infrastructure failures, or specific human activities and can result in loss of life, injuries, illnesses, or other health effects, property damage, loss of livelihoods and services, social and economic disruption, or environmental harm (UNISDR, 2009). Given their complex nature, the potential for severe and serious consequences, conflicting interests, and incomplete knowledge of mitigation measures, it can be freely said that industrial disasters represent a malignant problem of modern society (De Abreu & De Andrade, 2019).

The analysis of industrial disasters shows that their specifics are directly related to the following characteristics: a) raw materials used in the production process; b) method and technology of production; c) the level of technical-technological development and innovation in the production process; d) preventive and protective measures implemented; e) characteristics related to geographical location, natural resources, workforce, transportation links, etc.; f) the degree of implementation of information systems and automation; g) collective awareness of employees, etc. (Cvetković, 2024).

What is often emphasized in the literature is that the incubation period is crucial for the occurrence of technological disasters. It represents the imperceptible accumulation of small events that directly or indirectly lead to such a disaster (Shaluf, 2007). If the factors contributing to such events were summarized, they could be grouped into three categories: a) human errors; b) organizational errors; and c) technological errors. The combination of these errors, as well as their other interactions, creates the conditions for the manifestation of harmful effects of technological hazards. The most well-known technological disasters are the Chernobyl disaster in 1986, the Bhopal disaster in 1984, the coal mine explosion in France in 1906, etc.

Considering all the circumstances, it can be stated that the stability and safety of industrial facilities depend on: a) the reliability and safety of production management systems; b) the capacity and ability of industrial facilities to withstand the effects of various harmful factors; c) protective measures taken to safeguard workers and other personnel from the negative consequences of various hazards; d) measures to protect facilities from damage caused by secondary hazards; e) the capacity of facilities to recover and restore production to its previous state (Мастрюков, 2011).

Certain technological disasters, such as incidents in Bhopal, Mexico City, Basel, Seveso, Exxon Valdez, and Chernobyl, have attracted serious international attention. Such attention led to the engagement of various expert groups, institutions, and organizations in addressing issues of prevention and remediation at the local, regional, national, and international levels. Furthermore, it is important to emphasize that the Chernobyl disaster directly led to the International Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. Additionally, the release of chemicals into the Rhine River was the starting point for bilateral and multilateral agreements regarding early warning systems for accidental discharges of hazardous substances into rivers (Krejsa, 1997).

1.1. Definition of Industrial Hazards and Disasters

In the literature, there are various definitions of industrial hazards used by authors to describe the basic elements and consequences of such events. It is important to note that there is no universally accepted definition for industrial disasters, and the criteria (number of victims, costs, damages) used in their definition vary and are not universally accepted (Ibrahim, Fakharu'l-razi, & Aini, 2003). The term technical-technological (anthropogenic) disaster is most commonly used to describe events caused by intentional or unintentional actions and activities undertaken by humans (Cvetković, 2019; El-Mougher, Abu Sharekh, Abu Ali, & Zuhud, 2023; Mohammed Mohammed El-Mougher & Mahfuth, 2021; Kachanov, 2021; Mohammed & Maysaa, 2022). According to Richardson, a socio-technical disaster occurs in four types of organizational situations: a) failures in plants and factories (major accident); b) failures in transportation; c) accidents at stadiums and other "public places"; and d) failures in the production process (Richardson, 1994).

Industrial disasters can be defined as specific events caused by human activity, involving hazardous substances, and capable of causing severe consequences to health and the environment (Lillibridge & Brennan, 2005). According to authors (Cole & Wicks, 1994), major industrial hazards are dangerous events that arise from the use of industrial technology and have the potential to cause serious injuries or inflict significant damage outside of working hours (Cole & Wicks, 1994). In contrast to this definition, industrial hazards can also be interpreted as high-risk events with potentially harmful effects on people and the environment, including fires, explosions, and the spread of toxic materials (Pasman, 2015). Akbar (2006) defines industrial hazards as all possible dangers, losses, and risks present in the industry, which may be caused by human error or other physical or mechanical failures.

According to the Serbian Law on Disaster Risk Reduction and Emergency Management (Official Gazette RS, No. 87/18), a technical-technological accident is defined as a sudden and uncontrolled event or series of events that have escaped control during the management of certain work tools and while handling hazardous substances in production, use, transportation, trade, processing, storage, and disposal. Such hazards, according to the mentioned law, include: fire, explosion, breakdown, traffic accidents in road, river, rail, and air transport, accidents in mines and tunnels, stoppages of cable cars for human transport, dam failures, breakdowns in power, oil, and gas plants, accidents involving handling radioactive and nuclear materials, severe pollution of land, water, and air, consequences of war destruction and terrorism, whose consequences can endanger the safety, life, and health of a large number of people, material and cultural goods, or the environment on a larger scale.

1.2.Classification of Industrial Risk, Hazards and Disasters

In the literature, there are various criteria for classifying industrial hazards and disasters, as well as different types of such events. Technological disasters include: a) industrial (related to production, processing, distribution, storage, usage); b) structural (various forms of collapse); c) nuclear; d) computer-related; e) transportation (transport) (Cvetković, 2019, pp. 104-105). Generally speaking, all industrial disasters can be classified based on: a) the type of incident; b) the cause; and c) the materials involved. Each type of industrial disaster carries specific risks and consequences for people, the environment, and material assets. Considering that industrial disasters fall under the category of technological disasters, it is important to note that technological disasters are divided into (Cvetković, 2024ab): transport-related (disasters involving transportation infrastructure, aviation, maritime, rail, and road); infrastructural (failures of telecommunication systems, computer network crashes, critical levels of water supply, main pipeline failures); industrial (disasters caused by improper handling and storage of hazardous substances); and international, civil, and political disasters – terrorism, crime, and war.

Additionally, industrial disasters can also be distinguished by certain criteria (Cvetković, 2024): development phases (the accumulation stage, initiation of the emergency event, culmination, and resolution); the speed of spread (sudden, rapid, moderate, and gradual); scale (local, municipal,

regional, national, international, and global); nature of the cause (natural, technological, ecological, and social); frequency (rare, occasional, and frequent).

Industrial disasters generally include: explosions caused by gas leaks or pressure buildup in enclosed spaces; fires, as uncontrolled combustion processes, that occur due to faulty electrical installations, machinery, devices, or flammable materials; chemical spills, involving numerous hazardous substances that can pollute the environment and threaten human health; gas leaks, such as the release of toxic gases like ammonia or chlorine; collapses, typically of industrial facilities like mines or buildings; radiation incidents, involving the release of radioactive materials; and poisonings, often caused by improper handling or storage of toxic chemicals.

It is important to emphasize that industrial disasters differ depending on the type of industry in which they may occur. Thus, industrial disasters can arise in the following sectors (Cvetković, 2024): heavy industry (mining, energy, metallurgy, construction industry, chemical industry); light industry (food, textile, wood, tobacco, printing, construction materials, and leather and footwear industries); extractive and processing industries, etc.

The specifics of such disasters are directly related to the following characteristics of the industry: a) the raw materials used in the production process; b) the production method and technology; c) the level of technical-technological development and innovations in the production process; d) the preventive and protective measures implemented; e) characteristics related to geographical location, natural resources, workforce, transportation, connections, etc.; f) the level of information system utilization and automation; g) the collective awareness of employees, etc. (Cvetković, 2024).

In the process of providing technical and organizational tools for the prevention, mitigation, and remediation of disasters, the International Working Group (UN) has created an indicative list of different types of actions that may represent technological hazards (Krejsa, 1997; Silei, 2014): chemical releases into the atmosphere due to explosions, and fires; chemical releases into water (groundwater, rivers, etc.) due to tank ruptures, pipeline breaks, chemicals dissolved in water (fire); oil spills into marine ecosystems; satellite crashes (radionuclides); radioactive sources in metallurgical processes; other sources of radionuclide release into the environment; contamination from waste management activities; soil contamination; accidents with groundwater contamination (road, railway); groundwater contamination due to waste dumps (slow-moving contamination); airplane crashes; releases and contamination as a result of military actions (e.g., depleted uranium) or the destruction of facilities; releases as a result of industrial use of biological material (e.g., viruses, bacteria, fungi).

A comprehensive analysis of the significant characteristics of natural and technological (industrial) hazards highlights that the following differences can be identified: a) destructive power; b) predictability and mitigation potential; c) suddenness of occurrence; d) speed of harmful impact dissemination; e) prevention and response methods, etc. On the other hand, according to Coppola (2006, p. 35) the fundamental difference between natural and technological disasters stems from the fact that natural disasters are acts of higher power, beyond human control or cause. In contrast, in technological disasters, humans are the most critical factor participating in the interaction that leads to negative outcomes.

2. Etiological Factors of Industrial Disasters

Industrial disasters can be triggered by numerous individual and interconnected factors originating from anthropogenic or technological spheres. It can be said that they have their roots in deeper systemic contradictions that include (Shrivastava, 1994): a) human; b) organizational; and c) technological factors. These contradictions are based on poor and underdeveloped communication, inadequate safety procedures and protocols, the use of outdated and faulty technology, as well as poor strategic and tactical risk management for such events. Over time, in line with the mentioned phases of industrial disaster development, these problems grow, become more complex, and accumulate, which collectively leads to a systematic increase in vulnerability and a weakening of resilience across all lines and sectors.

Certain studies (Ale et al., 2014) show that disasters in high-risk industries, such as oil and gas exploration (Deepwater Horizon) and petrochemical production (Texas City), reveal that the causes of such events vary significantly, ranging from direct technical failures to organizational shortcomings, insufficiently developed regulations, and inadequately developed corporate cultures. A further complication is that risk management processes are often based on risk models focused on technical failures, while the primary causes are rooted in the organization's culture itself (Ale et al., 2014).

2.1. Technical Causes of Industrial Disasters

Industrial facilities are composed of complex technical, technological, informational, mechanical, and other processes that can be threatened in various ways. A disruption or inadequate functioning of these systems, if preventive safety measures are not taken, can lead to different types of industrial disasters. For example, in the case of earthquakes, floods, or lightning strikes, pipes and storage tanks may be the most vulnerable equipment (Krausmann, Renni, Campedel, & Cozzani, 2011). It is important to note that such critical infrastructure and equipment are vulnerable due to the transport of hazardous materials that may be highly flammable, toxic, corrosive, poisonous, etc. Minor to major tremors caused by earthquakes can lead to small and large cracks, resulting in leaks due to such damage. Additionally, floods can cause equipment submersion, leading to corrosion or hazardous material spills. All of this, following the principle of interconnected vessels, can trigger chain reactions that may be difficult to stop.

Certainly, the technical causes of industrial disasters vary depending on the type of industry, as each industry has specific technologies, processes, and materials that carry certain risks:

a) Heavy industry (production of large and heavy materials and equipment, involving energy-intensive processes and the use of large machinery, mining industry): primary metallurgy (steel, aluminium, copper production); machinery industry (production of large machines, vehicles, ships); construction industry (production of concrete, cement, building materials);

b) Light industry (production of smaller, consumer goods, with less need for raw materials and energy): textile industry (production of clothing, fabrics); pharmaceutical industry (production of medicines); consumer electronics industry (production of electronic devices); food industry (production of food and beverages);

c) Chemical industry (production of chemical products from raw materials such as oil, natural gas, ore, and minerals): petrochemical industry (production of plastics, rubber, synthetic fibres); fertilizer and pesticide industry; pharmaceutical chemistry (production of active substances for medicines); paint and coatings industry;

d) Manufacturing industry (transformation of raw materials into finished products, which can be used as final products or components in other industries): automotive industry; electronics and electrical industry; wood and paper industry;

e) Energy industry (production and distribution of energy, including renewable and non-renewable sources): oil and gas industry; coal industry; nuclear industry; renewable energy sources (wind farms, solar power plants, hydroelectric power plants);

f) Agricultural industry (activities related to food production, industrial raw materials, and fibers, including crop production, livestock, and aquaculture): agribusiness (agricultural production, plant and animal husbandry); food and beverage industry (food processing, packaging);

g) Service industry (not producing physical products, the service industry provides support and services to other industries and end consumers);

h) Financial industry (banking, insurance): IT industry (information technologies, software services); transportation industry (transport of goods and passengers); healthcare industry (hospitals, clinics, pharmaceutical services);

i) Extractive industry (extraction of natural resources from the earth and their transportation to processing plants or directly to the market): mining industry (extraction of coal, metals, minerals);

oil and gas industry (exploration and extraction of oil and natural gas); forestry (logging and wood processing); fisheries (catching and processing fish);

j) Renewable resource industry (production and management of renewable resources): renewable energy (solar, wind, hydro); recycling industry (processing waste into useful materials).

Fires can threaten all types of industrial facilities, especially those that produce or use hazardous materials in the production process. Regarding specific industries, equipment failures and process breakdowns are typical for heavy industry. In primary metallurgy, industrial disasters can occur due to furnace failures, inadequate temperature control, molten metal leaks, or gas explosions. In the machinery industry, which can be highly diverse, failures may occur in the production of vehicles or ships, leading to collapses, fires, or explosions. In the construction industry, improper application of safety procedures during the production of cement and concrete, structural weaknesses, explosions, or chemical leaks can result in catastrophic events.

In contrast to heavy industry, industrial disasters in light industry can be caused by: machine malfunctions in weaving or dyeing, which may lead to fires due to high temperatures (textile industry); technical problems that could cause product contamination, faulty medicines, or chemical reactions in laboratories (pharmaceutical industry); overheating, malfunctions, or other damage that can cause fires or explosions (electronics industry); food contamination or failures in cooling systems, which can lead to serious health risks (food industry).

In the chemical industry, the technical causes of such disasters are often related to faulty facilities for storing or processing chemicals. In the petrochemical industry, fires or explosions can occur due to chemical leaks. Equipment failures in chemical synthesis can lead to disasters caused by contamination or the release of toxic gases.

In the manufacturing industry, which relies on the proper transformation of raw materials into finished products, various breakdowns or damage can occur. For instance, in the automotive industry, failures frequently occur on assembly lines, in electrical systems, or in fuel storage components. Electrical components can overheat, leading to melting and sparks that cause fires. On the other hand, sawdust or dryer malfunctions can result in serious fumes.

On the other hand, the energy industry carries many risks of industrial disasters. Explosions at drilling sites, oil spills, or pipeline failures are the most common causes of oil and gas industrial disasters. Gas explosions (methane), various collapses in mines, radiation leaks, reactor failures in nuclear plants, or malfunctions in wind turbines or hydroelectric power plants can lead to various disasters.

In the agricultural industry, equipment failures for processing and storage, harvest machinery failures, irrigation system malfunctions, food processing equipment breakdowns, natural hazards (droughts, floods, strong winds, hail, etc.), biological hazards (pests, livestock diseases, invasive species), land degradation, and water and air pollution can be direct causes of various disasters. Conversely, typical causes of disasters in the service industry include software system failures, interruptions in banking or insurance institutions, vehicle breakdowns or logistical system failures, technical problems with medical devices or software, etc.

In the extractive industry, the causes of disasters are mainly related to equipment malfunctions for resource extraction, as well as other equipment for ensuring worker safety in such processes. Also, these may include explosions in mines, tunnel collapses, accidents caused by various mining machines, drilling platform failures, gas leaks, improper handling of cutting machines, or ship malfunctions. Finally, in the renewable resource industry, there may be various accidents associated with technology failures for energy production, such as wind turbine or solar panel failures, explosions in recycling facilities, etc.

2.1.1. Failures in Design and Engineering

In theory, but also in practice, industrial disasters cannot occur unless certain human or technical errors take place. However, considering that absolute safety is difficult to achieve, certain systemic

failures in design and engineering can create critical vulnerabilities that contribute to the conditions necessary for disasters to occur. When focusing on design errors, it is often highlighted that certain devices, equipment, or facilities are not adequately designed to withstand all external pressures (e.g., the manifestation of harmful effects of shock waves), which can lead to the collapse of the structure itself. For example, in architecture, the lack of detailed drawings and poor coordination between disciplines lead to the necessity of performing additional work and delays in construction processes (Ayalp & Metinal, 2023). Therefore, if all external and internal factors that could affect the collapse of a structure are not considered through design processes, analytical methods, and very detailed analyses, it is very likely that some type of incident or accident will occur. For instance, improper installation of inverters and the configuration of the system itself can lead to significant energy losses, requiring detailed on-site corrections, all due to inadequate design (Bakır & Merabet, 2023).

Incorrect engineering assumptions, which may be based on imprecise data or inaccurate calculations, can lead to catastrophic outcomes. Additionally, if materials that do not meet the required standards of resistance, durability, and elasticity are chosen during the design process, the likelihood of an accident increases. One particularly important precondition is improving the level of redundancy, meaning that failures in one part of the components do not cause cascading failures throughout the entire facility.

To mitigate poor levels of redundancy, backup systems need to be designed to support the key operations of the industrial process, particularly in high-risk industries such as nuclear, chemical, or energy industries (Samson, Michael, Akanni, Pelumi, & Avidime, 2023). Moreover, it is important to have basic and advanced safety systems, such as fire prevention systems, automated control systems, emergency shutdown systems, and systems for halting certain industrial operations. Their design, implementation, and functioning reduce the levels of risk, i.e., the likelihood of the initial event occurring, and if it does occur, the consequences are minimized (DeMott, 2018).

One of the prevalent problems and causes of industrial disasters relates to numerous deficiencies in the processes of short-term and long-term maintenance of technical components and the systems themselves (Silvestri, McVee, Shanahan, & English, 2023). Prolonged wear, the formation of micro-damage, corrosion, etc., first leads to a reduction in functionality and later to complete failure. On the other hand, it is very important to continuously improve employee training, through which workers would be familiarized with all present direct and indirect risks and ways to eliminate them. Furthermore, in all situations, it is important that everyone adheres to certain safety protocols.

2.1.2. Human Error and Its Role in Technical Failures

In industrial systems and facilities, although the level of automation in work processes and safety control has been elevated, human errors still remain an unavoidable factor in causing serious consequences. Human errors are understood as all unintended or inappropriate decisions made at different levels of the organization that are unsuitable for the given situation (Vondráčková, Voštová, & Nývlt, 2017).

Numerous studies (Rasmussen, 1990; D. Smith, 2000; Williamson, Webb, Sellen, Runciman, & Van der Walt, 1993) show that human errors play a key role in the occurrence of technical failures across various industries. Such errors create far-reaching consequences for safety, operational efficiency, and reliability in industrial processes. For this reason, various methodologies for assessing human factor reliability have been developed, aimed at evaluating the frequency and impact of human errors in industrial environments such as production or engineering processes (González-Prida, Parra, Crespo, Kristjanpoller, & Gunckel, 2022). By using the Cognitive Reliability and Error Analysis Method (CREAM) in the maritime industry, human errors in the auxiliary systems of ship diesel engines were systematically analyzed, revealing that such errors could critically endanger engine safety (Demirel, 2021). In construction, directly or indirectly, human errors can significantly contribute to structural failures. These errors can occur due to inadequate decision-making at various management levels under the influence of disruptive factors such as fatigue, stress, the quality of education, working hours, and organizational climate (Vondráčková et al., 2017).

In the prevention of technical failures, through the realization of potential human error analyses in complex systems, various methods are applied (Human Error Probability HEP assessment, CREAM cognitive reliability error analysis methods). These methods are based on identifying the probability of errors during operations and analyzing factors such as operator fatigue levels, the adequacy of training, and decision-making processes, allowing risk managers to predict potential errors. Based on these analyses, corrective measures are designed and implemented later (e.g., ergonomic adjustments, process automation) (González-Prida et al., 2022).

2.2. Organizational Causes of Industrial Disasters

Organizational factors, in addition to technical factors, can be among the most significant contributors to the occurrence and further development of industrial disasters. It can be assumed that even if a technical cause arises if all preventive and organizational planning measures are in place, the consequences can be mitigated or prevented. On the other hand, certain studies (Schmitz, Reniers, Swuste, & van Nunen, 2021) emphasize that organizational factors can indirectly influence the occurrence of certain disasters caused by ammonia leaks by affecting the quality or reliability of barrier systems.

In general, if an organization does not pay sufficient attention to safety requirements and prioritizes production over the development and implementation of safety measures, an incident, or disaster will likely occur. Furthermore, a weak safety culture among employees and managers can result in non-compliance with prescribed safety procedures and protocols. Safety culture addresses the subtle difference between formal regulations and the practised and collectively accepted way of acting, which is based on shared assumptions, values and norms (Hopkins, 2018). Thus, a weak safety culture can lead to delayed identification of potential hazards and improper use of safety equipment.

When it comes to the policy of maintenance and the implementation of regular, extraordinary, and inspection controls, it should be noted that poor planning of technical system maintenance and safety equipment upgrades can lead to the degradation of protective barriers. This, in turn, increases the risks of various mechanical failures or leaks, which can result in more serious safety threats. Additionally, if well-developed communication channels and procedures for reporting minor structural and non-structural deficiencies are lacking, this can lead to further negative developments.

The safety management of companies plays a decisive role in establishing and improving safety procedures. Maturity models can help to assess and develop a safety culture - from compliance to commitment, where safety is proactively managed (Cooper, 2018). If there are no assessments and sanctions for bypassing the implementation of key protective and preventive measures, a more serious safety threat scenario will likely occur in the future. Developing a culture of punishment can also have the opposite effect, where mistakes and near misses are not reported out of fear (Marx, 2018). Organizational structures reflect top leader's priorities, and addressing organizational factors can strengthen the reliability of preventive and protective systems within companies.

2.3. Environmental and External Causes of Industrial Disasters

The safe operation of various industries is conditioned by numerous external and internal risks and threats. Such external and internal events can seriously affect the occurrence and development of industrial disasters. Various natural hazards, which can originate from the lithosphere, hydrosphere, atmosphere, biosphere, or extraterrestrial sources, may lead to the most likely and severe scenarios of industrial safety threats.

Disasters caused by natural hazards, such as earthquakes (e.g., the Fukushima earthquake), floods (e.g., in 2011 at a toxic chemical plant in Thailand, and in 2002 in the industrial zone in Dresden, Germany), hurricanes (e.g., in 2017, Hurricane Harvey caused massive flooding across Texas, particularly in the industrial belt around Houston), and extreme temperatures (e.g., excessive cold

causing pipeline ruptures in Siberia) can create both direct and indirect causes of industrial disasters. The direct impact of such natural events involves their harmful effects (shock waves, thermal, radiation, etc.) on the technical and non-technical aspects of the functioning of various industries. The indirect impact of disasters on industrial operations can be seen in the disruption of supply chains due to destroyed or damaged critical infrastructure (e.g., collapsed bridges, flooded roads, power outages, etc.), the interruption of telecommunications, the absence of labour, the generation of socio-economic consequences, and changes in regulations and insurance. Additionally, the influence of climate change, which increases the frequency and intensity of various natural hazards, cannot be overlooked.

In addition to the mentioned disasters, negative social phenomena, such as sabotage and terrorist attacks, can lead to disasters in various industrial sectors. Sabotage, which involves deliberate damage or disruption of the functioning of industrial facilities, equipment, and processes, can result in serious industrial damage (Taylor & Walton, 2020).

In acts of sabotage, various physical attacks, cyberattacks, equipment manipulation, or intentional shutdowns of key technical and other systems can be executed. There are numerous examples of such sabotage: sabotage at oil facilities in Nigeria, where armed groups carry out numerous sabotage attacks on oil platforms, pipelines, and refineries; the cyberattack on facilities in Saudi Arabia in 2017, where security systems (compromising the automatic shutdown of facilities) at a Saudi oil and gas processing plant were attacked; drone and missile attacks on refinery facilities in Saudi Arabia in 2019; the explosion caused inside the Iranian uranium enrichment plant in Natanz; in the USA, an unknown individual added cyanide to Tylenol capsule bottles; and Volkswagen engineers deliberately installed emissions manipulation software in diesel vehicles in 2015.

Besides sabotage, other economic and political factors and conflicts can contribute to the occurrence of industrial disasters. For example, cost-cutting in the maintenance of the "Deepwater Horizon" oil platform in the Gulf of Mexico in 2010 led to a serious incident resulting in a massive oil spill in the gulf. Dangers arising from armed conflicts can also pose a massive threat to safety. The fighting around the Zaporizhzhya nuclear power plant during the war in Ukraine could have caused a reactor accident with far-reaching consequences for Europe.

3. Nature, Dynamics and Unpredictability of Industrial Disasters

Accelerated industrial development worldwide is characterized by chaotic systems, which are largely marked by their unpredictable nature, complexity, and sensitivity to numerous factors (Ndofor, Fabian, & Michel, 2018). The unpredictability refers to its likelihood of occurrence, the extent of damage, and how that damage may be distributed or manifested. This is especially true for technological innovations and related emerging risks. In difference, large industrial facilities harbour a complex risk: if an incident happens, its consequences can be immense because of complex interrelations and cascading effects (Renn, 2017).

In chemical or nuclear facilities, operations are conducted under specific and extreme conditions. Minor deviations in temperature, pressure, or system integrity can quickly escalate and lead to very dangerous consequences. Human errors can creep in every day during the production process because the employees themselves represent a source of danger. Stress or time pressure can affect their attention and diligence; inadequate training or familiarization, as well as a lack of physical or mental ability, can be the cause of incidents. Although innovative technologies are used to reduce the likelihood of human error, such as various alarm and sensor systems, both minor and major incidents still occur frequently.

Analyses show that current methods for managing human factors and risks are insufficiently effective in identifying and addressing the challenges arising from complex interactions between humans, technology, and organizational structures in industrial environments. It is thus very difficult to understand the complex interplay between human errors, technological failures, and deficiencies in organizational processes (Hassall, 2015). A deeper examination of the interconnectedness within industrial systems reveals that their elements are interdependent, meaning that a minor failure in

one area can lead to catastrophic consequences in another sector (Silei, 2014). This can be described as a domino effect, which explains the interaction of interconnected components. The inherent uncertainty in industrial processes and the impact of human errors on all process levels from design, construction, and operation to maintenance show the importance of precaution, precisely because incidents can have massive consequences (Mannan, 2005).

4. Consequences of Industrial Disasters

Industrial hazards and disasters possess an immense energy potential to cause serious material and immaterial consequences. Analyses show that the scope and magnitude of the consequences of industrial disasters depend on the physical characteristics of the events themselves (size, scale, duration, frequency), as well as on the demographic, socio-economic, and psychological predispositions of the affected population in the impacted area (Hofer & Messerli, 2006). Similarly, Paul (2011) emphasizes that the consequences of disasters also depend on complex social, economic, demographic, political, and cultural factors. K. Smith and Ward (1998, p. 35) advocate a classification into direct and indirect consequences, which can be both material and immaterial. According to them, direct material consequences arise from the damage to buildings, structures, and infrastructure, while indirect consequences include lost production, income, and work absences (Cvetković, 2024).

Overall, it can be stated that industrial disasters can cause both direct and indirect damage and losses. Direct consequences typically refer to material (buildings, artefacts, work equipment) and immaterial damage, while indirect damage can be material (malfunctions in strategic services, decreased production levels) or immaterial (psychological and physiological impacts, abandonment of cultural assets, etc.). Thus, the consequences of industrial disasters are often multidimensional and multisectoral, which can significantly complicate the efforts of responsible government authorities to prevent them.

In an interesting study, the authors (Cvetković, Renner, Aleksova, & Lukić, 2024) analyzed the geospatial and temporal distribution of natural and technological disasters that occurred between 1900 and 2024. The study found that 25,836 disasters occurred worldwide, of which 69.41% were of natural origin (16,567), while 30.59% were of technological origin (9,269). The study also highlighted that technological disasters were most frequent in Africa, accounting for 43.79% of all disasters on the continent. Asia followed with 38.11%, while Europe and South America reported 35.46% and 33.44%, respectively. Oceania had the lowest percentage of technological disasters, with only 8.49%. Although Asia had the highest total number of disasters, it also had a significant share of technological disasters (38.11%), indicating the presence of technological accidents in the region. The high percentage of technological disasters in Africa (43.79%) may reflect various socio-economic factors and levels of infrastructural development (Cvetković et al., 2024).

4.1. Impact on Human Health

Industrial disasters produce multiple consequences for human health, and their specifics depend on the type of industrial hazard involved. Chemical industrial disasters can have widespread effects on public health in the immediate vicinity and the broader area surrounding the facility where the incident occurred. Such consequences require urgent and immediate medical measures to provide first aid and medical assistance to contaminated individuals (Clements & Casani, 2016). In such chemical disasters, it is crucial to quickly identify the hazardous or toxic substances involved. For these reasons, numerous technical systems are available to facilitate the identification of hazardous materials during disasters. Additionally, emergency and rescue personnel are equipped with mobile technical devices (pagers) that allow them to continuously monitor the presence and quantity of hazardous substances.

In addition to identifying the hazardous material, it is important to know the length of exposure to understand the safe levels and the potential courses of action in such situations. After chemical

industrial disasters, the responsible authorities must establish a registry of individuals, documenting who has been exposed to certain chemicals and for how long. To promptly implement all operational, tactical, and technical protective measures for safeguarding human life and health during chemical industrial disasters, close cooperation is crucial between the industrial complex where the disaster occurred and the authorities and citizens before, during, and after the disaster. The exchange of information, timely notifications, and preventive public education on potential hazards and how to respond during such disasters are of utmost importance for preventing or mitigating the consequences of such events.

Industrial disasters bring serious and unique challenges in providing an adequate and timely response, particularly for medical services, considering the many gaps in scientific knowledge and the insufficient training of citizens and service personnel (Keim, 2011).

According to some research, such disasters have the potential to seriously affect the quality of life of employees, causing industrial pathology, occupational diseases, and cases of poisoning (Каширина, Салмина, & Каширина МВ, 2020). Of course, it is also important to note that when it comes to industrial disasters, there are double standards in health protection, where underdeveloped technologies are exploited in developing countries rather than in the countries of origin, exposing entire communities, societies, and workers to a wide range of health consequences.

Globally, the development of science and technology has contributed to the rapid emergence and proliferation of numerous hazardous materials that can endanger people and their health. These materials are often called "silent killers," and it is not uncommon for households to possess various chemicals that can directly or indirectly cause harm. For this reason, a prerequisite for the preventive protection of people is knowledge about the basic characteristics of how these hazardous materials react and behave. Certainly, there are different ways hazardous materials can enter the body: a) inhalation; b) absorption through the skin or eyes; c) ingestion; or d) injection. Depending on the specific material and the method of contamination, the entire response strategy of emergency and rescue services will be determined (Cvetković, 2022).

4.2. Economic Impacts of Industrial Disasters

The inevitable consequences of industrial disasters include serious economic damages both within and outside industrial complexes. These damages can have short-term or long-term economic effects and often depend on the type of industrial disaster. It is an undisputed fact that they lead to significant financial and social costs, which can also affect entire local communities where industrial complexes are located.

One study shows that industrial accidents causing offsite injuries, property damage, and requiring immediate evacuations can lead to a decrease in local property values by 5 to 8%, translating into an average financial loss of $12,000 to $20,000 per household within a five-kilometre radius (Guignet, Jenkins, Belke, & Mason, 2023). Additionally, industrial disasters can cause serious environmental consequences, as well as production losses. The dam failures in Brumadinho and Mariana in Brazil resulted in losses of approximately $13.48 billion (Gonzalez, da Silveira Rossi, & Vieira, 2022).

In terms of financial losses for the companies themselves, in the short term, such accidents can lead to numerous financial losses due to cleanup costs, decontamination, remediation, regulatory fines, business interruptions, hiring additional labour, etc. Conversely, in the long term, industrial disasters can also lead to financial crises in the market, especially within related industrial sectors. This occurs due to investors' predictions that, following previous industrial disasters, there will be higher regulatory costs and stricter safety procedures (Corbet, Larkin, & McMullan, 2018). In addition to the direct financial impacts, it should be noted that such accidents also have significant socio-economic implications for the labor market, where affected individuals may face prolonged periods of unemployment and reduced income (Parro Greco, 2023).

4.3. Environmental Impacts and Long-term Effects

The environmental consequences of industrial disasters can pose a significant challenge for disaster risk management professionals. The specific characteristics and extent of such environmental impacts depend on the type of disaster. Due to their diverse nature, these consequences can cause harmful effects on the soil, water, and air. Industrial accidents could have harmful effects on the environment, the health of a community, and ecosystems (Cvetković, 2024; Parro Greco, 2023; Poortinga, Pidgeon, Capstick, & Aoyagi, 2014; Schmitz et al., 2021). Also, industrial disasters have both immediate effects (injuries and fatalities), as well as long-term health impacts in the form of chronic diseases or disabilities. For instance, it can be said that many years after the Bhopal gas tragedy, people who were not even born at that time still had higher rates of cancer and several disabilities while in their mother's womb (McCord, Bharadwaj, McDougal, Kaushik, & Raj, 2023). On the other side, it can be mentioned that the economic implications are also significant, especially for global mega-corporations that potentially cause existential environmental crises. Markets reveal this year after year by continuing to price out risks from environmental damage, with financial losses extending far into the future. Investors react similarly, showing concern about potential future liabilities (Carpentier & Suret, 2013).

Additionally, industrial disasters are often associated with long-term transgenerational consequences. Also, they are more pronounced and prevalent in susceptible subpopulations such as neonates. We saw that the mining dam collapse in Brazil led to heightened infant mortality rates coupled with lower birth weights, signifying devastating health implications (Carrillo, Da Mata, Emanuel, Lopes, & Sampaio, 2020). This is why remnants of chemical spills can linger in the environment for years to decades. For instance, residents of Seveso, who developed chloracne, had increased long-term concerns about cancer risks even 20 years after the dioxin release (P. A. Bertazzi, 1991). These industrial disasters deliver not only physical harm but also an emotional toll — the latter can be just as devastating in communities already burdened with social and environmental challenges. For example, uranium mining in the Navajo community resulted in high levels of mental health issues such as anxiety and depression (Markstrom & Charley, 2003). Industrial accidents cause massive and enduring harm — ecologically, as well as to public health and economies, both immediate and intergenerational. Effectively responding to these effects and assisting recovery, while hastening the adoption of strategies that build resilience, requires a focus on prevention, regulation, and an effective response system.

5. Historical Overview of Industrial Disasters

5.1. Major Industrial Disasters: Case Analysis

In 1600, Bernardino documented the first recorded industrial chemical disaster. In his report, more than three centuries old, he noted that the toxic effects of industrial activities could affect not only workers but also the general population. This report was triggered by a citizen filing a complaint against the owner of a chemical laboratory (P.-A. Bertazzi, 1989).

In Seveso (with 17,000 residents), a commune in Lombardy, Italy, an industrial disaster occurred in 1976 at a chemical production plant, about 20 km from Milan. The disaster was caused by the interruption of a process that involved removing ethylene glycol from the reaction mixture by distillation. There was a serious drop in the load on the turbine, leading to an increase in the temperature of the released steam to around 300 degrees. The operators did not notice these changes in time, which resulted in the activation of a safety valve, releasing around 6,000 liters of chemicals within an 18 km radius. Immediately after, the affected area was divided into three zones: A (greater than 50 micrograms), B (between 5 and 50 micrograms), and R (negligible concentration less than 5 micrograms), based on the declining values of TCDD concentrations in the soil. Numerous preventive measures were taken, one of the most significant being the immediate euthanasia of over 80,000 animals to prevent them from entering the food chain. Zones A and B were fully evacuated, and all individuals underwent rigorous health examinations. Extensive decontamination and cleaning of the affected

areas were carried out. The chemical leak led to an increased mortality rate due to cardiovascular and respiratory diseases (Cvetković, 2022).

Shortly after, in 1982, the Seveso Directive was introduced, strengthening preventive measures in industries. Updates to the Seveso III Directive followed in 1996, 2008, and 2012, prompted by various disasters. In 1987, after the Bhopal disaster and again after the fire at the Sandoz agrochemical warehouse near Basel, where chemicals, mainly organophosphate pesticides, spilled into the Rhine River, causing severe pollution and the death of nearly the entire European eel population spawning downstream of the spill (Güttinger & Stumm, 1992).

Another major industrial disaster occurred in India on December 3, 1984, in the city of Bhopal. A technical malfunction at the plant owned by the American chemical company Union Carbide caused a leak of 45 tons of toxic gas, methyl isocyanate, into the atmosphere, with devastating consequences for the environment and human health (Cvetković, 2024). Although this substance is often used in the industrial production of pesticides, it possesses dangerous properties, making it extremely hazardous (it is highly unstable, volatile, reacts violently with water, a hundred times more lethal than cyanide, and more dangerous than phosgene, a chemical weapon) (Lewis, 1992).

According to official reports, the disaster was caused by inadequate maintenance of safety devices, and no warning systems were in place (Peterson, 2009). A dense gas cloud covered an area of about seven kilometres, and according to the official report of the Indian government, 15,000 people died, and about 60,000 were injured. The poorest areas of the city were the most affected due to the high population density. There were no well-developed evacuation plans, and people inhaled the gas; local knowledge was poor, no proper evacuation was conducted, and there were no decontamination recommendations. The American legal system opposed compensation, and the Indian government paid damages totalling $470 million (Keith Smith & Petley, 2009, pp. 292-293). This event is recorded in history as the deadliest industrial disaster ever (Cvetković, 2024).

Furthermore, in Ukraine, near the city of Pripyat, a nuclear disaster occurred in 1986. At the Lenin Nuclear Power Plant near Pripyat, an experiment was conducted to test whether the electrical generator could provide sufficient power to cool the reactor while the diesel generator was activated. During the test, the routine steam supply from the reactor was cut off, and the power level dropped below 20 percent. The reactor was not shut down, and enormous amounts of steam and chemical reactions created pressure that caused an explosion. Pieces of radioactive material were ejected from the reactor and deposited about 1 km away from the plant, igniting other fires. The main component of the radioactive dust and gas released into the atmosphere contained iodine-131 and cesium-137, both of which can easily be absorbed by living tissue. The consequences of the event were catastrophic: about 30 people died while trying to extinguish the fires, and another 200 people sustained serious injuries due to exposure to radiation doses 2,000 times higher than normal. More than 130,000 people were evacuated from a 30-kilometer radius of the radioactive zone, and the city of Pripyat was abandoned (Cvetković, 2024; Keith Smith & Petley, 2009).

Another significant example of this type of disaster occurred in 2011 when Japan was struck by a powerful earthquake that triggered a tsunami, leading to a series of nuclear accidents in Fukushima. Before the earthquake, six nuclear reactors were operational, three of which were shut down during the earthquake, while the other three were automatically shut down. The tremor did not cause the disaster, but the tsunami waves flooded the entire area, causing water infiltration that left the remaining diesel generators without power. As a result, the necessary cooling of reactors 1, 2, and 3 could not be maintained, leading to partial core meltdowns and hydrogen explosions. Acting according to the disaster plan, the population within a 20 km radius of the nuclear plant was evacuated in a short period (Cvetković, 2024; Cvetković & Martinović, 2021).

5.2. Lessons Learned from Past Events of Industrial Disasters

Every industrial disaster carries numerous causes and consequences, and analyzing these can provide valuable lessons for improving conditions in this field. Such analyses can offer important insights regarding safety management in the industry, regulatory policies and practices, as well as

the level of preparedness for future challenges, risks, and security threats. The analysis of the Fukushima Daiichi nuclear disaster revealed significant shortcomings in safety protocols concerning workers, particularly regarding the prevention of heatstroke and the long-term health effects of radiation exposure. The lessons learned from this event highlight the importance of continuous health monitoring for workers directly involved in the remediation of nuclear incidents (Mori et al., 2024).

Moreover, the Fukushima disaster also pointed to broader global health issues that such a catastrophe can cause (Said, Ahmadun, Kadir, & Daud, 2009). Also, an analysis of several industrial disasters was conducted, resulting in recommendations grouped into the following categories (Said et al., 2009):

a) Technical recommendations (improving specific technical specifications such as design parameters, implementing additional physical safety measures, enhancing the physical condition of the facility or demolishing and rebuilding it, conducting specific technical tests);

b) Recommendations regarding authority (improving the implementation of existing laws and regulations, introducing additional appropriate measures by the government, taking legal actions against those who do not comply with regulations, increasing penalties, revoking licenses or registrations);

c) Recommendations regarding existing laws and regulations (formulating more effective laws, regulations, and guidelines, amending existing laws, adding additional clauses, introducing new registration systems, and changing jurisdictions);

d) Recommendations regarding the revision of current work procedures (improving the appropriate monitoring and control systems, enhancing supervision, establishing and further strengthening comprehensive security procedures, improving horizontal and vertical coordination, developing proper documentation procedures, establishing financial management and quality resource allocation);

e) Recommendations regarding professional engagement (improving the hiring process of highly qualified and skilled workers, ensuring an adequate number of expert staff, ensuring that only qualified workers perform tasks related to safety);

f) Recommendations regarding education and training (increasing the current level of public awareness about safety, establishing adequate training for employees and emergency response personnel);

g) Recommendations regarding the formation and maintenance of specialized bodies or agencies (mandatory establishment of a national body for coordinating and overseeing issues related to the construction industry, mandatory introduction of specialized firefighting units within facilities handling hazardous materials).

6. Conslusion

A pace of technological advance means the opportunity for industrial disasters is never far away, and safety challenges continue to exist in various industries. It can be said that this multifaceted context of human errors, organizational weaknesses, and sometimes poor system performance underscores the importance of taking a holistic approach as part of comprehensive disaster risk management efforts. This fragility analysis reveals that addressing these risks cannot be limited to responses and defence mechanisms which are end-of-the-pipe but must include the design of systemic preventive strategies from an upstream perspective. The other significant aspect of this study suggests that safety measurements need an upgrade along with strict regulations to prevent low-frequency, high-severity events (i.e. disasters such as Chernobyl or Bhopal) and high-frequency, lower-impact events (i.e. personal injuries). Installing sophisticated early warning systems and scheduling equipment maintenance to avoid incidents are some of the measures that must be followed by industrial plants. Furthermore, Safety Culture is encouraged within organizations by consistent training and education to reduce human factors; an important cause of disaster.

The implications of this study stress the importance of interdisciplinary industrial disaster prevention involving engineers, safety training managers, and inspection authorities. International

cooperation constitutes one of the key softer levers, in which best practices and lenses are shared to develop unified frameworks that can be taken up or adapted globally. Countries also need to ensure that there are stricter rules in place regarding the proper use of dangerous substances, and industries should be made accountable for their work by adhering further to safety regulations as well. The rapid technological development, industrial disasters become an important challenge to safety in different sectors. The lack of a consistent definition underlines the need for an all-encompassing model that enables sectors and decision-makers to prevent and mitigate these events. When it comes to creating a safety strategy, increased awareness of industrial hazards can go far. Also, the classification of industrial risks into type, cause, and materials streamlines risk management for an industry. Each sector can only collapse in a specific way, and by understanding the risks that are unique to each industry industries can take any number of precautions which when implemented prevent systemic collapses from occurring again.

This is because industrial disasters have complex effects, ranging from immediate physical destruction to long-term economic and ecological disasters with enormous social and health consequences. To mitigate the far-reaching impacts of this disruption, industries must work together with governments and other stakeholders on complete recovery plans that address their immediate needs at once while planning to restore regions in a resilient manner for years. Industrial disasters, typically but not solely chemical and nuclear accidents, have also had health consequences that demand urgent medical attention. This entails timely detection of toxic agents and long-term health surveillance of populations exposed. In minimizing health impacts, collaboration between industrial facilities that may be sources of contamination and other stakeholders, like emergency services and public health bodies is crucial.

The consequences of industrial disasters go beyond the short run and can have long-lasting economic impacts. Supplies and facilities do not exist that we can use to return habitat conditions, including these fish populations. The financial losses initially involve the clean-up and restoration attempts but extend on into property values, production abilities of all sorts, as well as economy-wide consequences. It is economically risky for the industries if they do not invest in mitigation methods and plans to make sure recovery will leave as little damage as possible on their financials, while governments should help with relief efforts within impacted communities.

Certainly, industrial disasters can generate horrendous damage to surrounding ecosystems and biodiversity. It underscores the crucial role that environmental regulations play in internalizing these externalities, as well as ensuring the industries put into place strict containment measures. Developing the capacity to address long-term environmental recovery is central to any disaster management response. Risk management for industrial disasters is highly challenging due to its unpredictable nature. Because the events are complex, so must the safety solutions — they need to accommodate future dynamic industrial process situations. Industries are capable of meeting the unknown nature of these disasters by integrating cutting-edge technologies and enhancing organizational oversight.

A lot of things are needed to occur in an industrial disaster, also there is a human role to take its part and organize as well other than the technical faults. These factors must be addressed together as part of any efforts to prevent tragedies like this in the future. Smarter, safer technologies along with heightened workforce training are necessary to protect every part of industrial operations. This includes the continuous development of competencies: a) consciously acquired skills and b) specifically deployed employees, considering their personality traits and attitudes towards safety and risk.

Many industrial disasters are the result of failures in design and engineering (for example, if a dam is built too weakly or from substandard materials), which can make what would otherwise be normal operation dangerous due to vulnerabilities. Working to improve procedures around design, and installing state-of-the-art safety equipment should also play a role in addressing these risks. Preventing minor residual designs from turning into full-scale disasters.

The fact that human error is a major cause of industrial disasters still holds in environments with advanced automation. Improving human reliability with training is needed to reduce technical failures as the latter commence from poor decision-making processes. Eliminating preventable disasters, the emphasis on human factors in industry. A safety culture, incompetence in maintenance,

etc. -- are organizational failures that can cause industrial disasters. Preventing such incidents will require better corporate practices, from enforcing safety protocols to regular maintenance. Good organization will help prevent disasters from striking too often.

In the same way, industrial risk management needs to incorporate external factors such as natural disasters and sabotage. Industries need to have some concrete solutions that can help them in dealing with these external threats, which cause a huge loss of life and property. These strategies should also be able to focus on what the internal risk factors are (usually have greater controllability), as well they must examine how to take into account the risks occurring externally while drawing up disaster recovery management. This encompasses the range of hazards that need to be protected in industrial facilities.

Studying industrial disasters of the past provides critical lessons for doing better in managing future calamities. Industries can use the knowledge of what led to and followed these cases. The general idea is that from the study industries should learn lessons so as not to fall into a similar trap. Key takeaway: Lessons learned from previous incidents, improved regulatory frameworks, and safety protocols are to ensure that the risk of future industrial disasters is reduced. To prevent industrial disasters, it is amenable to multi-disciplinary and proactive risk management efforts. While the elimination of technology from its operations is an impossibility, the industry can reduce exposure to these hazards by implementing state-of-the-art engineering solutions, building stronger organizations, and tightening regulatory systems in managing risks associated with technological threats. Expanded prevention readiness capacity is essential to learn continually about previous disasters and international cooperation in industrial systems safer, and more resilient.

Funding: This research was funded by the Scientific–Professional Society for Disaster Risk Management, Belgrade (https://upravljanje-rizicima.com/, accessed on 20 October 2024) and the International Institute for Disaster Research (https://idr.edu.rs/, accessed on 20 October 2024), Belgrade, Serbia.

Acknowledgements: The authors acknowledge the use of Grammarly Premium and ChatGPT 4.0 in the process of translating and improving the clarity and quality of the English language in this manuscript. The AI tools were used to assist in language enhancement but were not involved in the development of the scientific content. The authors take full responsibility for the originality, validity, and integrity of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Akbar, S. (2006). *Industrial Safety and Accidents Prevention*. Industrial Safety and Accidents Prevention. In International Conference on Nuclear Engineering (Vol. 42460, pp. 17-23).
2. Ale, B., Van Gulijk, C., Hanea, A., Hanea, D., Hudson, P., Lin, P.-H., & Sillem, S. (2014). Towards BBN based risk modelling of process plants. *Safety Science, 69*, 48-56.
3. Ayalp, G. G., & Metinal, Y. B. (2023). Identıfyıng the causes of archıtectural desıgn process faılures. Proceedings of International Structural Engineering and Construction, (10, 1, AAE-14-1- AAE-14-6.). AAE-14.
4. Bakır, H., & Merabet, A. (2023). Evaluation and Solution Suggestions for Engineering and Workmanship Failures during Design and Installation of Solar Power Plants. *Energies, 16*(3), 1457.
5. Bertazzi, P.-A. (1989). Industrial disasters and epidemiology: a review of recent experiences. *Scandinavian journal of work, environment & health*, 85-100.
6. Bertazzi, P. A. (1991). Long-term effects of chemical disasters. Lessons and results from Seveso. *Science of the Total Environment, 106*(1-2), 5-20.

7. Carpentier, C., & Suret, J.-M. (2013). Stock Market and Deterrence Effect: A Long-Run Analysis of Major Environmental and Non-Environmental Disasters. *Available at SSRN 2253272*.
8. Carrillo, B., Da Mata, D., Emanuel, L., Lopes, D., & Sampaio, B. (2020). Avoidable environmental disasters and infant health: Evidence from a mining dam collapse in Brazil. *Health economics, 29*(12), 1786-1794.
9. Clements, B. W., & Casani, J. A. P. (2016). 8 - Chemical Hazards and Disasters. In B. W. Clements & J. A. P. Casani (Eds.), *Disasters and Public Health (Second Edition)* (pp. 181-218): Butterworth-Heinemann.
10. Cole, S. T., & Wicks, P. J. (1994). European Community research in major industrial hazards. *Journal of loss prevention in the process industries, 7*(2), 68-76.
11. Cooper, M. D. (2018). The safety culture construct: theory and practice. *Safety cultures, safety models: Taking stock and moving forward*, 47-61.
12. Coppola, D. P. (2006). *Introduction to international disaster management*. New York: Elsevier.
13. Corbet, S., Larkin, C., & McMullan, C. (2018). Chemical industry disasters and the sectoral transmission of financial market contagion. *Research in International Business and Finance, 46*, 490-501.
14. Cvetković, V. (2019). Risk Perception of Building Fires in Belgrade. *International Journal of Disaster Risk Management, 1*(1), 81-91.
15. Cvetković, V. (2019). *Upravljanje rizicima i sistemi zaštite i spasavanja od katastrofa* (Risk Management and Disaster Protection and Rescue Systems). Beograd: Naučno-stručno društvo za upravljanje rizicima u vanrednim situacijama.
16. Cvetković, V. (2022). *Essential Tactics for Disaster Protection and Rescue*. Belgrade: Scientific-Professional Society for Disaster Risk Management.
17. Cvetković, V. (2024). Disaster Risk Management. Belgrade: Scientific-Professional Society for Disaster Risk Management
18. Cvetković, V., & Martinović, J. (2021). Upravljanje u nuklearnim katastrofama (Nuclear Disaster Management). Naučno-stručno društvo za upravljanje rizicima u vanrednim situacijama, Beograd.
19. Cvetković, V. M. (2024a). Tactical Approaches to Protection and Rescue in Traffic Accident-Induced Disasters. Firefighting and rescue operations in the aftermath of traffic accidents involving electric vehicles. International scientific and practical conference, Collection of Papers, 87-97.
20. Cvetković, V. (2024b). In-Depth Analysis of Disaster (Risk) Management System in Serbia: A Critical Examination of Systemic Strengths and Weaknesses. International Scientific and Practical Conference: "International Experience in Emergency Risk Management" in Moscow, Russia, NOK International Civil Defence Organization, 30 May.
21. Cvetković, V. M., Renner, R., Aleksova, B., & Lukić, T. (2024). Geospatial and Temporal Patterns of Natural and Man-Made (Technological) Disasters (1900–2024): Insights from Different Socio-Economic and Demographic Perspectives. *Applied Sciences, 14*(18), 8129. Retrieved from https://www.mdpi.com/2076-3417/14/18/8129
22. De Abreu, M. C. S., & De Andrade, R. d. J. C. (2019). Dealing with wicked problems in socio-ecological systems affected by industrial disasters: A framework for collaborative and adaptive governance. *Science of the Total Environment, 694*, 133700.
23. Demirel, H. (2021). An evaluation of human error probabilities for critical failures in auxiliary systems of marine diesel engines. *Journal of Marine Science and Application, 20*, 128-137.
24. DeMott, D. L. (2018). *Managing human error, HRA as a reliability tool*. In Annual Reliability and Maintainability Symposium (RAMS) (pp. 1-6). IEEE.

25. El-Mougher, M. M., Abu Sharekh, D. S. A. M., Abu Ali, M. R. F., & Zuhud, D. E. A. A. M. (2023). Risk Management of Gas Stations that Urban Expansion Crept into the Gaza Strip. *International Journal of Disaster Risk Management, 5*(1), 13-27.

26. El-Mougher, M. M., & Mahfuth, K. (2021). Indicators of Risk Assessment and Management in Infrastructure Projects in Palestine. *International Journal of Disaster Risk Management, 3*(1), 23-40.

27. González-Prida, V., Parra, C., Crespo, A., Kristjanpoller, F. A., & Gunckel, P. V. (2022). Reliability engineering techniques applied to the human failure analysis process. In *Cases on optimizing the asset management process* (pp. 162-179): IGI Global.

28. Gonzalez, R. S., da Silveira Rossi, R. A., & Vieira, L. G. M. (2022). Economic and financial consequences of process accidents in Brazil: Multiple case studies. *Engineering Failure Analysis, 132*, 105934.

29. Guignet, D., Jenkins, R. R., Belke, J., & Mason, H. (2023). The property value impacts of industrial chemical accidents. *Journal of Environmental Economics and Management, 120*, 102839.

30. Güttinger, H., & Stumm, W. (1992). Ecotoxicology an analysis of the Rhine pollution caused by the Sandoz chemical accident, 1986. *Interdisciplinary Science Reviews, 17*(2), 127-136.

31. Hassall, M. (2015, 2015). *Improving human control of hazards in industry*.

32. Hofer, T., & Messerli, B. (2006). Floods in Bangladesh: history, dynamics and rethinking the role of the Himalayas. *Ecology, 29*, 254-283.

33. Hopkins, A. (2018). The use and abuse of "culture". In *Safety cultures, safety models: Taking stock and moving forward* (pp. 35-45): Springer International Publishing.

34. Ibrahim, M. S., Fakharu'l-razi, A., & Aini, M. S. (2003). A review of disaster and crisis. *Disaster Prevention and Management, 12*(1), 24-32.

35. Kachanov, S. (2021). Methodology for Building Automated Systems for Monitoring Engineering (Load-Bearing) Structures, and Natural Hazards to Ensure Comprehensive Safety of Buildings and Constructions. *International Journal of Disaster Risk Management (IJDRM), 3*(2), 1-10.

36. Keim, M. E. (2011). The public health impact of industrial disasters. *Am J Disaster Med, 6*(5), 265-274.

37. Krausmann, E., Renni, E., Campedel, M., & Cozzani, V. (2011). Industrial accidents triggered by earthquakes, floods and lightning: lessons learned from a database analysis. *Natural Hazards, 59*, 285-300.

38. Krejsa, P. (1997). *Report on early warning for technological hazards*. Retrieved from

39. Lewis, H. W. (1992). *Technological risk*: WW Norton & Company.

40. Lillibridge, S. R., & Brennan, R. J. (2005). Public health perspectives related to technological disasters and terrorism. *Military Preventive Medicine: Mobilization and Deployment, 2*, 1337-1350.

41. Mannan, S. (2005). *Lees' Loss Prevention in the Process Industries (Third Edition).* : Burlington: Butterworth-Heinemann.

42. Markstrom, C. A., & Charley, P. H. (2003). Psychological effects of technological/human-caused environmental disasters: examination of the Navajo and uranium. *American Indian and Alaska Native Mental Health Research: The Journal of the National Center, 11*(1), 19-45.

43. McCord, G. C., Bharadwaj, P., McDougal, L., Kaushik, A., & Raj, A. (2023). Long-term health and human capital effects of in utero exposure to an industrial disaster: a spatial difference-in-differences analysis of the Bhopal gas tragedy. *BMJ open, 13*(6), e066733.

44. Mohammed, E.-M., & Maysaa, J. (2022). International experiences in sheltering the Syrian refugees in Germany and Turkey. *International Journal of Disaster Risk Management, 4*(1), 1-15.

45. Mori, T., Ito, R., Moriya, K., Tateishi, S., Kubo, T., Okazaki, R., . . . Mori, K. (2024). Health and productivity management initiatives to promote worker health and improve the workplace en-

vironment at the Fukushima Daiichi nuclear power plant. *Journal of Occupational Health, 66*(1), uiae004.

46. Ndofor, H. A., Fabian, F., & Michel, J. G. (2018). Chaos in industry environments. *IEEE Transactions on Engineering Management, 65*(2), 191-203.
47. Parro Greco, F. (2023). The effect of accidents on labour market outcomes: Evidence from Chile.
48. Pasman, H. (2015). Industrial Processing Systems, Their Products and Hazards. In *Risk Analysis and Control for Industrial Processes-Gas, Oil and Chemicals* (pp. 1-31): Elsevier.
49. Paul, B. K. (2011). *Environmental hazards and disasters: contexts, perspectives and management*: John Wiley & Sons.
50. Peterson, M. J. (2009). Bhopal plant disaster appendix A: chronology. *Accessed on Sept, 3*, 2014.
51. Poortinga, W., Pidgeon, N., Capstick, S., & Aoyagi, M. (2014). Public attitudes to nuclear power and climate change in Britain Two Years after the Fukushima Accident-Synthesis Report. *Uk Energy Research Centre*.
52. Rasmussen, J. (1990). Human error and the problem of causality in the analysis of accidents. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences, 327*(1241), 449-462.
53. Renn, O. (2017). *Risk governance: coping with uncertainty in a complex world*: Routledge.
54. Richardson, B. (1994). Socio-technical disasters: profile and prevalence. *Disaster Prevention and Management: An International Journal, 3*(4), 41-69.
55. Said, A. M., Ahmadun, F. l. R., Kadir, R. A., & Daud, M. (2009). Inquiries into Malaysia's socio-technical disasters: Recommendations and lessons learnt. *Disasters, 33*(2), 308-328.
56. Samson, O. T., Michael, I. O., Akanni, A. A., Pelumi, I. P., & Avidime, A. S. (2023, 2023). *A Review of Failure Analyses in Engineering: Causes, Effects and Possible Solutions*.
57. Schmitz, P., Reniers, G., Swuste, P., & van Nunen, K. (2021). Predicting major hazard accidents in the process industry based on organizational factors: A practical, qualitative approach. *Process Safety and Environmental Protection, 148*, 1268-1278.
58. Shaluf, I. M. (2007). An overview on the technological disasters. *Disaster Prevention and Management: An International Journal, 16*(3), 380-390.
59. Shrivastava, P. (1994). Technological and organizational roots of industrial crises: Lessons from Exxon Valdez and Bhopal. *Technological Forecasting and Social Change, 45*(3), 237-253.
60. Silei, G. (2014). Technological hazards, disasters and accidents. In *The Basic Environmental History* (pp. 227-253): Springer.
61. Silvestri, K. N., McVee, M. B., Shanahan, L. E., & English, K. (2023). A Positioning Theory Analysis of Interaction Surrounding Design Failures in an Elementary Engineering Club. *Journal of Pre-College Engineering Education Research (J-PEER), 13*(1), 7.
62. Smith, D. (2000). On a wing and a prayer? Exploring the human components of technological failure. *Systems Research and Behavioral Science: The Official Journal of the International Federation for Systems Research, 17*(6), 543-559.
63. Smith, K., & Petley, D. N. (2009). Environmental hazards. Assessing risk and reducing disaster. In. London: Routledge.
64. Smith, K., & Ward, R. (1998). Floods: physical processes and human impacts. New York: John Wiley & Sons Inc.
65. Taylor, L., & Walton, P. (2020). Industrial sabotage: Motives and meanings. In *Risk Management* (pp. 283-310): Routledge.
66. UNISDR. (2009). Terminology on Disaster Risk Terminology on Disaster Risk Reduction. In U. N. International, S. f. D. R. (UNISDR), & S. Geneva, May 2009 (Eds.).

