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DISASTER RISK REDUCTION IN THE MUNICIPALITY OF LEZHË. SEISMIC RISK AS PART OF A MULTI-RISK ANALYSIS

Merita Guri [(1)], Endri Duro [(2)]

[(1)] *Lecturer, POLIS University, merita_guri@universitetipolis.edu.al*
[(2)] *Assistant Lecturer, POLIS University, endri_duro@universitetipolis.edu.al*

Abstract

Disaster Risk Reduction (DRR) and community resilience is considered as a global priority. For several decades the focus has been on changing the approach from emergency response towards prevention strategies. Within this approach local authorities have a fundamental role in reducing such disasters as they represent the link between the community and other stakeholders; from central authorities to engineers, planners and disaster specialists. As such the quality, efficiency and the way the risk information is provided to such authorities is of the utmost importance.

Albania is located in one of the most active areas from the seismic point of view and therefore is an earthquake-prone country. The latest seismic event was the 6.4 Magnitude earthquake of November 2019 in Durrës which caused several fatalities and a considerable amount of economic damage, whose impact is still evident nowadays, three years after the event, with the recovery phase still ongoing. Such consequences clearly reflect the low levels of resilience and preparedness urban and non-urban systems in Albania unfortunately have. The aim of this paper, is the evaluation of seismic risk in semi-quantitative terms based on indices, within a wider multi-risk analysis including also flooding, fire, wind, snow etc. for one of the most strategic municipalities of Albania, Lezhë. The analysis is done by taking into consideration several aspects of vulnerability; physical, social, economic, environmental and cultural. The results of such analysis are aimed to be used for several decision-making processes by the local authorities as part of improving the strategies for Disaster Risk Reduction (DRR) and Disaster Risk Management (DRM).

Keywords: decision-making, disaster, earthquake, seismic risk, vulnerability,

1. Introduction

Due to a combination of several external and internal factors, Albania is a country prone to natural disasters including mainly flooding and seismic events. The Mw 6.4 earthquake of November 26, 2019 that struck the city of Durrës, at the Adriatic coast clearly showed several issues amongst which the lack of proper coordination and disaster management. This event brought to the attention of local and central authorities the need for preparedness and special attention to civil protection and disaster risk reduction [1].

Disaster Risk Reduction (DRR) and community resilience is a global priority. It is expected that local authorities play a central role in developing strategies and policies to achieve resilience. The importance of local authorities is clearly emphasized in the SENDAI Framework, in which the need for a focused action in understanding disaster risk, the strengthening disaster governance, the investment in DRR for resilience and the enhancement disaster preparedness are all developed around not only on a national but specifically on a local level [2].

The Lezhë municipality, located in the western part of Albania, consists of 10 administrative units with 2 urban areas (Lezhë and Shëngjin) and a total of 65 rural areas with the total area of approximately 508.9km^2. Due to its location, Lezhë is considered as one of the most strategic municipalities in Albania, having great potential mainly in tourism. Lezhë is a hazard prone area due to its geographic location, natural and anthropogenic features. Floods are the main hazard for this municipality due to the flow from the two main rivers Mat and Drin river, flash floods and also coastal flooding. Such events are

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often due to the climate change. Seismic events are also a constant hazard since the entire country is located near several faults and many historical events were registered in the 20th century. In addition to floods and earthquakes, other hazards like landslides, rock fall, wildfires and snow are also present [3].

Taking into consideration the diversity of hazards a research study was developed to conduct a multi-risk analysis and improve the risk information and perception and help the municipality to improve policies in terms of decision-making and DRR. Such methodology is also aimed to serve as a model for other municipalities in Albania. From the methodological point of view, the research applies an integrated and participatory approach, since participatory planning is considered as an optimal method that helps in the identification of the problem and also aims at training not only the local authorities, but also the community. The focus of this paper is on the analysis of seismic risk as part of a broader multi-risk assessment study.

2. Multi-risk analysis and methodological approach

According to the terminology related to Disaster Risk Reduction, risk represents a "...*combination of the probability of an event and its negative consequences*" [4]. Mathematically the risk (R) can be expressed as a product of three components:

$$R = H \times V \times E \tag{1}$$

The first component is hazard (H), which is based on historical and instrumented data of previous earthquakes in order to determine the severity of such an event. Seismic hazard is characterized mainly in terms of return period, magnitude, intensity, probability of exceedance etc.

Vulnerability (V) and Exposure (E) are components of the risk which determine the level of impact which a hazardous event might have in a built environment. The former represents

"The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard." [4]

while the latter represent

"People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses." [4]

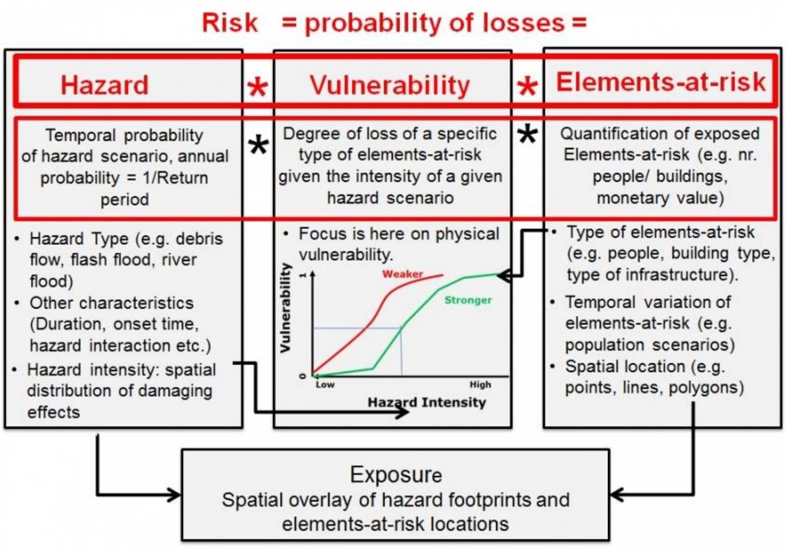

Figure 1. Schematic representation of risk [4]

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From the methodological point of view, the approach for assessing seismic risk, includes the following activities:

1. Site visits
2. Interviews with stakeholders e.g. local community, experts, organizations etc.
3. Participatory hazard maps
4. Focus on thematic groups based on the hazard (in this case earthquakes), and
5. Presenting risk assessment results using the GIS platform

2.1 Indicator- Based Approach (IBA)

A literature review revealed previous studies provide a variety of approaches and methodologies that can be used for risk assessment ranging from qualitative deterministic methodologies to more advanced probabilistic approaches. For the research purposes, the proposed methodology corresponds to a semi-quantitative approach. According to the approach, the overall risk is divided into several components, and for each component a number of indicators are selected, and subsequently standardized within a specific range based on the provided data (qualitative or quantitative) using various analysis methods and then weighted to determine the relative importance of each parameter.

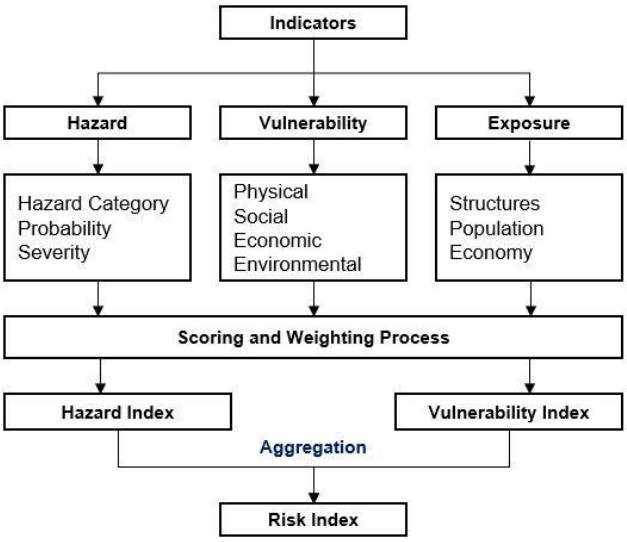

Figure 2. An overview of the Risk Indicator Based Approach (IBA)