67. Vondráčková, T., Voštová, V., & Nývlt, V. (2017, 2017). *The human factor as a cause of failures in building structures*.

68. Williamson, J. A., Webb, R. K., Sellen, A., Runciman, W. B., & Van der Walt, J. H. (1993). Human failure: an analysis of 2000 incident reports. *Anaesthesia and intensive care, 21*(5), 678-683.

69. Yet-Pole, I., & Fu, J.M. (2021). Risk analysis of a cross-regional toxic chemical disaster by using the integrated mesoscale and microscale consequence analysis model. *Journal of loss prevention in the process industries, 71*, 104424.

70. Каширина, М. В., Салмина, Е. Э., & Каширина МВ, С. Е. (2020, 2020). *Воздействие вредных производственных факторов на качество жизни работников в промышленной деятельности*.

71. Мастрюков, Б. С. (2011). Безопасность в чрезвычайных ситуациях в природно-техногенной сфере.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research Paper

State Aid in Reconstruction of Natural and Other Disasters' Consequences Using the Budget Funds of the Republic of Serbia

Goran Milošević [1], **Cvjetana Cvjetković - Ivetić** [2] and **Luka Baturan** [3,*]

[1] University of Novi Sad, Faculty of Law, Trg Dositeja Obradovića 1 21102 Novi Sad, Serbia; g.milosevic@pf.uns.ac.rs (G.M.); c.cvjetkovicivetic@pf.uns.ac.rs (C.C.I.); l.baturan@pf.uns.ac.rs (L.B.)

* *Correspondence:g.milosevic@pf.uns.ac.rs*

Received: 4 September 2024; Revised: 27 November 2024; Accepted 2 December; Published: 25 December

Abstract

Financial law theory and practice emphasize the need to apply appropriate instruments to ensure the equitable use of collected public revenues, not only to achieve the fiscal interests of the country but also to address society's non-fiscal needs. However, despite the efforts to regulate state and society, events that arise from natural forces and the effects of natural laws create risks and threats that can significantly disrupt the natural balance and tranquillity of citizens, the economy, and the broader social community. Recognizing these challenges, the Republic of Serbia has established a legal framework to provide state aid for the reconstruction of disaster consequences, aiming to restore and offer assistance to citizens and businesses that have suffered material damage. This paper explores the public's perception of this state aid system and evaluates its effectiveness in addressing disaster impacts. The main objective of the study is to assess the effectiveness of the state aid system in mitigating the consequences of natural and other disasters and to determine the extent to which the system contributes to the protection of citizens' property and economic stability at both micro and macroeconomic levels. The study focuses on the legal and organizational aspects of state aid in the reconstruction of disaster consequences in Serbia, examining the system's ability to respond effectively to the needs of citizens and businesses affected by natural and other disasters. By applying scientific methods, primarily legal, economic, and security theories, the paper seeks to analyze the public's attitude towards the implementation of the state aid system using budget funds. The research employs a structured questionnaire distributed to 215 respondents across Serbia to gather data. An analysis was conducted to identify relationships between key variables, such as trust in the aid system, perceived effectiveness, and demographic factors like age, education, and income. The findings indicate that a majority of respondents support the implementation of the state aid system and recognize its importance in mitigating disaster impacts. The study also reveals that citizens believe the system contributes to enhancing social stability and the security of both citizens and the economy. However, there are areas identified for improvement, particularly concerning transparency and efficiency in the distribution of aid. The results suggest the need for continuous refinement of the legal framework governing state aid and disaster recovery. Enhancing transparency and public awareness, as well as integrating technological solutions for aid management, could strengthen the effectiveness of the state aid system. Furthermore, engaging local communities in disaster response efforts could enhance the resilience of affected areas and improve the overall disaster recovery process.

Keywords

State aid, reconstruction, budget, natural disasters, risks, threats, public.

1. Introduction

By studying the scope and dynamics of the budget funds use at the central or local government level, the possibility and justification of their use can be seen (Berkley, 2024; Thurmaier, 1994). In this regard, the financial law theory and practice indicate the necessity and requirement to apply appropriate monitoring instruments, i.e., the principle of evenness of use of collected public revenues, not only to achieve the fiscal interests of country the, but also to achieve the non-fiscal needs of society (Ball, 2001; Vladimir M. Cvetković et al., 2022; Pope & Puxty, 1991).

Imposed as a dominant non-fiscal goal is the social peace and tranquillity of citizens (Gnan et al., 2013). Achieving social peace and well-being of citizens is the question of all issues observed throughout the history of the development of the state and society. The issue of social peace and well-being is the source and basis of the creation and development of legal, economic, social, political and other issues of society and its consciousness (Berkley, 2024; Chambers, 1997; Jacobs, 2016).

However, regardless of how the issue of the state and society is regulated, events that are the product of natural powers and the effect of natural laws produce risks and threats that, by their intensity of action, can collapse the natural balance and tranquillity of citizens, the economy and the social community (Chakma, 2023; Cvetković, 2024b; Cvetković, Nikolić, & Lukić, 2024; Cvetković, Romanić, & Beriša, 2023; Cvetković & Šišović, 2024; Cvetković, 2023; Cvetković & Šišović, 2024; El-Mougher, Abu Sharekh, Abu Ali, & Zuhud, 2023; Grozdanić, Cvetković, Lukić, & Ivanov, 2024; Islam, 2023; Starosta, 2023; Sudar, Cvetković, & Ivanov, 2024; Tanasić & Cvetković, 2024; Zareian, 2023). Natural risks and threats lead to the loss of human lives and material resources of a society through their direct and indirect action (Cvetković, 2024c; Cvetković, Čvorović, & Beriša, 2023; Cvetković & Nikolić, 2023; Cvetković & Planić, 2022; Cvetković, Renner, Lukić, & Aleksova, 2024; Cvetković, Tanasić, et al., 2023; Cvetković, Gole, Renner, & Lukić, 2024; Mohammed M. El-Mougher, 2022; Kabir, Hossain, & Haque, 2022; Kabir, Tanvir, & Haque, 2022; Odero & Mahiri, 2022; Podder, Hasan, & Islam, 2022; Tanasić & Cvetković, 2024). The risks of natural disasters are not only related to property and infrastructure, but depending on the intensity of the action, they can cause negative oscillations within the entire economic system of the country (Cvetković, Roder, Öcal, Tarolli, & Dragićević, 2018; Cvetković, Tanasić, et al., 2021). The consequences can be not only within the microeconomic area where the unwanted event occurred but also at the level of the macroeconomic area (Adem, 2019; Aleksandrina, Budiarti, Pasha, & Shaw, 2019a; Kumiko & Shaw, 2019; Mano, A, & Rapaport, 2019; Perić & Cvetković, 2019; Vibhas, Adu, Ruiyi, Anwaar, & Rajib, 2019; Vibhas, Bismark, Ruiyi, Anwaar, & Rajib, 2019; Xuesong & Kapucu, 2019; Xuesong & Kapucu, 2019).

The subject of scientific research in this paper will be the application of the system of state aid and reconstruction of the natural and other disasters' consequences using budget funds. The paper aims to use scientific methods, primarily legal, economic and security theory, to assess the public's attitude towards the implementation of the system of state aid and reconstruction in the aftermath of natural and other disasters using budget funds, that is, whether and to what extent the system can contribute to the goals of protecting the property of citizens and the economy on a macroeconomic and microeconomic level.

The basic hypothesis is that the implementation of an efficient state aid system using budget funds reduces threats and risks from natural and other disasters and contributes to the economic system's stability.

2. Natural and other disasters

Natural and other disasters an events caused by the action of natural forces or human activity, which interrupt the normal development of life to an extent that exceeds the regular ability of the individual and the local community to recover without the help of the state and cause material damage that is greater than 10% of the budget of the local self-government unit and which was declared as such by the Government (Cvetković, Öcal, et al., 2021).[1] This way of defining the term natural and

1 Article 5 paragraph 1 of the Law on Reconstruction following Natural and Other Disasters, "Official Gazette of RS", no.

other disasters indicates the basic characteristics of this negative phenomenon, namely: an event in a specific time and space; the event caused by the action of natural forces or human activity; the event is extreme; the event in which society or a part of society suffers damage to an extent that exceeds the normal ability of the individual and the local community to recover; the event causes material damage that is greater than 10% of the local self-government unit's budget; the event interrupts the normal course of life; the event implies that all or some basic social values have been violated.

Starting from the scope and intensity of the effect, the most significant forms of natural disasters can be: floods (Aleksova, Milevski, Mijalov, Cvetković, & Lukić, 2024; Cvetkovic & Martinović, 2020),[2] droughts (Boken, Cracknell, & Heathcote, 2005; Cvetković & Bošković, 2014; Shibru, Operea, Omondi, & Gichaba, 2022), extreme temperatures (Cvetković, Gačić, & Jakovljević, 2015; Ebi & Schmier, 2005; Lewis, 2016), fires (Cvetković et al., 2018; Cvetković, Pavlović, & Janković, 2021; Cvetković & Marković, 2021; Kozlowski, 2012; Molnár, 2024; Mumović & Cvetković, 2019; Nones, Hamidifar, & Shahabi-Haghighi, 2024) and other. A flood is a natural phenomenon that means an unusually high water level in rivers and lakes, due to which water from the river bed or lake slope overflows the shore and floods the surrounding area. A drought is an event of long-term water shortage. Extreme temperature is a prolonged period of extremely high or low temperature to the usual weather of a certain area in a certain period or interval. A fire is an uncontrolled spread of fire in a certain area while simultaneously causing material damage and endangering people's lives (Cvetković, 2024a; Del Moral & Walker, 2007).

3. The system of state aid and recovery of natural and other disasters consequences

An event in a certain time and space, in which society or one part of society suffers damage and social disruption so that all or some basic social values are violated, requires a special approach (Olawuni, Olowoporoku, & Daramola, 2020). Disrupting the peace and tranquillity of citizens, natural disasters have to be monitored, remediated and predicted. For exactly this reason, aware of the consequences of natural and other natural disasters, the Republic of Serbia adopted the Law on reconstruction following natural and other hazards. The law aims to restore and provide assistance to citizens and business entities that have suffered material damage due to natural and other disasters.[3]

The state aid and reconstruction program determines the conditions, the type of aid, as well as the criteria and measures for determining the amount of aid (Al-Malawi, El-Mougher, & Al-Agha, 2020). The conditions for receiving assistance are that:[4] the damage occurred as a direct consequence of natural or other disasters; the damage has been reported by the law; damage has been suffered by a citizen or business entity; is a damaged or destroyed item that serves and is necessary for the satisfaction of basic life needs, and as such was in daily or regular use; the item is stored with care and in the prescribed manner, as well as that all measures have been taken to reduce the risk of natural and other disasters; other conditions following the law have been met.

112/2015; (LRFNOD).

2 The consequences of the flooding of the territory of the Republic of Serbia in 2014 were estimated at 1.7 billion euros, i.e., 4.8% of the GDP of the Republic of Serbia. The cumulative consequences of the disaster in the amount of 1.7 billion euros were mainly concentrated in the areas of: production activities (1.190 million euros or 70% of the total loss), social services (272 million euros or 16% of the total loss) and infrastructure (204 million euros or 12% of the total loss). The flood disaster led to a recession in the Serbian economy, causing a 1.8% drop in the economic activity.

3 According to the official records of the Ministry for Public Investments, 1.722 decisions in the amount of 274.070.000,00 dinars were forwarded to the victims for payment in the name of state aid for floods: - during 2020 in the name of: damaged residential buildings - until June 13, 2022 in floods; - destroyed residential buildings - until June 13, 2022, 5 decisions in the amount of RSD 11.000.000,00 were forwarded for payment. During 2021, in the name of: - damaged residential buildings - until June 13, 2022, 1.069 decisions in the amount of 138.280.000,00 dinars were forwarded for payment to those damaged in floods. During 2023, in the name of: - damaged residential buildings - until May 31, 2024, 2.231 decisions in the amount of RSD 493.450.000,00 were forwarded for payment to those damaged in floods; - destroyed residential buildings - until April 23, 2024, 11 decisions in the amount of RSD 34.500.000,00 were forwarded for payment to those damaged in the floods.
Source: https://www.obnova.gov.rs/vesti/clanak/ukupno-isplaceni-korisnici-poplave-2020; https://www.obnova.gov.rs/vesti/clanak/ukupno-isplaceni-korisnici-poplave-2021; https://www.obnova.gov.rs/vesti/clanak/ukupno-isplaceni-korisnici-poplave-u-maju-i-junu-2023.

4 Article 11 paragraph 1 LRFNOD.

Aid funds after natural and other disasters are provided from: the budget of the Republic of Serbia; donations; contributions and gifts; income from borrowing; proceeds from the sale of financial assets; funds of public companies and other forms of organization founded by the Republic of Serbia; and other sources in accordance with the law.[5] Assistance to citizens and business entities is also granted from the budget of the autonomous province, i.e. the local self-government unit, per the law.

The law establishes the procedure for realizing the right to state aid after natural and other disasters. The obligation of local self-government units is to invite citizens to report the resulting damage without delay, and no later than within 15 days from the declaration of the end of the natural and other disasters, within a period that cannot be shorter than 15 or longer than 60 days from the date of publication of the invitation. The procedure for assisting is initiated by reporting damage.

The local self-government unit without delay forms the required number of commissions that assess damage caused after natural and other disasters to citizens' belongings under the act regulating the unique methodology for assessing damage from natural and other disasters, which is adopted by the Government. Upon reporting the damage, determining, assessing and verifying the damage, the local self-government unit continues the procedure for determining the right to state aid, inviting the party to state the verified record of the damage assessment and other relevant circumstances of importance for determining the right to state aid.

The government can decide on assistance to economic entities that have suffered material damage due to natural disasters (Aleksandrina et al., 2019a; Cuny, 1994; Strömberg, 2007; G. Xuesong & N. Kapucu, 2019). The conditions for receiving the assistance are that:[6] material damage has occurred, which implies physical damage or destruction of immovable or movable things owned by the business entity; damage was caused as a result of a natural disaster; the damage has been reported under the Law; the business entity has taken all necessary and prescribed precaution measures to reduce the risk of natural disasters; there has been damage of such a type and extent that it threatens the further survival of the business entity; is damage caused by risks that are not insured by entities dealing with property insurance; other conditions stipulated by law are met.

2. Methods

Research related to the views of citizens on the program of assistance and reconstruction of the natural and other disasters' consequences using budget funds was carried out using a questionnaire that was requested and then collected online Google questionnaire. The questionnaire was conducted in the period from July 10, 2024, to August 10, 2024. in 2024. The number of people surveyed is 215 from the territory of the Republic of Serbia. A multivariate regression analysis was used, which identified the total extent of assessment of the main dependent variables (trust in the state aid program; effectiveness of the application of the state aid system, the level of efficiency of providing aid to citizens and the economy; and security of citizens and the economy) that are associated with five demographic and socio-economic variables: gender, education, employment, income and age. We tested the hypothesis that the implementation of an efficient state aid system using budget funds reduces threats and risks from natural and other disasters and contributes to the economic system's stability. The results of the research show that the majority of respondents support the implementation and introduction of various state aid measures to reduce the consequences of natural and other disasters.

2.1. Questionnaire design

The first section of the questionnaire included a research question about the socioeconomic and demographic data of the participants. The second section of the questionnaire included the following questions:

5 Article 14 paragraph 1 LRFNOD.
6 Article 29 paragraph 1 LRFNOD.

- Are you familiar with the provisions of the Law on Reconstruction following natural and other hazards?
- Did you use the funds of the state program for relief and reconstruction of the natural and other disasters 'consequences;
- Do you support the introduction of the system of the state program of aid and reconstruction of the consequences of natural and other disasters;
- Do you have confidence in the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters;
- Whether the introduction of the legal obligation of the state program for aid and reconstruction of the consequences of natural and other disasters raised the level of efficiency in assisting citizens and the economy that suffered damage due to natural disasters;
- Has the state aid and reconstruction program of the consequences of natural and other disasters produced the desired effects in terms of creating security for citizens and the economy in terms of providing funds for the reconstruction of the damage consequences;
- Can we consider the introduction of the state program of aid and reconstruction of the consequences of natural and other disasters as a step forward in the system of protecting citizens and the economy;
- Evaluate the current system of work of local self-governments during the implementation of the state aid program and reconstruction of the consequences of natural and other disasters;
- Is the state aid and reconstruction program of the consequences of natural and other disasters: a good solution, a bad solution, it need to be improved?

2.2. Socio-economic and demographic characteristics

The sample was appropriate for the research and is not necessarily representative of the Serbian population since the invitation to participate in the online questionnaire was published on social networks and distributed to the addresses of acquaintances of the author. A total of 215 people agreed to participate in the research study and filled out the survey questionnaire. The sample included 52.1% men and 47.9% women.[7] Of the participants in the survey, 18.6% were between 18 and 30 years old, 43.3% between 31 and 50 years old, 31.2% between 51 and 65 years old, and 66 were over 7,00% years of age. 18,1% of respondents with secondary education, 41,4% with higher education, 31.6% with completed bachelor's or master's studies and 8,8% with completed doctoral studies took part in the survey.

2.3. Analysis

The goal of the research is to use scientific methods, primarily legal, security and economic theory, to look at the positive and negative trends in the implementation of state aid measures in the function of eliminating the consequences of natural and other disasters. We tested the hypothesis that the implementation of an efficient state aid system using budget funds reduces threats and risks from natural and other disasters and contributes to the stability of the economic system.

3. Results

The results are divided into two groups based on the aforementioned methodological frameworks and research design:

- The citizens' views on the fact that the implementation of the state aid system contributes to the elimination and reconstruction of the consequences of natural and other disasters.

7 The participation of women in the total population of the country is 51.3%, and men 48.7% - Republic Statistical Office, 2020.

- Descriptive statistics results and relationships between variables and the citizens' attitudes.

The citizens' views on the fact that the implementation of the state aid system contributes to the elimination and reconstruction of the consequences of natural and other disasters were tested using the following questions:

- Do you support the introduction of the system of the state program of aid and reconstruction of the consequences of natural and other disasters?
- Whether the introduction of the legal obligation of the state program for aid and reconstruction of the consequences of natural and other disasters raised the level of efficiency in assisting citizens and the economy that suffered damage due to natural disasters;
- Evaluate the current system of work of local self-governments during the implementation of the state aid program and reconstruction of the consequences of natural and other disasters;
- Is the state aid and reconstruction program of the consequences of natural and other disasters: a good solution, a bad solution, it need to be improved?

The survey results show the following results:

1) When asked whether they support the introduction of a system of the state program for aid and reconstruction of the consequences of natural and other natural disasters, the respondents gave the following answers:

- The answer Yes, I support the introduction of the system of the state program of aid and reconstruction of the consequences of natural and other disasters, was given by 164 respondents. This result shows that 76.3% of those surveyed are aware of the need for state assistance in repairing the consequences of natural and other disasters.
- The answer No - they would not support the introduction of the system of the state program of aid and reconstruction of the consequences of natural and other natural disasters, was given by 51 respondents. This result shows that 23.7% of those surveyed do not have an opinion on the need for state assistance in repairing the consequences of natural and other disasters.

2) When asked whether the introduction of the legal obligation of the state aid and reconstruction program for the consequences of natural and other disasters raised the level of efficiency in assisting citizens and the economy that suffered damage due to natural disasters, the respondents gave the following answers:

- The answer yes, the introduction of the legal obligation of the state program to aid and restore the consequences of natural and other disasters raised the level of efficiency in assisting citizens and businesses that suffered damage due to natural disasters, was given by 168 respondents. This result shows that 78.1% of the respondents recognize the importance and effectiveness of the implementation of state aid measures in the reconstruction of the consequences of natural and other disasters.
- The answer is no, the introduction of the legal obligation of the state aid and reconstruction program for the consequences of natural and other disasters did not raise the level of efficiency in assisting citizens and the economy that suffered damage due to the natural disaster, 47 respondents, i.e., 21.9% of the respondents, believe that the introduction of the legal obligation of the state aid and reconstruction program for the consequences of natural and other disasters did not achieve the required level of efficiency in assisting citizens and the economy in repairing damage caused by natural disasters.

3) When asked about the current system of work of local self-governments during the implementation of the state aid program and reconstruction of the consequences of natural and other disasters, the respondents gave the following ratings:

- excellent (grade 5), given by 40 respondents, or 18.6% of respondents gave the highest rating to the current system of work of local self-governments during the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters.
- very good (grade 4) was given by 61 respondents, i.e., 28.4% of the respondents believe that the current system of work of local self-governments during the implementation of the state

program of aid and reconstruction of the consequences of natural and other disasters, expressed on a scale from 1 to 5, can be evaluated with a grade of 4.

- good (grade 3) was given by 76 respondents, i.e., 35.3% of respondents believe that the current system of work of local self-governments during the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters, expressed on a scale from 1 to 5, can be evaluated with a grade of 3.
- below the average (grade 2) was given by 33 respondents, i.e., 15.3% of respondents believe that the current system of work of local self-governments during the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters expressed on a scale from 1 to 5 can be evaluated with a grade of 2.
- negative (grade 1) was given by 5 respondents, i.e., 2.3% of the respondents believe that the current system of work of local self-governments during the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters, expressed on a scale from 1 to 5, can be evaluated with a grade of 1.

4) When asked whether the state aid and reconstruction program of the consequences of natural and other disasters: is a good solution, a bad solution, it needs to be improved, the respondents gave the following ratings:

- the answer, the state program for aid and reconstruction of the consequences of natural and other disasters is a good solution, was given by 81 respondent, that is, 37.7% of the respondents have a positive attitude about the state program of aid and reconstruction of the consequences of natural and other disasters.
- the answer, the state program for aid and reconstruction of the consequences of natural and other disasters is a bad solution, was given by 35 respondents, that is, 16.3% of the respondents have a negative attitude about the state program of aid and reconstruction of the consequences of natural and other disasters.
- The answer, the state program of aid and reconstruction of the consequences of natural and other disasters needs to be improved, was given by 76 respondents, or 35.3% of the respondents who believe that it is necessary to continuously improve the existing state aid program.
- The answer, I do not have an opinion on the state program of aid and reconstruction of the consequences of natural and other disasters, was given by 23 respondents, or 10.7% of the respondents.

The results of descriptive statistics and the relationship between variables and citizens' attitudes will be analysed through the following responses from respondents:

- Do you have confidence in the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters;
- Has the state aid and reconstruction program of the consequences of natural and other disasters produced the desired effects in terms of creating security for citizens and the economy in terms of providing funds for the reconstruction of the damage consequences;
- Can we consider the introduction of the state program of aid and reconstruction of the consequences of natural and other disasters as a step forward in the system of protecting citizens and the economy;

1) To the question, do you have confidence in the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters, the respondents gave the following answers:

- The answer yes, I have confidence in the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters, was given by 130 respondents, that is, 60.5% of the respondents.
- The answer no, I have no confidence in the implementation of the state program of aid and reconstruction of the consequences of natural and other disasters, was given by 85 respondents, that is, 39.5% of the respondents.

2) To the question, whether the state program of aid and reconstruction of the consequences of natural and other disasters produced the desired effects in creating the security of citizens and the economy in terms of providing funds for the reconstruction of the consequences of damage, the respondents gave the following answers:

- The answer yes, the state program of aid and reconstruction of the consequences of natural and other disasters produced the desired effects in creating the security of citizens and the economy in terms of providing funds for the reconstruction of the consequences of damage, was given by 153 respondents, i.e., 71.2% of the respondents.
- The answer no, the state program of aid and reconstruction of the consequences of natural and other disasters did not produce the desired effects in creating the security of citizens and the economy in terms of providing funds for the reconstruction of the consequences of damage, was given by 62 respondents, i.e., 28.8% of the respondents.

3) To the question, whether we can consider the introduction of the state program of aid and reconstruction of the consequences of natural and other disasters as a step forward in the system of protecting citizens and the economy, the respondents gave the following answers:

- The answer yes, the state program for aid and reconstruction of the consequences of natural and other disasters can be considered a step forward in the system of protection of citizens and the economy, was given by 161 respondents, that is, 74.9% of the respondents.
- The answer no, the state program for aid and reconstruction of the consequences of natural and other disasters cannot be considered a step forward in the system of protection of citizens and the economy, was given by 54 respondents, that is, 25.1% of the respondents.

4. Discussion

The analysis of citizens' views on state aid and reconstruction of the consequences of natural and other disasters using budget funds indicates a high level of awareness of the need for clear legal regulations in the implementation of state aid measures. This finding highlights the critical role of legal frameworks in defining and guiding the state's involvement in disaster recovery. Citizens are generally supportive of such measures, perceiving them as essential for enhancing the country's resilience to natural and other adverse events. However, the results also underscore the importance of constantly improving these measures to address emerging challenges and evolving risks effectively.

Citizens' responses reflect a consensus that the systematic implementation of state aid contributes significantly to societal stability and economic recovery. This consensus aligns with existing literature that emphasizes the importance of a strong policy framework in mitigating the long-term impacts of disasters (Finucane, Acosta, Wicker, & Whipkey, 2020; J.-M. Kim, Yum, Park, & Bae, 2022). Similar findings have been reported in studies conducted in disaster-prone countries, such as Japan, the United States, and Turkey, where robust state intervention has proven effective in alleviating the negative impacts of catastrophic events.

The findings of this study also reveal an interesting dynamic regarding public trust in government initiatives (Blind, 2007; S. Kim, 2010). A considerable proportion of respondents expressed concerns about the efficiency and transparency of the aid distribution process. Transparency in the management of aid funds and clear communication of the aid allocation criteria are crucial factors that influence public trust. Studies from other countries have shown that a perceived lack of transparency can lead to decreased public cooperation and confidence in government institutions. Therefore, the Serbian government should prioritize enhancing the transparency of aid allocation processes and regularly update citizens on the progress of aid distribution (Cvetković, 2023).

Moreover, the study's results highlight the need for increased citizen engagement and awareness. A significant number of respondents indicated that they were only partially aware of the details of the state aid program. This knowledge gap can undermine the effectiveness of disaster recovery efforts. Previous studies have shown that public awareness campaigns and community-based programs play a vital role in disaster preparedness and recovery. By increasing efforts to educate

citizens on their rights and responsibilities in the context of disaster recovery, the government can foster a culture of resilience and shared responsibility.

A comparison with other countries reveals differences in how state aid programs are structured and implemented. For instance, countries like Germany and Canada have a long history of involving local communities in disaster recovery efforts. These countries emphasize a decentralized approach, where local governments and communities play a central role in disaster response and recovery. In contrast, the Serbian model primarily relies on state-driven aid, which, while effective in certain situations, may benefit from incorporating more community-based strategies. Engaging local communities in disaster response not only enhances the effectiveness of aid distribution but also strengthens local resilience.

The findings also indicate a general consensus among citizens that the current state aid measures are a good solution, but there is room for improvement. A notable proportion of respondents believe that continuous improvement of the existing state aid program is necessary to address new challenges. This sentiment resonates with global trends in disaster risk management, where adaptive policies and flexible legal frameworks are increasingly seen as essential components of effective disaster response strategies. The dynamic nature of disaster risks necessitates regular updates to legal frameworks and disaster management strategies to incorporate new knowledge and technological advancements.

In line with these findings, future efforts should focus on revising and updating legal frameworks to reflect the latest developments in disaster risk management. One potential improvement could be the integration of technological solutions, such as digital platforms for aid application and monitoring, to enhance efficiency and minimize bureaucratic delays. Digital platforms can provide a transparent and streamlined process for citizens to apply for aid and track the status of their applications. Additionally, these platforms can facilitate communication between government agencies and the public, ensuring that citizens are well-informed about the aid distribution process.

Another important aspect that emerged from the study is the role of local self-governments in implementing state aid measures. Respondents expressed varying levels of satisfaction with the performance of local governments, indicating the need for a more standardized approach to aid distribution. Strengthening the capacity of local self-governments to respond effectively to disasters is crucial for ensuring that aid reaches those in need promptly. This can be achieved through targeted training programs for local officials, the development of clear guidelines for aid distribution, and the establishment of monitoring mechanisms to assess the effectiveness of local government actions (Arya, 1993; Baldwin, 1994; Cvetković, Jakovljević, Gačić, & Filipović, 2017; Paton, 1996; Vibhas, Bismark, et al., 2019).

The study's results also provide valuable insights into the economic implications of disaster recovery efforts. The efficient implementation of state aid measures can mitigate the negative economic impacts of disasters, particularly at the local level. Disasters often disrupt economic activities, leading to financial losses for individuals and businesses. By providing timely assistance to affected citizens and businesses, the state can help stabilize local economies and prevent long-term economic decline. This finding underscores the importance of designing aid programs that not only address immediate recovery needs but also contribute to long-term economic resilience.

The findings further suggest that the introduction of the state aid program can be considered a step forward in protecting citizens and the economy. However, there are still challenges to be addressed, particularly in terms of ensuring the sustainability of aid programs. The long-term success of disaster aid programs depends on their ability to adapt to changing circumstances and to incorporate lessons learned from past disasters. In this context, it is essential to establish mechanisms for regular evaluation and review of state aid programs to identify areas for improvement and to implement necessary changes.

In conclusion, the analysis of citizens' views on state aid and reconstruction efforts highlights the need for a comprehensive and adaptive approach to disaster recovery. Legal frameworks must be continually revised to incorporate new knowledge and best practices in disaster risk management. Additionally, efforts to increase public awareness and engage local communities in disaster recov-

ery should be prioritized to enhance resilience at all levels of society. By adopting these measures, the state aid system in Serbia can become more robust and responsive to the evolving nature of disaster risks.

The study's findings have several policy implications. First, there is a need for continuous monitoring and assessment of state aid measures to ensure that they remain effective and responsive to citizens' needs. Second, public trust in state aid programs can be strengthened through increased transparency and efficient communication. Finally, integrating technological solutions and community-based approaches can enhance the overall effectiveness of state aid measures and contribute to a more resilient society.

Future research should explore the effectiveness of different models of state aid in disaster recovery, particularly in terms of their impact on local resilience. Comparative studies involving countries with different approaches to state aid can provide valuable insights into the strengths and weaknesses of various models. Additionally, qualitative studies involving in-depth interviews with key stakeholders can shed light on the practical challenges of implementing state aid programs and identify potential solutions.

Overall, the findings of this study contribute to the growing body of knowledge on disaster risk management and highlight the importance of continuous improvement and adaptation in state aid programs. By addressing the identified challenges and building on existing strengths, the Serbian state aid system can better fulfil its role in protecting citizens and promoting economic stability in the face of natural and other disasters.

5. Conclusions

Examining the views of the respondents on the state aid program and reconstruction of the consequences of natural and other disasters by using budget funds, indicates that citizens are aware of the necessity and need for legal regulation of the implementation of state aid measures in remediating the consequences of natural and other disasters. Strengthening the system of social responsibility and raising the level of citizens' awareness of the need to implement effective systemic measures of state aid in remediating the consequences of natural and other disasters contributes to the prevention and reduction of the risk of negative events in society. According to the opinion of the respondents, the current state aid measures in remediating the consequences of natural and other disasters are a good solution, but it is necessary to constantly improve them.

Based on the results of the research, we can conclude that there are no major differences in the views of citizens on the need to strengthen social awareness and social responsibility in the processes of application and development of the concept of the state program of aid and reconstruction of the consequences of natural and other disasters using budget funds. The general assessment is that the implementation of social responsibility measures will increase the level of efficiency in the state aid program and the recovery of the consequences of natural and other disasters by using budget funds.

Natural risks and threats, by their direct and indirect action, lead to the loss of human lives and material resources, but depending on the intensity of the action, they can also cause negative oscillations within the entire economic system of the country. That is precisely why, aware of the consequences of natural and other disasters, the Republic of Serbia adopted the Law on Reconstruction following natural and other hazards. In this manner, the existing budget financing system undoubtedly provides a form of protection to the country's economic system in terms of creating conditions for reconstruction and providing assistance to citizens and business entities that have suffered material damage due to natural and other disasters.

New challenges of time, new technologies and new forms of risks and threats require monitoring, analysis and taking other preventive measures in order to reduce the consequences of unwanted natural and other disasters for both citizens and the economy. It is necessary to create an environment of constant strengthening of social awareness and social responsibility in the processes of ap-

plication and development of the concept of the state program of aid and reconstruction of the consequences of natural and other disasters by using budget funds, with the simultaneous application of some new models of protection, such as the model of risk insurance, the issue of risk securities and similar.

Author Contributions: All authors contributed equally to the conceptualization, methodology, investigation, and writing of this manuscript.

Acknowledgements: The paper was created as a result of work on the project "Legal Tradition and New Legal Challenges", whose holder is the Faculty of Law in Novi Sad.

Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflict of interest."

References

1. Adem, O. (2019). Natural Disasters in Turkey: Social and Economic Perspective. *1*(1), 51-61.
2. Al-Malawi, A., El-Mougher, M., & Al-Agha, M. (2020). The Role of Al-Shifa Medical Complex Administration in Evacuation & Sheltering Planning. *2*(2).
3. Aleksandrina, M., Budiarti, D., Yu, Z., Pasha, F., & Shaw, R. (2019a). Governmental Incentivization for SMEs' Engagement in Disaster Resilience in Southeast Asia. *International Journal of Disaster Risk Management, 1*(1), 32-50.
4. Aleksova, B., Milevski, I., Mijalov, R., Marković, Slobodan, Cvetković, V., & Lukić, T. (2024). Assessing risk-prone areas in the Kratovska Reka catchment (North Macedonia) by integrating advanced geospatial analytics and flash flood potential index. *Open Geosciences, 16*(1), 20220684.
5. Arya, A. (1993). Training and drills for the general public in emergency response to a major earthquake. *Training and Education for Improving Earthquake Disaster Management in Developing Counties*, 103-114.
6. Baldwin, R. (1994). Training for the Management of Major Emergencies. *Disaster Prevention and Management, 3*(1), 16-23. doi:10.1108/09653569410049621
7. Ball, R. (2001). Infrastructure requirements for an economically efficient system of public financial reporting and disclosure. *Brookings-Wharton papers on financial services, 2001*(1), 127-169.
8. Berkley, L. A. (2024). Inner Economy: A Leadership Tool for Peace, Transformation, and Well-Being. In *Leadership at the Spiritual Edge* (pp. 201-222): Routledge.
9. Blind, P. K. (2007, 2007). *Building trust in government in the twenty-first century: Review of literature and emerging issues*.
10. Boken, V. K., Cracknell, A. P., & Heathcote, R. L. (2005). *Monitoring and predicting agricultural drought: a global study*: Oxford University Press New York.
11. Chakma, S. (2023). Water Crisis in the Rangamati Hill District of Bangladesh: A Case Study on Indigenous Community. *International Journal of Disaster Risk Management, 5*(2), 29-44.
12. Chambers, R. (1997). Responsible well-being—A personal agenda for development. *World development, 25*(11), 1743-1754.
13. Cuny, F. C. (1994). *Disasters and Development*: Intertect Press.
14. Cvetkovic, V. M., & Martinović, J. (2020). Innovative solutions for flood risk management. *International Journal of Disaster Risk Management, 2*(2), 71-100.
15. Cvetković, V. (2024a). Disaster Resilience: Guide for Prevention, Response and Recovery. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
16. Cvetković, V. (2024b). Disaster Risk Management. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
17. Cvetković, V. (2024c). Essential Tactics for Disaster Protection and Rescue. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.

18. Cvetković, V., & Bošković, D. J. B., Beograd. (2014). Analysis of spatial and temporal distribution of drought as natural disaster. *56*(3), 148-164.
19. Cvetković, V., Čvorović, M., & Beriša, H. (2023). The Gender Dimension of Vulnerability in Disaster Caused by the Corona Virus (Covid-19). *PREPRINT (Version 1) available at Research Square https://doi.org/10.21203/rs.3*.
20. Cvetković, V., Gačić, J., & Jakovljević, V. (2015). Impact of climate change on the distribution of extreme temperatures as natural disasters. *Vojno delo, 67*(6), 21-42.
21. Cvetković, V., Giulia, R., Adem, O., Marina, F., Bojan, J., & Eric, N. (2018). Childrens and youths' knowledge on forest fires: Discrepancies between basic perceptions and reality. *Vojno delo, 70*(1), 171-185.
22. Cvetković, V., Jakovljević, V., Gačić, J., & Filipović, M. (2017). Obuka građana za reagovanje u vanrednim situacijama - Citizens' training for emergency situations. *Ecologica*, In press.
23. Cvetković, V., & Nikolić, A. (2023). The Role of Social Media in the Process of Informing the Public About Disaster Risks. *Preprint*, 10-20944.
24. Cvetković, V., Nikolić, N., & Lukić, T. (2024). Exploring Students' and Teachers' Insights on School-Based Disaster Risk Reduction and Safety: A Case Study of Western Morava Basin, Serbia. *Safety, 10*(2), 2024040472.
25. Cvetković, V., Pavlović, S., & Janković, B. (2021). Private security preparedness for disasters caused by fires. *Journal of Criminalistic and Law, NBP, 26*(1), 35-59.
26. Cvetković, V., & Planić, J. (2022). Earthquake risk perception in Belgrade: implications for disaster risk management. *International Journal of Disaster Risk Management, 4*(1), 69-89.
27. Cvetković, V., Renner, R., Lukić, T., & Aleksova, B. (2024). Geospatial and Temporal Patterns of Natural and Man-made (Technological) Disasters (1900-2024): Insights from Different Perspectives. *Preprints*(https://doi.org/10.20944/preprints202408), 2024080175.
28. Cvetković, V., Roder, G., Öcal, A., Tarolli, P., & Dragićević, S. (2018). The Role of Gender in Preparedness and Response Behaviors towards Flood Risk in Serbia. *International Journal of Environmental Research and Public Health, 15*(12), 2761. doi:https://doi.org/10.3390/ijerph15122761
29. Cvetković, V., Romanić, S., & Beriša, H. (2023). Religion Influence on Disaster Risk Reduction: A case study of Serbia. *International Journal of Disaster Risk Management, 5*(1), 66-81.
30. Cvetković, V., & Šišović, V. (2024). Understanding Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. *Preprints 2024, 2024020950.*, 2024020950.
31. Cvetković, V., Tanasić, J., Ocal, A., Živković-Šulović, M., Ćurić, N., Milojević, S., & Knežević, S. (2023). The Assessment of Public Health Capacities at Local Self-Governments in Serbia. *Lex localis - Journal of Local Self Government, 21*(4), 1201-1234.
32. Cvetković, V. M. (2023). A Predictive Model of Community Disaster Resilience based on Social Identity Influences (MODERSI). *International Journal of Disaster Risk Management, 5*(2), 57-80.
33. Cvetković, V. M., Dragašević, A., Protić, D., Janković, B., Nikolić, N., & Milošević, P. (2022). Fire safety behavior model for residential buildings: Implications for disaster risk reduction. *International Journal of Disaster Risk Reduction*, 102981. doi:https://doi.org/10.1016/j.ijdrr.2022.102981
34. Cvetković, V. M., Gole, S., Renner, R., & Lukić, T. (2024). Qualitative Insights into Cultural Heritage Protection in Serbia: Evaluating Legal and Institutional Gaps.
35. Cvetković, V. M., & Marković, K. (2021). Examining the Impact of Demographic and Socio-Economic Factors on the Level of Employee Preparedness for a Disaster Caused by Fires: A Case Study of Electrical Power Distribution in Serbia.
36. Cvetković, V. M., Öcal, A., Lyamzina, Y., Noji, E. K., Nikolić, N., & Milošević, G. (2021). Nuclear power risk perception in serbia: Fear of exposure to radiation vs. social benefits. *Energies, 14*(9), 2464.
37. Cvetković, V. M., & Šišović, V. (2024). Community Disaster Resilience in Serbia. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.

38. Cvetković, V. M., Tanasić, J., Ocal, A., Kešetović, Ž., Nikolić, N., & Dragašević, A. (2021). Capacity Development of Local Self-Governments for Disaster Risk Management. *International Journal of Environmental Research and Public Health, 18*(19), 10406.
39. Del Moral, R., & Walker, L. R. (2007). *Environmental disasters, natural recovery and human responses*: Cambridge University Press New York.
40. Ebi, K. L., & Schmier, J. K. (2005). A stitch in time: improving public health early warning systems for extreme weather events. *Epidemiologic reviews, 27*(1), 115-121.
41. El-Mougher, M. M. (2022). Level of coordination between the humanitarian and governmental organizations in Gaza Strip and its impact on the humanitarian interventions to the Internally Displaced People (IDPs) following May escalation 2021. *International Journal of Disaster Risk Management, 4*(2), 15-45.
42. El-Mougher, M. M., Abu Sharekh, D. S. A. M., Abu Ali, M. R. F., & Zuhud, D. (2023). Risk Management of Gas Stations that Urban Expansion Crept into in the Gaza Strip. *International Journal of Disaster Risk Management, 5*(1), 13-27.
43. Finucane, M. L., Acosta, J., Wicker, A., & Whipkey, K. (2020). Short-term solutions to a long-term challenge: Rethinking disaster recovery planning to reduce vulnerabilities and inequities. *International Journal of Environmental Research and Public Health, 17*(2), 482.
44. Gnan, E., Nowotny, E., Simor, A., Begg, I., Bosomworth, A., Panizza, U., . . . Kraemer, M. (2013, 2013). *The interaction of political, fiscal and financial stability: lessons from the crisis*.
45. Grozdanić, G., Cvetković, V., Lukić, T., & Ivanov, A. (2024). Sustainable Earthquake Preparedness: A Cross-Cultural Comparative Analysis in Montenegro, North Macedonia, and Serbia. *Sustainability, 16*, 3138.
46. Islam, F. (2023). Anticipated Role of Bangladesh Police in Disaster Management Based on the Contribution of Bangladesh Police during the Pandemic COVID-19. *International Journal of Disaster Risk Management, 5*(2), 45-56.
47. Jacobs, G. (2016). Integrated Approach to Peace & Human Security in the 21st Century. *Cadmus, 3*(1).
48. Kabir, M. H., Hossain, T., & Haque, M. W. (2022). Resilience to natural disasters: A case study on the southwestern region of coastal Bangladesh. *International Journal of Disaster Risk Management, 4*(2), 91-105.
49. Kabir, M. H., Tanvir, H., & Haque, M. W. (2022). Resilience to natural disasters: A case study on the southwestern region of coastal Bangladesh. *International Journal of Disaster Risk Management, 4*(2), 91-105.
50. Kim, J.-M., Yum, S.-G., Park, H., & Bae, J. (2022). Strategic framework for natural disaster risk mitigation using deep learning and cost-benefit analysis. *Natural Hazards and Earth System Sciences, 22*(6), 2131-2144.
51. Kim, S. (2010). Public trust in government in Japan and South Korea: Does the rise of critical citizens matter? *Public Administration Review, 70*(5), 801-810.
52. Kozlowski, T. T. (2012). *Fire and ecosystems*: Elsevier.
53. Kumiko, F., & Shaw, R. (2019). Preparing International Joint Project: Use of Japanese Flood Hazard Map in Bangladesh. *International Journal of Disaster Risk Management, 1*(1), 62-80.
54. Lewis, S. C. (2016). Can public perceptions of Australian climate extremes be reconciled with the statistics on climate change? *Weather and Climate Extremes, 12*, 33-42. doi:https://doi.org/10.1016/j.wace.2015.11.008
55. Law on Reconstruction following Natural and Other hazards, ("Official Gazette of RS", No. 112/2015)
56. Mano, R., A, K., & Rapaport, C. (2019). Earthquake preparedness: A Social Media Fit perspective to accessing and disseminating earthquake information. *International Journal of Disaster Risk Management, 1*(2), 19-31.
57. Molnár, A. (2024). A Systematic Collaboration of Volunteer and Professional Fire Units in Hungary. *International Journal of Disaster Risk Management, 6*(1), 1-13.

58. Mumović, N., & Cvetković, V. (2019). Factors influencing decision-making on evacuation in the context of induced fire disasters. *Vojno delo, 71*(7), 142-163.
59. Ministry for Public Investment: https://www.obnova.gov.rs/vesti/clanak/ukupno-isplaceni-korisnici-poplave-2020; https://www.obnova.gov.rs/vesti/clanak/ukupno-isplaceni-korisnici-poplave-2021; https://www.obnova.gov.rs/vesti/clanak/ukupno-isplaceni-korisnici-poplave-u-maju-i-junu-2023; https://docs.google.com/forms/d/1JjRWHiw1wuge0EM0_X6APoCyrE4EtaAVoUDa6uirll0/edit#responses.
60. Nones, M., Hamidifar, H., & Shahabi-Haghighi, S. M. B. (2024). Exploring EM-DAT for depicting spatiotemporal trends of drought and wildfires and their connections with anthropogenic pressure. *Natural Hazards, 120*(1), 957-973.
61. Odero, N. A., & Mahiri, I. (2022). The Complacency of Flood Victims, Socio Economic Factors, and Effects and Vulnerabilities of Floods in Lower Kano Plains, Kisumu County, Kenya. *International Journal of Disaster Risk Management, 4*(2), 59-77.
62. Olawuni, P., Olowoporoku, O., & Daramola, O. (2020). Determinants of Residents' Participation in Disaster Risk Management in Lagos Metropolis Nigeria. *International Journal of Disaster Risk Management, 2*(2), 1-18.
63. Paton, D. (1996). Training disaster workers: promoting wellbeing and operational effectiveness. *Disaster Prevention and Management, 5*(5), 11-18. doi:10.1108/09653569610131735
64. Perić, J., & Cvetković, V. J. I. J. o. D. R. M. (2019). Demographic, socio-economic and phycological perspective of risk perception from disasters caused by floods: case study Belgrade. *1*(2).
65. Podder, M., Hasan, M. K., & Islam, M. J. (2022). Seismic Vulnerability Assessment of Existing Buildings by Rapid Visual Screening Method: A Study on Ward 27 in Dhaka South City Corporation. *International Journal of Disaster Risk Management, 4*(2), 77-91.
66. Pope, P. F., & Puxty, A. G. (1991). What is equity? New financial instruments in the interstices between the law, accounting and economics. *The Modern Law Review, 54*(6), 889-911.
67. Shibru, M., Operea, A., Omondi, P., & Gichaba, M. (2022). Impact of 2016-2017 drought on household livestock assets and food security: the case of pastoralists and agro-pastoralists in Borana zone, southern Ethiopia. *International Journal of Disaster Risk Management, 4*(1), 49-69.
68. Starosta, D. (2023). Raised Under Bad Stars: Negotiating a culture of disaster preparedness. *International Journal of Disaster Risk Management, 5*(2), 1-16.
69. Strömberg, D. (2007). Natural disasters, economic development, and humanitarian aid. *Journal of Economic perspectives, 21*(3), 199-222.
70. Sudar, S., Cvetković, V., & Ivanov, A. (2024). Harmonization of Soft Power and Institutional Skills: Montenegro's Path to Accession to the European Union in the Environmental Sector. *International Journal of Disaster Risk Management, 6*(1), 41-74.
71. Tanasić, J., & Cvetković, V. (2024). The Efficiency of Disaster and Crisis Management Policy at the Local Level: Lessons from Serbia. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
72. Thurmaier, K. (1994). The Evolution of Local Government Budgeting in Poland: From Accounting to Policy in a Leap and a Bound. *Public Budgeting & Finance, 14*(4), 84-97.
73. Vibhas, S., Adu, G. B., Ruiyi, Z., Anwaar, M. A., & Rajib, S. J. (2019). Understanding the barriers restraining effective operation of flood early warning systems. *1*(2), 1-17.
74. Vibhas, S., Bismark, A. G., Ruiyi, Z., Anwaar, M. A., & Rajib, S. (2019). Understanding the barriers restraining effective operation of flood early warning systems. *International Journal of Disaster Risk Management, 1*(2), 1-19.
75. Xuesong, G., & Kapucu, N. (2019). Examining Stakeholder Participation in Social Stability Risk Assessment for Mega Projects using Network Analysis. *International Journal of Disaster Risk Management, 1*(1), 1-31.
76. Xuesong, G., & Kapucu, N. J. I. J. o. D. R. M. (2019). Examining Stakeholder Participation in Social Stability Risk Assessment for Mega Projects using Network Analysis. *1*(1), 1-31.
77. Zareian, M. (2023). Social capitals and earthquake: A Study of different districts of Tehran, Iran. *International Journal of Disaster Risk Management, 5*(2), 17-28.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research Article

Optimising Disaster Resilience Through Advanced Risk Management and Financial Analysis of Critical Infrastructure in the Serbian Defence Industry

Nikola Vidović[1], **Hatidža Beriša**[1,2]*, **Vladimir M. Cvetković**[2,3,4,5]

[1] University of Defence, Military Academy – Belgrade, Republic of Serbia; vidovicnikola.finance@gmail.com (N.V.); berisa.hatidza@gmail.com (H.B.)

[2] Department of Disaster Management and Environmental Security Studies, Faculty of Security Studies, University of Belgrade, Gospodara Vucica 50, 11040 Belgrade, Serbia; vmc@fb.bg.ac.rs;

[3] Safety and Disaster Studies, Department of Environmental and Energy Process Engineering, Montanuniversität of Leoben, Franz Josef-Straße 18, 8700 Leoben, Austria; vladimir.cvetkovic@unileoben.ac.at

[4] Scientific-Professional Society for Disaster Risk Management, Dimitrija Tucovića 121, 11040 Belgrade, Serbia;

[5] International Institute for Disaster Research, Dimitrija Tucovića 121, 11040 Belgrade, Serbia.

* *Correspondence: berisa.hatidza@gmail.com*

Received: 2 August 2024; Revised: 5 September 2024; Accepted 28 October; Published: 25 December

Abstract

This paper presents a comprehensive analysis of the financial factors and risk management strategies essential for optimizing disaster resilience within the Serbian defence industry's critical infrastructure. The significance of this sector is multi-faceted, impacting national security, economic stability, and technological advancement. Primarily, the Serbian defence industry ensures the preservation of vital defence interests, maintaining Serbia's independence from foreign sources for weapons and military equipment in both peacetime and wartime. Economically, it is a significant employer of the working-age population, directly affecting local employment rates, fostering economic development, and ensuring the sustainable growth of this crucial sector. This, in turn, stimulates broader economic activity and enhances social cohesion while strengthening the national balance of payments through increased export potential. From a technological perspective, the defence industry drives scientific, technological, and industrial development, reinforcing Serbia's global political and military standing within the Western Balkans and on the international stage. Consequently, the paper aims to examine the risk management and protection of the Serbian defence industry's critical infrastructure, offering concrete and actionable measures to improve and develop these systems with a particular emphasis on security. The research's utility and contribution lie in identifying similarities and differences in the operational performance of defence industry companies, a vital segment of the national economy. The presentation of these findings focuses on the protection of critical infrastructure. The results will form the basis for further investigation into the underlying causes of business performance and the effective management of critical infrastructure security.

Keywords

Disaster risk management; resilience; risk management, financial analysis, critical infrastructure, security, defence, Serbia.

1. Introduction

National security, as well as overall security, heavily depends on the robustness of critical infrastructure. Initially viewed as a logistical function that supports other logistical operations, critical infrastructure has gained prominence due to the rising threat of asymmetric attacks, particularly terrorism. Both theoretical analyses and practical experiences have shown that critical infrastructure systems, services, and assets—whether physical or virtual—are crucial for societal well-being. The disruption or destruction of these systems can severely impact citizens' health, safety, economic stability, and the effective functioning of government (Škero & Ateljević, 2015).

Critical infrastructure comprises large-scale, man-made systems that are crucial for the production and distribution of essential goods and services. These systems include but are not limited to, the provision of energy, water, data, transportation, finance, and healthcare. According to the Council Directive 2008/114/EC, an infrastructure is deemed critical if its incapacitation or destruction would have a significant impact on public health, safety, security, economic stability, and social well-being. The failure or disruption of critical infrastructure can lead to severe societal and economic repercussions, potentially causing cascading failures across other interconnected infrastructures, and resulting in catastrophic consequences (Carreras et al., 2004; Zio, 2016).

Recent research underscores the growing interconnectedness of critical infrastructure systems, which heightens their susceptibility to both natural and human-made hazards. For instance, the rising integration of information and communication technologies has introduced new cyber risks that could jeopardize physical infrastructure (Petit et al., 2015). Additionally, climate change has brought about new challenges, such as extreme weather events, that can disrupt essential services and demand stronger resilience planning (Rinaldi et al., 2001). Hence, a thorough approach to risk management is crucial to safeguarding these essential systems and maintaining their operation amid various threats.

Regarding that, the objective of this paper is to systematically examine the vulnerabilities and risk factors associated with the critical infrastructure of the Serbian defence industry through a financial performance analysis. This study reflects on the inherent complexities of these systems, identifies related challenges, and proposes potential solutions for their analysis and management. Specifically, the paper explores the framework of vulnerability and risk analysis in protecting and enhancing the resilience of six key entities within Serbia's defence industry. Given the complexity of these systems, the study argues for the integration of various modelling perspectives and innovative analytical approaches (Bouchon, 2006). This integration is crucial for accurately capturing the structural and dynamic complexities of critical infrastructures, thereby enabling confident decision-making regarding protection and resilience actions (Zio, 2016).

2. Critical Infrastructure Resilience: A Risk and Vulnerability Approach

The Republic of Serbia has a wealth of experience in handling disasters, particularly those stemming from electrical incidents. In the last ten years, the country has recorded over 150,000 fires (Cvetković, Pavlović, & Janković, 2021; Cvetković, Pavlović, & Janković, 2021; Cvetković et al., 2022; Cvetković & Marković, 2021; Cvetković & Janković, 2021). Significant incidents, such as the 2014 floods in Obrenovac and the 2009 earthquakes in Kraljevo, have driven Serbia to establish a comprehensive protection and rescue system to effectively address threats to critical national resources (Cvetković, Babić, & Gačić, 2017; Cvetković, Bošković, & Ocal, 2021; Cvetković & Martinović, 2020; Cvetković, 2016; Cvetković, 2024). The legislative framework, including the Law on Emergency Situations and various strategic documents, lays the groundwork for adopting the Critical Infrastructure Law and aligns with numerous European regulations in this area (Cvetković & Synodinou, 2024; Cvetković, Nikolić, & Lukić, 2024; Cvetković, Nikolić, & Lukić, 2024; Cvetković & Šišović, 2023; Cvetković & Šišović, 2024; Cvetković et al., 2021).

Serbia's defence industry's critical infrastructure faces numerous hazards, risks, and threats, including natural disasters, ageing components, increased load demands, climate change, intentional

attacks, and terrorism. As a result, protecting critical infrastructure (CIP) has become a major global priority. Regional countries like Slovenia and Croatia are actively addressing these issues through specific legislation that outlines institutional roles during disasters (Lewis, 2006), with a focus on physical protection and asset reinforcement (Cimellaro et al., 2010). To protect the defence industry's critical infrastructure, it is crucial to model its components under various threats and perform thorough risk and vulnerability assessments at the system level.

The importance of resilience in critical infrastructure—its ability to endure, adapt, and quickly recover from disruptions—has been highlighted by recent catastrophic disasters (Moteff, 2012). The 2005 World Conference on Disaster Reduction emphasized the need for disaster resilience, fostering a new culture of disaster response (Zio, 2016). Systems must be not only reliable but also capable of recovering from disruptions. Government policies now encourage efforts to ensure systems can continue operating at some level or return to full functionality after a disruption (Cvetković, Rikanović, & Knežević; Cvetković & Šišović, 2024; Grozdanić & Cvetković, 2024). Consequently, resilience is now seen as an essential attribute for critical infrastructure, integrated into its design, operation, and management. Serbia should play a significant role in further defining and regulating this area.

The national well-being of Serbia's defence industry, along with all interconnected entities and stakeholders, relies on secure and resilient critical infrastructure—resources, systems, and networks crucial for the seamless functioning of society. To achieve security and resilience, critical infrastructure partners must collaboratively prioritize goals, mitigate risks, measure progress, and adapt to changing conditions (U.S. DHS, 2013). Although Serbia has recently established and prioritized critical infrastructure compared to the European Union, the United States, and neighbouring countries, substantial efforts by the academic, professional, and scientific communities, along with institutional support, guide national efforts toward critical infrastructure risk management.



Figure 1. The interdependence of risk components: a comprehensive analysis of their interconnected nature and implications for effective risk management.

The community involved in critical infrastructure risk management is diverse, including partnerships between owners and operators, government entities at various levels, regional organizations, non-profit groups, and academia. Effective risk management requires an integrated approach across this community (Carla, 2019; Cvetković, 2019; Goyal, 2019; Mano & Rapaport, 2019; Öcal, 2019; Vibhas, Bismark, Ruiyi, Anwaar, & Rajib, 2019; Xuesong & Kapucu, 2019): a) identify, deter, detect, disrupt, and prepare for threats against the state's critical infrastructure, including the defence system, the Ministry of Defence, the Armed Forces of Serbia, and the defence industry; b) reduce the vulnerability of critical assets, systems, and networks within the defence industry and its external relations; c) mitigate the potential impacts of incidents or adverse events on critical infrastructure. The success of this integrated approach depends on leveraging a broad spectrum of skills, expertise, and

experience within the critical infrastructure community and related stakeholders. This has become increasingly evident in Serbia in recent years. Effective information sharing among partners is crucial for building situational awareness and enabling risk-based decision-making (U.S. DHS, 2013).

Traditionally, risk has been defined as a function of three elements: the threats to which an asset is susceptible, the asset's vulnerabilities to the threat, and the potential consequences of asset degradation (Petit et al., 2013). Today, resilience has emerged as a fourth component, alongside vulnerability, threat/hazard, and consequences, forming the comprehensive risk function. In the context of critical infrastructure, risk at an asset (such as an office building, hangar, factory, or machinery) for a given threat/hazard type is a function of the threat/hazard likelihood (Carlson et al., 2012), the asset's vulnerability (the likelihood of a successful threat event), the asset's resilience, and the magnitude of the resulting consequences (Petit et al., 2013). As depicted in Figure 1, the risk components are inherently interdependent. When considering a threat or hazard—whether manmade or natural—the vulnerability and resilience of the asset (infrastructure) will determine the resultant consequences. The intrinsic complexity of risk is amplified by dependencies and interdependencies that affect the components of risk (Petit et al., 2015). In today's interconnected world, the potential impacts are exacerbated by these dependencies and the diverse range of threats capable of exploiting them. Critical infrastructure now spans national borders and global supply chains, a crucial point in this case study.

Within the context of the risk framework depicted, policy, and operating environments, the structures of critical infrastructure sectors and cross-sector partnerships provide a framework to guide the collective efforts of partners. The national effort to enhance critical infrastructure security and resilience relies on the ability of public and private critical infrastructure owners and operators to make risk-informed decisions when allocating limited resources during both steady-state and crisis operations (U.S. DHS, 2013). The complex and uncertain risk environment affecting critical infrastructure, particularly the defence industry, has evolved significantly over the past decade. Daily threats to vital state entities have become increasingly relevant, as evidenced by developments globally, regionally, and in Serbia's southern province. For example, critical infrastructure that has long faced physical threats and natural disasters is now increasingly exposed to cyber risks, stemming from the integration of information and communication technologies with critical infrastructure operations and the hostile exploitation of potential cyber vulnerabilities.

As the number of threats in modern analyses and practice continues to grow, protecting critical infrastructure becomes increasingly important (Carla S., 2019; Cvetković, 2019; Frosdick, 1997; Kumiko & Shaw, 2019; Öcal, 2019; Perić & Cvetković, 2019; Vibhas et al., 2019). This protection is crucial not only because of the potential damage to the infrastructure itself but also because of the broader societal and economic consequences such damage can cause. Protecting critical infrastructure during emergencies should be viewed as part of a comprehensive prevention process and emergency response strategy. In this context, organizations establish, implement, and maintain procedures to identify potential incidents that could negatively impact them, their activities, and the environment (Cvetković, 2024b). These procedures aim to protect lives and property, prevent emergencies or disasters, minimize operational downtime, recover critical activities, return to normal operations, and safeguard the organization's reputation. As Rinaldi, Peerenboom, and Kelly note, "It is impossible to adequately analyze or understand the behaviour of a given infrastructure [organization] in isolation from the environment or other infrastructures" (Rinaldi, Peerenboom, and Kelly, 2001). Critical infrastructure constantly interacts with its environment, utilizing and transforming inputs from the environment to provide outputs back to it. Figure 1 illustrates how the critical infrastructure of Serbia's defence industry influences and interacts with its environment.

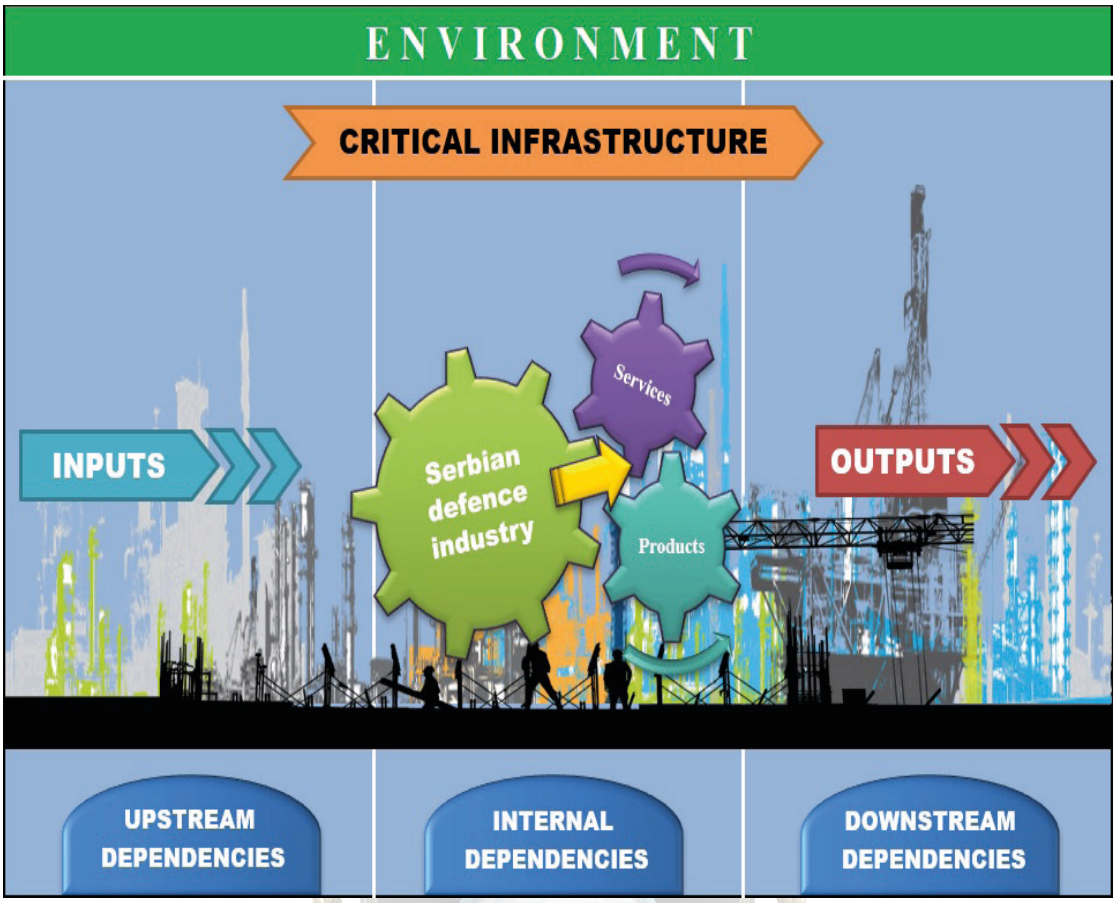


Figure 2. Influence and interaction between critical infrastructure of Serbian defence industry and environment.

These interactions can be classified into three main categories: a) upstream dependencies: which refer to the essential products or services provided to one infrastructure by another external infrastructure. In the context of the Serbian defence industry, there is a direct dependency on companies and entities that supply vital raw materials, supplies, and resources for the production of weapons and military equipment. Additionally, these external entities offer services that the defence industry cannot provide independently.

Protecting these upstream dependencies from various risks and threats across all operational domains is crucial; b) internal dependencies: involve the interactions among the internal operations, functions, and missions within the infrastructure itself. Internal dependencies are the internal connections among the assets that make up critical infrastructure. For example, the production of ammunition at "Prvi Partizan" a.d. Užice is directly reliant on the propulsion machinery and the moulds that determine the calibre; c) downstream dependencies: These pertain to the effects on a critical infrastructure's consumers or recipients resulting from the degradation of the resources provided by that infrastructure. In a more specific sense, the Ministry of Defence and all units of the Serbian Armed Forces would be directly impacted. In a broader sense, the entire state, the population, the environment, and the functioning of interstate entities and organizations would also be affected.

3. Improving National Efforts for Strengthening the Security of Critical Infrastructure

The government, particularly through the Ministry of Defence and the defence industry sector, has a vested interest in ensuring the robustness of critical infrastructure and the continuous provision of essential services under all conditions. Owners and operators of critical infrastructure often

stand to gain the most from investing in their security and resilience. They are motivated by both the direct benefits and a sense of social responsibility to adopt these practices. However, production sectors and companies may be rightfully concerned about the return on investments in security and resilience, as these may not yield immediately measurable benefits. Effective incentives can help justify the costs associated with enhanced security and resilience by balancing short-term expenses with near-term benefits (U.S. DHS, 2013).

Market-based incentives can drive significant changes in business practices and foster the development of markets such as insurance for cyber, chemical, biological, or radiological risks. Additionally, the Republic of Serbia and local governments can explore offering incentives to encourage investment in security and resilience measures. Effective measures and activities for implementation include: a) continuously identifying, analyzing, and, where appropriate, implementing incentives; b) supporting research and data collection to quantify the potential costs resulting from inadequate critical infrastructure security and resilience, and insufficient cyber preparedness; c) establishing innovation challenge programs to incentivize new solutions for strengthening infrastructure security and resilience during the planning, design, and redesign phases, including technological, engineering, and process improvements.

The dependencies and interdependencies of critical infrastructure represent complex elements that are challenging to identify and analyze. They are characterized by various interactions (e.g., upstream, internal, and downstream), classes (e.g., physical, cyber, logical, and geoFigureic), and dimensions (e.g., operating environment, coupling and response behaviour, type of failure, infrastructure characteristics, and state of operation). These factors influence all components of risk (threat/hazard, vulnerability, resilience, and consequence), can themselves become threats or hazards, affect the resilience and protection performance of critical infrastructure, and lead to cascading and escalating failures. It is essential to integrate dependencies and interdependencies into risk and resilience methodologies.

A data-driven capability that operationalizes the analysis of dependencies and interdependencies would not only provide an unprecedented level of situational awareness but also enable decision-makers to anticipate disruptions. Achieving this ultimate goal requires the development of a comprehensive and interactive assessment of critical infrastructure dependencies and interdependencies. This necessitates the combination of multiple areas of expertise (e.g., engineering, social sciences, business continuity, and emergency management) within an adaptive and flexible assessment framework (Petit et al., 2015).

Furthermore, the integration of advanced technologies and innovative methodologies plays a crucial role in enhancing the security and resilience of critical infrastructure (Vladimir Cvetković, 2024a, 2024b). Emerging technologies such as artificial intelligence, machine learning, and big data analytics can be leveraged to predict and mitigate potential risks more effectively (V. Cvetković & Filipović, 2017). By utilizing these technologies, critical infrastructure systems can benefit from real-time monitoring, predictive maintenance, and automated response mechanisms that can significantly reduce vulnerabilities and enhance overall resilience. Additionally, collaboration with international partners and participation in global initiatives can provide valuable insights and best practices, fostering a more comprehensive approach to critical infrastructure protection (Baruh, Dey, & Dutta, 2023; V. M. Cvetković, 2023; El-Mougher, Abu Sharekh, Abu Ali, & Zuhud, 2023; Rajani, Tuhin, & Rina, 2023; Sudar, Cvetković, & Ivanov, 2024). The Republic of Serbia, by embracing these advancements and fostering a culture of continuous improvement, can strengthen its national efforts to secure and sustain its critical infrastructure, ultimately contributing to the stability and prosperity of the nation (Cvetković & Kezunović, 2021; Hromada & Lukas, 2012; Murray & Grubesic, 2012).

4. Comprehensive Financial Analysis of Entities in the Defence Industry

The Defence Industrial Base Sector in Serbia is the national industrial complex responsible for research and development, design, production, delivery, and maintenance of military weapons systems, subsystems, and components or parts. This complex aims to meet the military requirements

of the Serbian Armed Forces, third countries, and developing nations, as well as some of the most powerful armies worldwide, including the U.S. military and security sectors (Table 1). The defence industry in Serbia comprises numerous companies engaged in the production and trade of weapons, military equipment, and dual-purpose goods (items usable for both military and civilian purposes). These companies are both state-owned and privately owned (Radić & Radić, 2018). The Ministry of Defence of the Republic of Serbia has significant authority over the majority of state-owned companies, managing and supervising their operations following the Law on Defence.

Table 1. Comparative Financial Analysis of Serbian Defence Industry Companies (2014-2017). Source: Authors' calculation based on financial reports.

No.		1	2	3	4	5	6
Company of Serbian defence industry		Holding corporation "Krušik" a.d.	"Milan Blagojević - Namenska" a.d.	"Prva Iskra namenska" a.d.	"Prvi Partizan" a.d.	"Sloboda" a.d.	"Zastava oružje" a.d.
City		Valjevo	Lučani	Barič	Užice	Čačak	Kragujevac
INDICATOR		RATIO OF CURRENT LIQUIDITY					
Business year	2014	0.9871	0.8361	2.3003	1.2667	1.0889	0.7228
	2015	0.9862	0.7259	2.5965	1.3680	1.0259	0.6938
	2016	0.9919	0.7895	1.9366	1.7782	1.0279	0.5769
	2017	0.9739	0.9151	3.3162	1.7924	0.9813	0.5768
INDICATOR		**BUSINESS PROFIT RATIO**					
Business year	2014	-0.0181	0.1490	-0.0972	0.0801	0.1565	-0.0407
	2015	0.1400	0.1376	-0.0481	0.1702	0.0249	0.0675
	2016	0.0971	0.1745	0.1650	0.1666	0.1607	-0.0335
	2017	0.1184	0.2340	0.1476	0.0424	0.1052	-0.0128
INDICATOR		**TURNOVER RATIO OF TOTAL ASSETS**					
Business year	2014	0.3277	0.4795	0.2602	0.6015	0.4398	0.2725
	2015	0.4735	0.5670	0.2927	0.7162	0.3823	0.2800
	2016	0.4701	0.7196	0.6947	0.6820	0.5034	0.2298
	2017	0.7534	0.6927	0.7222	0.4068	0.5752	0.1989
INDICATOR		**DEBT RATIO**					
Business year	2014	0.2896	0.4783	0.6173	0.5436	0.4355	0.2538
	2015	0.2760	0.4678	0.6622	0.5986	0.4229	0.1961
	2016	0.2107	0.5002	0.7271	0.6894	0.3787	0.1262
	2017	0.1820	0.5238	0.6804	0.4619	0.3659	0.0863
INDICATOR		**LEVERAGE**					
Business year	2014	3.4529	2.0907	1.6200	1.8396	2.2962	3.9401
	2015	3.6232	2.1375	1.5102	1.6704	2.3647	5.1001
	2016	4.7472	1.9993	1.3754	1.4506	2.6407	7.9249
	2017	5.4934	1.9093	1.4697	2.1648	2.7333	11.5905
INDICATOR		**ROE (Return on Equity)**					
Business year	2014	-0.1617	0.0087	0.0136	0.1241	0.0073	-0.4573
	2015	0.1076	0.0146	0.0076	0.2189	0.0149	-0.0617
	2016	0.2056	0.1372	0.0354	0.1604	0.1143	-0.3887
	2017	0.3482	0.2418	0.1046	0.0701	0.0850	-0.3132
INDICATOR		**ROA (Return on Assets)**					
Business year	2014	-0.0059	0.0714	-0.0253	0.0482	0.0688	-0.0111
	2015	0.0663	0.0780	-0.0141	0.1219	0.0095	0.0189
	2016	0.0456	0.1256	0.1146	0.1137	0.0809	-0.0077
	2017	0.0892	0.1621	0.1066	0.0173	0.0605	-0.0025

A special group called the "Defence Industry of Serbia," which includes seven state-owned enterprises, is allocated by the Ministry of Defence (Ministry of Defence, report, 2018). These companies are HK "Krušik" a.d. Valjevo, "Milan Blagojević – namenska" a.d. Lučani, "Prva Iskra" a.d. Barič, "Prvi partizan" a.d. Užice, "Sloboda" a.d. Čačak, "Zastava oružje" a.d. Kragujevac, and "Yugoimport" SDPR (Figure 3). Beyond this group, another 216 companies, licensed for the production and trade of weapons and military equipment, cooperate closely with the dedicated defence industry (Ministry of Trade, Tourism, and Telecommunications, 2018). These companies, which include numerous institutes and faculties from the professional and academic community as subcontractors, vary in ownership structure, core business, and size. Predominantly small enterprises, and to a lesser extent medium-sized enterprises, they are mostly privately owned and collectively employ around 8,000 people.

This second segment of the Serbian defence industry includes companies primarily belonging to the metal complex, electrocomplex, and chemical complex. These entities, along with the aforementioned seven primary factories, form a robust industrial base for defence capacities. The third segment focuses on the development and enhancement of resources and comprises the Military Technical Institute, the Technical Expert Center, and three technical repair institutes within the defence system, namely the Ministry of Defence and the Army of Serbia.

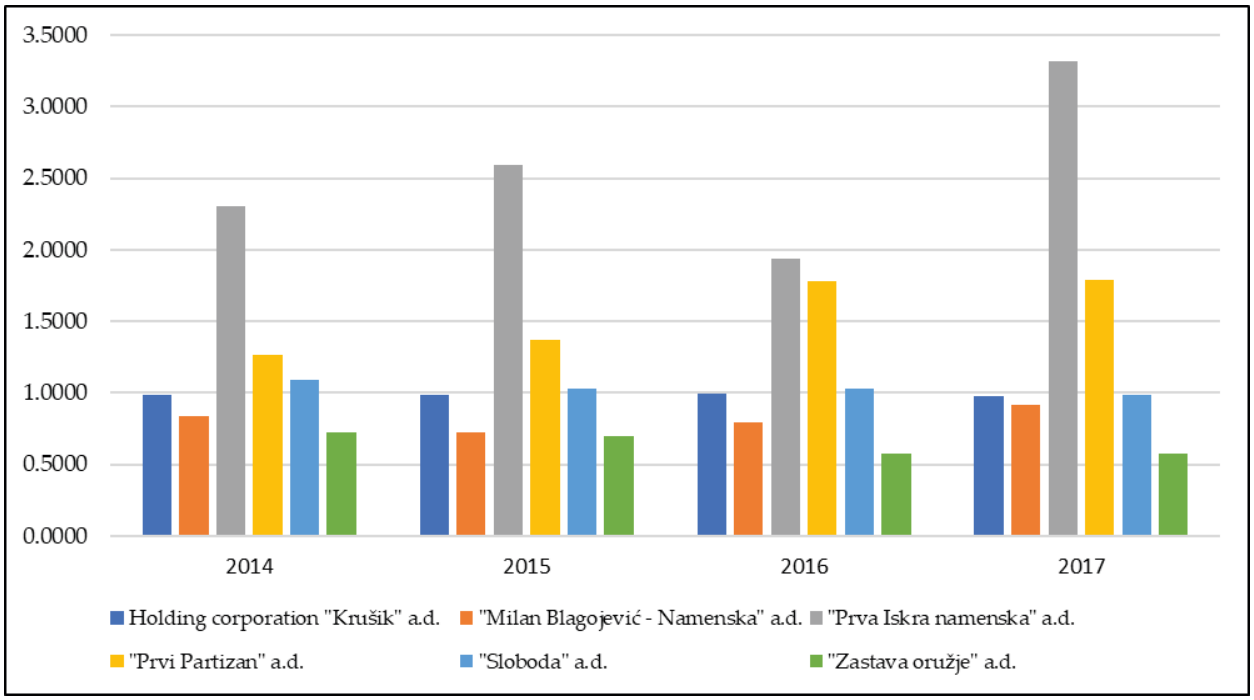


Figure 3. Current Liquidity Ratio: A Comprehensive Measure of Financial Health and Short-term Solvency. Source: Authors

Nowadays world is moving rapidly toward globalization, and the fact is that business performance evaluation of the defence industry's companies through financial analysis its importance. The financial ratios involved in this research, provide useful quantitative and qualitative financial information so we can evaluate the operation of a defence industry enterprise and analyze its financial position within a sector (Figure 4).

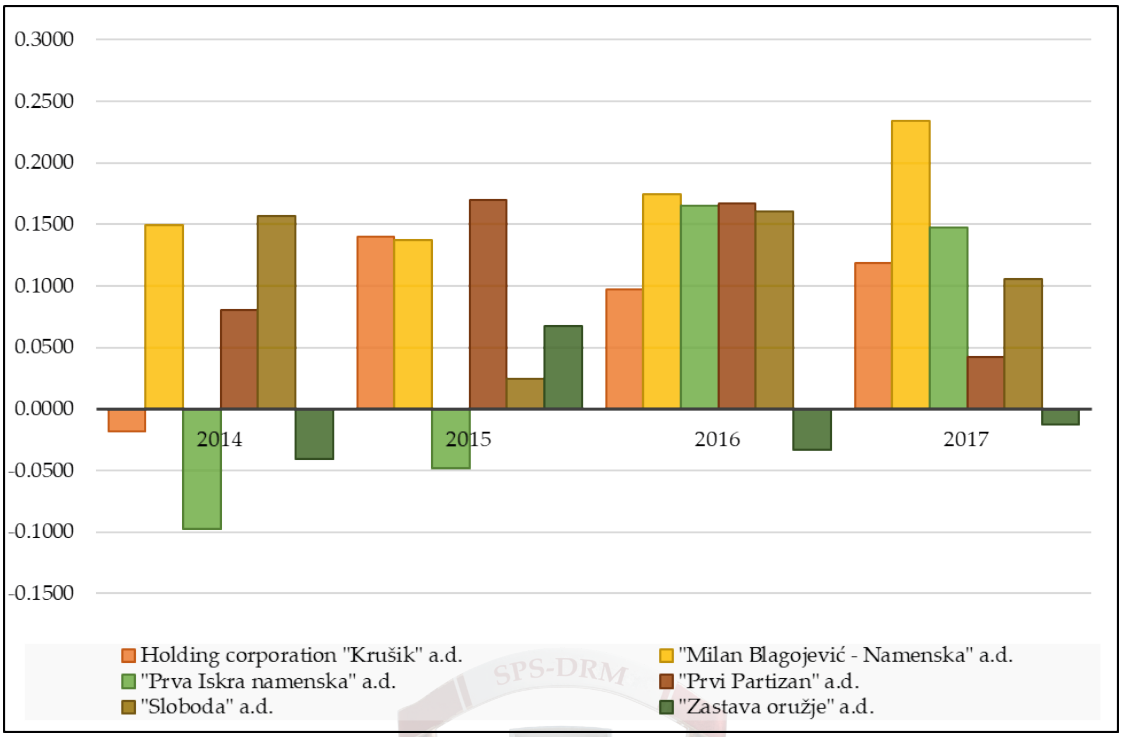


Figure 4. Analysis of Business Profit Ratio. Source: Authors.

This type of analytic financial research brings awareness to managers as to which features they have to focus on. As shown in Table 1, financial analysis was carried out for 6 companies from the group "Defence Industry of Serbia" in the period from 31 December 2014 to 31 December 2017 business year, where, based on the indicators of profitability, indebtedness, liquidity and business efficiency, we can valorize the achieved results and perceive the financial position of the companies concerned. At the same time, we can also see the risk of business assets and capital, as well as the sustainability of these companies' operations.

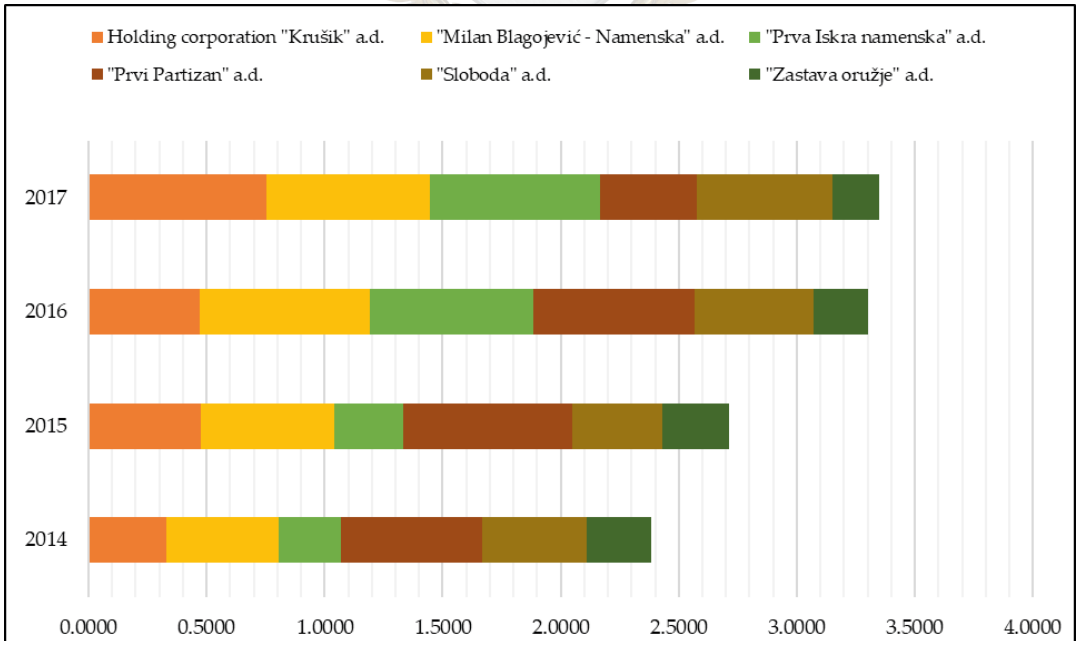


Figure 5. Total Asset Turnover Ratio Analysis. Source: Authors

The research findings have demonstrated the impact of structural and dynamic changes in balance sheets and income statements on the business performance of the analyzed subjects. Financial

ratios, serving as reliable indicators, reveal specific trends in business operations and provide critical signals for making informed business decisions within the company. These ratios not only track the historical performance but also predict future trends, enabling management to identify potential opportunities and risks. As a result, they form an essential part of the strategic decision-making process, guiding companies toward sustainable growth and operational efficiency.

The financial leverage indicator shows the value of total capital (total liabilities) supported in a monetary unit of a shareholder or own capital, and at the same time, the purposefulness of the same is reflected in the fact that it limits the excessive reliance on borrowing to minimize risk-taking in the search for higher yields. Indicator values in enterprises "Milan Blagojević-namenska" a.d. and "Prva iskra namenska" a.d. have a downward trend, with a small level of variation of value. A constant trend of growth of this coefficient was observed in "Zastava oružje" a.d., and in the other entities of the Serbian defence industry some level of variations, which is shown in Figure 6.

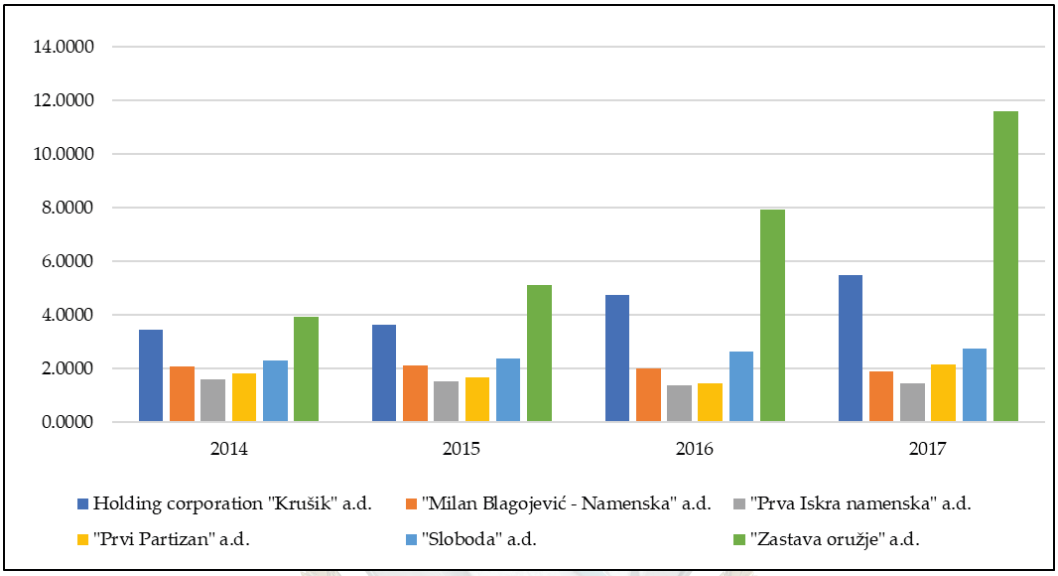


Figure 6. Leverage Analysis. Source: Authors.

The indicators return on equity - ROE and return on assets – ROA, represent the indicators of profitability, that is, the performance of the business, in which the values of these are specifically reduced to the requirement to achieve the maximum profit and return from the least engaged funds in the business process. The rate of ROE is the return on capital invested, which is obtained when the operating result is allocated to the capital, ie it is an indicator of the profitability of own capital.

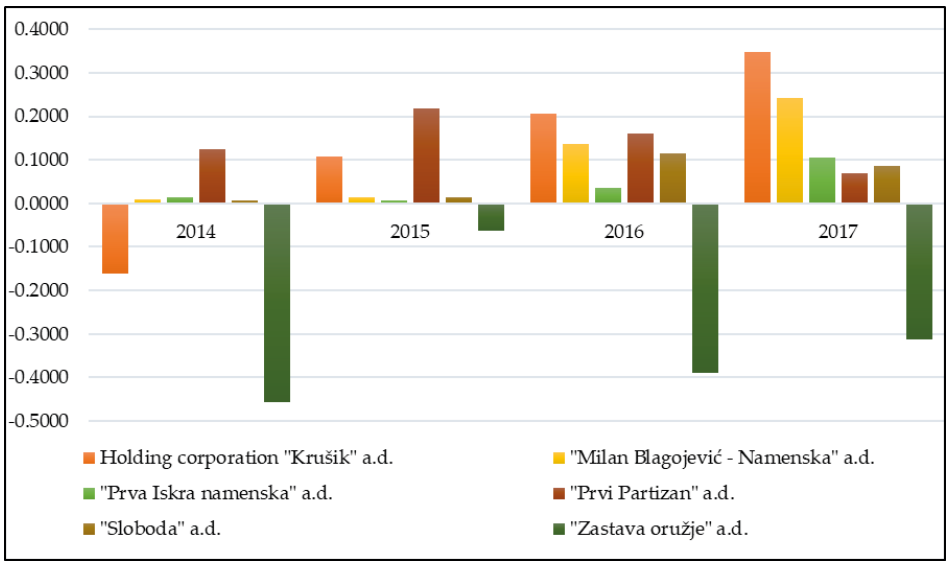


Figure 7. Return on Equity (ROE): An In-Depth Analysis.

This indicator shows how much profit is generated on the invested equity capital, or how much the company will earn by investing the invested funds of the shareholders. The highest level of ROE has entreprice "Krušik" a.d., then follow "Milan Blagojević – namenska" a.d. and "Prva iskra namenska" a.d. with constant growth, which indicates great business operations, and sustain development of the companies. Great variations of indicators during the researched period have "Prvi partisan" a.d., a company which had great business results in 2014 and 2015, and "Sloboda" a.d. The lowest value, as we can see in Figure 6 has "Zastava oružje"., with constant negative results. This is due to large customer receivables, whereby current liabilities can not be settled, which in turn affects the company's final business result and income (Figure 7).

The rate of return on total assets is the return on the invested assets, ie the total assets involved, ie the degree of efficiency. This indicator shows how much the company's management manages effectively to maximize profits (Figure 8).

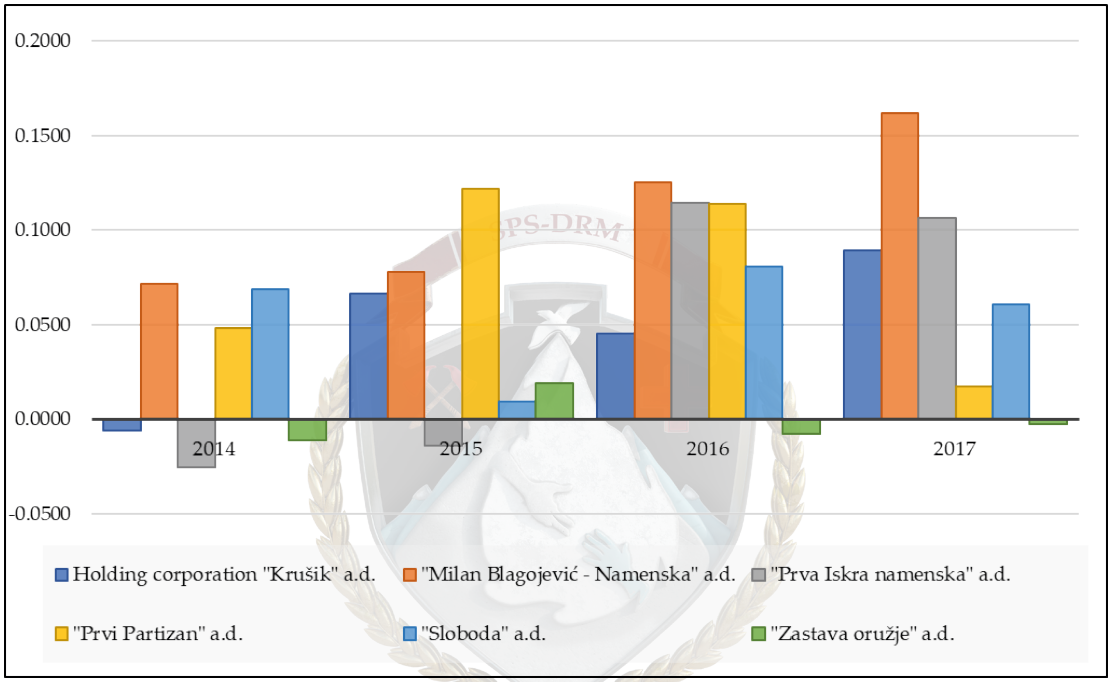


Figure 8. Return on assets (ROA). Source: Authors

Comparative advantage is the systematization of experience in a rounded cycle of independent development and production of a wide range of assets, weapons and military equipment, as well as complex combat systems. Knowledge of standards for development and technologies for the production of Eastern and Western origin. High-quality human capital is also distinguished by dedicated industries.

Table 2. Analysis of Employment Levels in Serbia's Leading Defence Industry Companies During the 2015-2017 Business Years.

No.		1	2	3	4	5	6	TOTAL
Company of Serbian defence industry		Holding corporation "Krušik" a.d.	"Milan Blagojević - Namenska" a.d.	"Prva Iskra namenska" a.d.	"Prvi Partizan" a.d.	"Sloboda" a.d.	**"Zastava oružje" a.d.**	
City		**Valjevo**	**Lučani**	**Barič**	**Užice**	**Čačak**	**Kraguje-vac**	
INDICATOR					**Employment**			
Business year	2015	1385	1121	149	933	1621	2300	**7509**
	2016	1922	1202	151	1541	1803	2375	**8994**
	2017	2615	1297	152	1546	2015	2422	**10047**

As illustrated in Table 2, the analysis of employment based on annual financial statements, publicly available on the Business Registers Agency's website, reveals a notable trend. During the period from 2015 to 2017, the level of employment in the analyzed companies within Serbia's defence industry increased by approximately 30%, which is an extremely positive development. The defence industry directly employs over 10,000 individuals, and when considering its cooperative companies, this number exceeds 20,000 people. Economically, this industry's restructuring and the rising demand for both professional and junior personnel significantly benefit the entire Serbian economy by fostering sustainable development.

From the perspective of critical infrastructure security, the Serbian defence industry has made substantial efforts in recent years, drawing from past experiences and disasters. These efforts are focused on modernizing existing protection capacities, with active participation from Serbia's professional and academic communities. This modernization not only enhances the industry's resilience but also supports broader national security objectives.

4. Recommendations for Enhancing the Security and Resilience of Critical Infrastructure in Serbia's Defence Industry

The following recommendations aim to bolster the security and resilience of critical infrastructure within Serbia's defence industry, ensuring robust protection and sustained functionality:

a) Continuously identify, analyze, and implement incentives to justify the costs of improved security and resilience;
b) Balance short-term expenses with near-term benefits to support additional investments;
c) Develop market-based incentives to drive significant changes in business practices and foster markets for insurance against cyber, chemical, biological, and radiological risks;
d) Support research and data collection to quantify the potential costs of inadequate infrastructure security, resilience, and cyber preparedness;
e) Utilize collected data to enhance risk management strategies and enable data-driven decision-making;
f) Establish innovation challenge programs to incentivize new solutions for infrastructure security and resilience during the planning, design, and redesign phases;
g) Collaborate with international partners and participate in global initiatives to gain valuable insights and best practices;
h) Apply emerging technologies such as artificial intelligence, machine learning, and big data analytics to predict and mitigate potential risks more effectively;
i) Use these technologies for real-time monitoring, predictive maintenance, and automated response mechanisms to reduce vulnerabilities and enhance resilience;
j) Continue national efforts in Serbia to propose a resilience assessment framework for critical infrastructures, focusing on risk assessment to address identified gaps;
k) Ensure this framework captures interdependencies across different infrastructures, sectors, and borders, with a particular focus on resilience;
l) Promote effective information sharing among partners to build situational awareness and enable risk-based decision-making;
m) Foster collaboration between infrastructure owners and operators, government entities, academia, and non-profits to ensure successful risk management;
n) Achieve consensus on common risk metrics across sectors to ensure consistency and effectiveness in measuring and managing risks;
o) Harmonize the national risk assessment framework with EU policies and strategies for critical infrastructure;

p) Recognize the rapid integration of the defence industry into economic flows as a vital element of Serbia's national security policy;

q) Align with European standards and regulations, and establish preventive and control mechanisms for critical defence infrastructure to maintain Serbia's defence, security, and foreign policy interests;

r) Develop mechanisms to protect critical infrastructure from global, regional, and internal threats, making this a national security priority for Serbia;

s) By implementing these recommendations, Serbia can significantly enhance its efforts to secure and sustain critical infrastructure, contributing to national stability and prosperity.

By implementing these recommendations, Serbia can significantly enhance its efforts to secure and sustain critical infrastructure, contributing to national stability and prosperity.

5. Conclusion

The impact of infrastructure disruption is typically quantified in terms of aggregated figures that represent economic losses. This approach allows policymakers to evaluate various disruption scenarios, including cascading effects across sectors, and to assess the costs and benefits of mitigation measures (Giannopoulos et al., 2012). A comprehensive risk assessment is achievable when the impact data is combined with the likelihood of these scenarios. Without this information, the analysis remains an impact assessment and cannot effectively prioritize risk mitigation measures, especially for High Impact Low Probability (HILF) events. A significant challenge for risk assessment methodologies is to address these gaps and develop a harmonized framework at the national level, extending to the defence industry.

Such a framework should accurately capture interdependencies across different infrastructures, sectors, and borders—a critical requirement for the West Balkan countries in coordination with EU critical infrastructure policies and strategies. Additionally, there must be consensus on a common risk metric across sectors. In summary, risk assessment for critical infrastructures should be an integral part of a broader framework, with resilience analysis as the primary tool. The continuation of this work at the national level in Serbia should focus on proposing a resilience assessment framework for critical infrastructures, where risk assessment serves as a subset to bridge the gaps identified in this research.

The social and economic stability of the world now heavily relies on the reliable supply of basic goods and services, transported and distributed through extensive technological network infrastructures. National security today depends significantly on these capacities, including the smooth functioning of the defence industry's complexes, as seen in Serbia. These critical infrastructures are subject to potential disruptive factors from hazardous natural and human environments, such as the global political climate, human capital, financial crises, severe damage, explosions in warehouses, and organized (cyber) crime or cyber warfare (Zio, 2016). The infrastructure systems within the Serbian defence industry are exposed to numerous external and internal influences, creating a potential base from which dangerous hazards and harmful events can quickly and globally spread throughout the system. This has increased systemic risk exposure, characterized by cascading failures that can significantly impact both national and regional levels. Indeed, significant disruptions have highlighted the need for the protection and resilience of critical infrastructures as a national and international priority.

In conclusion, the integrity, economic, and security stability of Serbia is closely tied to the state and developmental potential of the defence industry. Its rapid development and integration into national and international economic flows, through the acquisition of new technologies, has been recognized as a vital element of Serbia's national security policy. Aligning with European standards and regulations, and establishing preventive and control mechanisms for critical defence infrastructure, are fundamental prerequisites for maintaining the integrity of defence, security, and foreign policy interests, as well as enhancing the overall credibility of Serbia. Given the context of global,

regional, and internal threats, developing adequate mechanisms for the protection of critical infrastructure has become a national security priority for Serbia.

Funding: This research was funded by the Scientific–Professional Society for Disaster Risk Management, Belgrade (https://upravljanje-rizicima.com/, accessed on 10 July 2024) and the International Institute for Disaster Research (https://idr.edu.rs/, accessed on 10 July 2024), Belgrade, Serbia.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Baruh, S., Dey, C., & Dutta, N. P. M. K. (2023). Dima Hasao, Assam (India) landslides' 2022: A lesson learnt. International Journal of Disaster Risk Management, 5(1), 1-13.
2. Bouchon S. (2006). The vulnerability of interdependent critical infrastructures systems: epistemological and conceptual state-of-the-art. Ispra, Italy: European Commission, Directorate-General Joint Research Centre, Institute for the Protection and Security of the Citizen.
3. Business Registers Agency, Financial reports of defence industry's companies, Retrieved from www.apr.gov.rs, accessed on 15th November 2018.
4. Carla S., R. (2019). School-community collaboration: disaster preparedness towards building resilient communities. 1(2), 45-59.
5. Carlson L., Bassett G., Buehring W., Collins M., Folga S., Haffenden B., Petit F., Phillips J., Verner D., and Whitfield R. (2012). Resilience Theory and Applications, Argonne National Laboratory, Decision and Information Sciences Division, ANL/DIS-12-1, Argonne, Ill., USA, Retrieved from http://www.dis.anl.gov/pubs/72218.pdf, accessed November 16th, 2018.
6. Carreras BA, Newman DE, Dobson I, Poole AB. (2004). Evidence for self-organized criticality in a time series of electric power system blackouts. Circuits Syst I: Regul Pap, IEEE Trans;51(9), pp. 1733–1740.
7. Cimellaro GP, Reinhorn AM, Bruneau M. (2010). Framework for analytical quantification of disaster resilience. Eng Struct, 32(11), pp. 3639–3649.
8. Cvetković, V. (2024). Disaster Risk Management. Belgrade: Scientific-Professional Society for Disaster Risk Management.
9. Cvetković, V. (2014). Spatial and temporal distribution of floods like natural emergency situations. International scientific conference "Archibald Reiss days" Thematic conference proceedings of international significance (3-4 march 2014), Belgrade, The Academy of Criminalistic and Police Studies, 371-389, volume II.
10. Cvetković, V. (2019). Risk Perception of Building Fires in Belgrade. International Journal of Disaster Risk Management, 1(1), 81-91.
11. Cvetković, V. (2024b). Essential Tactics for Disaster Protection and Rescue. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
12. Cvetković, V. M. (2016). Fear and floods in Serbia: Citizens preparedness for responding to natural disaster. Zbornik Matice srpske za drustvene nauke, 155(2), 303-324.
13. Cvetković, V. M. (2023). A Predictive Model of Community Disaster Resilience based on Social Identity Influences (MODERSI). International Journal of Disaster Risk Management, 5(2), 57-80.
14. Cvetković, V. M., & Marković, K. (2021). Examining the Impact of Demographic and Socio-Economic Factors on the Level of Employee Preparedness for a Disaster Caused by Fires: A Case Study of Electrical Power Distribution in Serbia. International Scientific Conference 30 Years of Independent Macedonian State 13-15 September 2021, Ohrid.
15. Cvetković, V. M., & Šišović, V. (2023). Capacity Building in Serbia for Disaster and Climate Risk Education. In Disaster and Climate Risk Education: Insights from Knowledge to Action (pp. 299-323). Springer Nature Singapore Singapore.
16. Cvetković, V. M., & Šišović, V. (2024). Community Disaster Resilience in Serbia. Scientific-Professional Society for Disaster Risk Management, Belgrade.
17. Cvetković, V. M., Dragašević, A., Protić, D., Janković, B., Nikolić, N., & Milošević, P. (2022). Fire safety behaviour model for residential buildings: Implications for disaster risk reduction. International Journal of Disaster Risk Reduction, 102981. doi:https://doi.org/10.1016/j.ijdrr.2022.102981

18. Cvetković, V. M., Nikolić, N., & Lukić, T. (2024). Exploring Students' and Teachers' Insights on School-Based Disaster Risk Reduction and Safety: A Case Study of Western Morava Basin, Serbia. Safety, 10(2), 50.
19. Cvetković, V. M., Tanasić, J., Ocal, A., Kešetović, Ž., Nikolić, N., & Dragašević, A. (2021). Capacity Development of Local Self-Governments for Disaster Risk Management. International Journal of Environmental Research and Public Health, 18(19), 10406.
20. Cvetković, V. P. S., & Janković, B. (2021). Private security preparedness for disasters caused by fires. Journal of Criminalistics and Law, NBP, 26(1).
21. Cvetković, V., & Filipović, M. (2017). Information systems and disaster risk management. Paper presented at the International Scientific and Professional Conference – 40 years of higher education in the field of security – Theory and Practice, Skopje, Republic of Macedonia.
22. Cvetković, V., & Kezunović, A. (2021). Security Aspects of Critical Infrastructure Protection in Anthropogenic Disasters: A Case Study of Belgrade. Research Squares - Preprint, 10-21203.
23. Cvetković, V., & Martinović, J. (2020). Innovative solutions for flood risk management. International Journal of Disaster Risk Management, 2(2).
24. Cvetković, V., & Šišović, V. (2024). Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. Sustainability, 16(7), 2620. Retrieved from https://www.mdpi.com/2071-1050/16/7/2620
25. Cvetković, V., Babić, S., & Gačić, J. (2017). Religiousness level and citizen preparedness for natural disasters. Vojno delo 69(4):253-262
26. Cvetković, V., Bošković, N., & Ocal, A. (2021). Individual citizens' resilience to disasters caused by floods: a case study of Belgrade. PREPRINT (Version 2) available at Research Square [https://doi.org/10.21203/rs.3.rs-923368/v2].
27. Cvetković, V., Nikolić, N., & Lukić, T. (2024). Exploring Students' and Teachers' Insights on School-Based Disaster Risk Reduction and Safety: A Case Study of Western Morava Basin, Serbia. Safety, 10(2), 2024040472.
28. Cvetković, V., Pavlović, S., & Janković, B. (2021). Private security preparedness for disasters caused by fires. Journal of Criminalistics and Law, NBP, 26(1), 35-59.
29. Cvetković, V., Pavlović, S., & Janković, B. D. (2021). Factors of influence on the preparedness of the private security members for fire emergencies. NBP-Journal of Criminalistics and Law, 26(1), 35-59.
30. Cvetković, V., Rikanović, S., & Knežević, S. (2022). The resilience of society in disasters caused by nuclear accidents. IAI International Academic Conference, 5th May 2022 at Corvinus University in Budapest, HungaryAt: Budapest, Hungary.
31. Cvetković, V. M., Tanasić, J., Renner, R., Rokvić, V., & Beriša, H. (2024). Comprehensive Risk Analysis of Emergency Medical Response Systems in Serbian Healthcare: Assessing Systemic Vulnerabilities in Disaster Preparedness and Response. Healthcare 12 (19), 1962.
32. El-Mougher, M. M., Abu Sharekh, D. S. A. M., Abu Ali, M.., & Zuhud, D. E. (2023). Risk Management of Gas Stations that Urban Expansion Crept into the Gaza Strip. International Journal of Disaster Risk Management, 5(1), 13-27.
33. Frosdick, S. (1997). The techniques of risk analysis are insufficient in themselves. Disaster Prevention and Management: An International Journal, 6(3), 165-177.
34. Giannopoulos G., Filippini R., Schimmer M. (2012). Risk assessment methodologies for Critical Infrastructure Protection. Part I: A state of the art, European Commission: Joint Research Centre, Institute for the Protection and Security of the Citizen, pp. 1-53.
35. Goyal, N. (2019). Disaster governance and community resilience: The law and the role of SDMAs. International Journal of Disaster Risk Management, 1(2), 61-75.
36. Grozdanić, G., & Cvetković, M. V. (2024). Exploring Multifaceted Factors Influencing Community Resilience to Earthquake-Induced Geohazards: Insights from Montenegro. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
37. Hromada, M., & Lukas, L. (2012). Critical Infrastructure Protection and the Evaluation Process. International Journal of Disaster Recovery and Business Continuity, 3.
38. Kumiko, F., & Shaw, R. (2019). Preparing International Joint Project: Use of Japanese Flood Hazard Map in Bangladesh. International Journal of Disaster Risk Management, 1(1), 62-80.
39. Law on Critical Infrastructure (2018), Official Gazette of the Republic of Serbia, no. 87/18.

40. Lewis TG. (2006). Critical infrastructure protection in homeland security: defending a networked nation, Wiley.
41. Mano, R., A, K., & Rapaport, C. (2019). Earthquake preparedness: A Social Media Fit perspective to accessing and disseminating earthquake information. International Journal of Disaster Risk Management, 1(2), 19-31.
42. Ministry of Defence, Report of the defence industry of the Republic of Serbia, Retrieved from www.mod.gov.rs on 29th November 2018.
43. Ministry of Trade, Tourism and Telecommunications (2018). Report and list of persons registered for foreign trade in weapons and military equipment, Retrieved from www.mtt.gov.rs, on 2nd November 2018.
44. Moteff JD. (2012). Critical infrastructure resilience: the evolution of policy and programs and issues for congress. Congr Res Serv/12.
45. Murray, A. T., & Grubesic, T. H. (2012). Critical infrastructure protection: The vulnerability conundrum. Telematics and informatics, 29(1), 56-65.
46. Nikčević S. (2009). Security integration and the Serbian defence industry. Chance for sustainable development. Economics and Security, Center for Civil-Military Relations, Belgrade, pp. 169-179.
47. Obama B. (2013). Presidential policy directive 21: critical infrastructure security and resilience. Washington, DC, U.S.
48. Öcal, A. (2019). Natural Disasters in Turkey: Social and Economic Perspective. International Journal of Disaster Risk Management, 1(1), 51-61.
49. Perić, J., & Cvetković, V. M. (2019). Demographic, socio-economic and phycological perspective of risk perception from disasters caused by floods: case study Belgrade. International Journal of Disaster Risk Management, 1(2), 31-45.
50. Petit F., Verner D., Brannegan D., Buehring W., Dickinson D., Guziel K., Haffenden R., Phillips J., Peerenboom J. (2015). Analysis of critical infrastructure dependencies and interdependencies. Risk and Infrastructure Science Center, Global Security Sciences Division, Argonne National Laboratory.
51. Petit F.D., Bassett G.W., Buehring W.A., Collins M.J., Dickinson D.C., Haffenden R.A., Huttenga A.A, Klett M.S., Phillips J.A., Veselka S.N., Wallace K.E., Whitfield R.G., and Peerenboom J.P., (2013). Protective Measures Index and Vulnerability Index: Indicators of Critical Infrastructure Protection and Vulnerability, Argonne National Laboratory, Decision and Information Sciences Division, ANL/DIS-13-04, Argonne, Ill., USA, Retrieved from http://www.ipd.anl.gov/ anlpubs/2013/11/77931.pdf, accessed November 5th, 2018.
52. Radić N., Radić V. (2018). Foreign Direct Investments in the Defence Industry of Serbia, Military Work 5/18, pp. 163-190.
53. Radić V., Radić N. (2018). Economic Aspects and National Self-Sufficiency of the Defence Industry of Serbia, Military Work Vol. 70, No. 4, pp. 162-179.
54. Rajani, A., Tuhin, R., & Rina, A. (2023). The Challenges of Women in Post-disaster Health Management: A Study in Khulna District. International Journal of Disaster Risk Management, 5(1), 51-66.
55. Rinaldi S.M., Peerenboom J.P., Kelly T.K. (2001). Complex Networks, Identifying, Understanding, and Analyzing Critical Infrastructure Interdependencies, IEEE Control Systems Magazine, December 2001, pp. 11–25.
56. Škero, M., & Ateljević, V. (2015). Protection of critical infrastructure and basic elements of compliance with Council Directive 2008/114 / EC. Vojno delo, 67 (3), 192-207.
57. Sudar, S., Cvetković, V., & Ivanov, A. (2024). Harmonization of Soft Power and Institutional Skills: Montenegro's Path to Accession to the European Union in the Environmental Sector. International Journal of Disaster Risk Management, 6(1), 41-74.
58. U.S. Department of Homeland Security - DHS (2013). NIPP 2013 – Partnering for Critical Infrastructure Security and Resilience, Retrieved from https://www.dhs.gov/sites/default/files/publications/NIPP%202013_Partnering%20for%20Critical%20Infrastructure%20Security%20and%20Resilience_508_0.pdf, accessed November 17th, 2018.
59. Vibhas, S., Bismark, A. G., Ruiyi, Z., Anwaar, M. A., & Rajib, S. (2019). Understanding the barriers restraining the effective operation of flood early warning systems. International Journal of Disaster Risk Management, 1(2), 1-19.

60. Xuesong, G., & Kapucu, N. (2019). Examining Stakeholder Participation in Social Stability Risk Assessment for Mega Projects using Network Analysis. International Journal of Disaster Risk Management, 1(1), 1-31.
61. Zio E. (2016). Challenges in the vulnerability and risk analysis of critical infrastructures, Reliability Engineering and System Safety, pp. 137-150.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Review Article

Disaster Risk Reduction and Disaster Risk Management: State of Play in North Macedonia

Aleksandar Ivanov[1]*

[1] University of St. „Kliment Ohridski" – Faculty of Security Studies – Skopje; aleksandar.ivanov@uklo.edu.mk

* *Correspondence: aleksandar.ivanov@uklo.edu.mk.*

Received: 3 August 2024; Revised: 1 October 2024; Accepted 29 November 2024; Published: 25 December 2024

Abstract

This paper explores the state of disaster risk reduction (DRR) and disaster risk management (DRM) in North Macedonia, highlighting their theoretical, normative, and institutional aspects. It examines the complex processes of crisis management, risk management, and DRR systems in the country, focusing on their alignment with international frameworks like the Sendai Framework for Disaster Risk Reduction. Key indicators for crisis identification and risk reduction are analyzed, along with the integration of national mechanisms into global and regional disaster risk platforms. The study emphasizes the challenges faced by the DRR system, including inefficiencies, coordination gaps, and resource constraints, and proposes strategic recommendations for improving preparedness, response, and recovery. The findings underscore the critical need for strengthening institutional capacity and enhancing interagency collaboration to build a resilient society capable of addressing the multifaceted risks of natural and anthropogenic disasters.

Keywords

Risk; management; reduction; crisis; disaster; North Macedonia.

1. Introduction

In a historical sense, it can hardly be said that there were societies that did not directly or indirectly face natural disasters. As a serious threat to human survival, natural disasters have long been perceived as «God's message» that was addressed to people for various reasons. For example, with the spread of Christianity around 2000 AD, natural disasters were believed to be special messages sent directly from God to punish sinners (Ivanov & Cvetkovik, 2016:6).

Risks, crises and security are not new problems and they will not be completely solvable in the future. Now the risks are not so much «related to God» but more related to human activities, human errors, irrationality, cultural misunderstandings, systemic flaws and omissions, or are they just a homeostatic need to maintain the level of risk in our lives? Even if we tried and succeeded in combining all these theories we still could not manage risk successfully (Borodzicz, 2005, p.152). Borodzicz compares risk management to weather forecasting, particularly, he says, in northwestern Europe.

There is undoubtedly a link between the economic, the social and the vulnerabilities resulting from environmental risks. It does not need to be proven at the level of a general assumption. When we talk about disaster risk reduction, we are talking about a global and systematic approach, in which the following are of critical importance:

- *The First International Conference on Disaster Risk Reduction in Hyogo* in 1994. from which derives the International Strategy for Disaster Risk Reduction;
- *The second international conference from Hyogo*, from which emerged the Global Platform for Disaster Risk Reduction in 2006; and
- *The Third Sendai World Conference on Disaster Risk Reduction*, 2015, from which the Sendai Framework for Disaster Risk Reduction emerged.

The 2017 Global Forum in Mexico confirmed the interdependence and connection between 1. Disaster Risk Reduction; 2. Achieving the goals for sustainable development; 3. The Paris Agreement on climate change; and 4. The new urban agenda (Ivanov, Babanoski, & Cvetkovik, 2023).

In North Macedonia, the first National Platform for Disaster Risk Reduction since 2009. is the result of the implementation of the Global Framework adopted in Hyogo. Namely, it is a global strategic action plan that was adopted with the support of 168 countries. It is also fully compliant with the Millennium Development Goals laid down at the 2002 Johannesburg summit. The establishment of this platform represented the operationalization of the normative assumptions of the Law on Crisis Management and the Law on Protection and Rescue (Figure 1). In an international context, disaster risk reduction is hierarchically organized as shown in the graphic below:

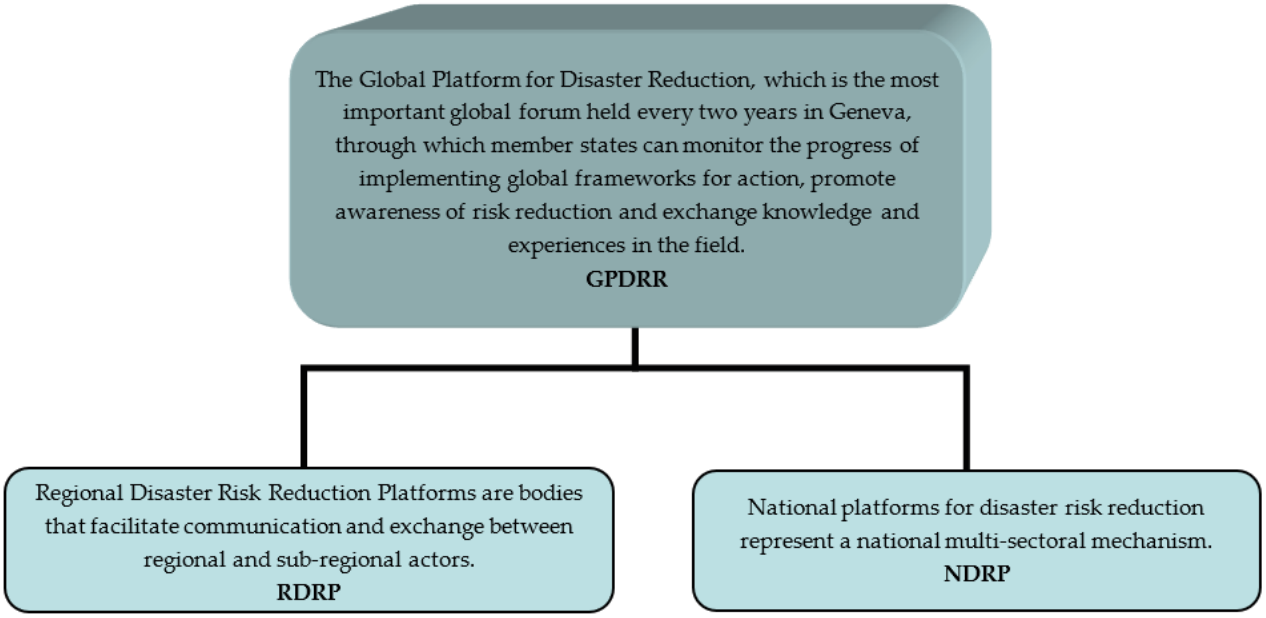


Figure 1. Disaster Risk Reduction Organization

2. Crisis management: theoretical fundamentals

Crisis can be defined as the separation/distinction of the structure/form between an emergency and a disaster. A risk can cause a crisis, which as a result can turn into a disaster. (Cvetković, 2024a, 2024b; Cvetković, Nikolić, & Lukić, 2024; Cvetković & Šišović, 2024; Cvetković & Šišović, 2024a, 2024b). The concept of crisis is relatively unexplored, although the analysis of human behaviour (the so-called human factor) in anticipation and resolution of a crisis is now receiving considerable attention from the academic community (Borodzicz, 2005, p. 74). In a theoretical sense, disaster management entails much of what is meant by crisis management. Disaster management is largely concerned with the practical problems of emergency planning, «picking up the pieces» when the unwanted and unexpected has happened. Such theoretical «apostrophes» are useful in discussing the deployment of crisis management and protection and rescue systems (Cvetković, 2023; Cvetk-

ović, Čvorović, & Beriša, 2023; Cvetković et al., 2022; Cvetković & Planić, 2022; Cvetković, Tanasić, et al., 2023; Janković et al., 2023).

In terms of security, the crisis gained a new significance at the global level in the context of terrorism and the attack on the USA in 2001. For the Macedonian state, the crisis in 2001 had such significance, both in terms of conceptualization and in terms of institutionalization and the implementation of security strategies and plans. The term crisis is today a subject of mass use. The simplest definition is that it is a large and unfavourable event that occurs suddenly and has negative results. But Postolov emphasizes in this part that although it is an event that occurs suddenly, it is an event that can be predicted to a certain degree (Postolov, 2011, p. 295). When we talk about a crisis, we are talking about a situation that is characterized by endangering values, goals, and resources, we are talking about an immediate or indirect danger to a certain system (state, municipality, economic entity, etc.). For the crisis, both variables are tied together: 1) The existence of danger; and 2) Time pressure to resolve the same.

On the other hand, crises may and may not have specific symptoms. For example, we cannot predict a crisis caused by an earthquake (this does not mean that we cannot take preventive actions). But a crisis caused by armed criminal groups, not only we can, I would say, we must foresee the literature talks about symptoms of crises. We can also name them as indicators or metrics. Theorists and practitioners agree that: «crisis management and dealing with risks and hazards are essentially different things.» Economic science differentiates two types of crisis management:

1) First, active crisis management that can be:
    a. Anticipatory which:
        i. It covers the activities for thoughtful preparation of countermeasures using specific scenarios in the form of alternative plans to obtain in time in the event of a crisis (standard operating procedures are a reflection of this system).
ii. It has a preventive character: and
iii. c. Which can, based on specific early warning information, plan, implement and control preventive strategies to avoid a latent state of crisis (many similarities can be observed, i.e. there is an explanation of what the Crisis Management Law calls the System for early warning); and

2) Reactive which:
    a. Is repulsive;
        i. It is applied under the conditions of the crisis that has already occurred and the attitude of the management that it can be overcome.
        ii. It is liquidation in nature:
        iii. And it represents a form of crisis management according to which there is no chance to get out of the crisis.

Active crisis management includes activities that take into account the problem before it happens, thus minimizing the likelihood of surprise. Reactive crisis management includes activities that quickly and efficiently respond to sudden discontinuities in the functioning of the organization (Postolov, 2011, p. 310).