Although this method is not purely quantitative it has several advantages. Firstly, it allows for risk to be evaluated in large areas, or in areas that have restricted or limited data. Secondly, the method gives a possibility to perform a holistic risk assessment by combining components of different nature (physical, social, economic, environmental etc). A considerable number of research studies and applied projects [5], [6], [7], [8] have shown that the indices can be easily combined with Spatial Multi-Criteria Evaluation (SMCE) to map the information. In mapping the information from the risk point of view the use of a risk matrix in addition to IBA can be helpful to combine and categorize the levels of risk based on its components.

2.2 Selected Indicators

For the multi-risk analysis, a total of 29 indicators were selected and analysed. Out of these, 6 indicators characterize the hazard, 12 indicators characterize the exposure and 11 indicators are used to

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characterize vulnerability. Based on the analysis, following the aforementioned methodological approach each of the indicators is standardized and for the purpose of this research the range of standardized values is from 0 to 4, where 0 represents the minimum (best) value based on the risk component and 4 the maximum (worst) value of the risk and its components. As part of a multi-risk analysis some indicators may be relevant for a specific hazard, and might be not applicable (n/a) for other hazards.

Table 1 – Summary of the indicators

HAZARD	EXPOSURE	VULNERABILITY
Normal Frequency	Number of Objects	The dependency on social help
Fatality Frequency	Infrastructure	Lonely elderly people
Duration of the Event	Service Objects	Age of population
Probability of Occurrence	Industrial Area in the Hazard Area	People with disabilities
Spatial Distribution (Hazard Area)	Population	Mean distance from municipality
Hazard Exposure	Natural Monuments	Mean distance from administrative unit
	Protected Areas	Services
	Forest Area	Percentage of hiring in service
	Agricultural Area	Distance to work outside residential unit
	Educational Institutions	Percentage of youngsters
	Cultural Monuments	Lack of sanitary systems in the family
	Buildings with cultural Relevance (ex. religious, museums etc.)	Working on agricultural systems

3. Seismic Risk Analysis

3.1 Seismic Hazard

The seismic hazard for Lezhë municipality is based on previous research studies [9] and is focused on the determination of peak ground acceleration on base rock for a return period of 475 years with a probability of exceedance 10% in 50 years. [9] gives the spatial distribution of PGA for the entire country (as seen in Fig. 3) and an analysis is done for all administrative units of Lezhë municipality with values of peak ground acceleration given in Table 2. The values of PGA show that Lezhë is characterized by a high level of hazard with values of PGA varying from 0.208g up to 0.373g which can potentially amplify due to soft soil deposits.

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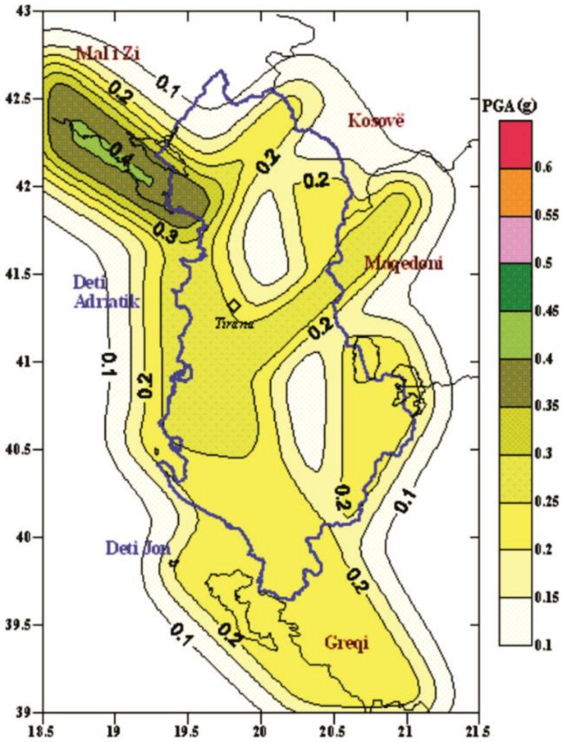