Latent crises, according to Postolov, can be recognized in time with active crisis management, which is the basis of the early warning system, which we should mention is the legal definition of the crisis management system. So this system has the task of identifying risks and dangers for them by providing information on:

- Timely notification of the users of the information about the occurrence of crises; and
- Getting time for an appropriate reaction from the «users», in the case - the Steering Committee.

The basis for the existence of the early warning system is the continuous and complete collection of all data, and their assessment, no matter how insignificant they seem at the moment. The information is subject to assessment according to several criteria, such as the intensity, ie how often it occurs, the significance in relation to the defined goals of the organization, the time of occurrence and the possibility of a reaction.

Reactive crisis management, as we have seen above, can be both manageable and unmanageable. He answers the questions of what steps are taken during the crisis and how to return the situation to its original state. This process consists of a rough and detailed analysis of the situation, determination of goals and strategy of management and application of concrete measures to deal with it.

The reason why this section is located at the head of this study entitled «risks» is to consider that crisis management is part of the overall reduction of disaster risks that can be caused by all the listed activities, while the management system with crises with the Center as its bearer (the Steering Committee and the Assessment Group) is largely related to the established risks and dangers which, in turn, are fully related to the risks and dangers that have the potential to cause disasters.

3. Risk management in North Macedonia

The basic ways to deal with natural disasters are assessment of the risk and the consequences of preventive and normative taking of the established measures, namely: planning, organizing, training and preparation of the reaction resources; reaction (organized provision of protection and rescue assistance after the occurrence of the disaster); and rehabilitation (recovery and reconstruction after the end of the disaster) (Toth, Čemerin & Vitas, 2011:167). It is safe to say that management is one of the most complex human activities that is aimed at managing it, i.e. establishing a normal or usual situation in the community (society) as quickly as possible (Ogorec, 2010; Cvetković, 2014; Cvetković & Petrović, 2015).

Mitigating the consequences of natural disasters consists of the effort/action aimed at minimizing the degree of risk, preventing the disaster and reducing the vulnerability of the ecological and social system, that is, the community (Alexander, 1993:52). This refers to activities designed to reduce or eliminate risks to the population, their property and the environment, as well as to reduce the consequences of natural disasters (Ivanov & Cvetkovic, 2016).

Most often, risks are divided into: 1) natural risks; and 2. human risks.

Risks from nature (biogenic):

⇒ *Terrestrial (planetary), including the risks of occurrence of various elementary (so-called natural) disasters (earthquakes, volcanic eruptions, destructive winds, floods, droughts, microclimatic disturbances, etc.);*

⇒ *Extraterrestrial (extra-planetary), which include the risks of planetary disasters caused by extra-planetary influences and processes (collision of celestial bodies with the Earth: asteroids, meteors, comets, etc.; cosmic nuclear explosions and explosions of stars-supernovae; changes in the structure of our solar system and our galaxy - the Milky Way; possible threats from other forms of life, civilizations and technologies in the form of attacks, invasions, intrusions, etc.. i.e. risks from so-called UFO (UFO) phenomena and threats); and*

Human/Man-made (anthropogenic) risks:

⇒ Risks from society, which include social estrangement - alienation; social disorganization – anomie; social anxiety - anxietization;

⇒ The malfunctioning of social systems: legal, economic, political, etc.; inappropriate and undeveloped multicultural and intercultural interaction and communication in multicultural and intercultural societies etc.;

⇒ Risks of a technical-technological nature, which include the production of genetically modified food (GMF), plants and animals; cloning; production of chemical, biological and nuclear weapons of mass destruction (WMD); inadequate management of large technical-technological systems that can cause large technical-technological breakdowns and disasters: nuclear and chemical factories, oil platforms, refineries, ferrous and non-ferrous metallurgy plants, large

information systems; inadequately regulated and unsafe traffic and transportation of raw materials, materials, dangerous substances: explosive and easily flammable substances; environmental pollution and externalities, etc. (Герасимовски, 2010, pp. 128-129)

Managing risks as well as assessing them are two parts of a process known as risk analysis. A complex scientific process involving various disciplines (eg physics, chemistry, toxicology, law, economics, sociology, political science and engineering) and inter-disciplinary disciplines (ecology and environmental sciences) and dealing with the complicated technical, life-related environment, economic and social problems where the dangers may threaten the population or the eco-systems (Ganoulis & Simpson, 2006, стр. 245)

On this occasion, we would state the basic assumptions of risk management, on which the security dilemmas related to disaster risk reduction are based. First, we need to assume anticipation (prediction) of the risks, their true structure, the most likely moment of their occurrence and the extent of possible effects if they occur. When we talk about risks, we are mostly talking about dealing with risks, mostly as a result of the risky character of today's society and the risk culture. Namely, dealing with risks implies choosing and applying the most appropriate response, determining and applying the reaction method and monitoring the course of dealing with performance feedback; in the broader sense of the word, where the management consists of five stages: 1) Detection of risks; 2) Their understanding; 3) Assessment; 4) Prognosis; and 5) Coping in the narrower sense of the word (Gerasimovski, 2010, p. 248). And this approach seems to correspond to reality. Especially if we consider that man cannot predict and has many organic means to prevent risks, especially not those related to environmental changes that have the epithet of risk or accident. In this sense, the activities of the United Nations, which declared the last decade of the 20th century as the «International Decade for Natural Disaster Reduction», continued with the declaration of the International Strategy for Disaster Reduction – ISD) have established the doctrine that natural disasters, by themselves, do not lead to disasters, but that disasters are the result of the impact of natural disasters on vulnerable social systems. In other words, disasters can be prevented through deliberate human action aimed at reducing vulnerability (Lazarevski, Ѓorgon, & Taleski, 2010, pp. 10-17).

Reducing the risks in key sectors, as well as strengthening the readiness to respond, are some of the basic prerequisites for realizing a higher level of risk management. They are determined as priorities at the international and national level. The environment, natural resources and their management are undoubtedly one of the key elements in this sense.

In the part of the sources of threats in the Republic of North Macedonia, the Decree on the methodology for the preparation of the assessment of the threat to security as indicators for risk assessment establishes (Table 1):

Table 1. Thematic Division of Territorial Characteristics and Risk Elements.

Thematically divided
⚜ **Geographical characteristics:**
Geographical position and size, relief features, forest cover and other vegetation cover, basic characteristics of the land, climatic conditions, hydrographic network, type and amount of atmospheric and other waters;
◎ Organization and use:
Socio-economic characteristics, natural resources, population and organization of settlements and activities, communication network, traffic and connections, environment and natural resources, cultural and historical heritage, road network, and other infrastructure;
◎ Populated places
Names, size and boundaries of each city and larger settlements, urban and rural structure of settlements, demographic profile;

⚜ **Economic profile**
Economic development, present industry and other production facilities (by cities and settlements), industry with hazardous material (with determination of the potential for endangerment);
⚜ **General characteristics of development**
The current purpose of the land and development characteristics, development goals for the territory (spatial plan for the Republic, General/detailed urban plan of the municipalities;) and
⚜ **Summary and detailed description of the represented risk elements according to the nomenclature of the unique methodology for damage assessment from natural (natural) disasters.**

When we talk about the manifestations of risks and dangers, we are talking about a moderate generalization of illegal behaviours, and natural or man-made accidents in the broadest sense of the word. In the following lines, we will try to present the manifestations that represent a security risk and danger that can have a wider scale and its impact is not limited to isolated case/s. These activities, if they meet a certain degree of endangerment, can cause a crisis and ultimately lead to disasters (Table 2).

Table 2. Risks in North Macedonia.

1)	Nationalism, religious intolerance and hatred, forms and activities related to international terrorism, organized crime, illegal trafficking in drugs, weapons and people, possession of large quantities of illegal weapons, corruption, urban terrorism, serious crime, including blackmail, murder and attacks on citizens and of their ownership and consequences of the means of mass destruction;
2)	Activities of foreign special services and other activities aimed at worsening the security situation;
a.	Incidents at the border;
b.	Airspace Violations;
c.	Terrorist activities, diversions and sabotages;
d.	Demonstrations, strikes and large-scale riots that threaten public order and peace;
e.	Unauthorized disclosure, publication and violation of the security of information and communications;
3)	Consequences of a conflict of interests for using the sources and routes of strategic energies, as well as hindering and blocking their import into the Republic of Macedonia;
4)	Natural and other disasters;
a.	Floods;
b.	Landslides and major landslips;
c.	Intense snowfall, snowdrifts and avalanches and freezing phenomena of river courses and lakes;
d.	Other natural disasters (lightning strikes, strong winds, thick fogs, extremely low or high temperatures, heavy rains, droughts, hail, hail and others;
e.	Large-scale fires;
5)	Technical-technological disasters;
a.	Explosions;
b.	Disasters in mines or production facilities;
c.	Cracks, collapses and other damage to dams threaten the population and material goods;
d.	Radiological, chemical or biological contamination and pollution of air, watercourses and the human environment;
e.	Accidents and major defects;
f.	Traffic accidents in road, rail, water and air traffic;
g.	Mass poisoning with food, chemicals or poisonous substances;
6)	Epidemics of quarantine and other infectious diseases in humans, animals and plants;
a.	Outbreaks of infectious diseases in humans (epidemics)
b.	Outbreaks of infectious diseases in animals (epizootics);
c.	Occurrence of infectious diseases in plants (epiphytes);
7)	Large-scale degradation and destruction of the environment; (safety relevant to the environment)

8)	Disturbance of regular conditions in the communal sphere, traffic and problems in the supply of food and material goods (interruptions in water supply, electricity supply, heating network, gasification network, telecommunications network, traffic diversions, the situation at border crossings, the situation with blood and blood products and other health conditions; and
9)	Finding unexploded ordnance left behind. (The decree on the type of data and information and the method and procedure of their delivery to the Crisis Management Center, 2007, p. article 3 – 12)

4. Disaster risk reduction system in North Macedonia: overview and challenges

The security systems of countries around the world are facing numerous threats. (Chakma, 2023; Cvetković & Planić, 2022; Cvetković, Romanić, & Beriša, 2023; El-Mougher, 2022; Iftikhar & Iqbal, 2023; Islam, 2023; Kabir, Hossain, & Haque, 2022; Kabir, Tanvir, & Haque, 2022; Molnár, 2024; Odero & Mahiri, 2022; Port & Jawahar, 2024; Sergey & Gennadiy, 2022; Starosta, 2023; Sudar, Cvetković, & Ivanov, 2024). Those threats can have a different nature, come from different sources, manifest differently and ultimately have the potential to harm people's usual behaviour and living. In the most general sense, security systems in the world are tasked with dealing with three (in the broadest sense of the term) groups of threats. The first is a traditional threat in the form of the use of organized violence aimed at threatening the territorial integrity and sovereignty of states. The second is related to preventing and dealing with internal security threats (crime, which can be at the national and international level, further, disruption of public order and peace, terrorism, illegal trade and smuggling, etc.). *The third type is the subsystem that is to the greatest extent our subject of interest, and it refers to the prevention, handling and management of natural and other disasters, technical-technological disasters (industrial, electrical, chemical, nuclear, telecommunication, information systems and as well as other large systems), epidemics and other infectious diseases, as well as for larger-scale degradations and destruction of the environment.*

If we imagine that the state is conditionally based on, among other important elements, the following pillars: 1. *Social regulation* (implies the normative activity of the highest sovereign authority in the political arrangement in the state, with which it frames and regulates social relations); 2. *Institutional architecture* (the political authority needs the operationalization of its policies, primarily intended for the application of social regulation in the everyday life of people, with the right to apply and the power it has at its disposal on monopolistic grounds) - then it is necessary to assert that from an organizational point of view, the institutional setting of the administrative system of the state is especially important, both for all state activities and for the realization of the function of security. Given that the state has equal goals, then its «apparatus» must act in harmony, synchronized with one will and aiming to achieve the same goal. This is not only an obligation, but more importantly, it is a prerequisite for the successful provision of the regulatory cycle of standardized behaviours that characterize societies.

Otherwise, systems (theoretically, in the social-organizational sense) as a complex set of elements, entities, and processes assume the existence of rules, competent entities, further establishment, implementation, control, evaluation, improvement of processes, etc. In the area of disaster risk reduction, we are talking about very numerous, differentiated threats, risks and threats of a different nature (listed in the previous part of this study), where the National Platform recognizes the importance of building a complex institutional mechanism that can respond of the different nature and degree of the threats and risks. Integrating the reduction of disaster risks in the direction of achieving security in North Macedonia is primarily the task of the Crisis Management Center and the Protection and Rescue Directorate. These institutions at the central level are most appealed to organize within the framework of its legal powers, activities that contribute to the reduction of the risks of disasters. In this sense, it is necessary for the state to continuously apply the policies and activities at all levels with the institutional tools, in this context to manage and reduce the risks and threats that ultimately can cause disasters.

In the text, we try to emphasize that the integral approach to the management of social processes is crucial for the organization of a society. When it comes to this kind of organization (creating a

resilient society that manages risks) it is a challenge of the most complex nature. The system of risk management and disaster reduction has been in a period of evolution during the past almost two decades. We can say that the concrete form it has now originates from 2005 together with the overall reform of the public administration, that is, the state administration and the process of synchronizing the security system in compatibility with that of the NATO member states.

The national platform for disaster risk reduction has four editions, the last of which is the one adopted by the Government of the Republic of North Macedonia in 2019. Of course, this platform is based on the priorities established in Sendai, namely: prevention, early warning, risk management and recovery.

The national platform for disaster risk reduction is a sublimation of the priorities, expectations and obligations that function for building an effective and efficient system for protection and rescue. (Aleksandrina, Budiarti, Yu, Pasha, & Shaw, 2019; Carla S, 2019; MacAskill, 2019; Mano, A, & Rapaport, 2019; Perić & Cvetkovic, 2019; Sudar et al., 2024; Vibhas, Bismark, Ruiyi, Anwaar, & Rajib, 2019). It is based on obligations arising from the Constitution of the Republic of North Macedonia, the National Concept for Security and Defense, the National Strategy for Protection and Rescue, the Law on Crisis Management, the Law on Protection and Rescue, the Law on Police, the Law on Defense, the Methodology for the content and method of hazard assessment and protection and rescue planning and other analyses, assessments, scientific papers, etc. The laws also define specific obligations of state institutions, public enterprises, companies, citizens and other subjects of the crisis system, especially the President of the Republic of North Macedonia, the Parliament of the Republic of North Macedonia, the Government of the Republic of North Macedonia, the Center for Crisis Management, the Protection and Rescue Directorate, the Ministry of Internal Affairs, the Ministry of Defense, the Ministry of Health, the Army of the Republic of North Macedonia and other subjects of the crisis system. As indicated, the priorities are also drawn from international strategies and frameworks adopted by the UN such as the Hyogo Framework for Action and the Sendai Framework for Action. In the platform, the global and regional context is naturally further developed at the national level and is increasingly focused on the local level. The main objective of this strategic document is to reduce the loss of human lives, the destruction of goods and the social and economic damage caused by natural disasters, such as earthquakes, strong winds, floods, landslides, forest fires, pest infestations, droughts and other natural disasters.

The national systems for risk management and protection and rescue are the two systems that should complement the process of disaster risk reduction. Currently, the National Platform for Disaster Risk Reduction is coordinated by a National Coordinator appointed by the Government of the Republic of North Macedonia. Almost two decades have passed since the operationalization of the two systems, during which both systems were «challenged» in terms of their functionality on several occasions, which can be singled out: the massive occurrences of forest fires on several occasions; the migrant crisis; river and urban flooding; crises caused by epidemics and the global COVID pandemic, heat waves in the last few years, the current energy crisis, and other natural and man-made events. Through dealing with these crises, both systems have shown certain weaknesses, which have affected their efficiency, effectiveness and full operation. So, in practice, it has been shown that measures and activities were not implemented to mitigate the previously foreseen risks, and for those new risks and threats that are currently appearing, the systems react very slowly. Furthermore, it was shown that there is no sufficient and established coordination between the institutions involved in the field, for easier and faster execution of tasks. Insufficient material and technical resources for work, and insufficient expertise to respond to risks and threats affect the provision of a quick and effective response on the ground and return the situation to the original state, or close to it, if possible.

From a strategic point of view, it is necessary to strengthen and consistently implement the priorities established by the Sendai framework:

- Understanding risks in all dimensions of vulnerability, capacity, exposure, hazard characteristics and the environment;
- Strengthening risk management: risk management must be implemented at all levels starting from local, regional, and global because as societies we are interdependent;

- Investing in reducing risks and building resilience: strengthening the economic, social, health and cultural resilience of people, communities and the environment as a whole;
- Improving preparedness and strengthening effective response in recovery, rehabilitation and reconstruction: destructive events can significantly or completely disrupt life, hence response and reconstruction preparedness is critical to restoring the previous state, if possible (Ivanov et al., 2023).

The overall organization of the government participates in the system at the general level by the Constitution of the Republic of Macedonia from 1991. In the most general terms, the legislative authority (competence for enacting Laws, Strategic Acts, National Plans and Assessments, etc.), the executive authority through the Government and the President of the Republic of Macedonia (state administration bodies: Ministry of Interior, Ministry of Foreign Affairs, MFA, all ministries, independent bodies of state administration such as the Intelligence Agency, the National Security Agency) and the judiciary (which exercises the function of determining responsibility for violations of the rules of the legal order).

Hence, when we talk about the reduction of disaster risks as an organization, we also talk about the complete organization of the government according to the constitutional order. It can be said with certainty that the placement of these organs based on mutual dependence, cooperation, complementarity and control conditions all these actors to function as a system, with all the theoretical assumptions of the system theory.

The personal and institutional structure of the political party in the broadest sense of the word is manifested at the level of representative bodies of the citizens, namely:

- Assembly of the Republic of Macedonia;
- Government of the Republic of Macedonia;
- Executive officials who are elected according to political criteria by the Assembly and the Government of the Republic of Macedonia (for example, ministers, state secretaries, directors of independent bodies of state administration and bodies in composition);
- And the representatives of the local self-government, above all the mayor, the Council, as well as managers within the municipalities;
- The executive part of the personnel structure in the Republic is manifested through the employees of the following institutions:
- Ministries (especially the Ministry of Interior and the Ministry of Defense have competence in the area of security, but we cannot avoid other ministries, especially in the context of the paradigm of multidimensionality of security, for example, the Ministry of Finance also has a role within to organizations that take care of security in terms of ensuring the security of financial transactions, the source of finance, prevention of money laundering, financing of prohibited activities, etc.); In the part of what is the interest of this paper, the Ministry of the Environment, the Ministry of Economy and other ministries (of course the Ministry of the Environment and Spatial Planning mostly) have a key role, both in the protection and in providing the overall philosophy of sustainable development;
- Other bodies of the state administration (Directorate for Protection and Rescue, Center for Crisis Management) which have a significant specialized role in certain departments of work, which also have a significant role in ensuring synchronized operation of the system (for example, the significant coordinating role that the Center for crisis management there is);
- Local self-government (mayor, council, municipal administration). The process of decentralization applies to almost all domains of social life (health, social protection, environmental protection, fire protection, education, etc.) and hence the functioning is subject to decentralization (for example Local risk assessments), also the municipalities have a key role in what is a narrower subject of interest in this text, which is crisis management, protection and rescue in the function of disaster risk reduction.

For North Macedonia at every level, especially for the preparation of strategic acts, here we would mention the threat assessments of the Center for Crisis Management, i.e. the Directorate for Protec-

tion and Rescue, we would propose some general bases for the functioning of the system and the establishment of capacities for managing risks in a part of their meaning and content. Namely, for the system to function, the following assumptions would have a strong meaning:

- Existence of database and data system;
- Such a database should be managed by an analytical centre;
- The analytical centre should be used with the most complex statistical operations, including predictive analyses based on mathematical models (quantitative research);
- Quantitative research must be parallel to qualitative research;
- Dissemination of data to policymakers;
- Making a strategy for the prevention of the crisis and active action contrary to its intentions; and
- Eliminate the causes.

5. Conclusion

In an international context, the active involvement of the state in the European Forum for Disaster Risk Reduction (regional platform) and the Euro-Atlantic Disaster Response Coordination Center (EADRCC), which is NATO's civilian response mechanism, and, of course, membership in The European Civil Protection Mechanism of the European Union.

The basic objectives of the disaster risk reduction system and the functioning subsystems are prevention (hazard identification and vulnerability assessment); early warning (integrated water management system, timely detection of fires, detection of air pollutants, regulation of riverbeds, clearing of canal network, full implementation of 112); response during crises (informing, protecting, organizing impact, protecting health, environment and property, providing food, water and medicines, strengthening the capacity for self-help and self-protection); and remedying the consequences of crises (recovery, reconstruction-rehabilitation).

In the evaluations of experts of the European Commission, the conclusions are given that all entities must implement the recommendations, where the reform of the crisis, protection and rescue system is proposed, ensuring functional unity, efficiency and effectiveness of the system in management, protection and rescue in conditions of crisis (Republika Severna Makedonija, 2022).

Over the past 10 years, the Government of the Republic of North Macedonia has adopted several conclusions that establish the need to redefine the crisis management system and the protection and rescue system, as the main subsystems of the disaster risk reduction system. This was also adopted in the 4th National Platform for Disaster Risk Reduction in 2019(Republika Severna Makedonija, 2022, p. 27).

References

1. Aleksandrina, M., Budiarti, D., Yu, Z., Pasha, F., & Shaw, R. (2019). Governmental Incentivization for SMEs' Engagement in Disaster Resilience in Southeast Asia. International Journal of Disaster Risk Management, 1(1), 32-50.
2. Carla S, R. G. (2019). School-community collaboration: disaster preparedness towards building resilient communities. International Journal of Disaster Risk Management, 1(2), 45-59.
3. Chakma, S. (2023). Water Crisis in the Rangamati Hill District of Bangladesh: A Case Study on Indigenous Community. International Journal of Disaster Risk Management, 5(2), 29-44.
4. Cvetković, V. M. (2023). A Predictive Model of Community Disaster Resilience based on Social Identity Influences (MODERSI). International Journal of Disaster Risk Management, 5(2), 57–80. https://doi.org/10.18485/ijdrm.2023.5.2.5

5. Cvetković, V. (2024a). Disaster Risk Management. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
6. Cvetković, V. (2024b). Essential Tactics for Disaster Protection and Rescue. Scientific-Professional Society for Disaster Risk Management, Belgrade.
7. Cvetković, V. M., & Šišović, V. (2024a). Capacity building in Serbia for disaster and climate risk education. In Disaster and Climate Risk Education: Insights from Knowledge to Action (pp. 299-323): Springer Nature Singapore Singapore.
8. Cvetković, V. M., & Šišović, V. (2024b). Community Disaster Resilience in Serbia. In: Scientific-Professional Society for Disaster Risk Management, Belgrade.
9. Cvetković, V., & Planić, J. (2022). Earthquake risk perception in Belgrade: implications for disaster risk management. International Journal of Disaster Risk Management, 4(1), 69-89.
10. Cvetković, V. M., & Šišović, V. (2024). Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. *Sustainability*, *16*(7), 2620. https://doi.org/10.3390/su16072620.
11. Cvetković, V., Čvorović, M., & Beriša, H. (2023). The Gender Dimension of Vulnerability in Disaster Caused by the Coronavirus (Covid-19). NBP Journal of Criminalistics and Law, 28(2), 32-54.
12. Cvetković, V., Dragašević, A., Protić, D., Janković, B., Nikolić, N., & Milošević, P. (2022). Fire Safety Behavior Model for Residential Buildings: Implications for Disaster Risk Reduction. International Journal of Disaster Risk Reduction, 75, 102981.
13. Cvetković, V., Nikolić, N., & Lukić, T. (2024). Exploring Students' and Teachers' Insights on School-Based Disaster Risk Reduction and Safety: A Case Study of Western Morava Basin, Serbia. Safety, 10(2), 2024040472.
14. Cvetković, V., Romanić, S., & Beriša, H. (2023). Religion Influence on Disaster Risk Reduction: A Case Study of Serbia. International Journal of Disaster Risk Management, 5(1), 66-81.
15. Cvetković, V., Tanasić, J., Ocal, A., Živković-Šulović, M., Ćurić, N., Milojević, S., & Knežević, S. (2023). The Assessment of Public Health Capacities at Local Self-Governments in Serbia. Lex localis - Journal of Local Self Government, 21(4), 1201-1234.
16. El-Mougher, M. M. (2022). Level of coordination between the humanitarian and governmental organizations in the Gaza Strip and its impact on the humanitarian interventions to the Internally Displaced People (IDPs) following May escalation 2021. International Journal of Disaster Risk Management, 4(2), 15-45.
17. Gerasimovski, S. (2010). Kulturnite vrednosti i rizikot vo sovremenoto opštestvo so poseben osvrt na makedonskoto opštestvo. Skopje: Univerzitet „Sv. Kiril i Metodij" - Skopje.
18. Iftikhar, A., & Iqbal, J. (2023). The Factors responsible for urban flooding in Karachi (A case study of DHA). International Journal of Disaster Risk Management, 5(1), 81-103.
19. Islam, F. (2023). Anticipated Role of Bangladesh Police in Disaster Management Based on the Contribution of Bangladesh Police during the Pandemic COVID 19. International Journal of Disaster Risk Management, 5(2), 45-56.
20. Ivanov, A., & Cvetkoviќ, V. (2016). Prirodni katastrofi (geoprostorna i vremenska distribucija). Skopje: Fakultet za bezbednost-Skopje.
21. Ivanov, A., Babanoski, K., & Cvetkoviќ, V. (2023, Juni 26). Sistemot za namaluvanje rizici od katastrofi vo Republika Severna Makedonija. Bezbednost.
22. Jakovljević, V., Cvetković, V., & Gačić, J. (2015). Prirodne katastrofe i obrazovanje. Beograd: Univerzitet u Beogradu, Fakultet bezbednosti.
23. Janković, B., Cvetković, V., Ivanović, Z., Ivanov, A., Jovanović, S., & Otašević, B. (2023). Sustainable development of trust and police presence in schools: Implications for school safety policy. Journal of Liberty and International Affairs, 9(3).
24. Jha, K. M. (2010). Natural and Anthropogenic Disasters: An Overview. In K. M. Jha (Ed.), Natural and Antropogenic Disasters (Vulnerability, Preparedness and Mitigation). New Delhi: Springer & Capitol Publiching Company.

25. Kabir, M. H., Hossain, T., & Haque, M. W. (2022). Resilience to natural disasters: A case study on southwestern region of coastal Bangladesh. International Journal of Disaster Risk Management, 4(2), 91-105.
26. Kabir, M. H., Tanvir, H., & Haque, M. W. (2022). Resilience to natural disasters: A case study on southwestern region of coastal Bangladesh. International Journal of Disaster Risk Management, 4(2), 91-105.
27. Lazarevski, P., Ѓorgon, N., & Taleski, M. (2010). Nacionalna platforma na Republika Makedonija za namaluvanje na rizici od nesreќi i od katastrofi. Skopje: Centar za upravuvanje so krizi.
28. Lazarevski, P., Ѓorgon, N., & Taleski, M. (2022, December 15). Retrieved from www.researchgate.net: https://www.researchgate.net/profile/Nikola_Gjorgon/publication/343819898_Nacionalna_platforma_na_Republika_Makedonija_za_namaluvane_na_rizici_od_nesreki_i_od_katastrofi_National_Platform_of_the_Republic_of_Macedonia_for_Disaster_Risk_Reduction_Vtoro_dopo
29. MacAskill, K. (2019). Public interest and participation in planning and infrastructure decisions for disaster risk management. International Journal of Disaster Risk Reduction. doi:10.1016/J.IJDRR.2019.101200
30. Makedonija, V. (2022, October 10). https://www.ncdrr.gov.mk/?q=node/625. Retrieved from www.ncdrr.gov.mk: https://www.ncdrr.gov.mk/?q=node/625.
31. Makedonija, V. n. (2019, January 15). www.ncdrr.gov.mk. Retrieved from https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.ncdrr.gov.mk%2Fsites%2Fdefault%2Ffiles%2Fdokumenti%2FNacionalna_platforma_2019.docx&wdOrigin=BROWSELINK
32. Mano, R., A, K., & Rapaport, C. (2019). Earthquake preparedness: A Social Media Fit perspective to accessing and disseminating earthquake information. International Journal of Disaster Risk Management, 1(2), 19-31.
33. Molnár, A. (2024). A Systematic Collaboration of Volunteer and Professional Fire Units in Hungary. International Journal of Disaster Risk Management, 6(1), 1-13.
34. Nations, U. (2009). UNISDR Terminology on Disaster Risk Reduction. Geneva: United Nations.
35. Odero, N. A., & Mahiri, I. (2022). The Complacency of Flood Victims, Socio-Economic Factors, and Effects and Vulnerabilities of Floods in Lower Kano Plains, Kisumu County, Kenya. International Journal of Disaster Risk Management, 4(2), 59-77.
36. Perić, J., & Vladimir, C. M. (2019). Demographic, socio-economic and phycological perspective of risk perception from disasters caused by floods: case study Belgrade. International Journal of Disaster Risk Management, 1(2), 31-43.
37. Port, K. J. N., & Jawahar, G. G. P. (2024). Management of COVID: The Creeping Disaster in the Indian Scenario. International Journal of Disaster Risk Management, 6(1), 103-110.
38. Postolov, K. (2011). Teorija na organizacija. Skopje: Univerzitet „Sv. Kiril i Metodij“ - Skopje.
39. Republika Severna Makedonija, V. (2022, May 31). www.ncdrr.gov.mk. Retrieved from https://www.ncdrr.gov.mk/: https://www.ncdrr.gov.mk/?q=node/625.
40. Sergey, K., & Gennadiy, N. (2022). Methodology for the risk monitoring of geological hazards for buildings and structures. International Journal of Disaster Risk Management, 4(1), 41-49.
41. Starosta, D. (2023). Raised Under Bad Stars: Negotiating a culture of disaster preparedness. International Journal of Disaster Risk Management, 5(2), 1-16.
42. Sudar, S., Cvetković, V., & Ivanov, A. (2024). Harmonization of Soft Power and Institutional Skills: Montenegro's Path to Accession to the European Union in the Environmental Sector. International Journal of Disaster Risk Management, 6(1), 41-74.
43. Vibhas, S., Bismark, A. G., Ruiyi, Z., Anwaar, M. A., & Rajib, S. (2019). Understanding the barriers restraining the effective operation of flood early warning systems. International Journal of Disaster Risk Management, 1(2), 1-19.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research Article

An Assessment of Socio-Economic Impacts of Rainstorm Disaster on the Livelihood of the Residents of Ikole Local Government Area in Ekiti State, Nigeria

Oluwayemisi Ireti Ogunleye[1]*, **Segun Joseph Arohunsoro**[1]

[1] Department of Geography and Planning Science, Faculty of the Social Sciences, Ekiti State University, P.M.B 5363, Ado-Ekiti, Ekiti State, Nigeria; amudayemisi@yahoo.com (O.I.O.); segunaros2002@yahoo.com (S.J.A.).

* *Correspondence: amudayemisi@yahoo.com.; +2347030096757*

Received: 5 August 2024; Revised: 18 October 2024; Accepted 10 November; Published: 25 December

Abstract

This study assessed the socio-economic impacts of the rainstorm disaster which occurred on 3rd March, 2023 on the livelihood of the residents of Ikole LGA in Ekiti State, Nigeria. The study area is prone to recurring rainstorms, a natural and metrological disaster that has ravaged the livelihoods of the residents of Ekiti State. The weather (sunshine hours, temperature, relative humidity, cloud cover, visibility, wind direction, wind speed and rainfall) information of Ikole LGA on 3rd March 2023 was obtained from the Nigerian Meteorological Agency, Oshodi, Lagos, and the incidence/profile of rainstorm in Ikole LGA on the same day was obtained from the Ekiti State Emergency Management Agency. A well–designed and structured questionnaire was administered to respondents to obtain information on the kind of losses encountered by the victims of rainstorm disasters in the locations and the coping strategies they adopted in mitigating the effects of the disaster. The data collected from the victims were analyzed with an SPSS package, presented in tables and followed with discussion. The results showed that the rainstorm brought about socio-economic hardship on the victims in the study area. It was discovered that some of the relief measures on the ground were short-term measures which provided no lasting solution to the menace. Some general measures suggested among others to mitigate the effects of rainstorms include proper construction of a storm-water drainage system in the study area and the Planting of low-height vegetation that can serve as wind-break.

Keywords

Disaster, rainstorm, rainstorm disaster, relief measures, livelihood.

1. Introduction

A disaster is a catastrophic and calamitous event that can be originated from both man-made and natural origin. It could also be geological (landslide, earthquake, soil creep), chemical and technological (Chornobyl disaster, oil spills, accidents), metrological (erosion, flooding, rainstorm) and biological (outbreak of epidemics such as pandemics like Ebola, covid-19) Sharif, (2020), (Ibidun

2010). Disaster occurs when a hazard impacts or strikes a vulnerable community with low capacity resulting in damages, loss and serious disruption of community functioning. The widespread human, material and environmental losses exceed the community's ability to cope using its resources Raheem et al (2024). Rainstorm disaster continues to wreak havoc on lives and properties in both high and low-income countries across the globe. The disaster nature of the climatic phenomenon appears to have constituted a grave concern for the global populace particularly with the onslaught of global warming and climatic fluctuation being experienced across the global environment. A rainstorm is a severe weather event characterized by heavy rain, reduced visibility, and maybe thunder and lightning Ohshimo et al (2018). Oluwayemisi et al (2019), define a Disaster as "an emergency event that involves the destruction of economic resources, depletion of environment and loss of lives which is caused by natural hazards or human-induced actions resulting in a significant change in circumstances over a relatively short period. Typical examples are death, displacement, disease, and loss of crops, damage to physical and service infrastructure, depletion of natural and social capital, institutional weakening.

It is good to note here that even though rainstorm disaster is a worldwide natural phenomenon, there is every tendency to believe that low-income countries are more at the receiving end and more prone to the impacts of the disaster. This could be attributed to a lack of or inadequate planning and preparation on the part of the government of the low-income countries. The occurrence of rainstorms as a natural and metrological disaster is exacerbated by global warming and extreme weather which has been causing the most fatalities per 100,000 inhabitants across the globe International Strategy for Disaster Reduction (2008). Ecosystems and natural occurrences are being impacted by the subtle shifts in atmospheric conditions that follow global warming. As a consequence, it puts more of the globe at risk from natural disasters. For example, in 2022, the U.S. experienced 18 separate weather and climate disasters costing at least 1 billion dollars, including floods, storms, very high temperatures, heat waves, tornados, cyclones droughts etc.

Federal Ministry of Economic Corporation and Development (FMECD, 2015) remarked that everyone should be very worried about the frequency of rainstorms since they increase the likelihood of natural disasters including landslides, landslips, and floods. The risk of natural hazards such as rainstorms often happens as a result of the link between natural and human factors Nura et al (2022). As a result, land use planners need to pay close attention to the rising frequency of rainstorms and the potential damage they pose to the ecosystem.

A rainstorm is a weather disaster which has been causing great effects on the residents and their livelihoods. In recent times, it has contributed to the public outcry concerning the damages caused to both individuals and the government. Several people in many parts of the world have been rendered homeless and properties worth millions of naira destroyed due to this menace of rainstorms (Eric, 2021). Rainstorm disaster has a great influence on the connectivity of roads and cause serious damage to the transportation system Zhenzhen (2024). It submerged or collapsed houses, damaged roads, and caused traffic congestion or paralysis Guo et al (2024). Government at different levels has spent more in providing temporary succour and relief for the victims. In many of those locations where it had occurred, particularly in low-income countries like ours, many of the buildings destroyed remained abandoned due to the poverty-stricken state of their victims. Rainstorms are one of the most comprehensive disasters in the world, which happen frequently and always bring great harm. The danger of rainstorms due to storms is a serious obstacle to the international sustainable development agenda (Saini et al, 2006). The world's largest, wealthiest and most vulnerable economies bear the brunt of the yearly average worldwide losses. Many poor and middle-income nations especially tiny island developing states have the largest concentration of risk according to the United States Department of Disaster Reduction concerning yearly capital investment or social spending, especially regarding Sudden Infant Death Syndromes (SIDS) (UN International Strategy for Disaster Reduction, 2015).

Communities in Ekiti State have been affected by rainstorm's menace in terms of destruction to the means of livelihoods. Rainstorms are very prevalent and are one of the most serious natural catastrophes like flooding. Its main characteristics are severe widespread flooding and have been widely reported due to the terrain, and regular features of the weather system. It comes without

warning and causes widespread devastation like economic damage, interrupting both traffic and telecommunication, loss of clean water supply, and loss of thousands of properties and human lives. According to the National Emergency Management Agency NEMA (2018), in the first two months of the year, over 200 homes were allegedly damaged by rainstorms in Ekiti state, resulting in physical harm to people, destruction of houses and buildings and trees, psychological trauma, economic losses, unplanned or unbudgeted spending on the part of the government and individuals and public and financial disgrace to the victims. The disaster affected more than five Local Government Areas of the state namely: Ado, Ise-Orun, Ekiti West, Agbado, Aisegba in Gbonyin Local Government Area and Ikole where the estimated damage ran into hundreds of millions of naira. Again, in March 2019, according to a report given by the National Emergency Management Agency and State Emergency Management Agency, a rainstorm disaster caused havoc across some towns in Ekiti State including; Ado- Ekiti metropolis, Afao, Are, Ilawe, Igbemo, Isan and Iludun etc.

Causative factors such as poverty, urbanization, weak building structure as well as poor landscape design of the environment are responsible for the devastating effects of this phenomenon. Loss of property, displacement of affected people and unplanned expenses which have been on the increase over the years can be found in the regions with low economic status Akintude et al (2019). It was reported that more than 80 houses including shops, and schools were blown off in Ado-Ekiti, and several electricity poles and trees in seven communities were thrown down causing traffic congestion. This disaster caused extensive socioeconomic dislocation with catastrophic consequences ranging from the destruction of human habitation, and resources, and human health affected and many communities were in blackout for several weeks National Emergency Management Agency and State Emergency Management Agency (2019). The communities in the study area have suffered from rainstorms for close to three decades and have a limited capacity to control these meteorological events.

The records of rainstorms in the study area are very rampant. The News Agency of Nigeria (NAN) reported that, the first rain of the year 2018 which lasted for only 40 minutes ravaged farmlands and destroyed crops, schools, church buildings and other economic trees in Ikole Local Government Area. It was reported that no fewer than 100 residential buildings were destroyed in Temidire, Oke Ijebu, Ayedun, Odo-oro and Oke Agbe (NAN 2018). The one available for 3rd March 2023 shows a very catastrophic experience. It is in the light of this that this research has become important. This research aims to assess the socio-economic impacts of the rainstorm disaster which occurred on the 3rd March, 2023 on the livelihood of the residents of Ikole- Ekiti Local Government Area of Ekiti State. The research is intended to ascertain the incidence and profile of rainstorm disasters in the study area, examine the economic implications of the hazard and assessment of the relief measures provided by the disaster managers to the victims.



Figure 1. Some of the buildings were affected by the rainstorm of 3rd March 2023 in the study area.

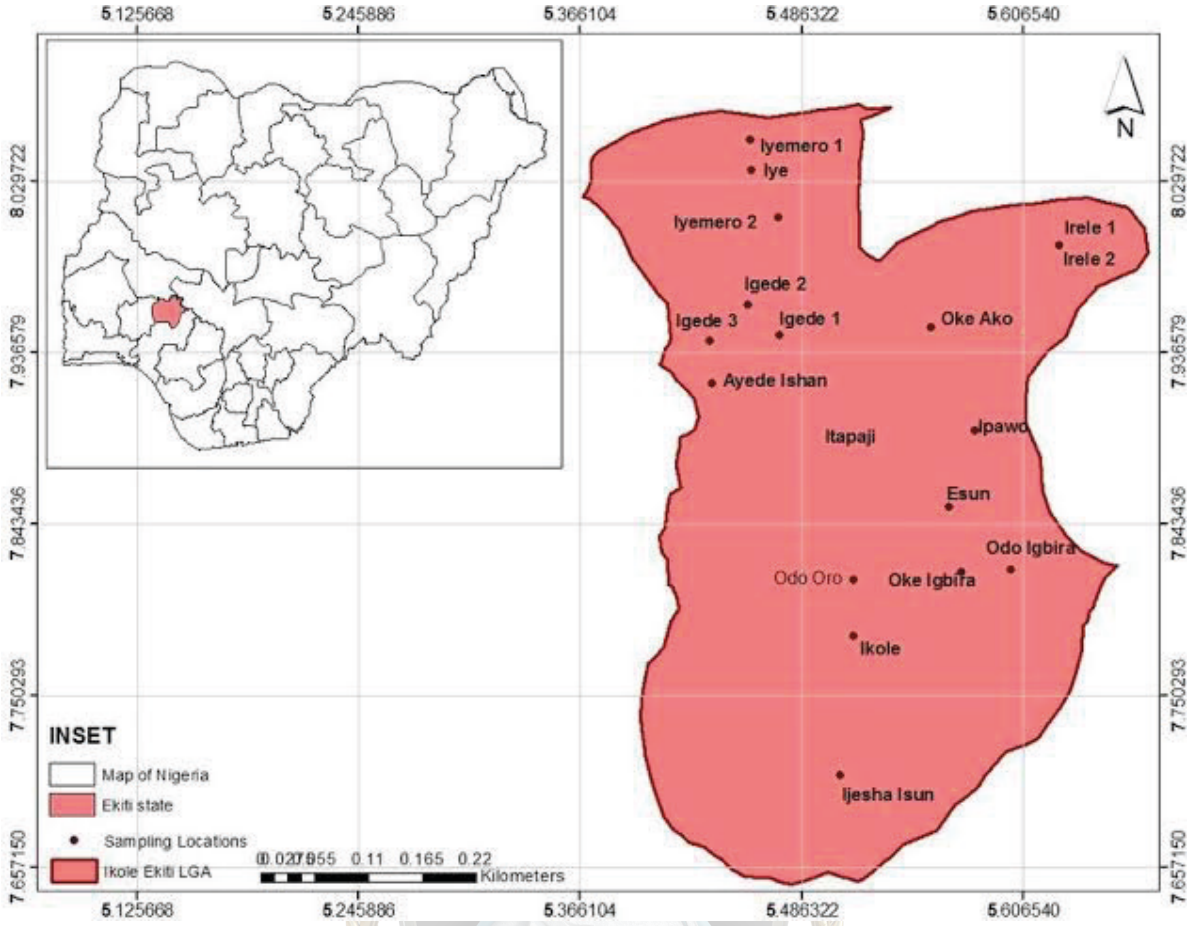


Figure 2. Map of Nigeria and Ikole Local Government showing the study area.

2. Materials and Method

Survey research was employed as a method in the choice of location for sampling. This was done by careful and purposeful selection based on the literature of districts in Ikole Local Government such as Oke-Ako, Ijesa-Isu and Ikole.

The research was made up of both qualitative and quantitative data with data sourced from both primary and secondary sources. The primary data were collected using copies of 400 questionnaires from which 389 were recovered in addition to an on-the-spot assessment of the victims' houses and the environment to determine their level of vulnerability. A well-designed and structured questionnaire was used for the collection of the primary data from the respondents, who experienced the incidence of rainstorm disaster and got their personal or rented apartments affected on 3rd March 2023 from the study area.

The secondary data comprised of data obtained from already existing information on the rainstorm of 3rd March 2023 in Ikole Local Government in Ekiti State from the Nigerian Meteorological Agency, Oshodi, Lagos and state agencies that are in charge of managing disasters. This record was collected from the Ekiti State Emergency Management Agency. The data used included the weather (sunshine hours, temperature, evaporation, relative humidity, cloud cover, visibility, wind direction, wind speed and rainfall) of Ikole on 3rd March 2023 obtained from the Nigerian Meteorological Agency, Oshodi, Lagos. Records to show the incidence and profile of rainstorms in the study area were also obtained from the Ekiti State Emergency Management Agency. The data obtained from the respondents were processed and analyzed using the Statistical Package for Social Sciences (SPSS) 25.0 version.

3. Results and Discussion

Table 1 provides a detailed summary of the recorded weather variables observed in Ikole Local Government Area (LGA) on the 3rd of March, 2023, offering critical insights into the climatic conditions during this specific period.

Table 1. The weather variables of Ikole LGA on 3rd March 2023**.**

S/N	**Weather variable**	**Value/Description**
1	Sunshine hours	12.1
2	Temperature	36.8°C
3	Wind direction	North-East
4	Wind speed	8km/h
5	Rainfall	36mm
6	Visibility	10km
7	Relative humidity	63%
8	Cloud cover	30%

Source: Nigeria Metrological Agency, Oshodi, Lagos, Nigeria (2023)

The sunrise hours in the study area on the 3rd of March 2023 are enough to increase the temperature to 36.8 °C for that particular day. High temperatures will give rise to high evaporation from the Earth's land and ocean surfaces. The outcome will give rise to high relative humidity. The relative humidity of (63% in the study area indicates saturation which leads to high cloud cover and usually results in condensation. The two important components here are relative humidity and cloud cover which eventually resulted in the precipitation (rainfall) of 36mm. The wind direction is the North-Eastern trade wind which prevails in the northern hemisphere at approximately 30 degrees latitude. It becomes **humid** and **warmer** as moisture accumulates along the way (Patil 2023). Wind speed of 8km/h with 4-6 knoth. Wind having 4-6 knoth is responsible enough to damage roof and pull down electricity poles. Meanwhile, the amount of rainfall recorded (36mm) in the study area is enough to destroy the livelihoods of the inhabitants of the study area. With these findings, it shows extreme weather events and climatic anomalies have serious effects on the socioeconomic status of the inhabitants of the study area. By implication, climate change adaptation strategies need to be put in place.

The incidence and profile of rainstorm disasters in the study area

Both primary and secondary data were obtained for this objective which sought to find out the profile/incidence of rainstorm disaster in the study area. The primary data was sourced from the victims of the rainstorm disaster of the 3rd March 2023. The secondary data was sourced from the Ekiti State Emergency Management Agency. Table 2 presents the incidence of rainstorm experience on 3rd March 2023.

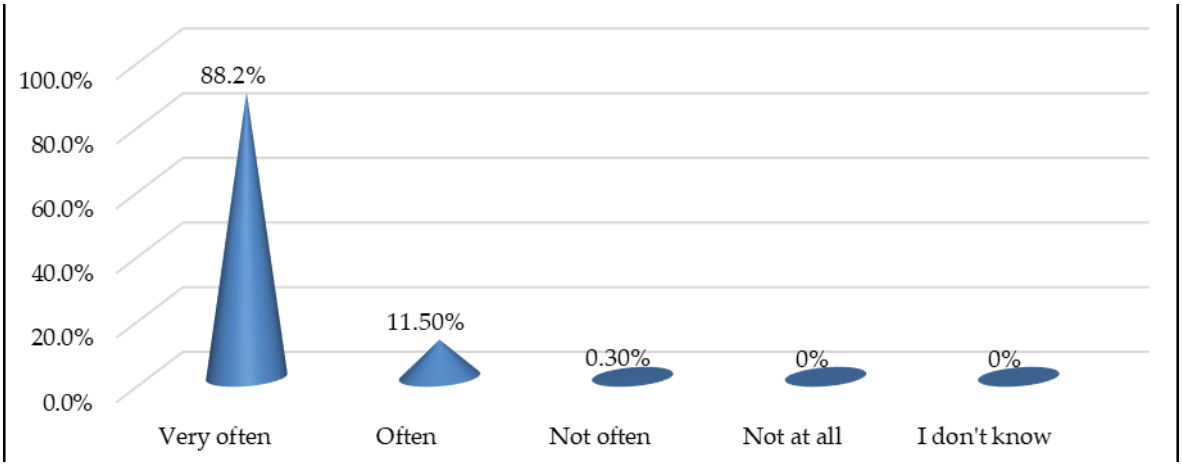


Figure 3. Showing the incidence of rainstorm disasters in the study area

Figure 3 presents the incidence of rainstorm experiences in the study area. The result of 88.2% of the respondents showed that rainstorm occurs very often in the area. Apart from primary data obtained from the respondents on the incidence of rainstorms in the study area, Secondary data was also obtained from the State Emergency Management Agency (SEMA) to support the occurrence of this disaster.

Table 2. Profile of Rainstorm in Ikole LGA Ekiti State on 3rd March 2023

S/N	Name of Locality	No of Victims	Items Destroyed
1	Oke–Ako district	62	Roofs were completely and partially blown off, and mattresses, books, ceilings, crops electricity facilities and economic trees were pulled down.
2	Ijesa –Isu district	48	Many Roofs were completely and partially affected mattresses, pillows food stuffs, markets, schools and electronics were damaged. Death of livestock. Walls collapsed
3	Ikole district	42	The roof was blown off completely, farm crops were destroyed walls completely collapsed, and documents, books, rugs, ceilings, mattresses, furniture and electronics. Crops and Institution buildings

Source: Field study and Ekiti State Emergency Management Agency (2023) Ekiti- State

Table 2 confirmed the incidence of rainstorm disasters in the Ikole Local Government area, through interviews of the disaster managers from Ekiti State Emergency Management Agency. Practically, the study area was seriously ravaged by this menace as obtained from the results. The study area is grouped into three districts with many towns and villages under them. Several persons have been rendered homeless after a two-hour torrential downpour which started at about 3 pm and destroyed more than 152 buildings, electricity facilities and another vital source of livelihood in Ikole Local Government Area of Ekiti State on Friday, March 3**.** Findings from the study showed that some frequently suffered from rainstorm disasters in the area. The implication is that most damages and injuries occurred when there was little or no early warning and preparedness for an impending rainstorm thereby causing the victims to be vulnerable. This is an eye-opener for government and disaster management authorities to have an existing rainstorm management plan. Having a strategy in place to handle rainstorms can lessen the likelihood of losses due to dangers, guarantee timely and suitable aid for victims when needed, and facilitate a speedy and long-lasting recovery. According to Peter (2017), individuals and the government alike should make it a priority to implement sound planning and development policies that raise awareness of the dangers posed by wind and rainstorms and encourage sufficient preparation for their rainstorms.

Table 3. The Cost Implications of the Rainstorm Damage to houses/apartments in Ikole LGA, Ekiti- State Following the Rainstorm of 3rd March, 2023.

Responses	Frequency	Percentage
Less than #250,000	98	26.8
#250,000-500,000	43	11.8
#501,000-750,000	3	.8
#751-1,000,000	4	1.1
Above #1,000,000	12	3.3
Reconstructed by government	80	21.9
Abandoned/No capacity	125	34.2
Total	**365**	**100.0**

Table 3 above shows the amounts of re-roofing of the buildings damaged through rainstorms. These amounts reflect the costs of buying roofing materials like bundles of roofing sheets, nails, ceilings, planks, and loads of sand and the cost of labour among others. Also, from Table 3, it could be seen that the result showed that 34.2% of the respondents abandoned their properties due to a lack of financial capacity and financial constraints. By implication, the impacts and frequency of rainstorm disaster in the study area is enormous in such a way that it has destroyed respondent's buildings for which they have no economic strength and capacity to put the roofs in the right shape thus, increasing their economic hardship. This is in agreement with Yande's (2009) study where an increasing number of people are at risk every year; most of them live in low-income nations where poverty makes them susceptible to natural catastrophes.

Table 4. Impacts of coping strategies/ relief measures on the victims of rainstorm disaster in the study area.

Items	Responses	Frequency	Percentage
Relief Strategy	Rope your roof down	23	5.9
	Add roof clips (Ojagba)	338	86.9
	Stone bonding (putting stones on the top of the roof)	15	3.9
	Trees planting	13	3.3
Modes of Educating Communities	Through the use of Non-Governmental Organization	54	13.9
	Through the use of community leaders	146	37.5
	Through the use of media such as TV/Radio	94	24.2
	Through sensitization by government agencies	95	24.4
Relief materials by the government	Nails	38	9.8
	Money	35	9.0
	Mattresses	16	4.1
	None	290	74.6
	Others	10	2.6

Source: Research work 2023

Table 4 presents the relief strategies used by individual household members for rainstorm adaptation. The majority of the respondents added roof clips. The residents in the study area chose to adopt the available and affordable strategies due to their socio-economic status. The economic base of the region is very poor because majority of the people live in rural areas where farming is their major preoccupation and source of income. By implication, all the relief measures mentioned were short-term measures which have limited capacity to control rainstorm events. This was supported

by Yang *et al.* (2018) in their study that, national and international collaboration may be required to alleviate a disaster if domestic cooperation is insufficient since foreign organizations sometimes have access to more resources (such as money, materials, and technology) than their domestic counterparts. Peter (2017), suggested that proactive measures by individuals and government should be in place to protect themselves and their communities from wind while constructing.

The research also showed that the best method used by communities to educate people on rainstorm disasters is majorly through the community leaders (37.5%) while the use of social media, TV/radio recorded 24.2% which happened to be the least. By implication, educating and giving the public early warning on the impending danger through social media is low. The result of this finding is in agreement with the United Nations Office for Disaster Risk Reduction (UNISDR) which states that Community-based preparedness and early warning systems help save lives, protect property, and reduce economic losses. I think this can be achieved if the communities are equipped and prepared. On the other hand, this negated Aysan (1993), who pointed out in his findings that other causes of vulnerability to rainstorms include lack of access to information and knowledge, as well as lack of public awareness. (Ayse et al., 2005) pointed out in their study that there should be awareness and preparedness by training the residents on preventive, protective and behavioural measures to combat rainstorm risk.

Meanwhile, the result showed that 74.6% of the study participants representing the majority did not receive any material from the government when their houses were affected by rainstorms. By implication, the efforts of the government to assist rainstorm disaster victims are limited and not effective. No wonder, most of the structures affected by rainstorms in the study area were abandoned. Probably due to poor involvement of the government in controlling rainstorms, corruption or embezzlement of funds earmarked for the victims.

4. Recommendations

Based on the findings of this study, the researchers recommended possible solutions that would ensure long-term measures in minimizing rainstorm menace and mitigate the effects as observed from the study area and for sustainable development. Therefore, the following measures were recommended:

- There should be adequate funding by the government for rainstorm disaster victims in the reconstruction of their buildings. This could be in the form of money, building materials, and evacuation of victims from disaster-prone areas to safer areas.
- There is a need for the construction of storm stormwater drainage system in the study area and the planting of low-height vegetation by individuals and the government to serve as a wind-break.
- To protect the physical and socio-economic systems in the study area, there are multiple mitigation options to implement at the building level for individuals such as the modification of the roof structures and styles. Use of gable roofs preferably than flat roofs because it is difficult to retain water and non-susceptible to roof damage.
- Government and disaster managers should frequently review the processes and activities used to develop the emergency response plan, such as hazard vulnerability and capacity assessment, disaster risk identification, community risk reduction planning and risk reduction management and disaster response, evacuation and first aid plans.
- Government, stakeholders and NGOs should consider the pre-disaster measure as a priority by setting up various information programmes to educate and provide an early warning system to the public on the dangers of rainstorm disasters and sensitize them on the benefits of planting trees.

5. Conclusion

It is now very important for the Government, all stakeholders and individuals to take definite steps to prevent rainstorm impacts. This is because of its socio-economic impacts such as emotional trauma, injuries to individuals and fatalities /deaths, financial and economic impact and. damage to equipment, buildings and infrastructure. Based on the information gathered from the victims and disaster managers about the effects of rainstorm disasters in the study area, it is clear that rainstorm disasters are highly destructive within the natural and man-made environment. Its impacts are enormous ranging from loss of life, massive economic, social, and environmental destruction, and exposing people to numerous risks and dangers. Similarly, most of the relief measures provided by individuals and government to cushion the effects of rainstorm disasters are short-term measures which at times, can be delayed or not getting to the victims at all. For a better and more efficient method of handling rainstorm disasters, the researcher gave recommendations below.

References

1. Akintunde, T. and Sanmi, A. (2019) Analysis of Rainstorm Disasters and Management in Ado Ekiti, Nigeria *EPRA International Journal of Research and Development (IJRD*). Volume: 4: 7: 89-95.
2. Aysan, Y. F. (2013). "Keynote Paper: Vulnerability Assessment." In: P. Merriman and C. Browitt, (eds.), *Natural Disasters: Protecting Vulnerable Communities*, 1-14.
3. Eric Mc Daniel (2021). Weather Disasters Have Become 5 Times as Common, Thanks In Part to Climate Change**.**
4. Federal Ministry for Economic Cooperation and Development, (FMECD), (2015). Disaster Risk Management. Approach and Contributions of German Development Cooperation, *9*.
5. *Guo, Hx., He, Xy., Lv, Xb. et al (2024)* Risk analysis of rainstorm-urban lifeline system disaster chain based on the PageRank-risk matrix and complex network. *Journal of Natural Hazards*. Volume 120, pages 10583–10606
6. Ibidun, O. A. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment & Urbanization. *International Institute for Environment and Development (IIED).* 22(2): 433–450.
7. INISDR (2018) UN International Strategy for Disaster Reduction ttps://sdgs.un.org/statements/un-international-strategy-disaster-reduction-unisdr-8377
8. International Strategy for Disaster Reduction, ISDR (2008). *Climate Change and Disaster Risk Reduction.*
9. National Emergency Management Agency (NEMA), (2018). Summary of relief interventions. Unpublished manual.
10. Nura, U. and Alison, G., (2022). Flooding in Nigeria: A review of its occurrence and Impacts and Approaches to modelling flood data. *International Journal of Environmental Studies*. Vol. 80: 540-561
11. Odero, N. A., & Mahiri, I. (2022). The Complacency of Flood Victims, Socio Economic Factors, and Effects and Vulnerabilities of Floods in Lower Kano Plains, Kisumu County, Kenya. International Journal of Disaster Risk Management, 4(2), 59-77.
12. Ohshimo, S. Takuma, S., Nobuaki, S. (2018). The Western Japan Chaotic Rainstorm Disaster: A Brief Report from Hiroshima. *Journal of Intensive Care.* (82): 1-3.
13. Oluwayemisi, I. and Idowu, O. (2019) Disaster Preparedness and Awareness among School Educators and Administrators – A Study of Selected Secondary Schools in Ekiti – State, Nigeria. *Journal of Education and Practice*.Vol.10, 25: 87-92
14. Perić, J., & Vladimir, C. M. (2019). Demographic, socio-economic and phycological perspective of risk perception from disasters caused by floods: case study Belgrade. International Journal of Disaster Risk Management, 1(2), 31-43.

15. Peter, A. O. (2017). Quantifying the Cost of Climate Change Impact in Nigeria: Emphasis on Wind and Rainstorms. *Journal of Human Ecology.* 28, Issue 2. 93-101.
16. Raheem A. Usman, F. Olorunfemi, G. Awotayo, A. Tunde and Usman, B. (2024) Disaster Risk Management and Social Impact Assessment: Understanding Preparedness, Response and Recovery in Community Projects.
17. Saini, Y. Guofan, Y. Xianwu, S. Hao, L. and Ying, Z. (2016). Modelling the Adverse Act of Rainstorms on a Regional Transport Network. *International Journal of Risk Science*. 7: 77-87
18. Sharif Amina (2020) Disasters Types and Causes. https://www.reseachgate.net/publication/343211640. Retrieved 15.09.2024.
19. Shibru, M., Operea, A., Omondi, P., & Gichaba, M. (2022). Impact of 2016-2017 drought on household livestock assets and food security: the case of pastoralists and agro-pastoralists in Borana zone, southern Ethiopia. International Journal of Disaster Risk Management, 4(1), 49-69.
20. Yande, P. M. (2009). *An Impact of Floods on the Socio-Economic Livelihoods Of People: A Case Study of* Rural Innovation, Wageningen University.*Sikaunzwe Community In Kazungula District* of Zambia the MSc, Sociology of Development and Change, Development.
21. Yang, C. 1, Lianshui, L. Ehsan, E. and Yueming, Q. (2018). Selection of Policies on Typhoon and Rainstorm Disasters in China: A Content Analysis Perspective. *Sustainability.* 10, 387, 2-5.
22. Zhenzhen Yang (2024) Assessing the Impacts of Rainstorm and Flood Disaster for Improving the Resilience of Transportation System. *Journal of Advanced Transportation.*

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Review article

Sustainable Recovery: the Link Between Development and Response to Disasters

Ivica Đorđević[1], **Jasmina Gačić**[1]

[1] Faculty of Security Studies, University of Belgrade, Gospodara Vučića 50, 11040 Belgrade, Serbia; djivica@gmail.com (I.Đ.); jasmina.gacic@fb.bg.ac.rs (J.G.)

* Correspondence: djivica@gmail.com

Received: 10 August 2024; Revised: 1 October 2024; Accepted 5 November; Published: 25 December

Abstract

This paper examines the critical role of sustainable recovery in strengthening disaster risk resilience through the integration of sustainable development principles into strategic planning and policy frameworks. Sustainable recovery comes as a result of respecting the basic principles of sustainable development when making strategic plans in all areas essential for responding to risk conditions that can lead to disasters. To raise awareness of the importance of sustainability, it is necessary to incorporate this concept into the teaching contents of all educational levels, especially when training personnel for disaster risk prevention and reduction. The aim is to analyze the interconnectedness of sustainability and resilience, focusing on how local knowledge, scientific methods, and strategic planning can mitigate vulnerabilities and enhance community preparedness for disasters. The findings highlight that communities which prioritize sustainable practices and incorporate disaster risk reduction measures into their development strategies demonstrate higher levels of resilience to hazards. Also, the practice has shown that the most resilient communities are those that base their development strategies on respect for local specificities and knowledge of scientific methods derived from previous experiences with numerous risks and their consequences. This study also identifies key factors contributing to vulnerability, emphasizing the importance of education, intersectoral collaboration, and policy reforms in fostering long-term resilience. Vulnerability comes as a result of many factors, the knowledge of which can contribute to raising the level of community resistance to hazards and risks to which the area is exposed. The phenomenon of sustainable development or sustainability as well as sustainable recovery is a major catalyst for change in government policies and legal frameworks, which has dramatically changed the role and behavior of nations. Politics, economy, ecology, geographical characteristics of the area and climatic conditions in combination with personnel potential can be part of the solution, but also the source of the problem. The results underscore the necessity for integrating sustainability principles at all levels of governance to achieve a holistic approach to disaster risk reduction and community resilience. Future research should focus on developing standardized indicators for measuring sustainable recovery and resilience across diverse socio-economic and geographical contexts.

Keywords

Disasters, hazards, sustainability, vulnerability, resilience, development, recovery.

1. Introduction

Man has always sought to adapt nature to his needs (Al-ramlawi, El-Mougher, & Al-Agha, 2020; Aleksandrina, Budiarti, Yu, Pasha, & Shaw, 2019; Cruz & Ormilla, 2022; Mohammed M. El-Mougher, 2022). Archaeological research has identified some periods in the development of human society when the inhabitants of certain areas, through their thoughtless actions, made their habitat no longer suitable for life (Cvetkovic & Martinović, 2020; Cvetković & Planić, 2022; Perić & Cvetković, 2019). This phenomenon becomes more pronounced with technological progress and the acquisition of tools that multiply human power, and therefore the potential for causing disasters caused by erroneous actions based on poor judgment. The tendency present in the capitalist era of civilization's development, based on belittling the value of natural resources and glorifying products that come from cheap raw materials and labour, particularly exacerbates the situation. The imposition of a model of social organization that recognizes happiness exclusively in economic growth and material progress leads to a threat to the survival of those happy individuals (Mohammed Mohammed El-Mougher & Mahfuth, 2021; Hasan & Sultana, 2024; Jehoshaphat & Oghenah, 2021; Kabir, Hossain, & Haque, 2022).

The model of functioning of modern civilization, based on the necessity of increasing the volume of economic activities and industry needs for new products to achieve market placement, reduces the reserves of safe drinking water, intensively pollutes the air and contaminates agricultural land (Artiola, Walworth, Musil, & Crimmins, 2019; Dhir, Jatayan, & Kumar, 2018; Hallberg, 1987; Kochar, Sushil, & Rahul, 2020; Macek, Pavlíková, & Mackova, 2004; Okorogbona et al., 2018; Parris, 2011; Sharma, 1996; Srivastav, 2020; Wu & Sun, 2016). Despite the obvious earlier negative effects, it is only with the internationalization of industrial processes that the true scale of human action on the planetary ecosystem is seen. In the early 1970s, a serious campaign began to raise awareness in society about the disruption of the ecological balance as a consequence of the mismatch between the exploitation of natural resources and the planet's ability to absorb the damage that humans cause to nature through their activities.

The concept of sustainable development is the result of the search for solutions to overcome problems arising from an irrational attitude towards limited resources and an economic model that does not recognize environmental costs. Perhaps the idea of the ecological footprint is the best illustration of the consequences of industrial civilization on the planet as a human habitat. Namely, meeting current global consumption exceeds the capacity of the planet by 70%, which means that to maintain ecological balance, we need another planet, or a planet 70% larger than the one we live on (GFN, 2024).

Sustainability as a concept is becoming synonymous with a rational relationship with nature, but also a term with which we want to point out the importance of a process for long-term planning and the effects of activities undertaken in the future (Cvetković & Šišović, 2024; Grozdanić, Cvetković, Lukić, & Ivanov, 2024; RajeevM, 2014). In this context, we say that a community or economic entity that manages to harmonize inputs with results so that negative effects do not put the survival of the entity and the environment in question is sustainable. Given the increased awareness of the global ecosystem, this means that no community or economic system should be allowed to transfer its pollution to someone else's backyard and thus create the illusion of its sustainability. At the same time, the planetary application of the principles of sustainability implies respect by all actors, but also the assistance of the developed to the underdeveloped so that they can overcome their development problems through new technologies that are currently not available to them. Given the fact that we are contemporaries of the process of an emerging global society, it is necessary to achieve a balance between economic processes, environmental standards and the needs of the community at the planetary level.

2. The link between disaster resilience and development

With the increasing frequency, intensity and scale of disasters caused by climate change (Cvetković, Renner, Aleksova, & Lukić, 2024), the concept of resilience to events that can lead to disasters is increasingly mentioned in public discourse (Sergey, 2021; Shibru, Operea, Omondi, & Gichaba, 2022; Thennavan, Ganapathy, Chandrasekaran, & Rajawat, 2020; Umer, 2024; Xuesong & Kapucu, 2019). For this occasion, we will use the United Nations International Strategy Disaster Reduction's definition of resilience as: "the ability of a system, community or society exposed to risk to resist, absorb, adapt and recover from the effects of risk in a timely and effective manner, including the preservation and restoration of essential basic structures and functions" (UNISDR, 2009).

The complexity of the definition itself indicates the need for a multidisciplinary approach that encompasses all aspects relevant to achieving resilience. Certainly, bearing in mind the previous remarks on sustainability, we can say that it is impossible to separate sustainability from resilience, i.e. sustainability is the main determinant of system resilience. No community can be resilient to disasters without being sustainable at the same time. There are exceptions when part of the risks and negative effects are transferred to neighbouring areas, that is when one's resilience is built on raising the vulnerability of others. Bearing in mind the character of the text, we are talking here about the emerging global community, and in that context, we ignore excesses such as the practice that instead of solving the problem of pollution in developed countries, the causative agents are displaced to underdeveloped regions. In those situations, the export of the cause of pollution only creates the illusion that the problem has been solved, because the effects of such a practice return like a boomerang in the form of worsening climate changes that also affect the local community from which the holder of said practice originates.

A holistic approach to the problem of sustainability, that is, resilience, is the only one that can lead to results. There should certainly be an awareness that reaching global goals implies creating conditions for their realization at the local level. When we talk about the community, we said that our commitment to analysis is on a global level. However, the global community is made up of several levels of international subjectivity, starting from universal organizations, through regional integrations to states. Again within the states there are several levels of different organizational forms from institutions at the state level, through federal units, districts, cities and villages.

Solving a problem of a global nature implies identifying its cause at the level at which it arises. Bearing in mind the current dominant system of organization of modern societies, the level of state institutions is the one that has the instruments for directing the functioning of the system and the behaviour of all actors in the area of their competence. And here it should be said that thanks to the instruments at their disposal, states can implement a certain policy and sanction all those who do not comply with the established norms. The problem arises when trying to harmonize national policies at the global level because some countries do not want to adhere to what was agreed or consider that the global agreement is not in their interest.

Given that we have opted for the analysis of phenomena of a global nature that are largely determined by local actors, below we try to present the basic elements of sustainability and the principles on which it is based. For a community to be considered viable, it should have continuity in duration resulting from a healthy living environment, social solidarity, resilience to disasters and economic vitality, all of which contribute to the quality of life of its members. Community members' satisfaction with life within it, among other things, stems from democratic processes that respect the needs of the majority and the opportunity to participate in the decision-making process actively.

Perhaps the best theoretical framework for analyzing the level of sustainability of both local communities and global civilization is the concept of human security, which offers a seven-dimensional matrix for analyzing the quality of life in an area. The quality of people's life determines their attitude towards their current habitat and based on their satisfaction with the conditions in which they live and work, citizens make a decision to stay or change their place of residence. In the concept of human security, the factors that are taken into account when assessing the situation in an area or within a community are: economic situation, health system, quality of nutrition, environmental conditions, political situation, personal and community security (Đorđević, 2013). The harmony of all

the mentioned elements is necessary so that the community can function normally for a long period of time and survive in its living space. Coherence is the result of the interaction between community members and their awareness of a common identity arising from coexistence in a certain territory.

The social sphere implies a minimum of common elements that result from the interaction of all members of the community, and whose catalyst is the corresponding political system. The functioning of complex social structures is not possible without appropriate mechanisms that enable reaching consensus on important matters. Starting from the level of local self-government, where rules of conduct, attitudes towards others, tolerance and a minimum of rules related to the arrangement of common space should be established, as well as standards related to individual construction and the relationship of individuals to the community. Building awareness that our every move affects not only the immediate environment but in the long term also on us as individuals, that is, our families, is the first step in the process of building community sustainability. When we manage to agree at the level of the local community on the basic principles of its functioning, then the nature of things is to harmonize with the neighbouring communities that may have some of their specifics in relation to nature and social norms. That is why the political system of representative democracy, which has mechanisms for harmonizing the interests of several entities, serves us. The majority of community members must participate in the process and feel that they influence the adoption of the rules, which ultimately contributes to the level of their compliance. It is normal that within every community there are individuals who do not want, or are unable, to follow the rules established by the majority. In those cases, it is necessary to activate mechanisms for sanctioning those who do not comply with the adopted rules so that the system can function normally.

For the existence of a community in an area, the existence of certain ecological conditions and an appropriate economic system are necessary. Certainly, people chose the place for their settlements following the natural characteristics of the terrain, such as healthy drinking water, fertile soil or mineral deposits. However, with time, if the mentioned elements are not taken care of, the ambience may change. Let's say that during the exploitation of ores, or excessive use of fertilizers in agriculture, there is pollution of drinking water sources and contamination of arable land. These processes can lead to mass migration of the population in search of new areas more suitable for living.

That is why it is necessary to take into account their long-term effects when making decisions about the exploitation of natural resources. What are the costs of the undertaken activities, not only in the form of financial resources but also the long-term effects on the natural environment should be decisive factors when making decisions about the economic model of the community. Let's say that cutting forests and the wood industry would bring a lot of profit in the short term, but deforestation leads to the degradation of the terrain, the initiation of landslides and the occurrence of flash floods. An example of an irresponsible attitude towards forests shows that short-term benefits can bring long-term damage that calls into question the survival of the community in a certain area.

Mileti lists six principles that communities should adhere to if they want to be sustainable (Mileti, 1999):

1. Maintain the existing level and, if possible, improve the quality of life of the residents.
2. To improve the local economic structure.
3. Ensure social and intergenerational equality.
4. Maintain and, if possible, improve the quality of the environment.
5. Include disaster resilience and disaster risk reduction in development plans.
6. When planning, use a participatory process so that decisions are made by consensus.

For each principle, Mileti states broader explanations that can also be linked to the concept of human security. For the sake of example, for important elements affecting the quality of life, we can mention: the level of earnings the cost of living, the quality and scope of education, the availability of health system services, housing conditions, the level of employment and the social welfare system, respect for the law and exposure to crime, respect moral norms, level of environmental pollution, exposure to diseases, disasters and other risks.

Mileti believes that the community should take care of economic vitality, which means a sufficient number of jobs under conditions worthy of a human being. In this context, it is necessary to engage the community to attract and retain companies that enable the local population to achieve their existence in the area of their permanent residence. When choosing an economic strategy, the basic criterion of selection should not be only the financial effect, but the ecological aspects of the process must also be taken into account; the degree of labour exploitation and the effect of the process on the health of the population is also an important criterion for the choice of investors.

Long-term effects on living space are also important here, the basic postulates of sustainable development should not be violated. The current generation should not leave their descendants a devastated living environment, polluted nature and devastated deposits of natural raw materials. When thinking about the ecological aspects of production processes, concrete relationships of intergenerational and intergenerational solidarity are often neglected. If the current processes are controlled by a small group of interest-organized owners of large capital, there is a high probability that the positive effects of the exploitation of natural resources will be enjoyed by a small number of people who can afford a standard far above the average. In that situation, the negative effects in the form of polluted waterways, depleted sites used for disposal of toxic substances contaminated soil with an increased risk of landslides, and occupational diseases of workers remain a burden on the local community. The uneven distribution of wealth from the exploitation of natural resources leads to the growth of social inequalities, inadequate solutions in the field of urban planning, the neglect of critical infrastructure and the outflow of the population that does not see the perspective in such an environment. As a rule, in such situations, the most educated personnel who could change the situation for the better leave.

Because of all the above, there must be an identity belonging to the community that is built through the education system, family tradition and participation in the political system. Work on maintaining existing resilience and raising its level can only be provided by a community that strategically thinks about long-term survival in the current living space. Only a community with a collective awareness of common interests can make decisions that increase the level of resistance to climate change. Consideration of topics that are important for the preservation of the existing entity implies appropriate scientific processing, which is achieved through research within the academic community. Through their activities, institutes and faculties not only contribute to the identity determination of members of the community but also point to possible scenarios bearing in mind climate change and its effects on the specific area.

3. International strategies and declarations for sustainability and disaster risk reduction

At the international level, the problem of the sustainability of the current civilizational paradigm became visible in the early 1970s after the publication of the Club of Rome's The Limits to Growth (Meadows et al., 1974): It was then that the bleak perspective of the current economic model and the functioning of modern civilization, based on the excessive exploitation of natural resources without their proper valuation, was first presented. The Club of Rome had several more publications that drew attention to the problem but without any significant resonance in profit-oriented circles.

The Brundtland report of the World Commission on Environment and Development continued the campaign to draw attention to the problem of the sustainability of the system, in which sustainability is placed in the context of the global effects of human activities on the environment. One of the results of the commission's work is the most quoted definition of sustainable development: Sustainable development can be considered to be "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The report points to the connection that exists between social capital, economic productivity and environmental quality. The authors of the report, inspired by the heated globalization, emphasized the need to build awareness of the planet as a common living space and a common destiny shared by all peoples of the world, which should lead to the construction of common global values (Brundtland, 1987).

The United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, from 3 to 14 June 1992 promoted sustainable development as a framework for international action and to guide future development projects at the global level. At the summit in Rio, Agenda 21 was adopted, which, in addition to emphasizing the ecological aspects of development, also pointed out the need for social contextualization of the new approach to development. The agenda promotes the concept of development, which, in addition to protecting the living world on the planet, should provide conditions in which vulnerable groups of people will get the opportunity to qualitatively improve their living conditions. One of the messages stemming from the Agenda is that with planned changes in people's behaviour patterns, it is possible to change the negative effects of human activities concerning the planet as ours, but also the habitat of plant and animal life as a unique ecological entity (UNCED, 1992)

A new world summit devoted to sustainable development was held in Johannesburg in 2002 to initiate the process of applying the principles of sustainable development adopted in Rio (UNCED, 2002). Then numerous gatherings deal with the same topic with the idea of finding a common content that would attract all actors to participate in the process and respect the adopted declarations. The main problem during this process is the obstruction by profit-oriented circles that used the representatives of their countries to work out a more favourable position for themselves. The most drastic example in this context is the withdrawal of the USA from the Paris Agreement with the explanation that its implementation harms the interests of the American economy (Chakraborty, 2017).

Given that attempts to take preventive action and reduce the negative impact of humans on the planetary ecosystem have largely been unsuccessful, the international community is trying to find ways to deal with the negative trends caused by climate change (Cvetković & Grbić, 2021; Cvetković, Milojković, & Mlađan, 2013; O'Gorman, 2015). International action to help underdeveloped countries deal with the consequences of climate change is particularly important. The recommendations adopted in Hyogo were in the direction of reducing the level of risk based on practices that gave good results in threatened areas (UNISDR, 2007). In Sendai, it went a step further with the idea of raising the level of efficiency of response in cases of large-scale disasters (UNISDR, 2015). The Global Platform for Disaster Risk Reduction (GPDRR) (UNDRR, 2019) was established based on experiences with the implementation of the conclusions of the aforementioned conferences. GPDRR brings together representatives of national governments, international organizations, academic institutions and the private sector every other year. The goal is to evaluate the level of achieved results in the implementation of the agreed at this forum, but also to exchange new experiences from practice. The number of actors involved and the commitment to the realization of the goals raises the hope that in due time we can expect a change in attitudes towards the negative impact of man on the living environment and that the negative trends of which we are contemporaries can be stopped.

4. Building local sustainability capacities

Understanding the importance and context of local sustainability capacities implies, first of all, determining the content of the concept of community as an entity on which the achievement of the goal of sustainability in an area depends most. In the Oxford Dictionary, community is defined in several ways, depending on the context in which the term is used. For this work, we opt for the definition that reads: "A body of people who live in the same place, usually sharing a common cultural or ethnic identity." Hence: a place where a particular body of people lives" (OED, 2024).

For a complete understanding of the term, it should be said that it is a group of people who share a common living space, have the same or similar needs, engage in social interaction, carry out joint actions and have a sense of belonging - an identity created based on tradition and history. For the validity of the analysis related to a specific community, it is necessary to know its territorial scope. We have already said that it can be the level of local communities, regions, and countries, but also the planetary level. The principles on which the analysis is based are the same, only the elements are complicated because there is a multi-layered level on which the interaction of community members depends. The simplest analysis is at the local level, where we only have citizens and institutions in

charge of their space. If we expand the area of analysis, then we have to include higher administrative levels starting from municipalities, through districts, republics, and up to universal organizations. That is why it is necessary to determine the context of the meaning of the community with an additional prefix such as local or global and thus specify the level of institutional competence.

Given that in this part of the material we are dealing with issues important to the local community, it should be borne in mind that we are talking about the level of local (self) administration as the lowest level of the institutional system. Territorial boundaries of local communities are most often determined according to the criteria of geographical units and represent areas with certain climatic characteristics. That is why the population living in the space of a community has a more or less similar history, collective memory of past events and needs related to the common space. The level of spatial organization and the degree of resistance to extreme phenomena such as floods, droughts or some other form of threat to the survival of people in their habitat depends on the behaviour of both individuals and narrow social groups. The individual attitude towards the interests of the community and the living space determines the level of quality of life of all members of the community. That is why it is important that within each community we can identify individuals or groups of people who are important for taking appropriate actions to realize the interests of that community. Past historical experiences have shown that the best form of identification of community representatives and their leaders is the direct election system. In the elections, the members of the community test their position on who has the greatest reputation and gains the trust of others that he can successfully contribute to the common interest.

Certainly, in addition to the territorial dimension of the organization of community members, its functional dimension should also be taken into account (Žganec, 2003). Namely, bearing in mind that local communities are by nature part of broader entities and that, following the rules related to administrative and administrative division, many actions of a local nature must be coordinated with plans adopted at the level of broader entities, local communities elect their representatives in higher institutional structures. This is already the point where certain problems can arise, considering that a functional community can include areas with different geographical and climatic characteristics. The alignment of needs at the level of functional communities largely depends on the quality of elected representatives at the level of local communities who should represent the interests of the members of their communities. At that level, too, misunderstandings and the imposition of the interests of more numerous and economically powerful social groups can occur. That is why it is important to establish institutional mechanisms that will enable the harmonization of everyone's interests to ensure the functionality of communities and their survival.

The specificity of the topic we are dealing with points us to the fact that the local community should have a key role and influence in raising resilience to disasters because its members are potentially the most vulnerable and suffer the greatest consequences (Chen & Lin, 2023; Cvetković, Milašinović, & Lazić, 2018; Cvetković, Tanasić, Renner, Roković, & Beriša, 2024; Kalantari, Ferreira, Keesstra, & Destouni, 2018). At the local level, there is the best knowledge about the characteristics of the local topography, available resources and living conditions. That is why local structures must be actively involved in the process of disaster management in all phases; from development plans and disaster response plans to dealing with their consequences. Each local community should have the initiative to develop its capacities, but also to build systems at higher levels that should contribute to the general resistance to disasters, as well as overcoming their consequences when they occur. It should always be kept in mind that local communities are not only in the role of victims, but they are also the first line of defence and assistance in the event of disasters when assistance to the affected is necessary. Therefore, a bottom-up management approach is necessary in this sector to obtain a model that solves the problem at its source.

For the effectiveness of the response system in emergencies, it is necessary to build participative strategies that, with the inclusion of all actors in the process, contribute to reducing the vulnerability of the area and increasing their resilience. By involving citizens in the process of risk assessment and making plans, awareness is raised about risks from the immediate environment, but also about the importance of their behaviour to urban plans and construction standards. It is also necessary for all public officials to familiarize themselves with their roles in the system so that when making

decisions, they also take into account the possible consequences of the risks faced by the community whose interests they represent.

Specific activities that can be undertaken to make the population aware of the importance of preventive action concerning potential risks are:

- Acquaintance of the population with handling in the event of disasters through the media and within the educational process.
- Acquaintance of the local population with the risks they are exposed to to the characteristics of the terrain and phenomena that can contribute to raising the level of risk. Given that floods and landslides are most often the result of reckless human action, the population should draw attention to the consequences that may occur as a result of deforestation, cutting roads on steep slopes, and building houses in flooded areas. A public demonstration and display of disaster-resistant construction methods should be organized with reference to the selection of locations for houses and commercial facilities.
- A good way to activate the local population is to establish working groups for the repair of water infrastructure, cleaning sediments and waste that can cause overflowing rivers, reforestation. Getting to know objects that can be a source of contamination and dealing with accidents by organizing exercises is a good way to approach abstract theoretical developments to citizens who are potential victims of identified risks.
- Preparation of facilities for shelters and evacuation in case of disasters. Acquainting the community with disaster response plans and actions can significantly contribute to a community's level of resilience.

We should certainly take into account the fact that from the perspective of local structures, it is not always possible to see the wider picture of all relevant facts regarding the mechanisms of the causes that lead to disasters, so coordination at the level of wider entities is also necessary. It is especially important to establish structures at the regional level that can raise the level of efficiency of the response system, but also of planned action in order to reduce risks and eliminate the causes of potential disasters. The establishment of a system in a wider area enables the rationalization of available resources because specialized units and equipment can be designed in accordance with the needs assessments of wider entities, which avoids the multiplication of organizational units and technical resources.

Just as it is important to establish a system based on local characteristics in accordance with the dangers and risks to which residents of certain areas are exposed, it is also important to analyze experiences from other areas that have already faced the consequences of certain natural or technical destructive phenomena. This is especially important considering the change in the characteristics of the area due to climate change, which also leads to a change in the spread of climate zones.

4.1. Reliance on tradition

Traditional knowledge and skills refer to historical experiences that contribute to the understanding of natural processes from the immediate environment. From today's perspective, we can say that it is the accumulation of knowledge resulting from interaction with the environment, which over time becomes part of the historical heritage of the community, a kind of philosophy of life. Tradition can also be defined as a local system of knowledge developed through practical action in everyday life activities. Tradition is an indispensable part of cultural heritage that manifests itself through a belief system, and a relationship with nature and community members. Certain rituals and traditions contribute to the preservation of traditional knowledge and their intergenerational transfer and can be recognized in the specificity of indigenous languages through terms used by the local population to express certain natural phenomena. (UNESCO, 2020)

Although there are significant differences in the way the traditional knowledge system and modern science were created, the potential and importance of tradition for reducing the risk of disasters is recognized. Tradition makes it possible to obtain a long-term dimension of sustainability and

community survival in their territory. The complementarity of modern and traditional contributes to the realization of the goals of sustainable development. The principles of modern science and the methodology of research and application of scientific achievements with respect for traditional experiential knowledge enable obtaining models that significantly contribute to the sustainability of the community and reduce the risk of natural disasters. (Hadlos et al., 2022).

Development plans in an area should be the result of an assessment of the characteristics of the terrain and the potential risks that the local community may face in the future. It is not a rare phenomenon that newly built buildings increase the probability of the realization of existing risks, but they can also create an environment that causes additional risks. When planning, it is certainly necessary to take into account the perception of risk that exists in the collective consciousness of the local population of the area where new construction is intended or an intervention that affects the change in the geographical characteristics of the area. Folk wisdom that comes as a result of collective experience with the destructive power of natural phenomena is transmitted through oral traditions or written down in historical documents. Among the highly educated part of the population, there is a tendency to underestimate folk traditions in the context of current processes and phenomena. However, the practice has shown that many lives and material goods were saved precisely thanks to the collective experience and heritage based on which the population recognized the danger in time. It is for this reason that the Hyogo Framework for Action (2005-2015) states that it is important to use "traditional and indigenous knowledge and cultural heritage" as a source of "knowledge, innovation and education to build a culture of security and resilience at all levels".

There is a significant number of publications dedicated to the need to include traditional knowledge in modern development strategies and the creation of emergency response systems. We do not have to cite foreign experiences in this sphere, we also have domestic examples. One of the good examples of the importance of collective consciousness for maintaining community resilience is the case of Sokobanja. During the transition period in Serbia, many people saw forest cutting as a good source of income. Many mountain areas were exposed to relentless deforestation regardless of all the negative aspects of that practice. After the slopes of Mount Ozren above Sokobanja also came, the local population rebelled against the intention to realize those plans, having experience with torrential floods that were a frequent occurrence in Sokobanja after the Second World War when the Germans completely stripped the hills above that town. It took several decades for the trees to grow, which now absorb a significant amount of rainfall and prevent flash floods. Thanks to the collective action of the people of Sokobanja, the surrounding forests have been preserved. Current protests against the cutting of forests to build a wind farm on Cestobrodica should also be interpreted in this context.

4.2. Application of international standards

The importance of international standards for building local sustainability capacities should be seen in the context of the previous unit. International standards are created based on successfully applied practice that is recognized by ISO system experts and practitioners who apply certain techniques and procedures in the performance of their professions. The success criterion of a process, among other things, takes into account its effects on the living environment as well as on its immediate participants. Here, it is particularly important to emphasize the criterion of success based on experience from practice, which means that every society doesn't need to go through all the stages of realizing the principles of functioning of a process. Bearing in mind the nature of climate change, today we are contemporaries of the shifting of climate zones, which implies changes in the living environment of communities. These changes are usually a new challenge or an already known phenomenon but with far more intense effects. That is why it is important to be able to use procedures and rules that are successful when dealing with some dangers.

The standards of the ISO system were created as a result of the need to standardize the quality of products and their technical characteristics. Later, with the development of global processes and the growth of awareness of the planet as a unique living space of the human population, the space

covered by the ISO system expands. It is particularly important to draw attention to profitability as the basic criterion of capital owners, which is often in conflict with citizens' interest in a healthy living environment. Namely, owners of investment capital make their investment decisions guided by indicators of profit rates, while the effects of investments on the living environment and quality of life are less taken into account. Developed countries with a democratic tradition have built institutional mechanisms to force capital owners to implement local laws when starting new investments that limit negative effects on air, water, soil and the health of the public. Investment funds in search of new sources of income offer their members cross-border investments in countries with corrupt rulers and areas where there is no insistence on systems for purifying polluting products of production processes.

This practice is one of the biggest challenges of the emerging global community and requires an answer to the question of how to reconcile the need of the underdeveloped for new technologies and facilities that will employ the population of underdeveloped countries and the need for those facilities not to threaten the survival of those same people who work in them. It is the activities that are carried out within the ISO system that can be the answer to the mentioned problem. Let's say that TNCs are obliged to apply the same protection standards in the business process, regardless of the location of the plant. If all the countries of the world insisted on applying the same business rules, then the problem with local corrupt systems would be solved. Certainly, in this process, the most developed countries have the greatest responsibility because they have the mechanisms to force companies originating from their areas to comply with established rules. At the same time, insisting on knowing the origin of the product and the availability of information on whether the product was created in a plant that respects the appropriate standards on environmental protection, workers' rights and the emission of harmful substances would prevent speculative actions in this sphere and solve a good part of the problems concerning the sustainability of modern civilization. (Djordjević & Keković, 2023)

Within the UN activities that are carried out to fulfil the goals of sustainable development, there is a lot of potential for the application of appropriate standards and the promotion of their importance. For each of the dimensions of human security that concern the quality of life of the population, there is a group of standards whose application can contribute to the realization of the goals of sustainable development and at the same time raise the existing level of the quality of life of all inhabitants of planet earth. One of the examples that best illustrates the stated thesis is the impact of ISO 20400 on the realization of sustainable development goals.

Table 1. The impact of the ISO 20400 Standard application on the goals of sustainable development is based on ISO (2018), UNDP (1994) and UNHSU (2016).

No.	Goal	Contribution
1.	No Poverty	Development based on the principles of sustainability eliminates poverty among the local population.
2.	Zero Hunger	Ensuring a minimum income for a life worthy of a human being implies sufficient funds for the procurement of food.
3.	Good Health and Well-Being	Thanks to the improvement of conditions at the workplace and the provision of sufficient resources for regular and healthy nutrition, the general well-being and health of people is contributed to.
4.	Quality Education	Sustainability also means allocation for investments in local infrastructure and public services. Education gains quality thanks to higher budget revenues, which enables better working conditions, as well as better teaching staff.
5.	Gender Equality	With economic development, conditions are created for the application of the principle of gender equality in the local community.
6.	Clean Water and Sanitation	Larger public funds enable investments in the water supply network and wastewater treatment systems.
7.	Affordable and Clean Energy	A higher economic standard implies the expansion of the electrical network and the availability of energy to all residents with a higher rate of investment in environmentally friendly energy sources.
8.	Decent Work and Economic Growth	Sustainability implies working conditions that do not endanger the health of employees. If the principles of sustainability are consistently applied, then in addition to economic growth, we also get development, which is a prerequisite for raising the quality of living and working conditions of the population.
9.	Industry, Innovation and Infrastructure	With the development of the economy, the outflow of civil servants decreases. The creative part of the population remains in the country of origin and contributes to its development and more rational use of local resources.
10.	Reduced Inequalities	With development comes a reduction in the gap between the rich and the poor.
11.	Sustainable Cities and Communities	The application of sustainability principles ensures cleaner air in cities, a lower level of water pollution and soil contamination. As the level of development increases, the level of criminal and socially undesirable forms of behavior also decreases.
12.	Responsible Consumption and Production	Insisting on sustainability reduces the unnecessary pollution that comes as a result of consumerism and reduces processes that are big polluters.
13.	Climate Action	A responsible attitude towards production and consumption contributes to reducing the negative effects of climate change.
14.	Life below Water	Insisting on recycling and treating wastewater reduces pollution of the world's seas and oceans.
15.	Life on Land	Respecting the principles of sustainability ensures the preservation of biological diversity on the planet.
16.	Peace, Justice and Strong Institutions	A higher level of public revenues enables the hiring of better quality personnel in public services, which increases the efficiency of their work and reduces corruption. It ensures the stability of institutions and reduces the likelihood of internal and international conflicts.
17.	Partnerships for the Goals	Awareness of common interests in the preservation of the planet as a common habitat of all people, plants and animals contributes to the establishment of global partner networks.

Source: (Djordjević & Keković, 2023).

Thanks to the application of good practice models at all levels, it is possible to contribute to the change of negative trends related to climate change, the cause of which is man's irresponsible behavior. By adopting proven models from community practice, they change their attitude towards the environment, raise the level of efficiency of institutions and contribute to their resilience in relation to potential dangers. Table 2 contains a list of the most important standards in the field of environmental protection.

Table 2. Selected ISO standards relevant for environmental security

ISO/TS/ASTM	The name of the standard
9806	Solar energy — Solar thermal collectors — Test methods
14000	Environmental management systems
14001	Environmental management systems — Requirements with guidance for use
14020	Environmental labels and declarations
14055	Environmental management – Guidelines for estabilishing good practices for combatting land degradation and desertification
14064	Greenhouse gases
14067	Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification and communication
14080	Greenhouse gas management and related activities — Framework and principles for methodologies on climate actions
20245	Cross-border trade of second-hand goods
20400	Sustainable procurement — Guidance
24518	Activities relating to drinking water and wastewater services — Crisis management of water utilities
24521	Activities relating to drinking water and wastewater services — Guidelines for the management of basic on-site domestic wastewater services
30500	Nonsewered sanitation systems – Prefabricated integration treatment units – General safety and performance requirements for design and testing
38200	Chain of custody of wood and wood-based products
50001	Energy management systems – Requirements with guidance for use

Source: (Djordjević & Keković, 2023).

The possibilities and potential offered by the ISO system in the field of managing local community affairs should be emphasized here. The resistance of institutions to the influence of self-interested organized profit-oriented groups through corrupt activities is a prerequisite for the community's resistance to the effects of natural and other disasters. Insisting on the application of appropriate standards (Table 3) lowers the probability of the realization of some risks due to the irresponsible operations of business entities, but also of the state administration.

Table 3. Selected ISO standards most relevant for community security.

ISO/TS/ASTM	The name of the standard
15392	Sustainability in buildings and civil engineering works
22311	Societal security — Video-surveillance — Export interoperability
22313	Security and resilience — Business continuity management systems — Guidance on the use of ISO 22301
22315	Societal security — Mass evacuation — Guidelines for planning
22319	Security and resilience — Community resilience — Guidelines for planning the involvement of spontaneous volunteers
22320	Security and resilience — Emergency management — Guidelines for incident management
22322	Societal security — Emergency management — Guidelines for public warning
22324	Societal security — Emergency management — Guidelines for colourcoded alerts
22325	Security and resilience — Emergency management — Guidelines for capability assessment
22326	Security and resilience — Emergency management — Guidelines for monitoring facilities with identified hazards
22327	Security and resilience — Emergency management — Guidelines for implementation of a community-based landslide early warning system
22328	Security and resilience — Emergency management — General guidelines for the implementation of a community-based disaster early warning system
22329	Security and resilience — Emergency management — Guidelines for the use of social media in emergencies
22370	Security and resilience — Urban resilience — Framework and principles
22393	Security and resilience — Community resilience — Guidelines for planning recovery and renewal
22395	Security and resilience — Community resilience — Guidelines for supporting vulnerable persons in an emergency
22397	Societal security — Guidelines for establishing partnering arrangements
22399	Societal security - Guideline for incident preparedness and operational continuity management
24526	Water efficiency management systems— Requirements with guidance for use
26000	Guidance on social responsibility
37101	Sustainable development in communities — Management system for sustainable development
37120	Sustainable cities and communities — Indicators for city services and quality of life
37122	Sustainable cities and communities — Indicators for smart cities
37123	Sustainable cities and communities — Indicators for resilient cities
37151	Smart community infrastructures — Principles and requirements for performance metrics
37152	Smart community infrastructures — Common framework for development and operation
44001	Collaborative business relationship management systems — Requirements and framework

Source: (Djordjević & Keković, 2023).

Certainly, one of the prerequisites for understanding the concept of sustainability and the connection between daily life activities and long-term effects on the planetary ecosystem is quality education for the public. In this context, we should also mention ISO 21001 (Educational organizations — Management systems for educational organizations — Requirements with guidance for use) whose goal is to raise the level of quality of work of formal educational institutions. No less important is the ISO 29993 standard, which covers all types of non-institutional education (adult education, professional education and training within the company), which is especially important considering the need for continuous improvement and familiarization with changes in our environment.

5. (Un)sustainable development and disaster risk reduction in Serbia

Sustainable development has become one of the key elements in the formulation and implementation of development policies in the world, but also a key determinant of the development of nation-states in the future. On the other hand, no matter how well-prepared a country is and how solid its policy frameworks are, it will often face disasters with inevitable and very devastating consequences. If recovery processes are only partially implemented and are not focused on strengthening resilience, the consequences of disasters can last for a very long time and affect the lives of entire generations (UNDP, 2014). As the Secretary-General of the United Nations reminds us: "Risk considerations should be included in all investments in sustainable development."

The new seventeen sustainable development goals are more comprehensive than those set out in the Millennium Development Goals of 2000. They cover a wide range of issues related to the economy, social issues, the environment, governance, human rights and gender relations. The Sustainable Development Goals reflect the understanding that development has multiple dimensions and that development in one area depends on the results achieved in other areas. The Sustainable Development Goals also place a much greater emphasis on the concept of resilience, including disaster risk reduction, which is an essential element for every country and a common theme that unifies the tasks set for each of the goals. In its recent history, Serbia has faced many challenges, of which, due to their scope and complexity, a significant place belongs to solving problems in the field of environmental protection, disaster risk reduction and sustainable development. The concept and issues of sustainable development, as well as risk management in our country, are not new and unknown.

At the UN Conference on Environment and Development, held in Rio de Janeiro in 1992, Serbia, as part of a federal state, supported the main guidelines of the conference, the most important of which are the following: peace, development and environmental protection are interdependent and indivisible, to achieve sustainable development, environmental protection is an integral part of the development process and cannot be considered separately from it. At the United Nations World Summit on Sustainable Development in Johannesburg in 2002, it opted for the implementation of the Johannesburg Plan of Action in its strategic documents, constantly bearing in mind the Rio Declaration, Agenda 21 and the three Rio Conventions. At the same time, enthusiasm and commitment to sustainable development did not have the same intensity in all phases. Particularly noteworthy are the years 2002 and 2003, when this process was given a significant boost by the message of the then leadership of the Republic of Serbia to the World Summit on Sustainable Development, that "the environment is a priority and a significant support for economic development", as well as the years 2009 and 2010, in which the confirmation of Serbia's commitment to sustainable development by the country's representatives at the Millennium Development Goals Summit can be highlighted.

The most important document in this area is the National Sustainable Development Strategy (Government of the Republic of Serbia, 2008), which bases its solutions on European documents: the EU Sustainable Development Strategy adopted in 2001 and revised in 2006, and the EU Lisbon Strategy from 2009. The Strategy is aligned with the UN Millennium Development Goals and the National Millennium Development Goals in the Republic of Serbia, which were adopted by the Government of the Republic of Serbia in 2006. The orientation towards sustainable development is a logical choice for our country in the future, given the long-standing experience of unsustainable development, especially in conditions of catastrophic consequences of risks, which require high costs and counted on short-term effects, even at the cost of a drastic slowdown in economic dynamics over a long period of time. Serbia has undoubtedly needed a decisive move towards the application of the principles of sustainable development in politics, the economy and all other areas of life, especially in disaster risk reduction. Instead of fragmented and poorly coordinated policy decisions affecting the economic, social and environmental dimensions of development, the aim was to achieve an integrated set of policies that work together to improve human well-being. Sustainable development cannot be achieved without good governance, which ensures that different (economic, social, environmental, and institutional) priorities are based on a broad consensus in society and that the voices of all, especially the most vulnerable, are heard when decisions are made on the allocation of resources. The responsibility for implementing sustainable development lies largely with the state,

but other institutions from the private sector and civil society should also become active partners in the process.

Along with the progress in the application of the concept of sustainable development and the clearly visible need for its synergy with other areas, the need for transformation in the field of disaster risk reduction has also been recognized. Globally, but also at the national level, the concept and practice of disaster risk reduction are reflected in systemic efforts to analyze the causal factors of disasters and to manage them, including reduced exposure to hazards, reduced vulnerability of people and property, sound land and environmental management, and improved preparedness for harmful events (UNISDR, 2009). One of the most important activities for preventive risk reduction and its consequences in Serbia in the process of transformation is building the capacity and resilience of society to risks and disasters, which is directly correlated with sustainable development. The transformation process also implies that reconstruction as a process must not be viewed only through the prism of financial assistance to the community in order to strengthen resilience.

A key component in this process, especially at the national level, is rehabilitation through education and training among the affected population, but also in society in general, which needs to be given special emphasis through the planning and design of comprehensive educational programs. Also, in risk reduction and risk management, one should not seek a solution based on subjective assessment and opinion, ignoring the socio-economic, environmental, institutional and other aspects that are highlighted in disasters. It is equally important that effective risk management implies, first of all, their understanding. This means that all those who analyze, assess risks and plan to manage them must understand its ambiguity - it is about the exposure of community components to a particular hazard, but also the likelihood of numerous consequences. These two components - exposure, and especially consequences - warn us that an even more important activity than risk management is disaster risk reduction. This activity, as a preventive one, is defined in international documents and in the national Law on Disaster Risk Reduction and Emergency Management from 2018 as a policy aimed at preventing new and reducing existing risks. This is done through the implementation of integrated economic, social, educational, normative, health, cultural, technological, political and institutional measures. They strengthen the preparedness of the community to respond to and mitigate the consequences of disasters. Therefore, in addition to risk assessment, a disaster risk reduction plan is of utmost importance.

The territory of the Republic of Serbia and the Western Balkans is threatened by numerous risks that threaten new consequences from year to year and directly endanger the further sustainable development of society. In the Republic of Serbia, in the period 1900–1940, 100 natural disasters occurred every ten years, in 1960–1970 there were 650, and in 1980–1990 as many as 2000, while in the ten-year period 1990–2000 the number of disasters increased to 2800. The trend shows that the number of hazards is increasing from year to year, so in recent years the economic costs have tripled. In the Study on the Economic Benefits of RHMS of Serbia, weather-dependent economic sectors in the Republic of Serbia were identified, their share in gross national income (excluding value-added tax), and recorded and estimated damages. The share of weather-dependent sectors in the gross national income of the Republic of Serbia, excluding the Autonomous Province of Kosovo and Metohija, at constant 2002 prices excluding value-added tax, ranged from 42% to 43.8% in the period 2000 to 2004. As early as 2005, the share of weather-dependent sectors in the gross national income of the Republic of Serbia was 47.18%. The World Bank study covered only 49% of weather-dependent sectors and did not take into account damages caused by forest fires. However, during 2007, 258 forest fires were registered. The forest fires caused damage of around 40 million euros. 24 million euros are needed for the restoration alone. Indirect damage has not been estimated. (Government of the Republic of Serbia, 2011).

Analysis of further trends in terms of the type, frequency, causes and severity of catastrophic events in Serbia shows that there has been an increase in damage and economic consequences, especially due to floods and earthquakes, droughts and climate change. According to climate change projections in the Second National Communication to the United Nations Framework Convention on Climate Change for Serbia 2001–2030. (UNDP, 2015), the temperature increase will range between 0.8 and 1.1 C°, while precipitation in most parts of the country is expected to increase moderately by

up to 5 percent in the period under review. Other climate change models predict a greater increase in temperature (up to 3.4–3.8 C°) and a decrease in precipitation of up to a maximum of 15 percent (Popović et al., 2009). Observations over the last two decades show that droughts usually affect the territory of Vojvodina in the north, as well as the southern parts of the country (Government of the Republic of Serbia, 2011). According to Andjelković and Kovač, the driest year in the last twenty-five years was 2012, when precipitation was very low and temperatures were high, over 35oC. It was the largest of the seven major droughts recorded and significantly affected agricultural production. Droughts cause significant economic losses in the Western Balkans and Serbia, especially in the agricultural, energy and water management sectors (Kovač & Andjelković, 2016).

The area of Serbia that is at risk from floods caused by hundred-year floods is 1.57 million ha, of which 1.45 million ha are located in Vojvodina. About 80% of the area at risk from floods is agricultural land, including 512 larger settlements, 515 industries, 4,000 km of roads and 680 km of railways. In Vojvodina, this is about 1 million ha of agricultural land, 260 settlements, 3 840 km of roads and about 150 km of railways (Republic of Serbia, 2014). Floods are occurring more frequently and are becoming more destructive as a result of unsustainable economic development, especially poor management of forests and agricultural land, as well as uncontrolled urbanization. As Varga states, during the development of this area of water management to date, the principle of "flood control" has been primarily applied in Serbia, which involved the construction of significant and expensive investment facilities (dams, reservoirs, embankments, watercourse regulation, relief channels, etc.) to ensure safety for people and goods located in flood zones. The principle of "flood control" was, until the last decades of the last century, most often applied in the world, when a new one was introduced - "living with floods". This new concept is far more sustainable and seeks to harmonize the requirements of the "human" component (protection of goods and human lives) and the "ecological" component (preservation or restoration of natural functions and resources of the floodplain) (Varga et al., 2001).

Serbia felt the unsustainability of the existing concept of flood risk assessment and the entire disaster risk reduction system most acutely in the period from 1999 to 2006, and then in May 2014, when it was faced with catastrophic floods, accompanied by landslides, which affected more than two-thirds of our country (119 out of 165 municipalities), or 1.6 million people. 57 Serbian citizens lost their lives, and the total damage was estimated at over 1.7 billion euros, or about 4.7% of GDP in the year. More than 400 houses were destroyed, and about 20,000 housing units were damaged. The impact of the floods was by far the greatest in the field of production, and then in the field of social services and infrastructure. Looking at individual sectors, mining and energy were the most affected, followed by housing, agriculture, trade and transport. It is estimated that 1.346 billion euros are needed for restoration and reconstruction, 51,800 jobs were temporarily lost due to the interruption of work activities in the 24 most severely affected municipalities, and damage to the housing stock is also extensive, leading to a significant deterioration in the living conditions of the local population (RS, 2014). This disaster triggered a recession in the Serbian economy, which recorded a decline of 1.8 percent in 2014, instead of the expected growth of 0.5 percent (Bijelić & Lazarević, 2015). The reconstruction began on 1 August 2014, immediately after the adoption of the Law on Flood Relief (Government of the Republic of Serbia, 2014). For these purposes, approximately 229 million euros in grants were approved (to the limited account of the Government of Serbia, from bilateral donations, from the EU Solidarity Fund and pre-allocated EU funds from pre-accession assistance) and 300 million dollars in World Bank loans (approved in October 2014 for reconstruction in the energy, agriculture and water management sectors). To this should be added the expected amount of the Japanese Government loan of 65 million euros, for which a request has been submitted and which is intended for the reconstruction of the entire energy sector. Although these are large amounts of money, it seems that this is only a small part of the estimated damage.

The state of disaster resulting from the inability to control flood risks negatively affected Serbia's key macroeconomic and social indicators in 2014. Serbia's vulnerable economy, affected by the floods, entered its third recession since the outbreak of the global economic crisis. Instead of the slow growth expected before the floods, real GDP fell by 1.8% in 2014. This was also contributed to by the slower-than-expected recovery of our largest foreign trade partners. Industrial activity decreased the most, and the floods caused the most damage to the mining and energy sectors, which are re-

sponsible for the decline in industrial production by more than 80%. Electricity exports practically stopped in the second half of the year, so in the whole of 2014 they were lower than in the previous year. The floods increased the import of electricity, as well as the import of coal for its production. In contrast, the export of petroleum derivatives increased compared to 2013, while the value of imports decreased significantly due to the modernization of plants in the petroleum industry. Similarly, the decline in activity in the chemical and metal processing industries was also influenced by lower imports of natural gas. Given the high share of energy products in total imports and significantly lower in exports, the trade balance of the energy sector in 2014 was negative (NBS, 2015). The floods created additional pressure on public finances, through lower tax collection and higher costs in mitigating their consequences. However, fiscal developments were favourable in the second half of 2014, primarily due to fiscal consolidation measures taken in the area of combating the shadow economy and tax evasion, as well as reductions in public sector wages and pensions.

Previous analysis of catastrophic floods, but also the impact of numerous natural risks, most notably recent climate shocks, has highlighted the importance of strengthening the resilience of the economy and population to risks, extreme weather events and climate change. Disaster risk management in the country and the region, according to World Bank experts, should be promoted and included in national development strategies (WBG, 2015). Disaster risk reduction is a development issue of paramount importance. Efforts to avoid risk bring the greatest long-term return on investment in development. However, the intangible benefits of avoiding losses can make these efforts less politically attractive, making it difficult to include them in strategic development documents. Effective disaster risk management requires collective action by a wide range of key actors across ministries, departments, agencies and at all levels. In addition, institutional stability is needed, as well as a strong coordination mechanism between different sectors, to ensure the sustainability of these activities.

6. Conclusion

Sustainability has become a fundamental principle of development in more and more activities and organizations, from local to national and global levels. There has been much discussion about indicators and other elements of development to determine development policies and assess the level of progress. To this day, although the concept of sustainability has been common in the world for several decades, the goals and practical implications of sustainable development have not yet been fully accepted. Discussions and debates about the term "development" have not ended, although development has been discussed since the first steps of humanity's civilization. The phrase "sustainable development" itself is in intensive use in many fields that analyze this concept from different angles and are associated with it, but also has different approaches, which often causes difficulties in its practical application.

The goal is to solve the problem of the state of disasters before they occur and threaten development, that is, to ensure that the development model does not lead to disasters. Disaster risk reduction focuses on risks, not disasters themselves, and the concept of disaster risk reduction emphasizes the need to reduce the exposure to hazards and the vulnerability of people and communities and to improve preparedness and early warning systems for potential risks. Disaster risks depend on the level of development in given contexts, including demographics, poverty, gender equality, urbanization, the environment, and climate change. The main lesson is that we as individuals and societies are still extremely vulnerable. It is therefore important to understand that the elements of sustainable resilience are ongoing risk assessment, improved early warning systems, support for decision-makers, long-term investment in risk reduction, planning and implementation of prevention measures, and international cooperation.

Summarizing the previous discussion, we can conclude that the current model of economic development is accompanied by numerous natural risks, climate change, poverty and inequality and as such increases the risk of disasters and is not sustainable in the long term. Disaster situations cause great loss of human life, destruction of economic and social infrastructure, as well as envi-

ronmental consequences. This undermines the capacity of many, primarily underdeveloped and middle-income countries, to undertake capital investments and provide social expenditures necessary to achieve sustainable development. To break this vicious circle and prevent a sharp increase in disaster risks, their causes must be addressed. This implies a transformation of the development model, taking into account sustainability criteria. Therefore, disaster risks should be managed from within, from the development process, which can play a key role in the transition of development from an unsustainable to a sustainable path.

References

1. Aleksandrina, M., Budiarti, D., Yu, Z., Pasha, F., & Shaw, R. (2019). Governmental Incentivization for SMEs' Engagement in Disaster Resilience in Southeast Asia. International Journal of Disaster Risk Management, 1(1), 32-50.
2. Al-ramlawi, A., El-Mougher, M., & Al-Agha, M. (2020). The Role of Al-Shifa Medical Complex Administration in Evacuation & Sheltering Planning. International Journal of Disaster Risk Management, 2(2), 19-36.
3. Andjelković, B., & Kovač, M. (2016). Izveštaj o humanom razvoju Srbija 2016. Socijalni Kapital: Nevidljivo Lice Otpornosti. Beograd: UNDP Srbija.
4. Artiola, J., Walworth, J., Musil, S., & Crimmins, M. (2019). Soil and Land Pollution. Environmental and Pollution Science. doi:10.1016/B978-0-12-814719-1.00014-8
5. Bijelić, M. & Lazarević M. (2015). Resilient Financing: The Economic Costs of Natural Disasters A Case Study of 2014 Serbia Floods. Belgrade: UNDP.
6. Brundtland, G.H. (1987) Our Common Future Report of the World Commission on Environment and Development. Geneva: UN-Document A/42/427. Retrieved from: https://digitallibrary.un.org/record/139811?v=pdf. Accessed: 16.10.2024.
7. Chakraborty, B. (2017) Paris Agreement on climate change: US withdraws as Trump calls it 'unfair', June 1, Fox News. Retrieved from: https://www.foxnews.com/politics/paris-agreement-on-climate-change-us-withdraws-as-trump-calls-it-unfair. Accessed: 16.10.2024.
8. Chen, I.-Y., & Lin, S.-Y. (2023). Resilience Analysis of Power System for Seismic Disaster Mitigation. Paper presented at the EGU General Assembly Conference Abstracts, Vienna, Austria. https://ui.adsabs.harvard.edu/abs/2023EGUGA..25..270C
9. Cruz, R. D. D., & Ormilla, R. C. G. (2022). Disaster Risk Reduction Management Implementation in the Public Elementary Schools of the Department of Education, Philippines. International Journal of Disaster Risk Management, 4(2), 1-15.
10. Cvetkovic, V. M., & Martinović, J. (2020). Innovative solutions for flood risk management. International Journal of Disaster Risk Management, 2(2), 71-100.
11. Cvetković, V., & Grbić, L. (2021). Public perception of climate change and its impact on natural disasters. Journal of the Geographical Institute Jovan Cvijic, 71(1), 43-58.
12. Cvetković, V., & Planić, J. (2022). Earthquake risk perception in Belgrade: implications for disaster risk management. International Journal of Disaster Risk Management, 4(1), 69-89.
13. Cvetković, V., & Šišović, V. (2024). Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. Sustainability, 16(7), 2620.
14. Cvetković, V., Milašinović, S., & Lazić, Ž. (2018). Examination of citizens' attitudes towards providign support to vulnerable people and voluntereeing during disasters. Journal for social sciences, TEME, 42(1), 35-56.
15. Cvetković, V., Milojković, B., & Mlađan, D. (2013). Climate change as a modern security threat. Paper presented at the International conference climate change impacts on water resources Belgrade.

16. Cvetković, V., Renner, R., Aleksova, B., & Lukić, T. (2024). Geospatial and Temporal Patterns of Natural and Man-Made (Technological) Disasters (1900–2024): Insights from Different Socio-Economic and Demographic Perspectives. Applied Sciences, 14(18), 8129.
17. Cvetković, V., Tanasić, J., Renner, R., Roković, V., & Beriša, H. (2024). Comprehensive Risk Analysis of Emergency Medical Response Systems in Serbian Healthcare: Assessing Systemic Vulnerabilities in Disaster Preparedness and Response. Paper presented at the Healthcare.
18. Dhir, K., Jatayan, M., & Kumar, S. (2018). Water Pollution Burden and Techniques for Control. 146-179. doi:10.4018/978-1-5225-3379-5.CH009
19. Djordjević, I. & Keković, Z. (2023). The Impact of International Standards on the Quality of People's Life. International Journal for Quality Research, 17(4), pp.1025–1040. DOI – 10.24874/IJQR17.04-04
20. Đorđević, I.Lj. (2013). Ljudska bezbednost – globalni kontekst i primena u Srbiji. Beograd: Institut za uporedno pravo i Dosije Studio.
21. El-Mougher, M. M. (2022). Level of coordination between the humanitarian and governmental organizations in the Gaza Strip and its impact on the humanitarian interventions to the Internally Displaced People (IDPs) following May escalation 2021. International Journal of Disaster Risk Management, 4(2), 15-45.
22. El-Mougher, M. M., & Mahfuth, K. (2021). Indicators of Risk Assessment and Management in Infrastructure Projects in Palestine. International Journal of Disaster Risk Management, 3(1), 23-40.
23. GFN (2024). Measure what you treasure. Oakland and Geneva: Global Footprint Network. Retrieved from: https://www.footprintnetwork.org. Accessed: 16.10.2024.
24. Gledaj RS (2024) Sokobanja protiv vetroparka "Čestobrodica": Zaustavite seču šuma! 25. Mart. Retrieved from: https://gledaj.rs/2024/03/25/sokobanja-protiv-vetroparka-cestobrodica-zaustavite-secu-suma/. Accessed: 23.10 2024.
25. Government of the Republic of Serbia (2008). Nacionalna strategija održivog razvoja. Službeni glasnik RS, 57. Retrieved from: https://pravno-informacioni-sistem.rs/eli/rep/sgrs/vlada/strategija/2008/57/1/reg. Accessed: 23.10 2024.
26. Government of the Republic of Serbia (2011). Nacionalna strategija zaštite i spasavanja u vanrednim situacijama. Službeni glasnik RS, 86. Retrieved from: https://pravno-informacioni-sistem.rs/eli/rep/sgrs/skupstina/ostalo/2011/86/1. Accessed: 23.10 2024.
27. Government of the Republic of Serbia (2014). Zakon o otklanjanju posledica poplava u Republici Srbiji. Službeni glasnik RS, 75.
28. Grozdanić, G., Cvetković, V., Lukić, T., & Ivanov, A. (2024). Sustainable Earthquake Preparedness: A Cross-Cultural Comparative Analysis in Montenegro, North Macedonia, and Serbia. Sustainability, 16, 3138.
29. Hadlos, A., Opdyke, A., & Hadigheh, S.A. (2022). Where does local and indigenous knowledge in disaster risk reduction go from here? A systematic literature review. International Journal of Disaster Risk Reduction. September, Vol.79. https://doi.org/10.1016/j.ijdrr.2022.103160
30. Hallberg, G. (1987). Agricultural chemicals in groundwater: Extent and implications. Renewable Agriculture and Food Systems, 2, 3-15. doi:10.1017/S0889189300001405
31. Hasan, M. K., & Sultana, N. (2024). Dynamics of Internal Migration in the Southwest Region of Bangladesh. International Journal of Disaster Risk Management, 6(1), 13-26.
32. ISO (2018). Contributing to the UN sustainable development goals with ISO standards. Geneva: International Organization for Standardization. Retrieved from: https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100429.pdf. Accessed: 23.10 2024.
33. ISO (2024). Online browsing platform. Geneva: International Organization for Standardization. Retrieved from: https://www.iso.org/obp/ui#home. Accessed: 23.10 2024.
34. Jehoshaphat, J. D., & Oghenah, B. (2021). Building resilience through local and international partnerships, Nigeria experiences. International Journal of Disaster Risk Management (IJDRM), 3(2), 11-24.

35. Kabir, M. H., Hossain, T., & Haque, M. W. (2022). Resilience to natural disasters: A case study on the southwestern region of coastal Bangladesh. International Journal of Disaster Risk Management, 4(2), 91-105.
36. Kalantari, Z., Ferreira, C., Keesstra, S., & Destouni, G. (2018). Nature-based solutions for flood-drought risk mitigation in vulnerable urbanizing parts of East Africa. Current Opinion in Environmental Science & Health. doi:10.1016/J.COESH.2018.06.003
37. Kochar, D., Sushil, & Rahul. (2020). Effect of Industrialization and Urbanization on Agriculture. Retrieved from https://consensus.app/papers/effect-of-industrialization-and-urbanization-on-kochar-sushil/db30a66392205cc5b0a9e2027f4b80ba/
38. Macek, T., Pavlíková, D., & Mackova, M. (2004). Phytoremediation of Metals and Inorganic Pollutants. 135-157. doi:10.1007/978-3-662-05794-0_7
39. Meadows, D.H., Meadows, D.L., Randers, J., & Behrens III, W. W. (1974). Granice rasta. Zagreb: Stvarnost.
40. Mileti, D. S. (1999). Disasters by Design. Washington, D.C.: The Joseph Henry Press.
41. NBS (2015). Izveštaj o inflaciji. Belgrade: National Bank of Serbia.
42. O'Gorman, P. A. (2015). Precipitation extremes under climate change. Current climate change reports, 1, 49-59.
43. OED (2024). The Oxford English Dictionary, Oxford University Press. Retrieved from: https://www.oed.com/dictionary/community_n?tl=true. Accessed: 23.10 2024.
44. Okorogbona, A., Denner, F., Managa, L., Khosa, T., Maduwa, K., Adebola, P., . . . Macevele, S. (2018). Water Quality Impacts on Agricultural Productivity and Environment. 1-35. doi:10.1007/978-3-319-75190-0_1
45. Parris, K. (2011). Impact of Agriculture on Water Pollution in OECD Countries: Recent Trends and Future Prospects. International Journal of Water Resources Development, 27, 33-52. doi:10.1080/07900627.2010.531898
46. Perić, J., & Cvetković, V. M. (2019). Demographic, socio-economic and phycological perspective of risk perception from disasters caused by floods: case study Belgrade. International Journal of Disaster Risk Management, 1(2), 31-45.
47. Popović, T., Djurdjević, V., Živković, M., Jović B. & Jovanović, M. (2009). Promena klime u Srbiji i očekivani uticaji. V regionalna konferencija EnE09-Životna sredina ka Evropi. Beograd: Ambasadori životne sredine i Privredna Komora Srbije, pp. 6-11.
48. RajeevM, M. (2014). Sustainability and Community Empowerment in Disaster Management. International Journal of Social Work and Human Services Practice, 2, 207-212. doi:10.13189/IJRH.2014.020601
49. RS (2014). Serbia Floods 2014. Belgrade: UN Serbia, EU, World Bank Group.
50. Sergey, K. (2021). Methodology for Building Automated Systems for Monitoring Engineering (Load-Bearing) Structures, and Natural Hazards to Ensure Comprehensive Safety of Buildings and Constructions. International Journal of Disaster Risk Management, 3(2), 1-10.
51. Sharma, M. (1996). Impact of Agriculture on Nutrient Contamination of Water Resources. 57-79. doi:10.1007/978-94-011-0393-0_5
52. Shibru, M., Operea, A., Omondi, P., & Gichaba, M. (2022). Impact of 2016-2017 drought on household livestock assets and food security: the case of pastoralists and agro-pastoralists in Borana zone, southern Ethiopia. International Journal of Disaster Risk Management, 4(1), 49-69.
53. Srivastav, A. (2020). Chemical fertilizers and pesticides: role in groundwater contamination. 143-159. doi:10.1016/b978-0-08-103017-2.00006-4
54. Thennavan, E., Ganapathy, G., Chandrasekaran, S., & Rajawat, A. (2020). Probabilistic rainfall thresholds for shallow landslides initiation – A case study from The Nilgiris district, Western Ghats, India. International Journal of Disaster Risk Management, 2(1), 1-14.

55. Umer, S. S. (2024). Analyzing in Post COVID-19 era: The Effect of Occupational Stress and Work-Life Balance on Employees Performance. International Journal of Disaster Risk Management, 6(1), 75-90.
56. UNCED (1992). Agenda 21. United Nations Conference on Environment and Development, Rio de Janeiro. Retrieved from: https://www.un.org/en/conferences/environment/rio1992. Accessed: 16.10.2024.
57. UNCED (2002). World Summit on Sustainable Development. 26 August-4 September 2002, Johannesburg. Retrieved from: https://www.un.org/en/conferences/environment/johannesburg2002. Accessed: 16.10.2024.
58. UNDP (1994). Human development report. New York: United Nations Development Programme.
59. UNDP (2014). Human Development Report 2014: Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience. New York: United Nations Development Programme.
60. UNDRR (2019). The Global Platform for Disaster Risk Reduction. The UN Office for Disaster Risk Reduction. Retrieved from: https://www.unisdr.org/we/coordinate/global-platform. Accessed: 16.10.2024.
61. UNESCO (2020). Report of the UNESCO expert meeting on indigenous knowledge and climate change in Africa, Nairobi, Kenya. 27–28 June 2018. Paris: United Nations Educational, Scientific and Cultural Organization. Retrieved from: https://unesdoc.unesco.org/ark:/48223/pf0000374999. Accessed: 23.10 2024.
62. UNHSU (2016). Human security handbook - An integrated approach for the realization of the Sustainable Development Goals and the priority areas of the international community and the United Nations system. New York: Human Security Unit of United Nations. Retrieved from: https://www.un.org/humansecurity/wp-content/uploads/2017/10/h2.pdf. Accessed: 23.10 2024.
63. UNISDR (2007). Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. Geneva: United Nations International Strategy for Disaster Reduction. Retrieved from: https://www.undrr.org/publication/hyogo-framework-action-2005-2015-building-resilience-nations-and-communities-disasters. Accessed: 16.10.2024.
64. UNISDR (2009). Terminology on Disaster Risk Reduction. Geneva: United Nations International Strategy Disaster Reduction.
65. UNISDR (2015). Sendai Framework for Disaster Risk Reduction 2015 – 2030. Geneva: United Nations International Strategy for Disaster Reduction. Retrieved from: https://www.unisdr.org/fi les/43291_sendaiframeworkfordrren.pdf. Accessed: 16.10.2024.
66. Varga, S. i Babić-Mladenović, M. (2001). Zaštita od poplava u Srbiji – novi pristup. U: Upravljanje vodnim resursima Srbije, Beograd: Institut za vodoprivredu „Jaroslav Černi".
67. Wackernagel, M., and Rees E.W. (1996): Our Ecological Footprint, Reducing Human Impact on the Earth. Gabriola Island, BC: New Society Publishers.
68. WBG (2015). Coping with Floods, Strengthening Growth. South East Regular Economic Report No 7, Washington: World Bank Group.
69. Wu, J., & Sun, Z. (2016). Evaluation of Shallow Groundwater Contamination and Associated Human Health Risk in an Alluvial Plain Impacted by Agricultural and Industrial Activities, Midwest China. Exposure and Health, 8, 311-329. doi:10.1007/s12403-015-0170-x
70. Xuesong, G., & Kapucu, N. (2019). Examining Stakeholder Participation in Social Stability Risk Assessment for Mega Projects using Network Analysis. International Journal of Disaster Risk Management, 1(1), 1-31.
71. Žganec, N. (2003). Pojmovno određenje zajednice, u Ajduković, D. ured. Socijalna rekonstrukcija zajednice : psihološki procesi, rješavanje sukoba i socijalna akcija. Zagreb: Društvo za psihološku pomoć.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Research article

Integrating Multi-Source Geospatial Data and AHP for Flood Susceptibility Mapping in Ain Smara, Constantine, Algeria

Nouh Rebouh[1]*,**Faicel Tout**[1],**Haythem Dinar**[1],**Yacine Benzid**[1] and **Zakaria Zouak**[1]

[1] Centre de Recherche en Aménagement de Territoire (CRAT), Campus Zouaghi Slimane, Route de Ain el Bey, 25000 Constantine, Algérie; nouhrebouh1@gmail.com (N.R.); faicel.tout@crat.dz (F.T.); aythem.dinar@crat.dz (H.D.); yacine.benzid@crat.dz (Y.B.); zakaria.zouak@crat.dz (Z.Z.)

* *Correspondence: nouhrebouh1@gmail.com & nouh.rebouh@crat.dz; Tel.: (+213)670382746*

Received: 2 October 2024; Revised: 25 November 2024; Accepted 2 December; Published: 25 December

Abstract

Mapping flood susceptibility is essential for identifying flood-prone areas and informing flood risk management strategies. This study applies a multi-criteria decision-making approach to assess flood vulnerability in Ain Smara and its surrounding areas in Constantine, Algeria, which are highly susceptible to flooding. The analysis combines the Analytical Hierarchy Process (AHP), Geographic Information System (GIS), Remote Sensing (RS), and the Google Earth Engine (GEE) platform. Ten key flood-related criteria were selected, including the Topographic Wetness Index, Elevation, Slope, Precipitation, Land Cover/Land Use, Normalized Difference Vegetation Index (NDVI), Distance from Rivers, Distance from Roads, Drainage Density, and Lithology, along with more than 25 sub-criteria. A pairwise comparison matrix (PCM) was used to assign relative importance to each criterion based on its impact on flood susceptibility. The Topographic Wetness Index was identified as the most significant criterion, while Distance from Roads was deemed the least significant. The results reveal that approximately 4.00% of the area is classified as having high to very high flood susceptibility, particularly near the Rhumel River. Roughly 30% of the area has low to very low susceptibility, and the remaining 66% is categorised as moderately susceptible to flooding. Notably, most of the identified flood-prone zones correspond with areas that experienced flooding events in 2019, 2020, and 2021, predominantly within 1,000 meters of river courses. These findings demonstrate the GIS-AHP technique's effectiveness in generating reliable flood susceptibility maps, especially when numerous criteria are considered.

Keywords

Flood susceptibility; Geographic information system (GIS); Analytical hierarchy process (AHP); Google Earth Engine (GEE); Ain Smara.

1. Introduction

Floods rank among the most destructive natural disasters, leading to extensive damage to infrastructure, property, agricultural land, and even loss of life (Tekeli and Fouli, 2016; Das, 2020; Diakakis et al., 2020; Choudhury et al., 2022). Algeria has endured several severe flood events across various

provinces, including Bab El Oued in 2001, Djanet in 2005, Ghardaïa in 2008, Djelfa in 2015, and multiple occurrences in Constantine from 2018 to 2023. These incidents have prompted researchers and government agencies to improve flood prediction models by incorporating advanced information systems, remote sensing, and the Analytical Hierarchy Process (AHP) (Tehrany et al., 2015; Terti et al., 2015; Das, 2020; Choudhury et al., 2022, Cvetkovic and Martinović, 2020). The recurrence of such events highlights the urgent need to adopt effective risk management strategies tailored to Algeria's diverse topography and climatic variability.

Flood risks can escalate quickly, especially in localized areas where sudden rises in water levels result from intense rainfall (Yang et al., 2020; Swain et al., 2020). The interplay of extreme weather patterns, urbanization, and inadequate infrastructure often exacerbates the severity of these events, necessitating robust predictive and preventive frameworks. Consequently, flood risk management has become a crucial research area, with flood susceptibility maps emerging as essential tools for decision-makers (Saharia et al., 2017; Pham et al., 2020; Lin et al., 2020; Papagiannaki et al., 2015, Perić and Cvetković, 2019). These maps are generated using both quantitative and qualitative methods that identify flood-prone areas by analyzing past flood events and environmental factors (Bui et al., 2019; Das, 2020; Choudhury et al., 2022).

Flood susceptibility is influenced by a mix of physical and human factors (Pappenberger et al., 2006; Lee et al., 2017; Chen et al., 2020). Comprehensive mapping requires assessing various factors, including topography, rainfall, land use, proximity to rivers, and drainage density (Tehrany et al., 2014; Swain et al., 2020). Properly identifying these elements is crucial for effective flood risk management and reducing potential damage (Wang et al., 2019b; Vafakhah et al., 2020; Swain et al., 2020; Das, 2020; Choudhury et al., 2022). The inclusion of advanced tools, such as remote sensing and GIS, further enhances the precision of these analyses, offering a scalable approach to assess flood risks across varied geographic settings.

Several methods exist for flood susceptibility mapping, such as multi-criteria decision analysis, logistic regression, and the frequency ratio method (Youssef et al., 2016; Das, 2020; Choudhury et al., 2022). Among these, AHP is recognized as a straightforward, adaptable method, especially when combined with remote sensing and Geographic Information Systems (GIS) (Razavi Termeh et al., 2018; Kanani-Sadat et al., 2019; Swa, 2020; Choudhury et al., 2022). This approach enables efficient spatial data management and analysis, facilitating the identification of flood-prone zones (Al-Juaidi et al., 2018; Chowdhuri et al., 2020; Shafapour Tehrany et al., 2019; Cao et al., 2020).

In Constantine, Algeria, the region's topography, seasonal rainfall, inadequate drainage, and presence of rivers such as Oued Rhumel and Oued Boumerzoug make it particularly vulnerable to flooding. This study applies the AHP method to map flood-prone areas within the urban agglomeration of Ain Smara and surrounding regions (Rebouh et al., 2021; Rebouh et al., 2024, Aktar et al., 2021). By assigning weights to various flood-inducing factors, the AHP method helps prioritize high-risk areas, serving as an invaluable tool for urban planners and disaster management authorities (Rahmati et al., 2016; Khosravi et al., 2016a; Sahana and Patel, 2019; Azareh et al., 2019; Kanani-Sadat et al., 2019; Kiani et al., 2019; Bouamrane et al., 2020; Mirzaei et al., 2021; Abedi et al., 2021; Prasad et al., 2021, Tout, 2023).

Overall, integrating AHP with GIS and remote sensing provides a robust platform for flood risk assessment, allowing for accurate and efficient mapping of flood-prone areas (Rahmati et al., 2016; Samanta et al., 2018; Ramesh and Iqbal, 2020; Siahkamari et al., 2018, Iftikhar and Iqbal, 2024). This approach supports the development of effective flood management strategies, helping to mitigate the impacts of future flood events in vulnerable regions like Constantine (Das, 2020; Dahri and Abida, 2017; Hammami et al., 2019; Joshi and Shahapure, 2020; Das and Gupta, 2021; Malik and Pal, 2021).

The main goal of this research is to develop a comprehensive flood susceptibility map for the Ain Smara region, Constantine, Algeria, by integrating multi-source geospatial data, such as Digital Elevation Models (DEMs), satellite imagery, and geological maps. The study employs the Analytical Hierarchy Process (AHP) to evaluate and prioritize key factors influencing flood susceptibility, including topography, precipitation, land use, and hydrology. The objective is to provide a scientifi-

cally grounded, spatially explicit map that can assist local authorities and urban planners in making informed decisions for flood risk management and disaster preparedness. Additionally, the research aims to assess the accuracy of the flood susceptibility map through validation techniques and explore uncertainties related to the AHP methodology and model outputs. Ultimately, the study seeks to improve flood risk assessment and offer a reliable framework for future geospatial flood susceptibility mapping in similar regions.

Study Area:

The study area is located in the central part of the high Constantine plains, within the North-Eastern region of Algeria's Maghrebian Mountain Range. Known as the South-West Constantinois, it extends across Constantine in the northeast, Oued Athmania in the northwest, Chelghoum Laid in the southwest, and Ain M'lila in the southeast (Chadi, 1991; Benabbas, 2006; Rebouh and Khiari, 2022).

The research area (Fig. 1) is situated in northeastern Algeria as part of the elevated Constantine plains. It includes the entire city of Ain Smara along with its surrounding areas (Derouiche, 2008; Rebouh and Khiari, 2022).

Among the most important data related to the study area is that it includes several prominent mountain ranges, such as Mount Fleten, Mount Ouled Salem, Massif of Chettaba, and Mount El Ouahch. The elevation range varies from 200 meters in low-lying areas to a maximum altitude of 1,400 meters in the mountainous regions. The slopes range from less than 10 degrees in flat areas to between 10 and 50 degrees in most other parts, with the steepest areas exceeding 50 degrees. The region's lithology is characterized by a dominance of claystones, followed by conglomerates, limestone, marlstone, and sandstone. Annual precipitation ranges between 300 mm and 450 mm, and the hydrological network features two major rivers: Oued Rhumel, which crosses the study area and drains into the Ain Smara Basin, and Oued Boumerzoug. Land use in the area includes agricultural lands, built-up areas, fallow lands (the most extensive), rivers, and forests. The study area includes three major cities: Constantine, El Khroub, and Ain Smara.

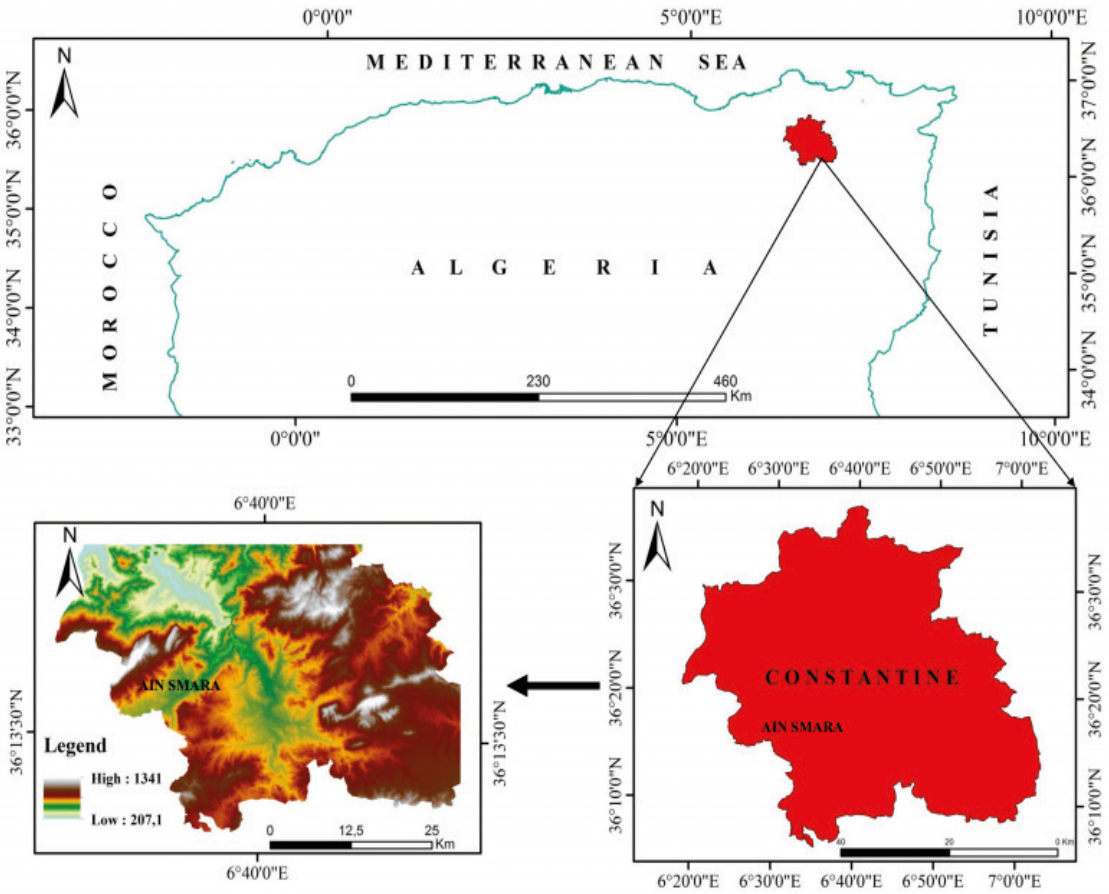


Figure 1. The location of the study area (https://earthexplorer.usgs.gov)

2. Methodology:

Data source selection

This study's primary achievement lies in generating a comprehensive set of multi-source geospatial thematic layers directly related to flood susceptibility (Khosvari et al., 2016b; Khosvari et al., 2019; Kanani-Sadat et al., 2019; Costache et al., 2019; Chakraborty and Mukhopadhyay, 2019; Souissi et al., 2020; Arabameri et al., 2020; Pham et al., 2020; Haque et al., 2021). Ten key factors influencing flood susceptibility were considered: Topographic Wetness Index, Elevation, Slope, Precipitation, Land Cover/Land Use, Normalized Difference Vegetation Index (NDVI), Distance from Rivers, Distance from Roads, Drainage Density, and Lithology. These factors were organized into a comprehensive database, supported by a high-quality Digital Elevation Model (DEM) with a spatial resolution of 30 × 30 m. Table 1 provides detailed data sources for these factors.

Geographic Information System (GIS) tools played a critical role in analyzing flood susceptibility. The study utilized software such as ArcGIS to generate thematic layers from data sources, including DEMs, satellite imagery, and geological maps. Key GIS techniques involved raster and vector analysis, spatial interpolation, and reclassification to refine flood risk zones. Layers like Topographic Wetness Index, Elevation, and Land Use were derived from DEMs and processed with spatial analysis tools. The Analytic Hierarchy Process (AHP) was applied for factor weighting, while Principal Component Analysis (PCA) further refined weight distribution to enhance accuracy.

Identifying key flood-conditioning factors is a crucial first step in developing an accurate flood map (Nachappa et al., 2020; Wang et al., 2020). According to Kia et al. (2012), the selection of these factors should account for their varying relevance over time. Extensive global studies (e.g., Tehrany et al., 2014; Hong et al., 2018; Choubin et al., 2019) have identified ten critical influencing factors, including the Topographic Wetness Index, Elevation, Slope, Precipitation, Land Cover/Land Use, NDVI, Distance from Rivers, Distance from Roads, Drainage Density, and Lithology (Pham et al., 2020).

The GIS-based mapping process involved collecting and preprocessing spatial data, such as topographic maps, satellite imagery, and land-use information. Data quality was ensured through cleaning, georeferencing, and standardization. Thematic layers were created for factors like Elevation, Slope, Land Use, and Hydrology, and integrated into a unified GIS environment. Spatial analysis techniques, including overlay analysis, buffering, and interpolation, were employed. The AHP method was used to assign weights and calculate susceptibility scores, with results visualized as flood susceptibility maps featuring clear symbology and legends. Validation was conducted using historical data and field observations, with accuracy assessed through statistical measures like ROC curves. Finally, maps were exported in user-friendly formats, ensuring practical utility for decision-makers in disaster management and urban planning.

Table.1 Data sources used in this study

Data	Description	Source (references)
Landsat 8 OLI	Downloaded	https://earthexplorer.usgs.gov
Aster GDEM (30m)	Downloaded	https://earthexplorer.usgs.gov
Slope angle	Derived from DEM 30 m	DEM 30 m
TWI	Derived from DEM 30 m	DEM 30 m
Elevation	Derived from DEM 30 m	DEM 30 m
NDVI	Image Sat LandSat Oli8	https://earthexplorer.usgs.gov
Drainage density	Derived from DEM 30 m	DEM 30 m
Lithology	Digitized from 1:200.000 geological map of Constantine	Geological map of Constantine (vila 1980)

Roads	Extracted	Google Earth
Rivers	Extracted	DEM 30 m
Precipitation	2019-2022	climate stations
Land cover/Land Use	Derived from Landsat 8 Oli image	Landsat 8 Oli image

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP), introduced by Saaty (1980), is a powerful method for solving multi-criteria decision-making problems by assigning relative weights to various factors to meet a specific objective. AHP depends on subjective judgments and marginal factors, which are transformed into scores to evaluate each criterion (Chakraborty and Mukhopadhyay, 2019). This approach is particularly effective in risk management, as demonstrated in studies by Swain et al. (2020), Das (2020), and Choudhury et al. (2022).

The AHP method follows several steps: building a hierarchical structure, conducting pairwise comparisons, constructing a judgment matrix, calculating priority vectors, and validating consistency through the consistency index (CI) and consistency ratio (CR) (Handfield et al., 2002). After applying Principal Component Analysis (PCA) to the dataset, the weights were further refined and adjusted to better reflect the variance in the data. This resulted in a more accurate distribution of weights, ensuring that the most significant factors, such as the Topographic Wetness Index (TWI) and Elevation, received higher weights, while factors with lesser influence, such as Distance from Roads, were assigned lower weights. The integration of PCA enhanced the robustness and validity of the flood susceptibility model.

These steps are essential to verify the reliability of assigned weights, ensuring consistency in the analysis. The CR, in particular, is crucial as it assesses the coherence of the study by comparing each pair of criteria and highlighting any inconsistencies. In our hierarchical classification study, we checked the consistency of the weights using the random index values specified by Equation (01) (Table 3), which serves as a validation test. This equation calculates the CR, a key mathematical indicator that helps evaluate the robustness of the decision-making process by identifying any discrepancies. (1)

$$\text{Eq: 01} \quad CR = \frac{CI}{RI}$$

where (CI) is the coherence index calculated and (RI) is the random coherence index using Equation (2).

$$\text{Eq: 02} \quad CI = \frac{\lambda max - 1}{n-1}$$

when (n) is the matrix's order and (max) is the matrix's dominant or main eigenvalue, which is determined from the matrix. According to Saaty, the consistency ratio must have an imprecision level of 10% or less. The foundation of this work's theory is the comparison of judgment with element weighting determined at random. Finally, using Equation (3), the acquisitive weights have been combined with the various triggered classes to create a single Flood susceptibility index.

$$\text{Eq: 03} \quad FSI = \sum_{i=1}^{n} Ri * Wi$$

Where (Wi) are the weights for each flood conditioning component and (Ri) are the rating classes for each layer.

Based on natural discontinuities, the resulting flood susceptibility map was divided into five classes (very low, low, moderate, high, and very high) to determine the class intervals.

Table.2 Fundamental scale of Saaty (1977)

Dominant values	Description	Explanation
1	Equal importance	Two factors contribute aqually
3	Moderate importance of one over other	Experience and judgment slightly or moderately favor one factor over another
5	Strong or essential prevalence	Experience and judgment is strongly favor over another
7	Very strong or demonstrated prevalence	An activity is strongly favor over another and its dominance is showed in practice
9	Extremely high prevalence	The evidence favoring one activity over another is of highest degree possible of an confirmation
2,4,6,8	Intermediate values	Used when comprises is needed

Table.3 Random index (RI) values of Saaty & Vargas (1991)

N	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Preparation of geospatial data

- Flood Inventory Map

Developing a flood inventory map is considered a foundational step in assessing flood vulnerability. Historical flood data from such maps can often be used to evaluate flood risks in other specific locations (Khosravi et al., 2018; Swain et al., 2020; Das, 2020; Choudhury et al., 2022). Although a flood inventory map for our study area is currently unavailable, we have identified flood-prone areas. Our goal, in collaboration with Algerian research institutes, is to create this essential map.

- Elevation

Elevation is considered the most significant determinant of flood susceptibility, as highlighted by several authors in various reviews (Pham et al., 2020). Water naturally flows from higher to lower elevations due to gravity, leading to stagnation and flooding in lower-lying areas (Nachappa et al., 2020). In our study area, which is specified in the title, the uneven distribution of elevation causes rapid water flow during unexpected downpours along the Oued Rhumel, Oued Boumerzoug, and Oued Seguen, directing water toward the interior flat areas of the lowlands and resulting in dangerous flooding (Swain et al., 2020; Das, 2020; Choudhury et al., 2022) (Fig. 2).

- Slope

The accumulation of water at any location is closely linked to the surface slope, with the slope directly influencing surface water runoff (Ngo et al., 2021). The strength and velocity of water movement are primarily determined by the topographical slope, while the infiltration process is typically controlled by the gradient of the terrain (Das, 2020; Choudhury et al., 2022). Areas with flat terrain or relatively gentle slopes are generally more prone to flooding, as water tends to stagnate there. The very steep and continuous regional slope runs along the escarpment at Djebel Felten, Massif du Chettaba, and the southern part of the study area. However, in the northern and northeastern regions, the slope is generally less than 10° (Fig. 3).

- Distance from drainage

Predick and Turner (2007) argue that the distance to the main river system is generally related to the factors that cause river flooding. Areas further from the drainage system are typically less prone to flooding (Pham et al., 2020). However, Pradhan (2009) observes that locations closer to drainage systems are more susceptible to flooding. There is no global consensus on the exact distance from

a drainage system that makes an area more vulnerable to flooding; what can be said is that the distance varies based on the river's flow and how quickly it fills with water (Samanta et al., 2016). Large rivers can flood areas several kilometers wide, while smaller channels may only flood a few meters (Das, 2020; Choudhury et al., 2022). In particular, areas within 500 meters of the drainage line are most vulnerable to flooding. Some experts suggest that a distance of 100 meters serves as a threshold for flood susceptibility(Termeh et al., 2018). According to Das (2019a), the distance most likely to experience flooding is 500 meters. In our study area, we identified low-lying and flood-prone regions near the rivers (Fig. 4).

- Drainage density

According to the majority of morphometric studies, the most significant and impactful factor in regions at risk of river floods is drainage density (Choudhury et al., 2022). Drainage density is defined as the ratio of the total length of drainage segments in a watershed to its total area (Das and Pardeshi, 2018b). Ogden et al. (2011) explain that a high drainage density indicates two factors: a large amount of surface runoff and a greater length of drainage channels per unit area. Areas with a dense river system are more vulnerable to flooding due to the increased drainage density. In our study area, we observed a significant drainage density along the rivers (Fig. 5).

- Topographic Wetness Index (TWI)

The Topographic Wetness Index (TWI), derived from topographical data, is considered one of the most significant factors for assessing the impact of terrain features on hydrological processes, particularly flooding (Das, 2020). As the TWI value increases, so does the likelihood of flood risk. For this study, we created a map of the topographic wetness index, which is divided into five categories: very low (3.4 - 6.2), low (6.3 - 7.8), medium (7.9 - 10), high (11 - 13), and very high (14 - 27) (Fig. 6).

- Normalized difference vegetation index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a key graphical indicator that represents the spread of vegetation in a given area (Chen and Yu, 2011). In this context, vegetation cover plays a significant role in the infiltration capacity and management of surface water. Therefore, the NDVI can also be considered an important factor in identifying areas prone to flooding. This index is typically calculated using satellite imagery. The following equation is used to determine the NDVI:

$$NDVI = \frac{Pnir - Pr}{Pnir + Pr}$$

Where Pnir represents the reflectance in the form of infrared part and Pr represents the reflectance for red.

In this study, a normalized difference vegetation index map was broken down into 5 categories (Fig.7).

- Land use/land cover (LU/LC)

Yalcin et al. (2011) argue that an area's land use and land cover have a significant impact on various hydrological processes, including surface runoff, infiltration, and evapotranspiration. As such, these factors are considered essential for mapping flood susceptibility (Vignesh et al., 2021). The land uses in the research area include agricultural land, built-up areas, fallow land, rivers, and vegetation (Fig. 8).

- Distance from roads

The road system, which connects various locations, is a factor contributing with minimal impact to flooding susceptibility. People often migrate closer to roads for convenience and easier access to resources. However, during floods, roads become submerged, which disrupts connectivity between areas in flood-prone regions. Flooding primarily affects the population living near roadways. In our study area, the distance from highways was categorized into five groups, as shown in (Fig. 9).

- Lithology

The lithological diversity of a region has a significant impact on flooding (Svoboda, 1991). The variation in sedimentary surface hydrology can be attributed to differences in soil types (Oikonomidis et al., 2015). While geology does not directly affect flood vulnerability, it influences the char-

acteristics of the river system. Generally, areas with more resistant rock types have lower drainage densities and are less prone to flooding (Kourgialas and Karatzas, 2011). The soil types in the study area mainly consist of clay, conglomerate, limestone, marl, and sandstone (Fig. 10).

- Rainfall

According to Hammami et al. (2019), rainfall intensity is one of the key climate factors directly influencing flood susceptibility. The risk of flooding increases with the amount of rainfall in a particular area (Marengo et al., 2021). A critical step in ensuring the accuracy of the flood susceptibility study is the creation of a precipitation map for the study area. This involves calculating the total amount of rainfall within a watershed, which is essential for determining runoff flow (Khaddari et al., 2022). In this study, a map of the maximum annual precipitation (Fig. 11) was created based on the highest total precipitation recorded over the year.

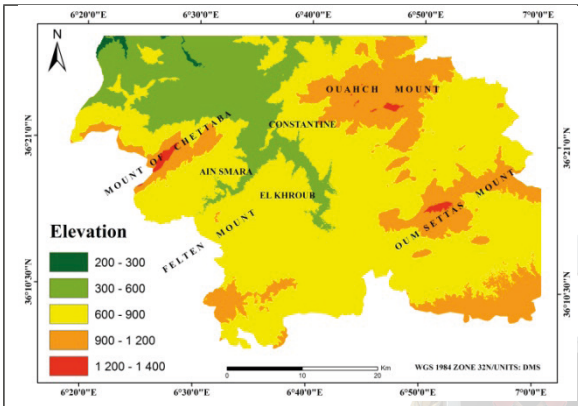


Figure 2. Elevation map of the Ain Smara area (DEM 30m https://earthexplorer.usgs.gov)

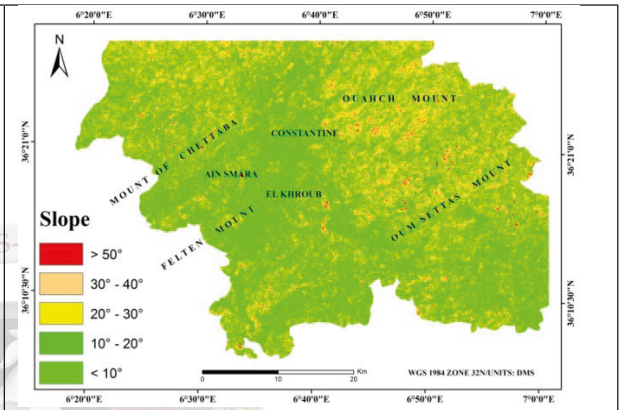


Figure 3. Slope map of the Ain Smara area (DEM 30m https://earthexplorer.usgs.gov)

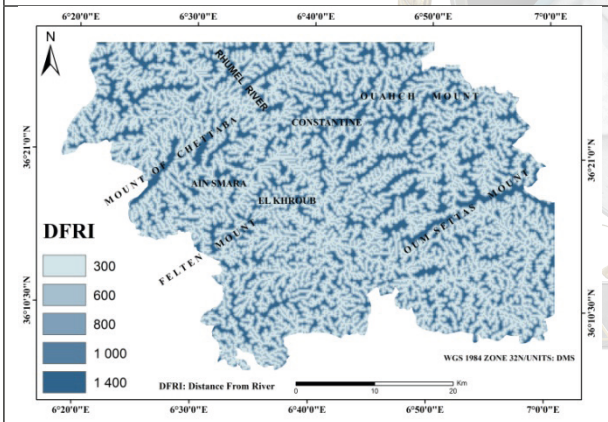


Figure 4. Distance from rivers map of the Ain Smara area (https://earthexplorer.usgs.gov)

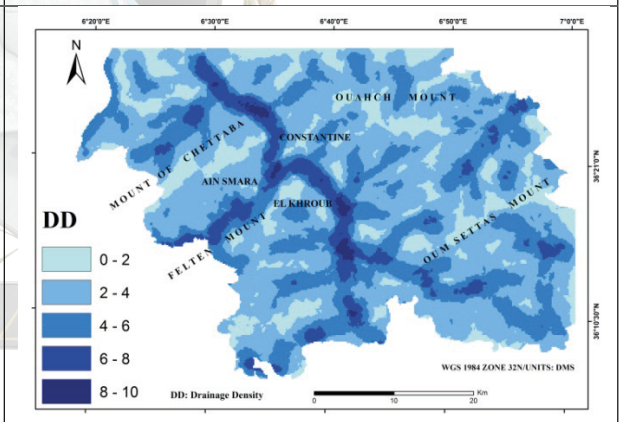


Figure 5. Drainage density map of the Ain Smara area (https://earthexplorer.usgs.gov)

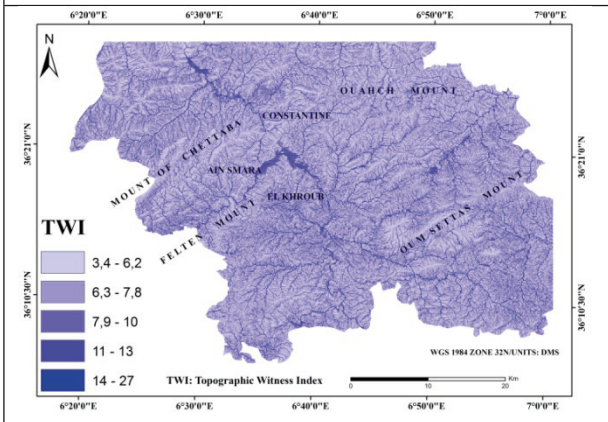


Figure 6. Topographic wetness index map of the Ain Smara (https://earthexplorer.usgs.gov) area

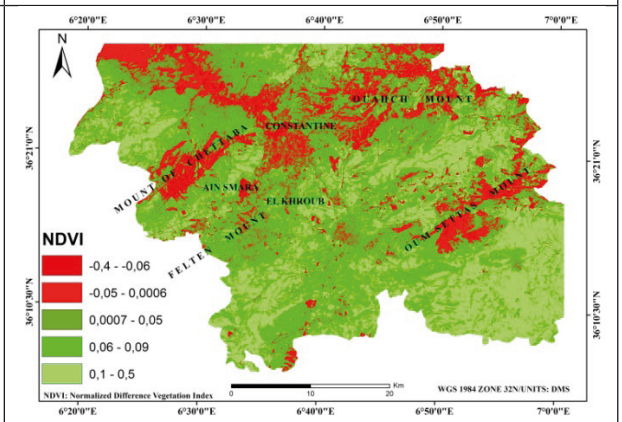


Figure 7. Normalized difference vegetation index map of the Ain Smara area

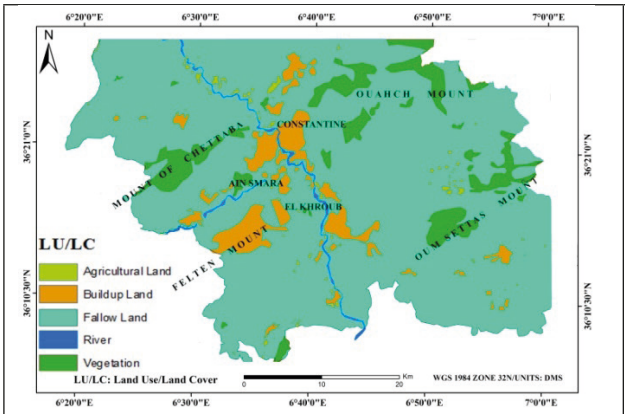


Figure 8. Land Use/ Land Cover map of the Ain Smara area (Image LandSat Oli8 from https://earthexplorer.usgs.gov)

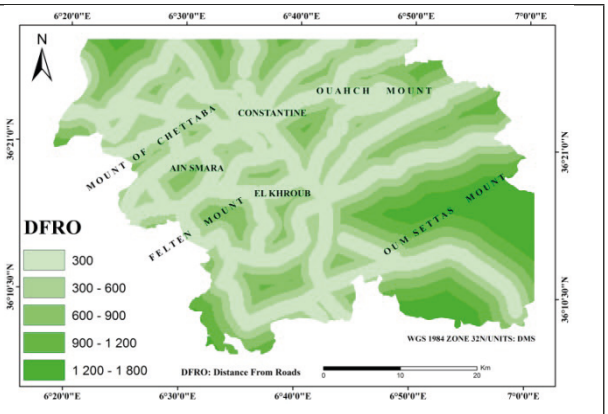


Figure 9. Distance from road map of the Ain Smara area (Open street maps)

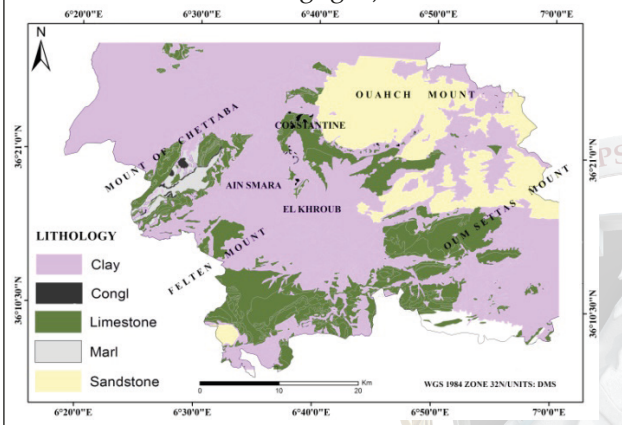


Figure 10. Lithology map of the Ain Smara area (Geological carte of Constantine 1/200000, Vila 1980)

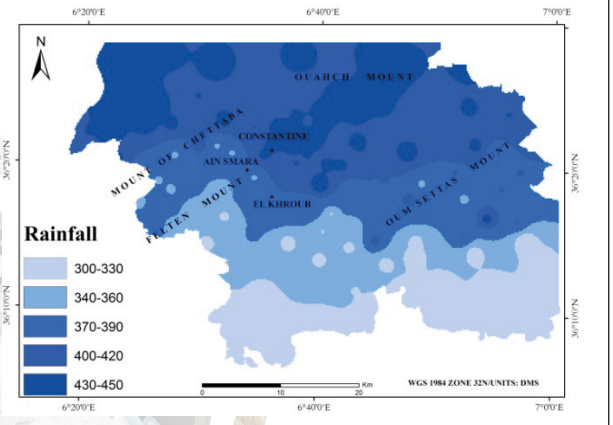


Figure 11. rainfall map of the Ain Smara area (Meteorological Station of Constantine 2019 to 2021)

3. Results and Discussion:

3.1.Results

- Flood susceptibility mapping

In this study, the values of various criteria were classified into five categories to create the flood-prone area map. Sub-criteria under each main criterion were used to generate the flood susceptibility map. To develop the final flood zoning map, the primary maps for each flood susceptibility criterion were integrated. After assessing each criterion, the significance of each was calculated using the Analytic Hierarchy Process (AHP) (Table 4). In this process, the values of each row and column were compared to generate a rating. The flood susceptibility map was constructed with a consistency ratio (CR) value of 0.05 (0.1, validated), using the weighted total of all contributing factors. The topographic wetness index criterion had the largest influence (13.78%), while the distance from highways had the smallest influence (5.59%) (Table 5).

Using actual flood data and topographical information from the study area, flood susceptibility maps for 25 sub-criteria were created through the AHP reclassification approach. Susceptibility maps based on key factors were also evaluated. The flood susceptibility map was divided into five categories based on the criteria, with approximately 4% of the total study area classified as high to very high flood susceptibility, located near the Oued Rhumel River. About 30% of the area was classified as very low to unlikely to flood, while the remaining 66% was considered to have moderate flood susceptibility (Fig. 12).

The study on flood susceptibility mapping in Ain Smara, Constantine, has some limitations, including reliance on available spatial data with varying accuracy, and the exclusion of dynamic factors like climate change and land-use changes. The scope of the study area may also limit its applicability to other regions. Additionally, the AHP method's subjectivity in assigning weights could influence results. Future research could incorporate real-time meteorological data, socio-economic factors, and expand criteria to account for climate change. Integrating machine learning with AHP could reduce subjectivity, and applying this approach to diverse regions could improve its generalizability and accuracy.

Table.4 Pairwise comparison matrix table

Matrix	TWI	Elevation	Slope	Precipitation	LULC	NDVI	Distance from river	Distance from road	Drainage density	Lithology	Weight
TWI	1	1	1	1	3	5	1	3	1	1	13,78%
Elevation	1	1	1	1	2	3	1	3	1	1	11,07%
Slope	1	1	1	1	3	1	1/2	1	1	1	9,90%
Precipitation	1	1	1	1	3	2	2	3	1	1	13,45%
LULC	1/3	1/2	1/3	1/3	1	1	1/3	3	1	1	6,62%
NDVI	1/5	1/3	1	1/2	1	1	1/5	1	1	1	5,87%
Distance from river	1	1	2	1/2	3	5	1	3	1	1	13,08%
Distance from road	1/3	1/3	1	1/3	1/3	1	1/3	1	1	1	5,59%
Drainage density	1	1	1	1	1	1	1	1	1	1	13,32%
Lithology	1	1	1	1	1	1	1	1	1	1	7,32%

Table.5 Flood susceptibility criteria and sub-criteria ranges for flood susceptibility assessment

Flood causative criterion	Unit	Class	Susceptibility class ranges and ratings	Susceptibility class ratings	Weight %
Topographic witness index (TWI)	Level	3,4 - 6,2	Very low	1	13.78
		6,3 - 7,8	Low	2	
		7,9 - 10	Moderate	3	
		11 - 13	High	4	
		14 - 27	Very High	5	
Elevation	m	200 - 300	Very High	5	11.07
		300 - 600	High	4	
		600 - 900	Moderate	3	
		900 - 1 200	Low	2	
		1 200 - 1 400	Very low	1	
Slope	Degree	<10°	Very High	5	9.90
		10°-20°	High	4	
		20°-30°	Moderate	3	
		30°-40°	Low	2	
		>50°	Very low	1	
Precipitation	mm/y	300 - 330	Very low	1	13.45
		340 - 360	Low	2	
		370 - 390	Moderate	3	
		400 - 420	High	4	
		430 - 450	Very High	5	

		River	Very High	5	
		Agricultural Land	High	4	
LU/LC	Level	Fallow Land	Moderate	3	6.62
		Buildup Land	Low	2	
		Vegetation	Very low	1	
		-0,4 - -0,06	Very High	5	
		-0,05 - 0,0006	High	4	
NDVI	Level	0,0007 - 0,05	Moderate	3	5.87
		0,06 - 0,09	Low	2	
		0,1 - 0,5	Very low	1	
		300	Very High	5	
		600	High	4	
Distance from river	m	800	Moderate	3	13.08
		1 000	Low	2	
		1 400	Very low	1	
		300	Very High	5	
		300 - 600	High	4	
Distance from road	m	600 - 900	Moderate	3	5.59
		900 - 1 200	Low	2	
		1 200 - 1 800	Very low	1	
		0 - 2	Very low	1	
		2 - 4	Low	2	
Drainage density	m/km	4 - 6	Moderate	3	13.32
		6 - 8	High	4	
		8 - 10	Very High	5	
		Clay	Very High	5	
		Marl	High	4	
		Silt	Moderate	3	
Lithology	Level	Limestone	Low	2	7.32
		Conglom-erate	Very low	1	

- Sentinel 1 Image Validation

In this study, Sentinel 1 data from before and after the 2019 floods were collected for the research area (Fig. 13). Using modified GEE code techniques, the VV and VH (dB) backscatter values for both pre- and post-flood conditions were evaluated. Heavy rainfall resulted in significant water accumulation in the Wadis, particularly in areas such as Oued Rhumel and Oued Boumerzoug.

The flood map for 2019, based on Sentinel 1 data, was compared with the flood susceptibility map created using the AHP method and Geographic Information System (GIS). The "Map Query" function was developed to compare areas with very high and high flood vulnerability (Fig. 14) against actual flooded locations. The resulting map indicated that areas with very high and high flood susceptibility were also affected by significant flooding. This finding highlights the usefulness of the susceptibility map as a flood warning system for identifying at-risk areas. However, the authenticity of the map could be questioned, as flooding predominantly affects regions with varying lithology, where water levels fluctuate during the rainy season.

- Flood zones near the river

A Geographic Information System (GIS) was used to analyze the location and distribution of flood-prone areas in the research region, specifically to assess the immediate effects of river flow. Our findings reveal that 65% of the areas identified as having extremely high or high flood susceptibility are situated closer to the rivers, while the remaining 35% of flood-prone areas are located further away (Fig. 15 and 16).

To assess the influence of each factor on the final flood susceptibility map, the "Map Query" method was employed. This approach helps validate and improve the applicability of the combined AHP and GIS methods, resulting in a more accurate and reliable flood susceptibility map for the study region.

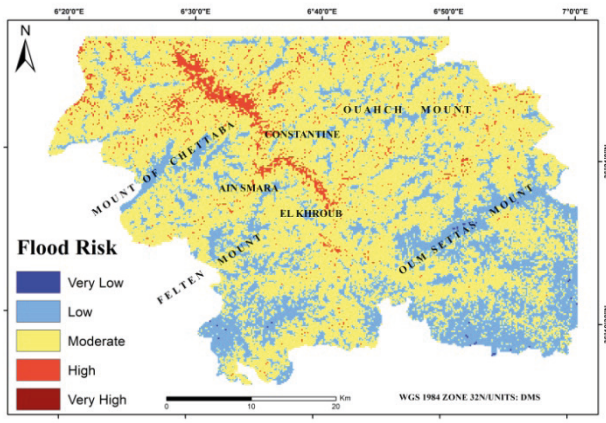


Fig. 12 Flood susceptibility map of the Ain Smara area

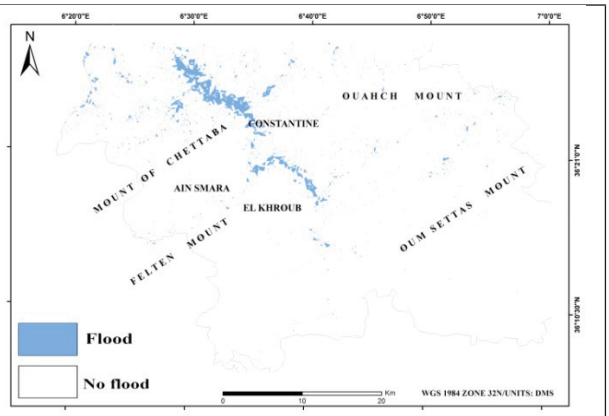


Fig. 13 Flooding in 2019 in the study area (Meteorological Station of Constantine 2019)

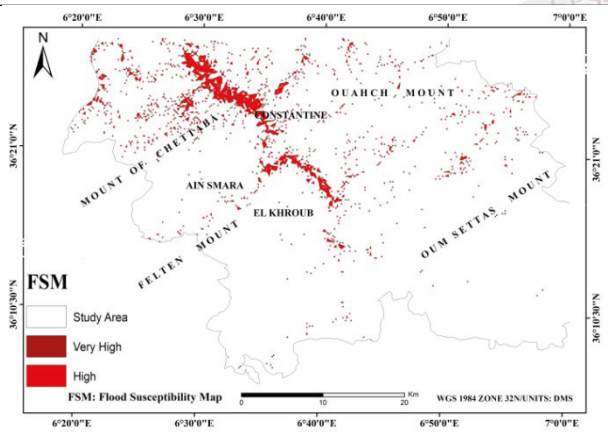


Fig. 14 Flood occurrence map in flood susceptible zones (under very high and high classes)

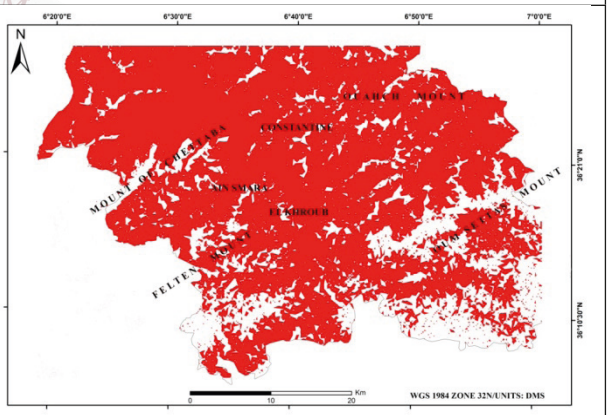


Fig. 15 Flood susceptible zone with respect to distance from river <600 m

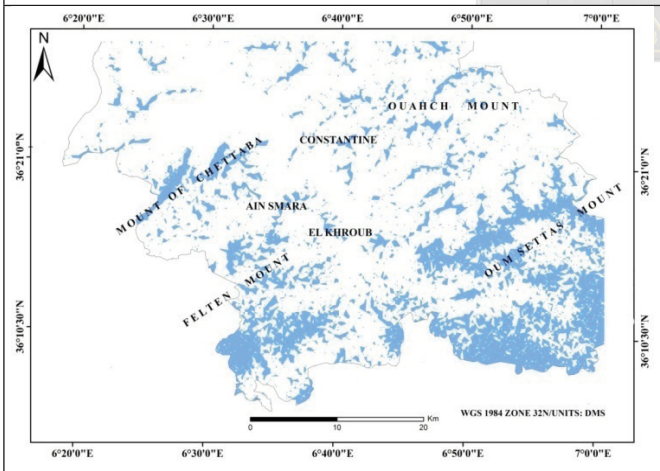


Fig. 16 Flood susceptible zone with respect to distance from river >600 m

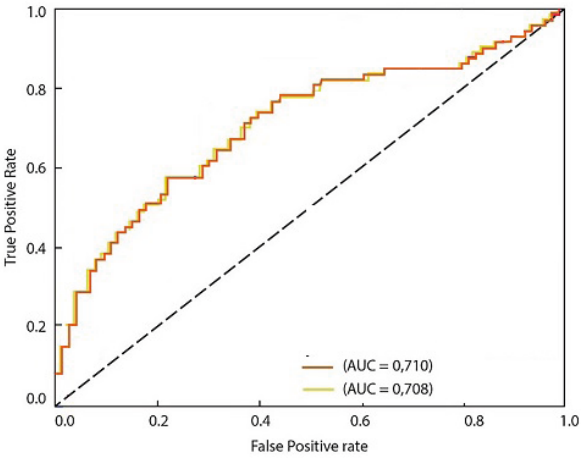


Fig. 17 Diagram for AUC and ROC analysis

3.2. Discussion

Our research area includes both plains and mountainous massifs, with well-known wadis such as Oued Rhumel, Oued Boumerzoug, and Oued Seguen. As previously established, areas near the wadis are the most vulnerable to flooding. Floods occur during the flood seasons due to the nature of Oued Rhumel, which necessitates frequent and rapid changes in its flow. The approach used in this study demonstrated that criteria such as the Topographic Wetness Index, Precipitation, and Drainage Density play a more significant role in determining flood-prone areas. In contrast, factors like lithology, slope, river distance, and elevation have a lesser impact compared to the first three.

The flooded areas in our study are typically characterized by their proximity to the wadis and very low slopes, similar to the findings of (Hitouri et al., 2024; Khaddari et al., 2023) and (Jemai et al., 2024), who obtained similar results. AHP is a method that calculates the weight of each criterion, relying on expert judgment worked on this study and the previous studies of (Das, 2020; Dahri and Abida, 2017; Hammami et al., 2019; Joshi and Shahapure, 2020; Das and Gupta, 2021; Malik and Pal, 2021) in the initial stages of allocating weights to the criteria, which can introduce some uncertainty (Swain et al., 2020). The key factors influencing the AHP approach in local and regional flood susceptibility studies include the Topographic Wetness Index, elevation, slope, precipitation, land cover/land use, vegetation index (normalized difference), distance from the river, distance from the road, drainage density, and lithology.

To improve flood susceptibility mapping, modern techniques such as Bayesian Naive Alternating Decision Tree (AD Tree) (Swain et al., 2020), Random Forest (RF) (Das, 2020; Choudhury et al., 2022), and the frequency ratio and vector support model (Khaddari et al., 2022) can be employed.

In this study, the flood susceptibility map was validated using data extracted from Sentinel 1, showing a positive correlation between the 2019 flood zones and areas identified as very high and high susceptibility in the AHP-GIS map.

The study's strengths lie in its comprehensive methodology, combining AHP and GIS to assess flood susceptibility, allowing for the integration of multiple factors like the Topographic Wetness Index, Precipitation, and Drainage Density (Choudhury et al., 2022; Cvetkovic and Martinović, 2020; Perić and Cvetković, 2019). This approach is effective for the region's specific flood risks. By focusing on local geographic features, such as proximity to wadis and low-slope areas, the study provides highly relevant and actionable insights (Prasad et al., 2021; Iftikhar and Iqbal, 2024; Das, 2020; Dahri and Abida, 2017; Hammami et al., 2019; Joshi and Shahapure, 2020; Das and Gupta, 2021; Malik and Pal, 2021). The validation using Sentinel 1 data further strengthens the study's credibility, showing a positive correlation with actual flood zones. Additionally, the mention of advanced techniques like Random Forest and Bayesian Naive Alternating Decision Tree indicates the potential for improving the model's predictive accuracy in future work.

However, the study also has notable weaknesses. The reliance on expert judgment for weighting criteria introduces subjectivity, which could compromise the consistency and reproducibility of results (Hammami et al., 2019; Joshi and Shahapure, 2020; Das and Gupta, 2021; Malik and Pal, 2021). There is limited transparency regarding how these weights were determined, leaving the methodology open to questions (Choudhury et al., 2022; Cvetkovic and Martinović, 2020; Perić and Cvetković, 2019). The study also overlooks the temporal dimension of flood risk, failing to account for how factors like climate change or seasonal variations may influence flood patterns. While the findings are valuable for the specific region studied, their applicability to other areas with different geographical or climatic conditions is uncertain(Prasad et al., 2021; Iftikhar and Iqbal, 2024; Das and Gupta, 2021; Malik and Pal, 2021). Finally, while the study mentions advanced models, it does not provide a detailed comparison or evaluation of these techniques, which could offer opportunities for further refinement of flood susceptibility mapping.

The ROC and AUC curve is one of the most widely accepted performance assessment techniques for validating the AHP model. The AUC curve represents the combination of susceptibility and specificity, with the area under the curve (AUC) serving as a measure of model performance. AUC is a valuable tool for assessing the accuracy of flood modeling. Its value ranges from 0 to 1, with higher

values indicating better model quality. A lower AUC value suggests insufficient adaptation of the model (Aleksova et al., 2024; Milevski et al., 2024.

In our study, the AUC value was 0.71, indicating a very good model. This result reflects the model's excellent ability to distinguish between the flood-prone and non-flood-prone areas within the data used to develop it. The AUC value also shows that the AHP model has been effectively modified to identify the flood susceptibility zone (Fig. 17).

4. Conclusions

Geologists, urban technology managers, and land developers must understand the importance of identifying flood-prone areas to effectively manage flood risks. This was achieved through the use of the AHP method, which helped develop a flood susceptibility map for Ain Smara and its surrounding urban agglomeration, considering ten influential factors. Expert estimates were used to determine the weights of these factors, and the most influential criteria for determining flood susceptibility were found to be the Topographic Wetness Index (TWI) (13.78%), precipitation (13.45%), drainage density (13.32%), and distance from the river (13.08%). In contrast, the least influential factors were distance from the road (5.59%), NDVI (5.87%), and land use/land cover (LU/LC) (6.62%).

This study's methodology, integrating multi-source geospatial data and the Analytical Hierarchy Process (AHP), offers several advantages. It provides a comprehensive and accurate flood susceptibility map by combining diverse datasets, utilizes GIS tools for detailed spatial analysis, and ensures a transparent weighting process through AHP. These methods enhance flood risk management by generating reliable maps for decision-makers. However, limitations include reliance on data quality and availability, potential subjectivity in AHP factor weighting, and the use of a 30x30 m DEM resolution, which may not capture fine-scale variations. Additionally, the model simplifies complex flood processes and may not fully account for dynamic environmental changes.

These flood influence criteria were combined to create a susceptibility map, which was then divided into five categories to describe the severity of flood vulnerability. According to the map, 1.13%, 2.87%, 66.00%, 28.35%, and 1.65% of the study area were classified as very high, high, medium, low, and very low flood susceptibility zones, respectively. The northern, northwest, and central regions of the study area were identified as being highly sensitive to unexpected floods, while the southern and eastern regions were classified as low or very low-susceptibility areas. This flood susceptibility map is considered an early warning system for flood-prone areas.

The accuracy of the model was verified using AUC curves, which showed a high accuracy (AUC = 0.71), confirming that the applied model is highly reliable. Given its consistent ability to accurately predict flood locations, this method is recommended for broader application in flood risk assessments and practical implications in the field of water management sectors.

Author Contributions: The research required the use of different tools in order to analyze the data, find and verify the results, and it required cooperation in many stages between the researchers, but some of them contributed to specific aspects in particular, Nouh Rebouh, the author of the research idea and its director, did the bibliographic research and determined the research methodology and is the owner of the results related to Google Earth Engine, Faicel Tout contributed to the analysis and interpretation of the different results and helped in the preparation of maps, an aspect in which Yacine Benzid and Dinar Haythem also contributed, in addition to verifying the results and following up the research. Zakaria Zouak also contributed to this, especially in field investigations, translation, and finalizing the text of the article.

Funding: There was no funding for this research

Conflicts of Interest: *"The authors declare no conflict of interest."*

References

1. Abedi, R., Costache, R., Shafizadeh-Moghadam, H., Pham, Q.B. (2021). Flash-flood susceptibility mapping based on XGBoost, random forest and boosted regression trees. Geocarto Int 1–18
2. Akay, H. (2021). Flood hazards susceptibility mapping using statistical, fuzzy logic, and MCDM methods. Soft Comput 1–22
3. Aktar, M. A., Shohani, K., Hasan, M. N., & Hasan, M. K. (2021). Flood vulnerability assessment by flood vulnerability index (FVI) method: a study on Sirajganj Sadar Upazila. International Journal of Disaster Risk Management, 3(1), 1-14.
4. Aleksova, B., Milevski, I., Dragićević, S., & Lukić, T. (2024). GIS-based integrated multi-hazard vulnerability assessment in Makedonska Kamenica municipality, North Macedonia. Atmosphere, 15(7), 774.
5. Al-Juaidi, A.E., Nassar, A.M., Al-Juaidi, O.E. (2018). Evaluation of flood susceptibility mapping using logistic regression and GIS conditioning factors. Arab J Geosci 11(24):1–10
6. Arabameri, A., Saha, S., Chen, W., Roy, J., Pradhan, B., Bui, D.T. (2020). Flash flood susceptibility modelling using functional tree and hybrid ensemble techniques. J Hydrol 587:125007
7. Azareh, A., RafieiSardooi, E., Choubin, B., Barkhori, S., Shahdadi, A., Adamowski, J., Shamshirband, S. (2019). Incorporating multi-criteria decision-making and fuzzy-value functions for flood susceptibility assessment. Geocarto Int 1–21
8. Benabbas, C. (2006). Évolution Mio-Plio-Quaternaire des bassins continentaux de l'Algérie nord orientale: apport de la photogéologie et analyse morpho structurale. Grands travaux d'aménagement et mouvements de versant dans la région nord de Constantine (Algérie Nord–Orientale). Doctorat d'état, Constantine, 245p.
9. Bouamrane, A., Derdous, O., Dahri, N., Tachi, S.E., Boutebba, K., Bouziane, M.T. (2020). A comparison of the analytical hierarchy process and the fuzzy logic approach for flood susceptibility mapping in a semiarid ungauged basin (Biskra basin: Algeria). Int J River Basin Manag 1–11
10. Bui, D.T., Ngo, P.T.T., Pham, T.D., Jaafari, A., Minh, N.Q., Hoa, P.V., Samui, P. (2019). A novel hybrid approach based on a swarm intelligence optimized extreme learning machine for flash flood susceptibility mapping. CATENA 179:184–196
11. Cao, Y., Jia, H., Xiong, J., Cheng, W., Li, K, Pang, Q., Yong, Z. (2020). Flashflood susceptibility assessment based on geodetector, certainty factor, and logistic regression analyses in Fujian Province China. ISPRS Int J GeoInf 9(12):748
12. Chadi, M. (1991). Géologie des monts d'Ain m'lila (Algérie orientale) (Doctoral dissertation, Université Henri Poincaré-Nancy 1).
13. Chakraborty, S., Mukhopadhyay, S. (2019). Assessing flood risk using analytical hierarchy process (AHP) and geographical information system (GIS): application in Cooch Behar district of West Bengal India. Nat Hazards 99(1):247–274
14. Chen, C.Y., Yu, F.C. (2011). Morphometric analysis of debris flows and their source areas using GIS. Geomorphology 129, 387–397.
15. Chen, W., Li, Y., Xue, W., Shahabi, H., Li, S., Hong, H., Ahmad, B.B. (2020). Modelling flood susceptibility using data-driven approaches of naïve Bayes tree, alternating decision tree, and random forest methods. Sci Total Environ 701:134979
16. Choubin, B., Moradi, E., Golshan, M., Adamowski, J., Sajedi-Hosseini, F., Mosavi, A. (2019). An ensemble prediction of flood susceptibility using multivariate discriminant analysis, classification and regression trees, and support vector machines. Sci. Total Environ. 651, 2087–2096.
17. Choudhury, S., Basak, A., Biswas, S., Das, J. (2022). Flash flood susceptibility mapping using GIS-based AHP method. In Spatial modelling of flood risk and flood hazards: Societal implications (pp. 119-142). Cham: Springer International Publishing.
18. Chowdhuri, I., Pal, S.C., Chakrabortty, R. (2020). Flood susceptibility mapping by ensemble evidential belief function and binomial logistic regression model on river basin of eastern India. Adv Space Res 65 (5):1466–1489

19. Costache, R., Pham, Q.B., Sharifi, E., Linh, N.T.T., Abba, S.I., Vojtek, M., Khoi, D.N. (2019). Flash-flood susceptibility assessment using multi-criteria decision-making and machine learning supported by remote sensing and gis techniques. Remote Sens 12(1):106
20. Cvetkovic, V. M., & Martinović, J. (2020). Innovative solutions for flood risk management. International Journal of Disaster Risk Management, 2(2), 71-100.
21. Dahri, N., Abida, H. (2017). Monte Carlo simulation-aided analytical hierarchy process (AHP) for flood susceptibility mapping in Gabes Basin (south-eastern Tunisia). Environ Earth Sci 76(7):302
22. Das, S. (2020). Flood susceptibility mapping of the Western Ghat coastal belt using multi-source geospatial data and analytical hierarchy process (AHP). Remote Sensing Applications: Society and Environment, 20, 100379.
23. Das, S. (2019a). Geospatial mapping of flood susceptibility and hydro-geomorphic response to the floods in Ulhas basin, India. Rem. Sens. Appl. Soc. Environ. 14, 60–74.
24. Das, S. (2020). Landscape Variables in the Indian (Peninsular) Catchments: Insights into Hydro-Geomorphic Evolution. https://doi.org/10.31223/osf.io/hbsq2.
25. Das, S, Gupta, A. (2021). Multi-criteria decision-based geospatial mapping of flood susceptibility and temporal hydro-geomorphic changes in the Subarnarekha basin, India. Geosci Front 12(5):101206
26. Das, S., Pardeshi, S.D. (2018b). Integration of different influencing factors in GIS to delineate groundwater potential areas using IF and FR techniques: a study of Pravara basin, Maharashtra, India. Appl. Water Sci. 8 (7), 197.
27. Derouiche, A. (2008). Contribution de la géophysique et de la photo interprétation à l'étude de l'instabilité de terrains dans la région de Constantine, Thèse de magister, Univ de Constantine 140p,.
28. Falah, F., Rahmati, O., Rostami, M., Ahmadisharaf, E., Daliakopoulos, I.N., Pourghasemi, H.R. (2019). Artificial neural networks for flood susceptibility mapping in data-scarce urban areas. In: Spatial modelling in GIS and R for earth and environmental sciences, pp 323– 336. Elsevier
29. Hammami, S., Zouhri, L., Souissi, D., Souei, A., Zghibi, A., Marzougui, A., Dlala, M. (2019). Application of the GIS based multi-criteria decision analysis and analytical hierarchy process (AHP) in the flood susceptibility mapping (Tunisia). Arab J Geosci 12(21):1–16
30. Handfield, R., Walton, S.V., Sroufe, R., Melnyk, S.A. 2002. Applying environmental criteria to supplier assessment: a study in the application of the analytical hierarchy process, 141, 70–87.
31. Haque, M.N., Siddika, S., Sresto, M.A., Saroar, M.M., Shabab, K.R. (2021). Geo-spatial analysis forflashflood susceptibility mapping in the North-East Haor (Wetland) Region in Bangladesh. Earth Syst Environ 1–20
32. Hitouri, S., Mohajane, M., Lahsaini, M., Ali, S. A., Setargie, T. A., Tripathi, G., ... & Varasano, A. (2024). Flood susceptibility mapping using SAR data and machine learning algorithms in a small watershed in northwestern Morocco. Remote Sensing, 16(5), 858.
33. Hong, H., Panahi, M., Shirzadi, A., Ma, T., Liu, J., Zhu, A.X., Chen, W., Kougias, I., Kazakis, N. (2018). Flood susceptibility assessment in Hengfeng area coupling adaptive neuro-fuzzy inference system with genetic algorithm and differential evolution. Sci. Total Environ. 621, 1124–1141.
34. Iftikhar, A., & Iqbal, J. (2024). Changes in Lulc and Drainage Network Patterns the Cause of Urban Flooding in Karachi City. International Journal of Disaster Risk Management, 6(1), 91-102.
35. Jemai, S., Belkendil, A., Kallel, A., & Ayadi, I. (2024). Assessment of flood risk using Hierarchical Analysis Process method and Remote Sensing systems through arid catchment in southeastern Tunisia. Journal of Arid Environments, 222, 105150.
36. Joshi, M.M., Shahapure, S.S. (2020). Flood susceptibility mapping for part of Bhima River basin using a twodimensional HEC-RAS model. In: Techno-societal 2018, pp 595–605. Springer, Cham
37. Kanani-Sadat, Y., Arabsheibani, R., Karimipour, F., Nasseri, M. (2019). A new approach toflood susceptibility assessment in data-scarce and ungauged regions based on GIS-based hybrid multi-criteria decision-making method. J Hydrol 572:17–31

38. Khaddari, A., Bouziani, M., Moussa, K., Sammar, C., Chakiri, S., Hadi, H.E., Jari, A., Titafi, A. (2022). Evaluation of Precipitation Spatial Interpolation Techniques using GIS for Better Prevention of Extreme Events: Case of the Assaka Watershed (Southern Morocco). Eco. Env. & Cons, 28, 1–10.
39. Khaddari, A., Jari, A., Chakiri, S., El Hadi, H., Labriki, A., Hajaj, S., ... & Abioui, M. (2023). A comparative analysis of analytical hierarchy process and fuzzy logic modeling in flood susceptibility mapping in the Assaka Watershed, Morocco. Journal of Ecological Engineering, 24(8), 62-83.
40. Khosravi, K., Pham, B.T., Chapi, K., Shirzadi, A., Shahabi, H., Revhaug, I., Bui, D.T. (2018). A comparative assessment of decision trees algorithms for flashflood susceptibility modeling at Haraz watershed, northern Iran. Sci Total Environ 627:744–755
41. Khosravi, K., Pourghasemi, H.R., Chapi, K., Bahri, M. (2016b). Flashflood susceptibility analysis and its mapping using different bivariate models in Iran: a comparison between Shannon's entropy, statistical index, and weighting factor models. Environ Monit Assess 188 (12):1–21
42. Khosravi, K., Shahabi, H., Pham, B.T., Adamowski, J., Shirzadi, A., Pradhan, B., Prakash, I. (2019). A comparative assessment of flood susceptibility modeling using multi-criteria decision-making analysis and machine learning methods. J Hydrol 573:311–323
43. Kia, M.B., Pirasteh, S., Pradhan, B., Mahmud, A.R., Sulaiman, W.N.A., Moradi, A. (2012). An artificial neural network model for flood simulation using GIS: Johor River Basin Malaysia. Environ. Earth Sci. 67 (1), 251–264
44. Kiani, M., Bagheri, M., Ebrahimi, A., Alimohammadlou, M. (2019). A model for prioritising outsourceable activities in universities through an integrated fuzzyMCDM method. Int J Constr Manag 1–17
45. Kourgialas, N.N., Karatzas, G. (2011). Flood management and a GIS modelling method to assess flood-hazard areas—a case study. Hydrological Sciences Journal–Journal des Sciences Hydrologiques 56(2):212–225
46. Lee, S., Kim, J.C., Jung, H.S., Lee, M.J., Lee, S. (2017). Spatial prediction of flood susceptibility using random-forest and boosted-tree models in Seoul metropolitan city, Korea. Geomat Nat Hazards Risk 8(2):1185–1203
47. Lin, K., Chen, H., Xu, C.Y., Yan, P., Lan, T., Liu, Z., Dong, C. (2020). Assessment of flash flood risk based on improved analytic hierarchy process method and integrated maximum likelihood clustering algorithm. J Hydrol 584:124696
48. Malik, S., Pal, S.C. (2021). Potential flood frequency analysis and susceptibility mapping using CMIP5 of MIROC5 and HEC-RAS model: a case study of lower Dwarkeswar River, Eastern India, S.N. App Sci 3 (1):1–22
49. Marengo, J.A., Camarinha, P.I., Alves, L.M., Diniz, F., Betts, R.A. (2021). Extreme rainfall and hydrogeo-meteorological disaster risk in 1.5, 2.0, and 4.0° C global warming scenarios: an analysis for Brazil. Frontiers in Climate, 3, 610433.
50. Milevski, I., Aleksova, B., Lukić, T., Dragićević, S., & Valjarević, A. (2024). Multi-hazard modeling of erosion and landslide susceptibility at the national scale in the example of North Macedonia. Open Geosciences, 16(1), 20220718
51. Mirzaei, S., Vafakhah, M., Pradhan, B., Alavi, S.J. (2021). Flood susceptibility assessment using extreme gradient boosting (EGB) Iran. Earth Sci Inform 14(1):51– 67
52. Nachappa, T.G., Piralilou, S.T., Gholamnia, K., Ghorbanzadeh, O., Rahmati, O., Blaschke, T. (2020). Flood susceptibility mapping with machine learning, multicriteria decision analysis and ensemble using Dempster Shafer theory. J Hydrol 125275
53. Ngo, P.T.T., Pham, T.D., Nhu, V.H., Le, T.T., Tran, D.A., Phan, D.C., Bui, D.T. (2021). A novel hybrid quantumPSO and credal decision tree ensemble for tropical cyclone induced flash flood susceptibility mapping with geospatial data. J Hydrol 596:125682
54. Ogden, F.L., Raj Pradhan, N., Downer, C.W., Zahner, J.A. (2011). Relative importance of impervious area, drainage density, width function, and subsurface storm drainage on flood runoff from an urbanized catchment. Water Resour. Res. 47 (12).

55. Oikonomidis, D., Dimogianni, S., Kazakis, N., Voudouris, K. (2015). A GIS/ remote sensing based methodology for groundwater potentiality assessment in Tirnavos area, Greece. Journal of Hydrology 525: 197–208
56. Papagiannaki, K., Lagouvardos, K., Kotroni, V., Bezes, A. (2015). Flash flood occurrence and relation to the rainfall hazard in a highly urbanized area. Nat Hazard 15(8):1859–1871
57. Pappenberger, F., Matgen, P., Beven, K.J., Henry, J.B., Pfister. L. (2006). Influence of uncertain boundary conditions and model structure onflood inundation predictions. Adv Water Resour 29(10):1430–1449
58. Perić, J., & Cvetković, V. M. (2019). Demographic, socio-economic and phycological perspective of risk perception from disasters caused by floods: case study Belgrade. International Journal of Disaster Risk Management, 1(2), 31-45.
59. Pham. B,T., Avand, M., Janizadeh, S., Phong, T.V., Al-Ansari, N., Ho, L.S., Prakash, I. (2020). GIS-based hybrid computational approaches for flashflood susceptibility assessment. Water 12(3):683
60. Pradhan, B. (2009). Flood susceptible mapping and risk area delineation using logistic regression, GIS and remote sensing. J. Spatial Hydrol. 9, 1–18.
61. Prasad, P., Loveson, V.J., Das, B., Kotha, M. (2021). Novel ensemble machine learning models inflood susceptibility mapping. Geocarto Int 1–23
62. Predick, K.I., Turner, M.G. (2007). Landscape configuration and flood frequency influence invasive shrubs in floodplain forests of the Wisconsin River (USA). J. Ecol. 96 (1), 91–102.
63. Rahmati, O., Pourghasemi, H.R., Zeinivand, H. (2016). Flood susceptibility mapping using frequency ratio and weights-of-evidence models in the Golastan Province Iran. Geocarto Int 31(1):42–70
64. Ramesh, V., Iqbal, S.S. (2020). Urbanflood susceptibility zonation mapping using evidential belief function, frequency ratio and fuzzy gamma operator models in GIS: a case study of Greater Mumbai, Maharashtra, India. Geocarto Int 1–26
65. RazaviTermeh, S.V., Pourghasemi, H.R., Alidadganfard, F. (2018). Flood inundation susceptibility mapping using analytical hierarchy process (AHP) and TOPSIS decision-making methods and weight of evidence statistical model (case study: jahrom township, fars province). J Watershed Manag Res 9(17):67–81
66. Rebouh, N., Khiari, A. (2022). La Cinématique et l'organisation des structures géologiques dans le Constantinois.
67. Rebouh, N., Oudni, A., Khiari, A., & Özgür, N. (2024). Mapping of Landslide Susceptibility Using Analytical Hierarchy Process (AHP) in the Ain Smara and its Surrounding Areas, Algeria (Northeastern of Algeria). Studies in Science of Science| ISSN: 1003-2053, 42(8), 1-15.
68. Rebouh, N., Oudni, A., Khiari, A., Benabbas, C., Özgür, N. (2021). Hydrothermal alteration mapping and structural features in the Ain Smara basin, Constantine (Northeastern Algeria): contribution of Landsat OLI8 data. AJGS, 14, 1-19.
69. Saaty, T.L. (1977). A scaling method for priorities in hierarchical structures.Journal of Mathematical Psychology15:59–62
70. Saaty, T.L. (1980). A scaling method for priorities in hierarchical structures.Journal of Mathematical Psychology15: 234–281
71. Sahana, M., Patel, P.P. (2019). A comparison of frequency ratio and fuzzy logic models for flood susceptibility assessment of the lower Kosi River Basin in India. Environ Earth Sci 78(10):1–27
72. Saharia, M., Kirstetter, P.E., Vergara, H., Gourley, J.J., Hong, Y., Giroud, M. (2017). Mappingflashflood severity in the United States. J Hydrometeorol 18(2):397–411
73. Samanta, R.K., Bhunia, G.S., Shit P.K., Pourghasemi, H.R. (2018). Flood susceptibility mapping using geospatial frequency ratio technique: a case study of Subarnarekha River Basin India. Model Earth Syst Environ 4 (1):395–408
74. Samanta S., Koloa C., Kumar Pal D., Palsamanta B. (2016), Flood risk analysis in lower part of Markham river based on multi-criteria decision approach (MCDA). Hydrology 29. https://doi.org/10.3390/hydrology3030029.

75. ShafapourTehrany, M., Kumar, L., NeamahJebur, M., Shabani, F. (2019). Evaluating the application of the statistical index method inflood susceptibility mapping and its comparison with frequency ratio and logistic regression methods. Geomat Nat Hazards Risk 10(1):79–101
76. Siahkamari, S., Haghizadeh, A., Zeinivand, H., Tahmasebipour, N., Rahmati, O. (2018). Spatial prediction of flood-susceptible areas using frequency ratio and maximum entropy models. Geocarto Int 33(9):927–941
77. Souissi, D., Zouhri, L., Hammami, S., Msaddek, M.H., Zghibi, A., Dlala, M. (2020). GIS-based MCDM–AHP modeling for flood susceptibility mapping of arid areas, south-eastern Tunisia. Geocarto Int 35(9):991–1017
78. Svoboda, A. (1991). Changes in flood regime by use of the modified curve number method. Hydrol Sci J 36(5):461–470
79. Swain, K.C., Singha, C., Nayak, L. (2020). Flood susceptibility mapping through the GIS-AHP technique using the cloud. ISPRS International Journal of Geo-Information, 9(12), 720.
80. Tehrany, M.S., Pradhan, B., Jebur, M.N. (2014). Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS. J Hydrol 512:332–343
81. Tehrany, M.S., Pradhan, B., Jebur, M.N. (2014). Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS. J. Hydrol. 512, 332–343.
82. Tekeli, A.E., Fouli, H. (2016). Evaluation of TRMM satellite-based precipitation indexes for flood forecasting over Riyadh City, Saudi Arabia. J Hydrol 541:471–479
83. Termeh, S. V. R., Kornejady, A., Pourghasemi, H. R., & Keesstra, S. (2018). Flood susceptibility mapping using novel ensembles of adaptive neuro-fuzzy inference system and metaheuristic algorithms. Science of the Total Environment, 615, 438-451.
84. Terti, G., Ruin, I., Anquetin, S., Gourley, J.J. (2015). Dynamic vulnerability factors for impact-based flash flood prediction. Nat Hazards 79(3):1481–1497
85. Tout, F. (2023). Flood policy in Algeria. International Journal of Disaster Risk Management, 5(1), 27-39.
86. Vafakhah, M., Mohammad Hasani Loor, S., Pourghasemi, H., Katebikord, A. (2020). Comparing the performance of random forest and adaptive neuro-fuzzy inference system data mining models for flood susceptibility mapping Arab J Geosci 13:1–16
87. Vignesh, K.S., Ananda kumar, I., Ranjan, R., Borah, D. (2021). Flood vulnerability assessment using an integrated approach of multi-criteria decision-making model and geospatial techniques. Model Earth Syst Environ 7 (2):767–781
88. Vila, JM. (1980). La chaîne alpine de l'Algérie orientale et des confins algéro-tunisiens. Thèse de Doctorat-es-sciences, Université Pierre et Marie curie.
89. Wang, Y., Hong, H., Chen, W., Li, S., Pamučar, D., Gigović, L., Duan, H. (2019a). A hybrid GIS multi-criteria decisionmaking method for flood susceptibility mapping at Shangyou China. Remote Sens 11(1):62
90. Yalcin, A., Reis, S., Cagdasoglu, A., Yomralioglu, T. (2011). A GIS-based comparative study of frequency ratio, analytical hierarchical process, bivariate statistics and logistic regression methods for landslide susceptibility mapping in Trabzon, NE Turkey. Catena 85, 274–287.
91. Yang, Q., Guan, M., Peng, Y., Chen, H. (2020). Numerical investigation of flashflood dynamics due to cascading failures of natural landslide dams. Eng Geol 276:105765
92. Youssef, A., Pradhan, B., Sefry, S. (2016). Flashflood susceptibility assessment in Jeddah city (Kingdom of Saudi Arabia) using bivariate and multivariate statistical models. Environ Earth Sci 75:1–16

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Review Article

Understanding Crowd Dynamics and Disaster Risks in Kerala Temple Festivals: Strategies for Effective Management

Rajagopal Parameswaran Kunjukrishnan[1]*, **Sreekala Krishnakumariamma**[2]

[1] Postgraduate and Research Department of Political Science, NSS Hindu College, Changanacherry, Kottayam, Kerala.

[2] Department of History, Government College, Attingal, Thiruvananthapuram, Kerala; sreekalasreerangom@gmail.com

* *Correspondence: pkrgopal@rediffmail.com*

Received: 5 September 2024; Revised: 25 November 2024; Accepted 3 December 2024; Published: 25 December 2024.

Abstract

Temple festivals in Kerala are vibrant cultural events that draw massive crowds, creating a complex environment where crowd dynamics can pose significant disaster risks. The large number of attendees, combined with limited space and inadequate safety measures, makes these festivals vulnerable to incidents such as stampedes, fires, and structural collapses. Despite the recurrence of crowd-induced disasters, there remains a gap in comprehensive disaster management strategies tailored to these unique events. This paper examines the critical aspects of crowd behaviour during Kerala's temple festivals and the associated disaster risks. It explores past incidents to identify key risk factors and assesses current preparedness and response mechanisms. This study explored a mixed-methods approach to examine crowd dynamics and disaster risks in Kerala temple festivals. Primary data were collected through field observations and semi-structured interviews with festival organizers, local authorities, and participants. Secondary data included incident reports and archival records of past festivals. The findings were synthesized to propose evidence-based management strategies. The analysis revealed critical risk factors associated with crowd dynamics during Kerala temple festivals, including overcrowding in confined spaces, inadequate evacuation routes, and lack of real-time communication systems. GIS-based spatial mapping highlighted congestion hotspots and high-risk zones. Interviews with stakeholders identified gaps in preparedness and coordination among organizers and emergency services. The proposed management strategies demonstrated the potential to mitigate risks, enhance crowd safety, and ensure efficient emergency response. Effective crowd management at temple festivals requires a multidisciplinary approach that involves spatial analysis, stakeholder collaboration, and robust catastrophe preparedness. The study highlights the significance of conducting preventive risk assessments and dynamic crowd monitoring techniques to avoid disasters. Implementing the proposed measures can considerably improve public safety, serve as a model for comparable cultural events, and help to shape legislation for disaster risk reduction in large crowds.

Keywords

Crowd Dynamics, Crowd-Induced Disasters, Temple Festivals, Stampedes, Public Safety.

1. Introduction

Kerala is a land of magnificent centres of holy pilgrimages. Temples of Kerala attract many people due to their architectural style, rituals, colourful festivals, and so on. Temple festivals attract not only people from surrounding places but also from neighbouring states. Temple festivals promote the true spirit of communal harmony and mass gathering as they attract people from inter-districts or even from inter-state. Temple festivals in Kerala are an integral part of the state's cultural and religious landscape, attracting large crowds of devotees and tourists alike. These events, renowned for their grandeur and elaborate rituals, often bring together tens of thousands of people in confined spaces, resulting in complex crowd dynamics. While these festivals serve as significant socio-religious gatherings, they also present considerable challenges to public safety, particularly in terms of disaster management.

Some of Kerala's temples draw large crowds because of their rich cultural heritage and historical significance. Sabarimala hill shrine pilgrimage, Attukal Devi temple, Thrissur Pooram, Nemmara temple festival, and so on are well-known. Many temple festivals include free food distribution, entertainment, pyrotechnics, and religious rituals. Therefore, religious festival sites attract people from a wide range of religious backgrounds by acting as venues for worship, entertainment, and business. Religious gatherings attract large groups with various physical and behavioural characteristics (Illiyas et al., 2013). Venues for large gatherings are vulnerable to crowd dangers, and implementing an efficient crowd control system presents several difficulties. According to studies, 67% of human stampedes in India occur at religious mass gatherings (Illiyas et al., 2020). The study focuses on major disasters in Kerala that coincide with temple festivals.

Temple festivals are strictly secular. However, the festivals of state-run big temples are entirely dedicated to temple arts and forms. Pooram-style displays combine activities such as drumming, elephant procession, and fireworks. In the past, Hindu reformers condemned the usage of fireworks during temple festivities. Mannathu Padmanabhan, a social reformer and the founder of the Nair Service Society has identified four harmful behaviours ("Nalukettu" means four knots). They are "Case Kettu"—bundles of litigation; "ThaliKettu"—child marriage; "KuthiraKettu"—processions with adorned idols of horses or temple cars; and "Vedi kettu"—fireworks. He had consistently pushed society to stop such practices. (Satisan, 2016). Around a century ago, Sree Narayana Guru, a saint, social reformer, and the founder president of SNDP Yogam, warned Hindu society about the excesses of fireworks displays. Guru emphasised that society should use its money for public good rather than waste it on pyrotechnics. He declared, "We don't need Kari. (Elephants) and Karimarunnu (gunpowder) anymore." (Satisan, 2016)

Crowd-induced disasters, including stampedes, fires, and structural collapses, have repeatedly occurred during temple festivals in Kerala, highlighting an urgent need for effective disaster risk management. The high density of participants, limited exit routes, minimal crowd control measures, and inadequate emergency response facilities can quickly escalate minor incidents into large-scale tragedies. Moreover, the presence of pyrotechnics, animals, and temporary structures during these festivals adds to the risk, complicating emergency management. Understanding crowd dynamics, particularly in situations where cultural and religious sentiments influence behaviour, is critical for identifying potential disaster risks and developing targeted strategies that ensure participant safety, minimise response times, and prevent catastrophic outcomes.

Kerala's temple festivals, renowned for their cultural and spiritual vibrancy, often attract massive crowds, creating potential disaster scenarios due to crowd mismanagement. These festivals, drawing millions of devotees, reflect the state's cultural richness and expose the vulnerabilities in managing large-scale gatherings. Historical instances highlight the dire need for effective crowd management strategies. Despite advancements in disaster management frameworks, there remains a critical gap in integrating localised strategies that address the unique dynamics of Kerala's temple festivals. This study seeks to analyse the crowd dynamics during Kerala temple festivals, identify disaster risks, and propose a framework for effective management strategies tailored to these culturally significant events. By addressing these gaps, the study aims to contribute to the development

of sustainable and culturally sensitive approaches to crowd management, ensuring the safety and sanctity of these festivals.

This paper aims to explore the dynamics of crowds during temple festivals in Kerala and assess the associated risks while proposing strategic interventions to enhance disaster preparedness and management. By examining past incidents and current disaster management practices, the study will highlight the need for a more systematic approach to prevent crowd-induced disasters and safeguard the lives of festival-goers

1.1. Objective

The primary objective of this paper is to analyze the crowd dynamics and disaster risks associated with temple festivals in Kerala, to propose effective strategies for disaster management. Specifically, the paper seeks to:

- Analyze the crowd dynamics and disaster risks associated with temple festivals in Kerala and propose effective strategies for disaster management.
- Examine the behavioural patterns and movement of large crowds during temple festivals, identifying the factors that contribute to crowd-induced disasters.
- Assess the current disaster management practices and response mechanisms employed during such events, highlighting gaps and areas of improvement.
- Analyze past incidents of crowd-induced disasters at temple festivals in Kerala to uncover recurring risk factors and the effectiveness of mitigation measures.
- Propose strategic interventions for improving disaster preparedness, including better crowd control, infrastructure enhancements, and emergency response coordination.
- Develop a framework for proactive disaster management at large cultural and religious gatherings, aimed at reducing the likelihood of tragedies and ensuring public safety.

The goals of this research are to contribute to the development of more effective disaster management strategies that can protect participants at temple festivals while retaining both their safety and the cultural importance of these events.

1.2. Review of Literature

The study of crowd dynamics and disaster risks has been a significant area of research in disaster management, particularly in the context of mass gatherings. Temple festivals in Kerala, known for their religious and cultural significance, also present a unique set of challenges due to the congregation of large crowds in often restricted spaces. This section reviews key studies and literature related to crowd behaviour, disaster management, and festival safety, focusing on both global and local perspectives.

Disaster Management: A Disaster Manager's Handbook by Carter W. Nick (2008), published by the Asian Development Bank, serves as a comprehensive guide for disaster management professionals, offering a practical framework for mitigating, preparing for, responding to, and recovering from disasters. The handbook emphasizes a systematic approach to disaster management, combining theory, case studies, and actionable strategies for practitioners. ADB's focus is on enabling countries to strengthen their disaster management capacities, particularly in developing regions where vulnerabilities to disasters are heightened due to socioeconomic factors. The book guides both natural and man-made disasters, offering insights into the critical elements required for building resilient communities. For Kerala's temple festivals, where large-scale events take place in potentially hazardous environments, preparedness and mitigation are vital. The handbook's guidance on structural planning and public awareness campaigns can help authorities develop strategies to ensure safer festival environments. For instance, crowd control barriers, designated exit routes, and clear signage can reduce risks during these events.

WHO's "Public Health for Mass Gatherings: Key Considerations" is one of the most thorough texts outlining basic public health concepts for mass gatherings. It offers a framework for evaluating health risks, as well as surveillance systems and response tactics designed for huge crowds. Effective disaster management in large crowds necessitates a multifaceted approach that includes planning, real-time monitoring, and prompt response. The United Nations International Strategy for Disaster Reduction (UNISDR, 2015) emphasises the need for preparedness, early warning systems, and risk assessment in managing major occurrences.

In Kerala, disaster management authorities have been increasingly focusing on festival safety. The Kerala State Disaster Management Authority (KSDMA, 2020) has laid out guidelines for large religious gatherings, though challenges remain in their implementation. Studies by Narayanan and Menon (2020) suggest that while safety measures are in place, coordination between various stakeholders—temple authorities, local government, and disaster management teams—remains fragmented, reducing the effectiveness of these measures.

The literature suggests that crowd-induced disasters at temple festivals in Kerala stem from a complex interplay of crowd behaviour, inadequate infrastructure, and fragmented disaster management efforts. While significant research has been done on crowd dynamics and mass gathering safety, there is a notable gap in studies focused specifically on the religious and cultural context of Kerala's festivals. Addressing these challenges requires a holistic approach that integrates traditional practices with modern disaster management strategies, including better planning, stakeholder coordination, and technological advancements.

2. Methodology

This study adopted a mixed-methods approach to investigate crowd dynamics and disaster risks associated with Kerala temple festivals. A descriptive and analytical methodology was employed to identify significant risk factors and evaluate the effectiveness of current management practices. Primary data were collected through field observations conducted during major temple festivals, focusing on crowd movement patterns, spatial layouts, and emergency response procedures.

To gain qualitative insights, semi-structured interviews were conducted with festival organizers, local authorities, and emergency responders. Secondary data, including incident reports, archival records, and documented case studies from previous festivals, were analyzed to understand historical trends and recurring issues.This study explored a mixed-methods approach to examine crowd dynamics and disaster risks in Kerala temple festivals. Primary data were collected through field observations and semi-structured interviews with festival organizers, local authorities, and participants. Secondary data included incident reports and archival records of past festivals. The findings were synthesized to propose evidence-based management strategies.

3. Issues of Crowd Management

The crowd management system includes the operational planning and procedures used to manage the process and facilitate mobility concerning crowd-related functions. Crowd management and crowd control are not interchangeable terms. Crowd control refers to the tactics used to respond when a crowd's behaviour begins to breach accepted crowd management expectations. (Soo & Avery, 2003). In Kerala, crowd control measures were implemented in all of the major pilgrimage sites. Massive crowds at religious sites during the pilgrimage or festival season cause tremendous worry among officials.

Disaster management is focused on disaster prevention and risk mitigation. "Organised or unplanned event if the number of people attending is sufficient to strain the planning and response resources of the community, state, or nation hosting the event" is the standard definition of a mass gathering (WHO, 2008). Mass gatherings present significant issues in terms of infectious and

non-communicable disease surveillance, emergency planning, environmental health, vaccination, crowd management, and so on (Lancet Infectious Diseases, 2010). A crowd refers to a large number of people group, with or without an organised structure. When big groups of people gather, crowd management becomes challenging. Crowd management is the ability and implementation of plans to organise or regulate a big group of people in an orderly manner (Deshpande & Gupta). Crowd disasters aren't a new phenomenon. However, the ever-increasing mass gatherings at religious sites raise worries.

Crowd disasters are a recurring problem in India. These instances underscore the importance of good crowd management in the country (Bala, 2018). It is vital to develop a systematic approach to identify gaps and increase crowd management capacity. The majority of crowd disasters are man-made and may be avoided or managed with proper planning and preparation. The biggest cause of crowd tragedies during mass gathering events in India has been recognised as "lack of planning and preparedness." Understanding visitors and stakeholders, risk assessments, safety and security measures, facility and emergency planning, and transportation and traffic management should all be part of the planning process (Bala 2018).

Table 1. Major events of disasters in temple festivals in Kerala.

Sl. No	Disaster	Date/ year	Enquiry commission	Nature of causalities
1	Sabarimala fire	1950	K.Kesava Menon	Temple fire
2	Guruvayur temple fire	1970	Gangadharan Thampy Commission	Temple fire
3	Malanada Temple Fire Cracker Accident	1990		25 people had been killed
4	Sabarimala stampede	1999	Justice Chandrasekhara-Menon Committee	52 killed
5	Sabarimala stampede pulled tragedy	2011	Justice M.R. Hariharan Nair	102 killed
6	Firecracker Accident at Puttingal Temple, Kollam District	2016	Justice N Krishnan Nair, Justice S Gopinath	109 were killed more than 400 injured
7	Firecracker accident Veerarkavu Temple near Kasaragod's Nileshwar.	2024	Special Investigation Team (SIT) appointed by the state government	150 people were injured four killed.

Source: Data collected from various sources.

In 1950, 1999, and 2011, the Sabarimala hill shrine witnessed three major unfortunate incidents, highlighting the risks associated with large-scale gatherings during temple festivals. The temple is governed by the state-sponsored Travancore Devaswom Board (TDB), an autonomous body responsible for temple management in Kerala. In 1999, approximately 52 pilgrims lost their lives in a tragic stampede. A similar but more catastrophic incident occurred in 2011 at the Pampa hilltop during the Makarajyothi festival, when a stampede caused by overcrowding claimed the lives of 102 pilgrims. These events underscore the persistent challenges in managing the influx of devotees during peak pilgrimage seasons.

In addition to stampedes, Kerala has witnessed several firecracker tragedies in connection with temple festivals, particularly in the Travancore and Malabar regions. Notable incidents include 1990: A firecracker mishap that caused significant casualties and property damage.2016: The Kollam Puttingal Temple tragedy, where an explosion during an unauthorised firework display resulted in over 100 deaths and hundreds of injuries. 2024: A recent firecracker incident in the Travancore region, again highlighted gaps in safety protocols during festivals. These tragedies point to the pressing

need for a comprehensive framework to ensure the safety and well-being of devotees while preserving the cultural essence of temple festivals. For detailed information, refer to Table 1, which provides a timeline and impact assessment of these incidents.

Temple festivals have become hotspots for all kinds of risks, and a few of them have turned into disasters. Casualties in religious incidents have resulted from elephants' violent behaviour, firework accidents, human stampedes, and other causes. The concentration of a huge population in a small geographical region for a short time, as well as the diversity of the audience, always provides a challenge to safety measures unless they are meticulously planned, executed, and monitored (Illiyas et al., 2015). In Kerala, disaster management authorities have been increasingly focusing on festival safety. The Kerala State Disaster Management Authority (KSDMA, 2020) has laid out guidelines for large religious gatherings, though challenges remain in their implementation. Studies by Narayanan and Menon (2020) suggest that while safety measures are in place, coordination between various stakeholders—temple authorities, local government, and disaster management teams—remains fragmented, reducing the effectiveness of these measures.

Table 2. Firecracker Incidents in Kerala(religious centre-based disasters)

Sl.No.	Year	Place	Impacts
1	1952	Sabarimala Temple	68 killed in fire cracker tragedy
2	1978	Thrissur Pooram	20 person lost life
3	1984	Kandashamkadavu Catholic Church Thrissur	20 dead
4	1987	Velur Kuttamooli temple	20 dead
5	1989	Kandashamkadavu Catholic Church	12 dead
6	1990	Malanada Peruviruthi Temple	33 dead
7	1999	Aloor Chamundikavu Temple, Palakad	8 dead
8	2006	Thrissur Pooram	7 dead
9	2006	Paramekkavu Temple	4 killed at a unit producing crackers
10	2008	Maradu Kottaram Temple festival	3 dead
11	2016	Kottaram Bahagvathy Temple	1 killed in a fire at a craker unit near temple
12	2016	Puttingal Temple	Fire and Explosion 107 dead several buildings damaged

Source Parkash, Surya. (2016). Brief Report on Reconnaissance Study of Puttingal Temple Fire Incident (Sunday, 10 April 2016), Paravur, Kollam District, Kerala State.

In 1952, at least 68 people were killed in a cracker bomb at the Sabarimala Lord Ayyappa temple. Another tragedy occurred in 1987 when 27 spectators sitting on a railway track and watching the fireworks at the Sri Jagannatha Temple in Thalassery were run over by a train. The deafening noise created by the display had drowned out the sound of the approaching train. In 1990, a blast at a cracker storeroom at a shrine in Malanada, Kollam, killed 26 people. In 2006, another explosion occurred in the storeroom where firecrackers were stored for the famous Thrissur Pooram celebration, killing seven people. An accident occurred on Saturday, April 13, 2013, during the Nenmara-Vallangi Vela event. Aside from one person who died in the subsequent uproar, more than 25 others were injured, including two female civil police officers. As the size of pyrotechnic displays has grown, so has the number of fireworks-related accidents. People have perished in explosions caused by the fabrication or bursting of firecrackers.

The Poruvazhy Malanada Temple is situated in the Kollam district of Kerala and is unique in India as the only temple dedicated to Duryodhana, the antagonist of the Mahabharata. The temple's festivals, including its annual Kettukazhcha festival held in March, draw large crowds of devotees.

The temple is known for its vibrant processions and elaborate fireworks displays that are an integral part of the celebrations. The Malanada Temple fireworks tragedy refers to a devastating incident that occurred at the Poruvazhy Malanada Temple in Kerala, known for its unique worship of Duryodhana, a character from the Mahabharata. Fireworks are a significant part of temple festivals in Kerala, but they also pose significant risks when safety measures are not adequately followed.

4. Disasters in the Sabarimala pilgrimage

Deadly stampedes are relatively common in temples in India, where large crowds - sometimes millions - gather in small areas without security measures or crowd control. Sabarimala is a well-known Hindu shrine situated on a hilltop in the Pathanamthitta district of Kerala. The pilgrimage, which honours Lord Ayyappa, requires a strenuous trek through the Western Ghats forests to reach the Sabarimala temple. During the pilgrimage, the Sabarimala temple received an unprecedented rush. Pilgrims had to wait for hours in long barricades to perform the holy vision. Pilgrims who complete the vision and continue for one or two days are suffering from a severe shortage of space because most nerves are used. This creates difficulties for the devotees who arrive later. During heavy days, pilgrims are forced to stand in queues for up to ten hours, as there is no place to be.

However, the pilgrimage has faced several disasters over the years due to various factors like overcrowding, inadequate infrastructure, and natural calamities. The following are some of the most notable disasters: the temple is surrounded by 18 hills in the Periyar Tiger Reserve forest area. The temple is open for worship for a limited amount of time—a total of 1,431 hours are available for darshan at the temple. The temple is also accessible for darshan on the first five days of each month. If 10 devotees received darshan per second—it is difficult to allow pilgrims to loiter before the sanctuary for too long—the pilgrims would only number 51,516. (Gurukkal 2018).

During the pilgrimage season, thousands of devotees visit Sabarimala every day. Due to the large influx of pilgrims during festival season, disaster management is a significant concern for the state administration. The pilgrims have to reach the temple through difficult treks in the forest as the vehicles cannot reach there. An inflow of more than two crore people during the pilgrimage season (November to January) results in significant environmental damage and considerable biotic pressure. Under the guise of wanting to satisfy the urgent requirements of pilgrims, the TDB has been enforcing urban development directly in the heart of the tiger reserve, completely disregarding the natural environment and its rules. Deforestation, the repurposing of forest land, and flagrant violations of the Kerala Forest Act of 1961, the Wildlife Protection Act of 1972, and the Forest Conservation Act of 1980 have all been implicated. (Gurukkal, 2018).

The temple witnessed two big crowd disaster occurrences. The first occurred in 1999, when a people stampede erupted on a mountaintop near Pamba in Sabarimala, killing 52 pilgrims. The second incident occurred in 2011 on Makarajyothi day in Pullumedu, killing 102 pilgrims. The rush at the Makara Jyothi viewpoint claimed the lives of 102 pilgrims from Tamil Nadu, Karnataka, and Andhra Pradesh. On Makaravilakku day, both occurrences occurred distant from the shrine, Sannidanam. Huge audiences watch Makaravilakku and Makara Jyothi from various perspectives scattered across two districts in remote locations, making catastrophe preparedness more complicated. Approximately 22 government ministries and central forces assist at Sabarimala to ensure the safe conduct of the pilgrimage season. Rumours, small accidents during the waiting period, bad crowd control, ineffective law enforcement, indiscipline, a lack of hygiene, and inadequate sanitary facilities are frequently cited as causes of such disasters.

Pullumedu is situated in the major section of the Periyar Tiger Reserve. The Sabarimala temple saw an unprecedented influx of devotees, who had to wait in lengthy, winding lines for hours to receive the hallowed darshan. The Sannidhanam is experiencing a severe lack of space because the majority of the nada pandal is being used by pilgrims who stay for a day or two after completing darshan. This generates challenges for devotees who arrive later. Because of the Sannidhanam's limited space, pilgrims are compelled to wait in lines for up to ten hours on busy days.

5. Preventive Measures and Current Situation

After the major stampedes in 1999 and 2011, authorities have taken several measures to improve safety. This includes improving road infrastructure, enhancing medical facilities, deploying additional security personnel, and implementing crowd management systems like virtual queue systems. The Kerala government has also focused on environmental conservation, as the influx of pilgrims has led to significant pollution in the ecologically sensitive Western Ghats region. Despite these efforts, challenges persist due to the sheer volume of devotees and the difficult terrain. The Sabarimala pilgrimage continues to be a test of physical endurance and spiritual devotion, but it is also a reminder of the need for better safety and crowd management practices. The investigation into the deaths found that the state government was negligent in ensuring public safety.

6. Firework Disasters in temple festivals

The severity of a disaster determines how fire threats affect medical care. Emergencies frequently challenge the healthcare system due to a lack of human preparedness, skills, knowledge, equipment, resources, and money. Fireworks displays are a traditional practice in southern India, particularly at temples. Numerous accidents have been documented as a result of earlier explosions. According to one estimate, similar rivalries in various places of worship have claimed the lives of over 700 people in the last two decades since independence. In 1978, six people were killed when a cracker accidentally fell on spectators in Thrissur. In 2006, another explosion occurred at the storage where firecrackers were stored for the famous ThrissurPooram festival, killing seven people. One of the primary reasons for such catastrophes is the lack of strict legislation governing the manufacture and exhibition of fireworks.

The fireworks industry is dangerous, and transportation and storage pose threats to life and property. Bursting fireworks on celebratory occasions is not unusual in any state of the country; nevertheless, public displays of fireworks are more common in Kerala. Many festivities in the state are celebrated along these lines. Thrissur pooram, Nenmara Vallangi Vela, Arattupuzha pooram, Chinakathur pooram, and others are among them. The most remarkable spectacle of the 'Pooram' festival is the majestic and thunderous display of fireworks, which begins late at night and ends just before daybreak (usually before 4:00 a.m.). Thousands of people from all over the state attend the fireworks show, which is a unique experience in Kerala.

Due to the rapidly growing number of temples and the size of festivals, fireworks are a common feature of Keralan temple celebrations and are only expected to grow in number. Fireworks displays are an important component of Kerala temple festivals, attracting a big crowd and potentially resulting in fatal accidents if proper security precautions are not taken. The organisers bear responsibility for the festival's safe conduct, and government ministries or agencies are not liable for the overall safety of religious audiences. For some high-priority events, state agencies would provide their assistance.Disasters, whether natural or man-made, can strike at any time and from anywhere in the country. These calamities are largely unforeseen, making them even more destructive because public government has a lower level of disaster preparedness. Fireworks displays are a traditional practice in southern India, particularly at temples. As a result, many explosion-related accidents have been reported. According to one estimate, approximately 700 people have died as a result of religious disputes in the last 20 years since independence.

The Kerala government has introduced stricter criteria for temple celebrations, including fireworks, which include obtaining district administration authorisation, guaranteeing appropriate explosive storage, and stationing safety officials at the event venues. There have been initiatives to promote awareness among devotees and temple committees about the dangers of fireworks and the need to follow safe practices. The emphasis has turned to supporting more regulated and controlled fireworks displays. Despite the regulations, fireworks remain an important element of Kerala's temple culture, and instances like the one in Malanada highlight the persistent contradiction between cultural tradition and public safety.

A fire accident during a Theyyam performance at a temple near Neeleswaram in 2024 October 29 left 154 people injured, eight of them seriously, when firecrackers stored in the vicinity exploded The incident happened at Anjoottanbalam Veererkavu Temple near Neeleswaram in this northernmost district of Kerala The safety precautions were not taken. The incident reportedly occurred due to inadequate safety precautions and improper storage of fireworks, emphasizing the need for more stringent regulations and compliance with safety protocols during such events.

7. Fire Cracker Accident at Puttingal Temple

None of the previous tragedies, however, matched the devastation at Paravur Puttingal Temple at the Kollam district of southern Kerala**.** (Devasia,2016) A major tragedy occurred in Paravur, Kollam district, due to a fireworks accident during a large religious gathering. The annual festival at the Puttingal Devi Temple near Kollam features a fireworks display, and the temple is located about 70 kilometres from the state capital, Thiruvananthapuram. The disaster unfolded when sparks from the fireworks ignited a storage area known as the 'Kambapura', where firecrackers were kept. This triggered a massive explosion, and the flames spread rapidly, trapping devotees within the temple grounds. After the incident, charred bodies and human remains were scattered throughout the temple compound (PTI, 2016). The explosions also caused chunks of concrete and plaster to fall from the temple and nearby structures, killing and injuring many. Numerous fatalities have occurred in fireworks-related accidents, often due to illegal storage, unauthorised manufacturing and display, and a lack of safety awareness. The Explosive Rules of 2008 regulate safety measures for fireworks displays at festivals, but the Paravur fireworks disaster remains Kerala's worst tragedy of the 21st century in terms of the number of deaths in a single incident and one of the most devastating in modern history. Fireworks accidents, though unintended, often result in some of the most horrifying injuries and fatalities (Thummarukudy, 2016).

Temple authorities should take lessons from the Kollam tragedy by prioritizing the safety of festival spaces before accommodating large crowds. Despite growing concerns over health and safety, the increasing number of pilgrims attending temple festivals continues. Authorities must develop strategies to manage these crowds, especially in high-risk areas. The government should implement stricter disaster management measures to ensure public safety. While safety guidelines for the use and storage of fireworks are in place, enforcement remains weak. Powerful supporters of religious centres, often shielded by political influence, must be held accountable for ignoring local governance and due process. Ignorance and negligence in the safe handling of fireworks chemicals have often led to fireside tragedies in Kerala, from 1952 until the newest incident at Puttingal Temple. Neither the temple nor its surroundings were impervious to disasters. Many people perished as a result of falling concrete debris caused by fireworks that burnt an explosives warehouse. If devotees and people are to be safeguarded from such disasters, temples and their surrounds must be disaster-proofed, which entails rationalising their scale and intensity. The usage of fireworks must be either prohibited or managed with the utmost caution.

There was no clearance for fireworks at the Kollam temple. The incident could have been avoided if the local authorities had followed the law. The organisers must have obtained the necessary authorisation by the rules established by the central government's Petroleum and Explosives Safety Organisation. There are additional guidelines for where fireworks can be held, how people should be evacuated from such locations, and the safe distances must be maintained. Certain chemicals and combinations (e.g., sulphur and potassium chlorates) are prohibited throughout the country, and the Kerala High Court has prohibited the manufacture of certain types of indigenous explosives due to their hazard. These issues were not resolved.

The fireworks contractors did not create an adequate buffer zone between the ignited explosives area and the assembled crowd. The fireworks were let up in a small location, and people gathered as close as they could. The most dangerous aspect was that many factions were competing against each other, making the event a test of their financial muscle and weaponry. Banned substances were freely utilised, and rules were broken with impunity. The district administration can also be

blamed. The district government, with the assistance of the local police, could have intervened, but they either ignored the risks or were overpowered by public opinion The loss of lives and property may have been avoided if they had investigated the sites, read the instructions to the organisers, and prevented the illegal fabrication of explosives (Kumar 2016).

The decision to ban fireworks is contentious and possibly impractical. The Kollam tragedy should serve as a warning to all temple administrators that the space available for staging festivities should be the major consideration for inviting crowds into festival grounds. True, safety and health concerns are not keeping many individuals from joining the growing number of pilgrims to temple towns and festivals. Good logic would suggest that authorities devise strategies to guarantee that huge groups do not congregate in high-risk regions. The government should also develop new and more robust disaster management plans that map out major public locations where huge crowds congregate and identify all hazards to them. The Kollam fire catastrophe serves as a message to leaders and citizens alike that public safety must take precedence over all other considerations.

Public safety is critical, but it requires the active participation of local governments, which have increasingly been marginalised. Disaster managers must be aware of potential dangers and develop comprehensive disaster prevention, readiness, and response strategies. Although fireworks displays are customary at temples, studies suggest that events at specific locations result in significantly greater mortality tolls. What made this calamity even more tragic was that the district government had instructed the temple authorities to cancel the fireworks display in response to objections from surrounding residents. Despite the District Magistrate's orders, the temple management, with the support of lower-level officials and security agencies, went ahead with the event. The explosion killed over 109 people and injured almost 400. A nearby three-story concrete building was extensively damaged, and debris from the bomb caused serious casualties within a 500-meter radius. Approximately 150 kg of pyrotechnics were lit during the event. The rescue attempts were led by a high-level team that included the Prime Minister.

In 2023, the Kerala High Court partially overturned a single-bench ruling directing raids on religious sites to seize illegally stored firecrackers. The division bench, led by Chief Justice AJ Desai and Justice VG Arun, ruled that no fireworks should be used between 10 p.m. and 6 a.m. However, it gave district administrations the authority to decide whether firecrackers might be used during limited hours if necessary. The judge further stated that bursting firecrackers is not a religious need and warned that infractions would result in contempt of court proceedings. The administration also claimed that the court had not considered whether fireworks were part of the necessary religious rites in Kerala's temples. It emphasised that fireworks have traditionally been an important feature of temple festivals, bringing people together and supporting the state's secular and cosmopolitan character.

In 2024, the Kerala High Court compelled the District Collector to issue fireworks rules, which permitted fireworks displays under tight restrictions. The court ruled that only certain fireworks items allowed by the court might be used and that qualified specialists must supervise the display. Fireworks storage areas were to be at least 200 meters from the show site. The Union government has recently implemented new limits for fireworks displays, sparking concerns about their influence on Kerala's historic festivals such as Thrissur Pooram. The requirements demand strict safety precautions, such as a minimum distance of 200 meters between fireworks storage and display areas and at least 100 meters between spectators and the display site. Additionally, fireworks must be kept at least 250 meters from hospitals and schools. The regulations require that fireworks be handled only by individuals who have been certified by the Petroleum and Explosives Safety Organisation (PESO).

These changes were introduced in response to the 2016 Puttingal Temple disaster, which heightened public concern about fireworks safety. Event organisers must submit applications 15 days in advance, explaining the types of fireworks used and potential risk zones in case of an accident. They must also secure public liability insurance and carry out a simulated safety exercise two days before the event. Potassium chlorate is prohibited, and organisers must follow fire safety requirements established by local fire departments. The fatal tragedy at the Veerarkavu Temple emphasises the critical need for more stringent enforcement of fireworks rules at religious celebrations. While the

Kerala High Court has decided on the conditions for allowing fireworks, and the state administration has advocated for tradition preservation, occurrences like this highlight the need to put public safety first. With the Union administration strengthening rules, the task will be to strike a balance between cultural traditions and the necessity to avert such catastrophes.

The comprehensive examination of crowd dynamics and disaster risks in Kerala's temple festivals underscores the critical need for integrating soft power and institutional skills to enhance disaster management frameworks, as highlighted in studies addressing Montenegro's EU accession strategies (Sudar, Cvetković, & Ivanov, 2024), COVID-19 management challenges in India (Port & Jawahar, 2024), flood vulnerability assessments (Aktar, Shohani, Hasan, & Hasan, 2021), school-community disaster preparedness (Carla, 2019), and community disaster resilience in Serbia (Cvetković & Šišović, 2024).

Effective crowd management planning should include a thorough carrying capacity assessment, which allows administrators to engage in risk-informed planning. Without this, it is difficult to accurately gauge the threshold of safe crowd sizes, heightening the risk of preventable disasters. Additionally, proactive disaster preparedness, coupled with strict monitoring and accountability measures, is essential to ensure that the use of fireworks remains within legal and safety guidelines. Effective crowd management at temple festivals requires a multidisciplinary approach that involves spatial analysis, stakeholder collaboration, and robust catastrophe preparedness. The study highlights the significance of conducting preventive risk assessments and dynamic crowd monitoring techniques to avoid disasters. Implementing the proposed measures can considerably improve public safety, serve as a model for comparable cultural events, and help to shape legislation for disaster risk reduction in large crowds.

Preventive Measures

- Better Crowd Control Mechanisms: Deploying trained personnel, using technology like RFID tracking for crowd movement, and creating more entry/exit points can help manage large crowds effectively.
- Infrastructure Improvements: Upgrading temple infrastructure, including expanding pathways and building additional exits, can mitigate risks.
- Real-time Monitoring: The use of surveillance systems and real-time monitoring of crowd density can help authorities act quickly during dangerous situations.
- Limiting Attendees: Imposing restrictions on the number of people allowed in the temple premises at any given time, especially during festivals, could reduce overcrowding.
- Public Awareness Campaigns: Educating devotees on safety measures, crowd behaviour and emergency protocols can play a vital role in preventing disasters.

Kerala's temples, with their deep spiritual and cultural importance, continue to draw vast crowds. Proactive measures, along with lessons learned from past tragedies, can significantly reduce the occurrence of crowd-induced disasters.

8. Conclusion

Clear and well-defined guidelines exist in the state for the use of fireworks and explosives, yet enforcement remains weak due to administrative limitations. Powerful religious custodians often supported by a political class that bypasses local authorities and due processes, significantly contribute to these enforcement challenges. Public safety must be a non-negotiable priority, but achieving this requires strengthening local administrative powers, which have been progressively eroded over time. Effective crowd management planning should include a thorough carrying capacity assessment, which allows administrators to engage in risk-informed planning. Without this, it is difficult to accurately gauge the threshold of safe crowd sizes, heightening the risk of preventable disasters. Additionally, proactive disaster preparedness, coupled with strict monitoring and accountability measures, is essential to ensure that the use of fireworks remains within legal and safety guidelines. Through the lens of crowd dynamics, this study highlights the challenges that disaster management

authorities face and offers strategic recommendations for improving crowd control, infrastructure planning, and emergency response. By proposing a framework for proactive disaster management, the paper seeks to enhance safety measures at temple festivals and minimize the potential for future tragedies. These recommendations include improving crowd control systems, enhancing stakeholder coordination, and utilizing technology to monitor and manage large gatherings. Kerala's temples, with their deep spiritual and cultural importance, continue to draw vast crowds. Proactive measures, along with lessons learned from past tragedies, can significantly reduce the occurrence of crowd-induced disasters.

Conflict of interest: The authors declare no conflict of interest.

Funding: This research received no specific grant from any funding agency in the public.

References

1. Aktar, M. A., Shohani, K., Hasan, M. N., & Hasan, M. K. (2021). Flood Vulnerability Assessment by Flood Vulnerability Index (FVI) Method: A Study on Sirajganj Sadar Upazila. *International Journal of Disaster Risk Management, 3*(1), 1-14.
2. Bala, K. (2018). Crowd management: Issues and challenges. *International Journal of Research and Analytical Reviews, 5*(3).
3. Carla S, R. G. (2019). School-community collaboration: disaster preparedness towards building resilient communities. *International Journal of Disaster Risk Management, 1*(2), 45-59.
4. Cvetković, V., Šišović, V. (2024). Community Disaster Resilience in Serbia. Belgrade: Scientific-Professional Society for Disaster Risk Management
5. Deshpande, N. P., & Gupta, R. (2010). Crowd management using fuzzy logic and GIS. *WIT Transactions on Information and Communication Technologies, 43*.
6. Devasia, T. K. (2016). Kerala temple fire: Will the state finally ban dangerous fireworks displays? *Scroll. in.* Retrieved from https://scroll.in/article/806455/kerala-temple-fire-will-the-state-finally-ban-dangerous-fireworks-displays
7. Gurukkal, R. (2018). Yes, Sabarimala is in peril, but not the way you think. *Outlook India.* Retrieved from https://www.outlookindia.com/magazine/story/yes-sabarimala-is-in-peril-but-not-the-way-you-think/300818
8. Illiyas, F. T., Faisel, M., & Mohan, K. (2015). Safety in religious mass gatherings: Guidelines for event organisers and stakeholder agencies. *Institute of Land and Disaster Management, Department of Revenue and Disaster Management, Government of Kerala.* Retrieved from https://sdma.kerala.gov.in/wp-content/uploads/2018/11/ILDM_2015.pdf
9. Illiyas, F. T., Mani, S. K., & Mohan, K. (2020). Carrying capacity assessment for religious crowd management: An application to Sabarimala mass gathering pilgrimage, India. *International Journal of Religious Tourism and Pilgrimage, 8*(1). Retrieved from https://www.researchgate.net/publication/348525529_Crowd_Management_-An_Application_to_Sabarimala_Mass_Gathering_Pilgrimage_India
10. Illiyas, F. T., Mani, S. K., Mohan, K., & Kumar, K. (2013). Human stampedes during religious festivals: A comparative review of mass gathering emergencies in India. *International Journal of Disaster Risk Reduction, 5*, 10–18.
11. Kumar, G. P. (2016, April 10). Kerala temple fire tragedy: Why temple sites in the state are disaster zones during festivals. *Firstpost.* Retrieved from https://www.firstpost.com/india/kerala-temple-fire-tragedy-why-temple-sites-in-the-state-are-disaster-zones-during-festivals-2721500.html
12. *Lancet Infectious Diseases*. (2010). Mass gathering medicine. *The Lancet Infectious Diseases, 10*(10), 653. Retrieved from http://www.thelancet.com/journals/laninf/article/PIIS1473-3099(10)70204-8/fulltext

13. Mohan Das, K., Nayar, R., & Shaffi, M. (2015). A perilous pilgrimage: The case of Sabarimala. *Economic and Political Weekly, 50*(25). Retrieved from https://www.epw.in/journal/2015/25/reports-states-web-exclusives/perilous-pilgrimage.html
14. Parkash, S. (2016). Brief report on reconnaissance study of Puttingal Temple fire incident (Sunday, 10 April 2016), Paravur, Kollam District, Kerala State. *ResearchGate.* https://doi.org/10.13140/RG.2.1.1782.4249
15. Port, K. J. N., & Jawahar, G. (2024). Management of COVID: The Creeping Disaster in the Indian Scenario. *International Journal of Disaster Risk Management*, *6*(1), 103–110.
16. PTI. (2016, April 10). 106 killed, 383 injured in Kerala temple fire. *Deccan Herald.* Retrieved from https://www.deccanherald.com/india/106-killed-383-injured-in-kerala-temple-fire-519724.html
17. Satisan, T. (2016). Obsession ends in tragedy. *Organiser.* Retrieved from https://organiser.org/2016/04/18/67306/general/rd563e3cc/
18. Soo, J., & Avery, J. (2003). *Emergency/disaster guidelines and procedures for employees.* CCH Canadian Limited.
19. Sudar, S., Cvetković, V. M., & Ivanov, A. (2024). Harmonization of Soft Power and Institutional Skills: Montenegro's Path to Accession to the European Union in the Environmental Sector. *International Journal of Disaster Risk Management*, *6*(1), 41–74.
20. Thummarukudy, M. (2016). Kerala temple fire: Time for better planning. Deccan Chronicle.
21. World Health Organization (WHO). (2008). Public health for mass gatherings: Key considerations. Geneva, Switzerland: WHO.

Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management

Journal homepage: https://internationaljournalofdisasterriskmanagement.com



Review Article

Implications of Artificial Intelligence and Cyberspace on Risk Management Capabilities

Hatidža Beriša[1,2], **Vanja Cvetković** [2*], **Aleksandar Pavić**[1]

[1] Military Academy, University of Defence, Veljka Lukića Kurjaka, 11042 Belgrade, Serbia, berisa.hatidza@gmail.com (H.B.).

[2] Scientific-Professional Society for Disaster Risk Management, Dimitrija Tucovića 121, 11040 Belgrade, Serbia, vanja.cvetkovic.drm@gmail.com.

*Correspondence: vanja.cvetkovic.drm@gmail.com

Received: 30 Juny 2024; Revised: 25 August 2024; Accepted 13 October; Published: 25 December

Abstract

The crisis management system is a key element of a modern, reliable, effective, and sustainable security system. In contemporary settings, management functions are implemented through the capabilities of a command-information system. Consequently, most activities are conducted within cyberspace, meaning that management functions cannot be effectively executed without adequate telecommunications and information technology support. The primary target of hostile cyber activities is precisely the command-information system. Developing an optimal methodology for the use of command-information systems, as well as for prevention and protection against cyber-attacks, is among the most critical tasks for modern defence and security systems. One approach to enhancing risk management is through the application of artificial intelligence (AI). AI should ensure superiority in cyberspace, primarily at the national level, providing the foundation for executing legitimate and lawful cyber activities in a state's defence system. This paper aims to explore the role and significance of artificial intelligence within the realm of cybersecurity by analyzing its implications for risk management in contemporary environments. Command in modern military operations, the nature of modern warfare risks, the protection of command-information systems, the autonomy of artificial intelligence in decision-making, and an understanding of cyber threats are factors through which the challenges of modern command systems can be understood.

Keywords

Artificial intelligence, autonomy, superiority in cyberspace, hybrid threats, risks, management

1. Introduction

The challenges of the modern command system within the defence framework have significantly evolved in the 21st century. Governance integrity in systems such as the military has always been a fundamental characteristic and structural pattern. The decision-maker stands as the central figure within a hierarchically organized system. Trust and accountability toward the system and its environment are vested in the commander or leader, who, through knowledge and authority, must

make decisions of utmost importance to the organization. The multidimensional nature of the contemporary operational environment presents leaders with numerous challenges. The risks faced by the modern defence and security system demand thorough consideration and analysis of all environmental (hazard) factors (Cvetković & Šišović, 2024; Cvetković, Renner, Aleksova, & Lukić, 2024; Cvetković, Čvorović, & Beriša, 2023a; Grozdanić & Cvetković, 2024), aiming to achieve timely and optimal decision-making. The core hypothesis of this paper is that the functioning of a management system in contemporary risks is unattainable without an understanding of cyberspace and artificial intelligence, as well as the utilization of their capabilities. This inherently drives us toward the integration and development of new competencies, supported by artificial intelligence capabilities, within systems that operate on a highly autonomous basis in a secure cyber environment.

The era in which activities increasingly shift from the visible domain to the information sphere and cyberspace presents a major challenge for leaders. Understanding the environment now requires a high level of abstraction and insight into hostile activities. On the other hand, technologies like artificial intelligence tend to assume part of the decision-making integrity traditionally held by leaders. The digital agenda—transferring a large number of activities into cyberspace and utilizing artificial intelligence—has created significant challenges for command systems. Although the use of artificial intelligence is widely accepted across various sectors of society, it is viewed with particular scrutiny in defence and security systems. Delegating a degree of autonomy to artificial intelligence in selecting targets and authorizing the use of lethal combat systems against humans confronts numerous ethical and legal concerns.

The primary aim of this paper is to explore the role and significance of artificial intelligence within the realm of risk management by analyzing its implications on risk management in contemporary crises. Despite the advanced technological capabilities and high interconnectivity brought by developments in the information and telecommunications sector, decision-making systems must be aligned and optimally positioned within this complex framework. To comprehend the challenges, risks, and threats faced by decision-making systems in today's environment, it is essential first to analyze and highlight the determinants of modern management systems, as well as the critical infrastructure within these systems. The challenges posed by the application of artificial intelligence in crisis and cyberspace represent a fundamental axiom influencing the capacity to execute management functions at the required level. A crucial segment to which the management system must respond in real time is AI-supported cyber activities. Mutual interaction in the 21st-century crisis field will demand the deployment of the most advanced technological capacities. Integrating human capabilities with artificial intelligence will be essential for achieving superiority in cyberspace and subsequently in other domains. Ultimately, how cyber threats and the use of artificial intelligence will impact management systems remains largely unknown, a question that the authors aim to partially elucidate in the following chapters.

2. Determinants of the modern management system

The concepts of crises have changed significantly. Regardless of the environment, technological development level, or crisis generation, two components remain constant: the involvement of humans as primary actors and management as the function that unifies all segments of risk (Cvetković & Šišović, 2023; Cvetković, 2024; Nikolić, Cvetković, & Ivanov, 2023). The shift in the crisis concept is primarily based on the ability to utilize the anthropological characteristics and features of nations and societies in determining the sources of conflict and transforming them into the fundamental causes and tools of what is now known as "modern crises." To understand some of the challenges faced by modern management, it is necessary to analyze the nature of contemporary crises, examine the protection of command-information systems, consider the level of artificial intelligence autonomy in decision-making, and comprehend cyber threats.

The challenges of modern risk management systems highlight the importance of integrating diverse approaches to address vulnerabilities across various domains. Akter, Roy, and Aktar (2023) emphasize the critical role of women in post-disaster health management, showcasing how gen-

der-specific challenges can hinder effective recovery processes. On the other hand, Goyal (2019) and Aleksandrina et al. (2019) explore systemic solutions, such as governmental incentivization and community resilience, as pivotal strategies to enhance disaster preparedness. In parallel, technological advancements in infrastructure monitoring and fire risk perception, as examined by Kachanov (2021) and Cvetković (2019), underline the need for robust systems that mitigate physical and cyber threats alike. Collectively, these studies contribute to a comprehensive understanding of disaster risk management by bridging social, systemic, and technological perspectives (Akter, Roy, & Aktar, 2023; Aleksandrina et al., 2019; Goyal, 2019; Kachanov, 2021; Cvetković, 2019).

Modern risk management systems in crises depend on various determinants that shape their structure and functioning (Cvetković, Sudar, & Ivanov, 2024; Cvetković, Andrić, & Ivanov, 2023). Key aspects include technology, education, communication, strategy, doctrine, leadership, and international cooperation (Jovičić, Gostimirović & Milašinović, 2024). These factors often interact with one another, forming complex risk management systems in contemporary crises. However, what primarily shapes the correlation of these factors are the challenges, risks, and threats faced by decision-makers, all of which have evolved alongside the risks over time.

2.1. Command-Information System

The central role in all military systems is the implementation of the management function. The core element of a modern management system is the command-information system. This system comprises a set of hardware and software solutions that enable real-time integration of all organizational structures, doctrines, technical-technological systems and resources, information flows, and processes. Its purpose is to achieve efficient and rational functioning of the military as a whole, as well as its individual segments (Manjak & Miletić, 2011, pp. 78-93). It is an information system that supports management in crises at all levels, where data and information are collected, transmitted, distributed, processed, displayed, and protected. Disruption of the integrity and functioning of this information system directly impacts the operational capabilities of forces managing risks.

2.2. Cyberspace

Various authors and organizations have attempted to define the concept of cyberspace. The primary fact is that cyberspace is simultaneously a source of cyber threats. However, it is undisputed that the essence of each definition is based on the same fundamentals. Cyberspace is understood as the "online" realm of computer networks, but also the digital world in general (Nedeljković, 2015). Cyberspace is created through technological and cybernetic means and represents a set of social relations that emerge when people begin to use computers, and when computers themselves start functioning as "assistive tools" for human activities. Cyberspace is an immaterial, artificially created world that is accessible to most. Not all rules are defined within it, which is why it is often described as both nobody's and everybody's property. It should not be confused with the internet, although they largely overlap. Cyberspace can exist within a single computer or other technical device, whereas the internet entails networking and communication (Vuletić, 2017).

Cyber threats are the result of malicious actors operating within cyberspace. Their actions harm information and communication systems that are the targets of cyber attacks. The sources of these threats can include states, corporations, specialized companies producing malicious software, dissatisfied individuals within the protected environment, terrorists, and botnet operators, and individuals who exploit the internet and social networks (Nedeljković, 2015). A similar principle can be applied to civilian command-information systems, which, like other systems of this type, are not immune to cyber threats.

2.3.The autonomy of artificial intelligence in the decision-making process

The rapid development of artificial intelligence-based systems in recent years has led to a paradigm shift across various sectors, including defence. Modern weapon systems, with increased autonomy, can independently track, select targets, and act upon them without further human intervention. The application of artificial intelligence in this manner has the potential to revolutionize warfare due to capabilities such as autonomous decision-making, enhanced precision, and faster response times (Kenneth, 2018). These advantages can certainly lead to strategic superiority and a reduction in casualties. However, such weapons also raise significant international security and ethical concerns, underscoring the need for comprehensive global regulation within international institutions, particularly the United Nations.

The capabilities of artificial intelligence will undoubtedly have a deterministic and potentially transformative impact on military power, strategic competition, and global politics more broadly. It could be a generator of future uncertainty and vulnerability due to its rapid proliferation, as well as a potential source of instability and strategic rivalry among major powers (Johnson, 2019). Crises are generally conducted at all levels, with vast consequences that can produce strategic effects. Artificial intelligence will certainly play a role in some of these crises, through modern tools and as part of systems for operational planning and decision-making.

Today, we can increasingly envision a concept where artificial intelligence takes control over crisis management (https://www.military.africa/2023/11/artificial-intelligence-in-the-military). However, such concepts are the subject of discussion in various academic circles, which seek to find the boundary between reality and imagination. Although there are both negative and positive effects of artificial intelligence in military operations, the fact remains that its vectors of application are rapidly expanding. By analyzing various sources, the scope of AI use can be categorized into the following areas: autonomous armed combat platforms, strategic decision-making, data processing and analysis, combat simulation, target recognition, threat tracking, drone swarms, cybersecurity, transportation, casualty care, and evacuation (https://sdi.ai/blog/the-most-useful-military-applications-of-). Among the listed areas of application, cybersecurity stands out as particularly important for risk management systems in crises. With its analytical capabilities, scenario creation, and adaptability, artificial intelligence can enhance cybersecurity during crises. The command-information system, which is the core of management within civilian structures, is especially vulnerable in the domain of cybersecurity, as it represents critical infrastructure in modern crises.

Complete determination of management in modern crises, regardless of the technologies or solutions used—whether advanced artificial intelligence or automation systems—still depends on the human factor. Modern risk management systems, in their manifestation, can be characterized as complex adaptive systems.

Academic theorists and practitioners have an incomplete understanding of the complexity of complex adaptive systems, which will characterize the future operational environment for implementing management functions. Existing methods and ways of perceiving the operational environment will need to adapt to new trends. It can be concluded that the primary challenge, to begin with, is understanding how best to manage this process over time, considering the scope and nature of the transformation of risk management functions (https://assets.publishing.service.gov.uk/media/65c4dde79c5b7f0012951b35/Command_Control_Future_C2_Complexity.pdf).

3. Critical management infrastructure

The command and risk management system is one of the pillars that directly impact the reliability and effectiveness of defence and protection systems. This system must be fully functional in both peacetime and during emergencies. A critical point is always the transition from one state to another, especially when moving from a peacetime to an emergency organization. Although traditional emergencies are not as prevalent today, this does not imply that activities are not being conducted.

The formation of mobile and temporary components of the command-information system invariably represents a critical point vulnerable to cyber attacks. Modern risk management activities have accelerated with the use of artificial intelligence, leading to the application of deception measures and the dissemination of content within cyberspace. In the absence of adequate responses and measures to counteract malicious activities in cyberspace, such content floods digital media. Public trust in government institutions continues its long-term decline, and a growing sense of cynicism spreads, which significantly impacts defence capabilities (https://www.csis.org/analysis/cyber-operations-during-russo-ukrainian-war). This can be explained by several factors.

First, the focus of operations shifts toward supporting military forces and conducting activities. Leadership structures concentrate on operational planning, developing new operations and branches of operations, and almost always overlook threats from cyberspace. It is often assumed that the command-information system will operate safely and reliably, which can lead to overlooking critical security aspects that impact the continuity and protection of communications. From this perspective, a disruption to system consistency can be more damaging than a temporary interruption. Second, during operations, part of the telecommunications equipment may be damaged due to disasters or theft. The loss of a platform with telecommunications equipment containing current cryptographic algorithms could open the door for access to a closed information system. This breach can then be exploited for cyber attacks, among other threats. Third, units connected via wireless communications are highly vulnerable to electronic interference. Such interference can completely or partially disable data transmission, significantly impacting the execution of assigned tasks. Fourth, there is a tendency among leadership to introduce the latest technological equipment, especially those with autonomous capabilities and no human crew. The introduction of such systems is very intensive today. Emphasis is always placed on their operational efficiency, while command-information systems are generally expected to ensure reliable communication for uninterrupted data transmission in the early stages of development. These systems, which are still in development, are often deployed to achieve an element of surprise or deterrence. However, this can also become a potential entry point into the command-information system.

The vulnerability of the command-information system is constant. Risk will always seek to find a weak point and attempt to disable parts or the entire system, as it is clear that without it, a management system in defence and protection does not exist. For this reason, it is essential to leverage the autonomous capabilities of artificial intelligence-based systems to prevent cyber attacks and potentially respond to cyber attacks. Unlike humans, artificial intelligence will not view the cyber segment as a peripheral system, especially during operations. Detecting attacks, identifying threats, and responding promptly are the foundations for defending the command information system.

4. Challenges of cyberspace and artificial intelligence

The national security of a state is now exposed to various challenges, risks, and threats, both conventional and unconventional. The shift from Cold War-era conventional and nuclear threats to an environment filled with elements of hybrid warfare—carried out in almost all phases within the cyber environment—poses a challenge for all nations. There is no defence system entirely immune to cyber threats (https://www.gao.gov/blog/u.s.-less-prepared-fight-cybercrime-it-could-be). The reason is simple: there is no single, dominant state system dictating activities in cyberspace; rather, it is now accessible to everyone. Cyber threats can be initiated by both state and non-state actors, extending to smaller groups and even individuals. An invisible attack from cyberspace is, above all, difficult to detect, and then challenging to counteract. When we add the capabilities of artificial intelligence to this, we get a very broad spectrum of possibilities. Whether artificial intelligence will develop to the point where it becomes the first non-human actor to independently execute a cyber attack remains uncertain, but to prevent this, robust protective instruments must be developed and utilized in the most effective way possible.

Artificial intelligence can be utilized to enhance cybersecurity during military operations in various ways. It can effectively detect threats and execute a preventive response to protect the system.

Detecting cyber attacks in real time is nearly impossible in modern information systems without high-tech support. Additionally, artificial intelligence can be used to identify vulnerabilities in military systems, which is crucial for preventing attacks before they occur. This may include developing new defense procedures and mechanisms. The final aspect focuses on improving training and planning within cybersecurity systems (Kaur, Gabrijelčić & Klobučar, 2023).

Military power is one of the fundamental components of each state's instrument of power. For this reason, the military is invariably an active target for those conducting cyber attacks. Today's armed forces are heavily developing numerous weapon platforms based on elements of artificial intelligence, aiming for greater autonomy in specific phases of engagement. The command-information system of the armed forces is the primary component that enables effective leadership and command at all levels. This system involves data transmission both horizontally and vertically, from the lowest to the highest levels. Additionally, information is transmitted across various media, through cables and increasingly through wireless channels. Commanding modern combat platforms, particularly at the tactical level, is impossible without advanced wireless communications. Despite typically being a leader in the realm of protection and attack prevention methods, the military command-information system remains an attractive target for various cyber attacks.

Cyberspace and artificial intelligence are two inseparable segments of the modern operational environment. The first important factor relates to the breadth and comprehensiveness of cyberspace. It spans from individuals using smart devices in nearly all activities to the highest national level that integrates all aspects of a state's functioning. Modern electronic communications occur entirely within cyberspace. The challenges, risks, and threats arising from cyberspace are real and daily. The second crucial factor that aims to influence our environment comprehensively is artificial intelligence. Its development and rapid global spread would not be possible without cyberspace. Artificial intelligence, without access to cyberspace, can only perform basic tasks defined by a limited dataset and an installed algorithm. To learn, it must be continually updated with new data and interact with other entities. Artificial intelligence that operates freely in cyberspace has the essential precondition for growth and learning. For this reason, artificial intelligence can be seen as a system that acts preventively against malicious activities in cyberspace but can also serve as a generator of threats.

The future of crisis management will undoubtedly be shaped by systems that utilize artificial intelligence and cyberspace. Modern disasters are practically unimaginable without the dimension of cyberspace and technologies based on artificial intelligence (https://www.rand.org/pubs/commentary/2022/11/ukraines-lessons-for-the-future-of-hybrid-warfare.html). A broad range of risks is manifested through various activities, including cyber activities, conventional military actions, economic, and social interventions (Sanz-Caballero, 2023). The weapons used in these activities could include computers, drones, mass media, hijacked airplanes, spy balloons, as well as artificial intelligence. An incomplete list of hybrid threats would also include cyber attacks, terrorism, organized crime, drug trafficking, migration flows, economic or financial warfare, media exploitation, and the use of covert psychological operations (Galan, 2018).

A crucial segment related to cyberspace is gaining importance, particularly because all states are digitizing their administration and operational agendas. This segment also includes military organizations. It can be said that modern state apparatuses could not function without cyberspace and information technologies. Although cyber threats are diverse, they represent a significant source of risk for the modern state, and therefore for the defense system as well. Modern threats are mostly invisible, and by the time their effects become apparent, it is often too late for an effective defense.

The use of artificial intelligence is increasingly shifting modern crises from conventional to cyber space. Although we cannot entirely abandon the principles of the conventional domain, as this type of threat remains the dominant form of operations, artificial intelligence is becoming an integral part of various platforms—from lethal autonomous platforms and systems that perform analytical tasks and data processing, to decision-making and operational planning processes. The wide range of AI applications, from tactical to strategic levels, ensures its development and presence in all aspects of operations.

The shift from automation toward autonomy will require exceptionally high system reliability (Scharre, 2006). One potential response to this challenge is the development of high-reliability organizations, which demonstrate certain characteristics enabling them to routinely manage high-risk systems with low accident rates. High-reliability organizations can be found across various fields and share common characteristics. These include not only highly trained individuals but also a collective awareness of risks and a continuous commitment to learning (Sutcliffe & Sutcliffe, 2015). The reliability of autonomous systems should be one of the core principles for organizations that utilize them.

The command-information system in all defense systems is the backbone for executing assigned missions and tasks. The part of the system responsible for transmitting digitized data and commands is stationed in cyberspace and, as such, is inevitably a target for cyber attacks. A pertinent question arises regarding the role of artificial intelligence in cyberspace—will artificial intelligence serve as part of the defense system, or will it be used to conduct cyber attacks (https://www.piranirisk.com/blog/artificial-intelligence-to-combat-cyber-attacks#:~:text=The%20use%20of%20artificial%20intelligence,materialization%20of%20cyber%20attacks%2C%20which). This is one of the significant challenges that cybersecurity components of defense systems will face. Artificial intelligence has the potential to make military systems more secure, resilient, and efficient, but it also introduces new challenges and risks (Jan Maarten, 2023).

5. Artificial intelligence in cyber operations

A significant advancement in the use of artificial intelligence will be its potential application in cyber operations. Whether offensive or defensive, these applications will undoubtedly have substantial effects. The capability to design and execute cyber-attacks faster and more efficiently than humans presents a major challenge for future cybersecurity. These operations are not limited to digital domains but extend to physical assets, including weapons and support systems. Potential targets of cyber operations include all systems and installations connected to cyberspace (https://www.aspistrategist.org.au/the-impact-of-artificial-intelligence-on-cyber-offence-and-defence/).

The definitions of cyber operations have evolved in line with technological advancements and changes in doctrine. Among others, Department of Defense Publication 3-12 of the United States outlines these definitions as "The employment of cyberspace capabilities where the primary purpose is to achieve objectives in or through cyberspace" (https://irp.fas.org/doddir/dod/jp3_12.pdf). A cyber operation consists of computer network attacks, computer network defense, and related operations that enable the exploitation of computer networks. This implies that the core tasks of cyber defense are: identifying threats, mitigating the impact of threats, and carrying out activities to counteract the consequences of threats (Doktrina kopnene vojske, 2012).

Examples include hacker attacks supported by Iran in 2012, as well as the Russian military intelligence attack in December 2015, which conducted a destructive cyber attack on Ukraine's power grid, leaving much of the country in darkness. Another example of an attack on a closed information system is the notorious "STUXNET" virus, which disabled centrifuges at a nuclear facility. All these examples are part of cyber operations that, through cyberspace, impacted the vital systems of the targeted state (https://www.iemed.org/publication/artificial-intelligence-machine-learning-and-cyber-command-as-a-tool-of-war-a-new-method-in-the-mediterranean-battlefield/). What these examples have in common is that the infrastructure of the information system was attacked, directly affecting the ability to command within the system. This is significant in the military context, as the inability to relay orders and commands to executing elements on the battlefield directly impacts the outcome of an operation. On a broader scale, it can completely paralyze the military's command-information system.

The previously mentioned examples demonstrate that the implications of cyber warfare can have global effects. Warfare is no longer confined to physical battlefields with soldiers; it has become an integral part of the digital domain, or cyberspace. The digital extension of global conflicts and proxy wars illustrates how cyber warfare has become an essential component of international relations and security.

In a RAND Corporation report titled "Cyber War is Coming!" as early as 1993, the author discussed the prospects of future warfare. Cyber warfare is described as an "information revolution" in which outcomes are no longer determined by kinetic elements or mobility but by strategic cyber operations. This environment enables powerful actors to compete indirectly, emphasizing a shift from traditional confrontation to more covert operations (https://www.rand.org/pubs/reprints/RP223.html). Such an approach aligns with the theory of strategic interaction, which emphasizes the shifting nature of global conflict (Arreguín-Toft, 2001).

Cyber warfare represents a significant shift in the way global conflicts are conducted. The rise of artificial intelligence in cyber operations, the information revolution, the digital evolution of warfare, the need for international norms, and the comprehensive impact of technology on society together create a vision of a future where cyber warfare is an integral part of international relations and security (https://medium.com/@mikevfuentes/the-future-of-cyber-warfare-1ad1a9a66d0c).

Future cyber operations will undoubtedly be enhanced by the capabilities of artificial intelligence. Whether defensive or offensive, such operations will become increasingly prevalent on the battlefield. The readiness of defense systems to implement new technologies to improve the command-information system is essential for effective attack prevention and for preserving the integrity of command functions. Dominance in cyberspace will become a key indicator of operational outcomes and a state's ability to defend itself not only in cyberspace but across other dimensions as well. In the following chapters, the authors will attempt to examine the challenges of AI operations in cyberspace, future concepts of conducting military operations, and ultimately, to model elements of cyber activities.

6. Integrating artificial intelligence into the management process

The integration of AI-supported technologies into the protection system can be achieved through the development of necessary capabilities and doctrinal structuring of usage methods. Key capabilities for management can be examined from three perspectives within the context of this study. The first pertains to the degree of autonomy of artificial intelligence in the decision-making process. The second aspect involves the prevention of cyber attacks on the command-information system, which is the primary support for risk management functioning in a crisis. Finally, the third aspect of integrating artificial intelligence should ensure the supremacy of AI in the risk management process during activities.

6.1. Autonomy and Cybersecurity

The military, as a driver of new technology development and implementation, has already widely adopted the use of artificial intelligence. The broad range of AI applications, as well as theoretical considerations of its potential uses, ultimately brings us to the question: How much autonomy can we allow artificial intelligence in military applications? This question extends beyond the military but is particularly compelling within defence systems, as only there could AI potentially gain autonomy in deploying lethal combat systems against humans. This ethical and legal dilemma is increasingly relevant as the use of AI in military contexts expands. However, artificial intelligence has a much broader scope beyond executing individual combat systems; it presents a significant opportunity for optimizing decision-support processes in decision-making and operational planning (Meerveld et al, 2023). This possibility leads us to the question of responsible use of artificial intelligence in the military, specifically concerning the delegation of a portion of responsibility and decision-making authority.

The defence and protection system, particularly its most critical operational component—the civil protection system—conducts its actions and activities according to doctrine. New challenges in risk management, especially within the domain of cybersecurity, necessitate the development of new capabilities. Artificial intelligence, with its broad range of possibilities, will undoubtedly serve

as a significant tool in developing the capabilities of forces, not only in the cyber domain but also in other aspects of force application. Part of these capabilities should include the ability to detect cyber attacks promptly, notify responsible personnel, and implement countermeasures. Cybersecurity faces increasingly complex challenges due to advances in information technology and artificial intelligence. The key question in capability development is whether it is justified to have artificial intelligence alongside humans in the decision-making loop or if, in the future, it will completely replace humans in the loop.

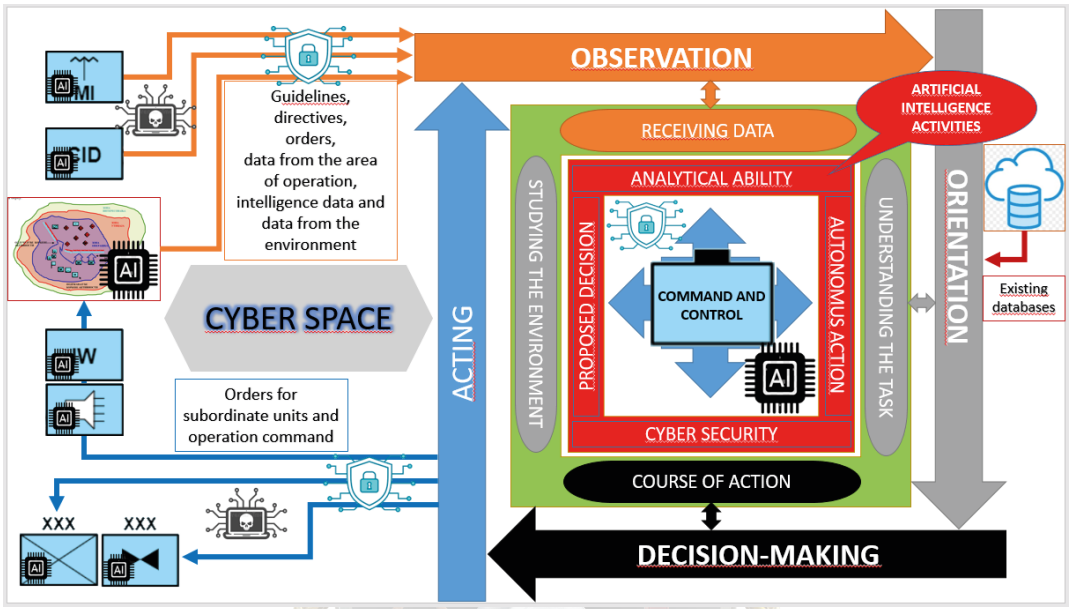


Figure 1 illustrates the modern complex operational environment in cyberspace. Artificial intelligence primarily executes tasks within the decision-making process, providing decision support. Positioned within the OODA decision loop alongside humans, AI enhances the speed of decision-making with its capabilities. In addition to its placement in the command center, artificial intelligence can also be integrated into tactical-level combat platforms, which require control and direction for new tasks. These assigned tasks include receiving data from sensors and managing autonomous combat systems on the battlefield by relaying engagement orders. Another segment of activity involves cybersecurity—specifically detection, notification, and counter-response to cyber attacks. The command-information system in cyberspace encompasses all combat power entities within a unified system, constantly exposed to cyber attacks during operations. The modern operational environment shown in Figure 1 suggests that clear coordination between the command system, cyberspace control, and AI-utilizing entities is essential. Such coordinated use ensures superiority in cyberspace and provides the fundamental prerequisite for the secure continuation of other combat activities.

The introduction of artificial intelligence into operational use within the defense and protection system requires doctrinal structuring that must align with the objective capabilities and new competencies of the forces. Without doctrine, it is impossible to effectively and optimally deploy forces that utilize AI resources in operations. For the doctrine to be fully applicable, it requires the necessary capabilities and specific knowledge about how to employ those capabilities (Ostojić, Karavidić & Projović, 2017).

6.2. Supremacy of Artificial Intelligence

The development of combat platforms integrating artificial intelligence capabilities has been evident for many years. The primary goal of integrating artificial intelligence should be to achieve supremacy over the adversary. Enhancing the performance of Boyd's OODA (Observe, Orient, Decide, Act) cycle in decision-making is one of the key factors in securing supremacy. Examining the role and position of artificial intelligence within the processes of observation, orientation, decision-mak-

ing, and action is essential for its integration into operations. Another critical factor in integration is a doctrinal framework that is aligned and prepared for use in modern operations. An inadequate doctrine for employing forces equipped with the latest technologies can negate all the advantages of modern autonomous systems.

The automation of processes in operations is not new; it has been systematically used for decades. Multi-sensor networks, the digital age rich with vast amounts of data stored across numerous databases, advanced algorithms for data processing, and decision support are all part of an agenda that requires high levels of process automation to provide real-time support to decision-makers.

Countries that maintain a technological edge, such as the United States, the People's Republic of China, the Russian Federation, and others, are leaders in the application of new and revolutionary technologies. The increasing use of autonomous combat systems is a clear example. From unmanned aerial vehicles to loitering munitions, automated combat vehicles, and tactical weaponry, all these systems significantly enhance the combat capabilities and operational effectiveness of units and the military as a whole. However, various indicators suggest that the adoption of these technologies will reach its full potential alongside advancements in the information agenda. The use of autonomous systems heavily relies on human potential for system maintenance and the processing of data generated by these systems (Mayer, 2023).

The development of the information age and the emphasis on the importance of cyberspace should serve as a new guideline for integrating artificial intelligence into future operations. Management across all systems requires a swift flow of information and the transmission of orders to subordinate units. In this process, artificial intelligence should act as a generator of progress. Another important factor is the security of cyberspace, which must ensure integrity, a high level of reliability, and the protection of information. The ability to fully integrate information gathering, communication, storage, and processing into timely and decisive action can result in new technological and conceptual advantages. These technologies, embodied in artificial intelligence and the development of autonomous systems, can cumulatively lead to what may be termed the "Third Offset" (Gian et al, 2021).

To fully leverage the advantages of artificial intelligence and autonomous systems, a more advanced integration into the decision-making process will be required. Additionally, significant influence on the previously stated position must be accompanied by trust in their ability to operate without human intervention. A key factor that arises here is who is authorized to make decisions. An interesting example can be illustrated with two highly automated systems used by the U.S. military (https://thebulletin.org/2021/04/worried-about-the-autonomous-weapons-of-the-future-look-at-whats-already-gone-wrong/). Specifically, the automation of the Patriot air defense system is designed to replace human involvement in the decision-making process and to independently respond to detected threats. Another significant system is Aegis, used by the Navy, which primarily aims to utilize automation to facilitate the commander's decision-making using appropriate doctrine. Of course, in both systems, there is the possibility for humans to control all options; however, there is also the potential for both to respond completely autonomously to identified threats. Another crucial factor influencing the decision-making process is the doctrine employed. A universal doctrine that consistently responds to the same threats in the same manner has many shortcomings that manifest in different circumstances. This implies that the complexity of using autonomous systems necessitates a corresponding doctrine that is aligned with the appropriate operational environment.

The speed that dominates Boyd's OODA loop is not always the primary factor that determines victory. Doctrine, environment, reliability, and adequate assessment should precede the correct decision regarding the use of combat power. Artificial intelligence integrated into Boyd's loop can be an ideal tool for exploring the performance of combat systems. The combination of human involvement and artificial intelligence in the loop is certainly a desirable and fully controlled system. The intuitive steps of the OODA loop are easily understood and closely aligned with the first four fundamental elements of artificial intelligence: perception, understanding, prediction, and manipulation, or learning (Johnson, 2023).

The integration of delegating autonomy to artificial intelligence and achieving supremacy in cyberspace are factors that will undoubtedly play a crucial role in the execution of military operations

in the future. They will directly reflect on the quality of command functions. The fight against a modern digital adversary operating in hybrid warfare is only possible by ensuring complete functionality and flexibility in command, which can only be achieved through the implementation of cutting-edge technological solutions.

7. Impact of cyber threats on crisis management

Using existing methods and knowledge, it is nearly impossible to ascertain the actual impact of cyber attacks on achieving objectives during a crisis (Musman, Scott & Temin; Aaron & Tanner; Mike & Fox; Dick & Pridemore, 2010). When considering the direct impact of cyber attacks on an ongoing crisis, it is essential to address several questions to undertake appropriate preventive actions before the crisis begins or to mitigate the consequences during its execution. Questions may include: Are we aware of which elements of the operational deployment are affected? Can we continue managing the ongoing crisis while under a cyber attack? Is it necessary to wait for the cyber attack to cease and for the damage to be rectified before resuming activities? Is it possible to mitigate damage during the crisis? Decision-makers often find it challenging to comprehend and assess the impact of a cyber incident on operations, which diminishes their ability to respond effectively. The very framework for the execution and impact of cyber attacks introduces significant uncertainty within organizations, resulting in responses that are generally misaligned and delayed. Enhancing awareness of the effects of cyber attacks on civil protection crises will undoubtedly lead to improved responses and the creation of systems that are more resilient to attacks.

Within the capacity for effective and efficient use of forces, cyber threats can be viewed as a set of activities that threaten to diminish the effectiveness of the forces and slow down the execution of assigned missions and tasks. Following this, it is essential to focus the work on assessing the impact of cyber attacks and to prepare a set of countermeasures aimed at protecting the forces and the infrastructure critical for conducting operations (Aljundi, Ibrahem & Rawashdeh; Morad & Al-Fayoumi; Mustafa & Al-Badarneh; Amer & Abu Al-Haija, 2023). To that end, it is essential to connect the capabilities of information technologies with the execution of strategies, specifically with measures that directly impact the effective and efficient use of forces. Understanding the critical requirements and capabilities necessary for executing assigned tasks is key, as well as knowing the activities that fulfil the needs of the assigned mission, the supporting cyberinfrastructure, and comprehending how the effects of attacks alter the course of a crisis.

The increased integration of computers and information technologies into crisis management processes has created an environment where compromising, damaging, or losing information and telecommunications infrastructure can lead to the failure of the entire crisis operation. Our expectations for the success of an operational group/unit under an active cyber attack—specifically an attack on the information and telecommunications infrastructure supporting the crisis—largely depend on understanding how a cyber attack degrades capabilities in the kinetic space. The kinetic space should be considered alongside all other infrastructure that is not related to the information and telecommunications segment.

In real actions, when a rapid response to an imminent threat is necessary, a commander may need to decide on the use of resources to neutralize that threat. The ability of commanders to select a means of responding to a disaster threat, for example, depends on the information about available resources both in the air and on the ground. Any type of resource can be useful depending on the target type. However, if at any point access to data about the systems or the management information system is lost, it will certainly impact the response. The sources of the problem can vary. If cyber attack detection systems identify certain activities on critical network equipment aimed at degrading functionality or ceasing operations, it can be concluded that a cyber attack has occurred on the information system or a part of it. One common example is the classic „DDoS" attack. Once it is established that the system is under attack, we still do not know what the ultimate target of the attack is or when it will end. All of this can significantly impact the final objective of force engagement and the achievement of the desired end state. The commander may decide to continue operations

with the resources available until the consequences of the cyber attack are resolved. From this, we can conclude that an indirect attack can be equally effective as a direct attack on the combat system itself. In both cases, the ability to counteract the source of the threat is temporarily disabled.

The previously mentioned practical example necessitates that modern crisis planning includes the need for protective measures and countermeasures against attacks on information infrastructure. Forces and resources in a crisis must be protected across all segments, as an asymmetric approach to conducting operations is pervasive, and all sources of direct threats must be thoroughly analyzed.

Currently, we have very few capabilities to assess the impact and effects of cyber incidents on the execution of operations. The analysis of the dependencies between objectives, missions, crisis tasks, and information-telecommunication resources is not common. During the operational planning process, the information network is rarely considered as an aspect from which a threat may arise. An exception occurs in crises that intentionally utilize cyberspace as a venue for risk, such as information crises. In all other cases, even if a risk is identified, it is generally deemed to be of minor importance to the outcome of the crisis and is not analyzed in detail (Grimaila & Fortson, 2007). If we consider a threat from cyberspace, it is possible to undertake certain preparations through the following steps (https://www.dnv.com/cybersecurity/cyber-insights/recognizing-the-seven-stages-of-a-cyber-attack/):

1. Assessing the dependencies between cyberinfrastructure and activities during the execution of tasks and the achievement of crisis objectives;
2. Determining the impact of cyber attacks on the crisis based on the timing and duration of the incident;
3. Analyzing and forecasting the impact of cyber threats on resources that are currently not in use;
4. Forecasting the impact of future operational branches and potential future crises.

The previously mentioned steps inherently set the requirements for the discovery and use of appropriate techniques to combat cyber threats. Here, it is essential to emphasize the importance of real-time response, as it is the only way to influence malicious cyber activity and prevent its impact on the execution of operations.

Since formal assessments of cyber risks occur during offline evaluations, they focus on the potential cyber effects against a wide range of possible threats. The effects of cyber attacks can be classified into the following categories: degradation of system characteristics, disruption of system operations, modification of system functions, user deception, unauthorized access to the system, and data interception (https://www.dnv.com/cybersecurity/cyber-insights/recognizing-the-seven-stages-of-a-cyber-attack/ ; Singh et al, 2011).

Damage analysis is an integral part of addressing the consequences of cyber attacks and, in addition to direct access, requires additional analysis and planning of preventive measures for future crises. It can be presented as a system of lessons learned. An important characteristic of assessing the impact of a given threat is its temporal nature. Time is a more significant factor than understanding the current capabilities of the information system when a cyber attack begins. It is essential to be able to anticipate threats or at least to configure the system so that vital functionalities are not compromised after an attack. Effective impact assessment involves understanding the exhibited activity, whether it is planned or based on expectations. Anticipated activity indicates what is likely to be lost in the event of a failure of defense or degradation of the part of the system that is under attack. It is also worth considering that depending on where and how the components of the information system are based, there may be an opportunity to monitor activity, that is, the effects of the attack, from the monitoring center. When the team actively working against the attack or simply monitoring it is well trained and equipped, if they timely detect the absence of the attacker, it can create an opportunity for a counterattack. If there is no capability for an effective and efficient response to the threat, it will certainly lead to an assessment of jeopardizing the entire operation and take preventive action to activate backup resources.

The challenge of assessing the impact of cyber attacks lies in the process of connecting the mission of crisis operations with the information and telecommunications infrastructure to support and

understand those relationships. An operation is viewed as a set of activities that must be carried out to accomplish the assigned task. Activities are executed using allocated resources, including the information and telecommunications infrastructure. During these activities, various types of information are exchanged, created, or utilized. Resources from the domain of information technology are allocated to users according to their needs, typically involving specific equipment that enables information exchange during the execution of combat operations.

8. Conclusion

The risk management system in modern civil and military organizations will, despite all the challenges they face, maintain a central role and significance in leadership at all levels. The automation of activities at various levels, along with the autonomy of certain combat systems, will undoubtedly contribute to making future military operations more efficient and effective. Increased precision, speed, and optimization resulting from the use of artificial intelligence should lead to crises being resolved with fewer casualties and less destruction, aligning with the international legal agenda and the ethical standards of the modern world. The cyber domain, as one of the most important sources of power in the 21st century, must ensure a secure management environment that provides decision-makers with an advantage and facilitates the timely and safe transmission of orders and essential information.

The challenge of utilizing high technologies integrated through the cyber agenda and artificial intelligence in risk management systems presents various advantages as well as certain uncertainties. The positive effects are reflected in the acceleration of the decision-making process, optimization of activities through reduced resource expenditure, and ultimately a shorter duration of crises. On the other hand, the uncertainties regarding the development vectors of artificial intelligence, particularly in terms of autonomy and the assumption of responsibilities currently exclusive to humans, will significantly shape future command systems. The dispersal of power among various actors, including non-state ones, will lead to a changed distribution of power from the national level, through the regional, to the global level.

The modern concept of management will primarily influence the enhancement of national security systems. As a rule, most malicious activities will first emerge from cyberspace and then from other dimensions. The superiority of cyberspace provides an advantage to risk management systems about contemporary risk and threat challenges, and the development of intelligence should facilitate this. Future leaders need to study, implement, and utilize modern technologies, as only then can they provide timely responses to contemporary risk and threat challenges through command systems. The most significant challenge is to achieve synchronization and correlation between natural and artificial intelligence. This means that humans must always be the ones making the final decisions, while also delegating tasks and responsibilities to artificial intelligence that do not compromise the command integrity of humans.

Acknowledgements: The authors acknowledge the use of Grammarly Premium and ChatGPT 4.0 in the process of translating and improving the clarity and quality of the English language in this manuscript. The AI tools were used to assist in language enhancement but were not involved in the development of the scientific content. The authors take full responsibility for the originality, validity, and integrity of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Akter, R., Roy, T., & Aktar, R. (2023). The Challenges of Women in Post-disaster Health Management: A Study in Khulna District. International Journal of Disaster Risk Management, 5(1), 51-66.
2. Aleksandrina, M., Budiarti, D., Yu, Z., Pasha, F., & Shaw, R. (2019). Governmental Incentivization for SMEs' Engagement in Disaster Resilience in Southeast Asia. *International Journal of Disaster Risk Management, 1*(1), 32-50.
3. Aljundi, I., Rawashdeh, M., Al-Fayoumi, M., Al-Badarneh, A., & Abu Al-Haija, Q. (2023). Protecting critical national infrastructures: An overview of cyber attacks and countermeasures.
4. Al-ramlawi, A., El-Mougher, M., & Al-Agha, M. (2020). The Role of Al-Shifa Medical Complex Administration in Evacuation & Sheltering Planning. *International Journal of Disaster Risk Management, 2*(2), 19-36.
5. Arreguín-Toft, I. (2001). How the weak win wars: A theory of asymmetric conflict. *International Security, 26*(1), 93–128. http://www.jstor.org/stable/3092079.
6. Australian Strategic Policy Institute. (2024, March 22). *The impact of artificial intelligence on cyber offence and defence*. Retrieved March 22, 2024, from https://www.aspistrategist.org.au/the-impact-of-artificial-intelligence-on-cyber-offence-and-defence/.
7. Bulletin of the Atomic Scientists. (2021, April). *Worried about the autonomous weapons of the future? Look at what's already gone wrong*. Retrieved March 17, 2024, from https://thebulletin.org/2021/04/worried-about-the-autonomous-weapons-of-the-future-look-at-whats-already-gone-wrong/.
8. Center for Strategic and International Studies (CSIS). (n.d.). *Cyber operations during the Russo-Ukrainian war*. Retrieved March 22, 2024, from https://www.csis.org/analysis/cyber-operations-during-russo-ukrainian-war.
9. Command and Control: Future C2 Complexity. (n.d.). Retrieved March 22, 2024, from https://assets.publishing.service.gov.uk/media/65c4dde79c5b7f0012951b35/Command_Control_Future_C2_Complexity.pdf.
10. Cruz, R. D. D., & Ormilla, R. C. G. (2022). Disaster Risk Reduction Management Implementation in the Public Elementary Schools of the Department of Education, Philippines. International Journal of Disaster Risk Management, 4(2), 1-15.
11. Cvetković, V. & Šišović, V. (2023). Capacity building in Serbia for disaster and climate risk education. Disaster and Climate Risk Education Insights from Knowledge to Action, edited by: Ayse Yildiz and Rajib Shaw, book series Disaster Risk Reduction, Springer Nature Singapore Pte Ltd., 152 Beach Road.
12. Cvetković, V. (2019). Risk Perception of Building Fires in Belgrade. International Journal of Disaster Risk Management, 1(1), 81-91.
13. Cvetković, V. (2024). Empowering the Regional Network of Experts for Disaster Risk Management in the Western Balkans by the Scientific-Professional Society for Disaster Risk Management. International Scientific and Practical Conference: "International Experience in Emergency Risk Management" in Moscow, Russia.
14. Cvetković, V. M., Tanasić, J., Ocal, A., Kešetović, Ž., Nikolić, N., & Dragašević, A. (2021). Capacity Development of Local Self-Governments for Disaster Risk Management. *International Journal of Environmental Research and Public Health, 18*(19), 10406.
15. Cvetković, V. M., & Šišović, V. (2024). Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts. Sustainability, 16(7), 2620.
16. Cvetković, V. M., Renner, R., Aleksova, B., & Lukić, T. (2024). Geospatial and Temporal Patterns of Natural and Man-Made (Technological) Disasters (1900–2024): Insights from Different Socio-Economic and Demographic Perspectives. Applied Sciences, 14(18), 8129.
17. Cvetkovic, V. M., & Martinović, J. (2020). Innovative solutions for flood risk management. International Journal of Disaster Risk Management, 2(2), 71-100.

18. Cvetković, V., Andrić, K., Ivanov, A. (2023). Comparative Analysis of Disaster Risk Management Systems in Germany, USA, Russia And China. Macedonia. International academic conference, Temporary security ripples or new world architecture of security, Dojran, N. Macedonia, September 4-7 2023.
19. Cvetković, V., Čvorović, M., & Beriša, H. (2023a). The Gender Dimension of Vulnerability in Disaster Caused by the Corona Virus (Covid-19). NBP, 28(2), 32-54.
20. Cvetković, V., Sudar, S., Ivanov, A. (2024). Harmonization of Soft Power and Institutional Skills: Montenegro's Path to Accession to the European Union in the Environmental Sector. International Journal of Disaster Risk Management, 6(1), 41–74.
21. DNV. (2024, March 22). *Recognizing the seven stages of a cyber attack*. Retrieved March 22, 2024, from https://www.dnv.com/cybersecurity/cyber-insights/recognizing-the-seven-stages-of-a-cyber-attack/.
22. *Doktrina Kopnene vojske* [Doctrine of the Army]. (2012). Medija centar "Odbrana", Beograd.
23. El-Mougher, M. M. (2022). Level of coordination between the humanitarian and governmental organizations in Gaza Strip and its impact on the humanitarian interventions to the Internally Displaced People (IDPs) following May escalation 2021. International Journal of Disaster Risk Management, 4(2), 15-45.
24. Fuentes, M. V. (2024, March 22). *The future of cyber warfare*. *Medium*. Retrieved March 22, 2024, from https://medium.com/@mikevfuentes/the-future-of-cyber-warfare-1ad1a9a66d0c.
25. Galán, C. (2018). Amenazas híbridas. Nuevas herramientas para viejas aspiraciones. *Elcano Documentos de Trabajo, 20/2018*, 3.
26. Gentile, G., Shurkin, M., Evans, A. T., Grisé, M., Hvizda, M., & Jensen, R. (2021). *A history of the Third Offset, 2014–2018*. RAND Corporation. https://www.rand.org/pubs/research_reports/RRA454-1.html.
27. Goyal, N. (2019). Disaster governance and community resilience: The law and the role of SDMAs. International Journal of Disaster Risk Management, 1(2), 61-75.
28. Grimaila, M. R., & Fortson, L. W. (2007). Towards an information asset-based defensive cyber damage assessment process. In *Proceedings IEEE Symposium on Computational Intelligence in Security and Defense Applications (CISDA 2007)*.
29. Grozdanić, G., Cvetković, V. (2024). Exploring Multifaceted Factors Influencing Community Resilience to Earthquake-Induced Geohazards: Insights from Montenegro. Belgrade: Scientific-professional Society For Disaster Risk Management.
30. IEMED. (2024, March 22). *Artificial intelligence, machine learning, and cyber command as a tool of war: A new method in the Mediterranean battlefield*. Retrieved March 22, 2024, from https://www.iemed.org/publication/artificial-intelligence-machine-learning-and-cyber-command-as-a-tool-of-war-a-new-method-in-the-mediterranean-battlefield/.
31. Johnson, J. (2019). Artificial intelligence & future warfare: Implications for international security. *Defense & Security Analysis, 35*, 1-23. https://doi.org/10.1080/14751798.2019.1600800.
32. Johnson, J. (2023). Automating the OODA loop in the age of intelligent machines: Reaffirming the role of humans in command-and-control decision-making in the digital age. *Defence Studies, 23*(1), 43-67. https://doi.org/10.1080/14702436.2022.2102486.
33. Jovičić, R., Gostimirović, L., & Milašinović, S. (2024). Use of New Technologies in the Field of Protection and Rescue During Disasters. *International Journal of Disaster Risk Management*, *6*(1), 111–122.
34. Kachanov, S. (2021). Methodology for Building Automated Systems for Monitoring Engineering (Load-Bearing) Structures, and Natural Hazards to Ensure Comprehensive Safety of Buildings and Constructions. International Journal of Disaster Risk Management (IJDRM), 3(2), 1-10.
35. Kaur, R., Gabrijelčič, D., & Klobučar, T. (2023). Artificial intelligence for cybersecurity: Literature review and future research directions. *Information Fusion, 97*, 101804. https://doi.org/10.1016/j.inffus.2023.101804.

36. LibreTexts. (2024, March 22). *Types of attacks*. Retrieved March 22, 2024, from https://eng.libretexts.org/Courses/Delta_College/Information_Security/01%3A_Information_Security_Defined/1.4_Attacks_-_Types_of_Attacks.
37. Manjak, M. M., & Miletić, S. M. (2011). Predlog koncepta komandno-informacionog sistema brigade KoV Vojske Srbije. *Vojnotehnički glasnik, 59*(2), 78-93. https://doi.org/10.5937/vojtehg1102078M.
38. Mayer, M. (2023). Trusting machine intelligence: Artificial intelligence and human-autonomy teaming in military operations. *Defense & Security Analysis, 39*(4), 521-538. https://doi.org/10.1080/14751798.2023.2264070.
39. Meerveld, H. W., Lindelauf, R. H. A., Postma, E. O., et al. (2023). The irresponsibility of not using AI in the military. *Ethics and Information Technology, 25*, 14. https://doi.org/10.1007/s10676-023-09683-0.
40. Military Africa. (2023, November). Artificial intelligence in the military. Retrieved March 22, 2024, from https://www.military.africa/2023/11/artificial-intelligence-in-the-military/.
41. Musman, S., Temin, A., Tanner, M., Fox, D., & Pridemore, B. (2010). Evaluating the impact of cyber attacks on missions.
42. Nedejkovic, S. (2015). *Evropska strategija bezbednosti i sajber pretnje - znala za Srbiju*. Beograd: Vojno delo. https://doi.org/10.5937/vojdelo.
43. Nikolić, N., Cvetković, V., Ivanov, A. (2023). Human resource management in environmental security. Belgrade: Scientific-Professional Society for Disaster Risk Management.
44. Ostojić, M., Karavidic, Z., & Projovic, D. (2017). Uticaj doktrine i koncepata na razvoj sposobnosti Vojske Srbije. *Vojno delo, 69*, 321-340. https://doi.org/10.5937/vojdelo17083210.
45. Payne, K. (2018). Artificial intelligence: A revolution in strategic affairs? Survival, 60(5), 7-32. https://doi.org/10.1080/00396338.2018.1518374.
46. Pirani Risk. (2024, March 16). *Artificial intelligence to combat cyber attacks*. Retrieved March 16, 2024, from https://www.piranirisk.com/blog/artificial-intelligence-to-combat-cyber-attacks.
47. RAND Corporation. (2022, November). *Ukraine's lessons for the future of hybrid warfare*. Retrieved March 16, 2024, from https://www.rand.org/pubs/commentary/2022/11/ukraines-lessons-for-the-future-of-hybrid-warfare.html.
48. RAND Corporation. (n.d.). *Reprints: RP223*. Retrieved March 22, 2024, from https://www.rand.org/pubs/reprints/RP223.html.
49. Sanz-Caballero, S. (2023). The concepts and laws applicable to hybrid threats, with a special focus on Europe. *Humanities and Social Sciences Communications, 10*, 360. https://doi.org/10.1057/s41599-023-01864-y.
50. Scharre, P. (2016). Assessing and managing the risks of autonomous weapons. In *Autonomous Weapons and Operational Risk: Ethical Autonomy Project* (pp. 49–52). Center for a New American Security. http://www.jstor.org/stable/resrep06321.12.
51. Schraagen, J. M. (2023). Responsible use of AI in military systems: Prospects and challenges. *Ergonomics, 66*, 10.1080/00140139.2023.2278394.
52. SDI. (2024). The most useful military applications of AI. Retrieved March 22, 2024, from https://sdi.ai/blog/the-most-useful-military-applications-of-ai/#:~:text=Generative%20AI's%20analysis%2C%20scenario%20generation,to%20help%20predict%20future%20attacks.
53. Singh, S., Singh, M., & Singh, D. (2011). A survey on network security and attack defense mechanism for wireless sensor networks. *1*.
54. U.S. Department of Defense. (n.d.). *Joint Publication (JP) 3-12, Joint Cyberspace Operations*. Retrieved March 21, 2024, from https://irp.fas.org/doddir/dod/jp3_12.pdf.
55. U.S. Government Accountability Office (GAO). (n.d.). *U.S. less prepared to fight cybercrime than it could be*. Retrieved March 22, 2024, from https://www.gao.gov/blog/u.s.-less-prepared-fight-cybercrime-it-could-be.

56. Usai, A., Fiano, F., Messeni Petruzzelli, A., Paoloni, P., Farina Briamonte, M., & Orlando, B. (2021). Unveiling the impact of the adoption of digital technologies on firms' innovation performance. *Journal of Business Research, 133*, 327-336.
57. Vuletić, D. (2017). *Upotreba sajber prostora u kontekstu hibridnog ratovanja*. Beograd: Vojno delo. https://doi.org/10.5937/vojdelo1707308V.
58. Weick, K. E., & Sutcliffe, K. M. (2015). *Managing the unexpected: Sustained performance in a complex world* (3rd ed.). Jossey-Bass.



Editor-in-Chief

Prof. Dr. Vladimir M. Cvetković

Biography

Prof. Dr. Vladimir M. Cvetković is recognized as a leading expert in Disaster Risk Management, with a focus on Risk Reduction, Preparedness, Response, and Recovery. He distinguishes himself as an esteemed Associate Professor specializing in Disaster Risk Management at the University of Belgrade, Faculty of Security, Department for Disaster Management and Environmental Security (Univerzitet u Beogradu, Fakultet bezbednosti). He (visiting professor) is a member of the Safety and Disaster Studies (SDS) working group at the Montanuniversität Leoben (https://www.sds-uni-leoben.at/arbeitsgruppe-sds/). With an illustrious career spanning over 15 years, he has dedicated his scholarly efforts to advancing the understanding and management of disasters. Dr. Cvetković's academic contributions are extensive, comprising a rich portfolio of over 300 research papers and 30 scientific monographs.

As a visionary leader in his field, Prof. Dr. Cvetković is renowned for founding significant initiatives such as the Scientific Professional Society for Disaster Risk Management in Serbia and the esteemed International Institute for Disaster Research. He also holds the distinguished position of Editor-in-Chief of the International Journal of Disaster Risk Management, exemplifying his influential role in shaping discourse and fostering collaboration within the academic community.

His doctoral thesis, titled "Citizens preparedness for responding to natural disaster caused by flood in Serbia," underscores his commitment to addressing real-world challenges in disaster management. Educationally, Prof. Dr. Cvetković's journey is marked by excellence. He completed his Undergraduate Studies in Criminalistic at the Academy of Criminal Investigation and Police Studies, Belgrade, graduating with a perfect GPA in 2010. Continuing his academic pursuit, he attained Postgraduate Studies in Criminalistic (2010-2012) and earned his PhD in Security, specializing in disaster risk management, from the University of Belgrade, Faculty of Security Studies (2012-2015).

Throughout his distinguished academic career, Prof. Dr. Cvetković has held various esteemed positions, including Assistant Professor at the University of Belgrade, Faculty of Security Studies (2017-present), where he imparts knowledge on disaster risk management and related subjects. Prior to this, he served as a Professor Assistant at the Academy of Criminal Investigation and Police Studies, Belgrade (2013-2017), and as a Teaching Associate (2011-2013) at the same institution, where he influenced and inspired future generations of scholars and practitioners.

Prof. Dr. Cvetković's impact extends beyond academia, as evidenced by his prolific research output and engagement in scholarly activities. He has reviewed over 200 scientific papers in national and international journals and proceedings, significantly advancing knowledge in his field. Additionally, he has actively participated in over 100 national and international scientific conferences, further solidifying his reputation as a thought leader and expert in disaster risk management.

His exemplary contributions have not gone unnoticed, as Prof. Dr. Cvetković has been honored with numerous awards and accolades throughout his career. Notably, he received the prestigious

Danubius Young Scientist Award for 2017, recognizing his extraordinary achievements in scientific activity and output. Furthermore, he has been the recipient of scholarships and awards for academic excellence, underscoring his dedication and scholarly prowess.

Prof. Dr. Vladimir M. Cvetković's multifaceted contributions, spanning academia, research, and leadership, reflect his unwavering commitment to advancing the field of disaster risk management. His pioneering initiatives and scholarly endeavors continue to shape discourse and drive innovation in addressing complex challenges posed by disasters globally.

MONTAN UNIVERSITÄT LEOBEN

SDS SAFETY AND DISASTER STUDIES

PANK-Postgraduate, extra occupational master study, 4 semesters
PANK-Academic, extra occupational expert training, 3 semesters



■ interdisciplinary ■ research-guided ■ practice-oriented

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

504
614.8.069

International Journal of Disaster Risk Management/Editor-in-Chief Vladimir M. Cvetković. - Vol. 1, no. 1 (2019) - Beograd: Scientific-Professional Society for Disaster Risk Management, 2019 - (Belgrade: Neven). - 24 cm