Figure 3. PGA map for Albania. RP= 475 years with probability of exceedance 10% in 50years [9]

Table 1 – Values of PGA for the administrative units in Lezhë Municipality

Administrative Units	PGA RP=475years 10%/50 years
Lezha	0.338
Shëngjin	0.338
Zejmen	0.238
Shënkoll	0.285
Balldren	0.338
Kallmet	0.274
Blinisht	0.373
Dajç	0.373
Ungrej	0.208
Kolsh	0.274

3.2 Aspects of Vulnerability and Exposure

The analysis of the vulnerability was done in a holistic way. The following four aspects of vulnerability were taken into consideration in this study:

1. Physical Vulnerability- physical aspects of buildings, such as age, structural typology, determination of buildings in liquefaction areas, informal settlement, critical infrastructure,
2. Social Vulnerability- Administrative Units having a high percentage of senior people (age 65 or above) percentage of people with disabilities and the part of community having the need of social support

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3. Economic Vulnerability- businesses located in buildings older than 30 years, businesses located in informal settlements and areas prone to liquefaction, tourism facilities were recorded,
4. Environmental Vulnerability- was not applied for the case of seismic risk
5. Cultural Vulnerability- Monuments located in areas prone to liquefaction were recorded and classified based on the soil type and the values of PGA in these areas

For the determination of the physical vulnerability in Lezhë municipality a thorough analysis of building typologies was done based on the building age and structural typology:

In terms of the building age the buildings constructed from 1945 up to 1960 were mostly low-rise masonry buildings, with only few buildings using concrete or steel.

Figure 4. Examples of buildings built in the 1945-1960 period

From 1960 up to 1979 some changes were made due to some important seismic events. The quality of materials improved, some additional structural elements were added to the masonry buildings. Prefabricated buildings were added as a new typology to be used for residential and industrial use.

Figure 5. Examples of buildings built in the 1960-1979 period

The 1979-1990 period was characterized by additional improvement in materials and construction technologies which resulted in improved building response to seismic actions. Vertical and horizontal confining elements were added in masonry buildings.

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Figure 6. Examples of buildings built in the 1979-1990 period

During the period, from 1990-2000 a considerable number of high-rise buildings were built and reinforced concrete technology was more widely used than masonry construction.

Figure 7. Examples of buildings built in the 1990-2000 period

From 2000 up to present important developments were made in construction technologies and the way buildings were designed taking into account the need for the implementation of Eurocodes. RC frame systems, shear walls and dual systems were widely used to construct high-rise buildings.

Figure 8. Examples of buildings built after 2000

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The buildings in Lezhë municipality can be classified into four main typologies:

1. Unreinforced masonry structures located mainly in "Besëlidhja" and "Grumbullimi" areas of the city, and also along Mother Teresa Boulevard in Shëngjin,
2. Reinforced masonry buildings with horizontal and vertical elements located mainly in the same areas as the unreinforced masonry structures,
3. Prefabricated concrete buildings located mainly along the Frang Bardhi street, and
4. Reinforced concrete buildings (frame, shear walls, dual systems, inverted pendulum) located along Franz Josef Strauss Street in "Besëlidhja" area, and also between "Qendër Plazh" and "Qendër Shëngjin".

A map of Lezhë municipality in terms of vulnerability and exposure for seismic action is shown in Figure 9.

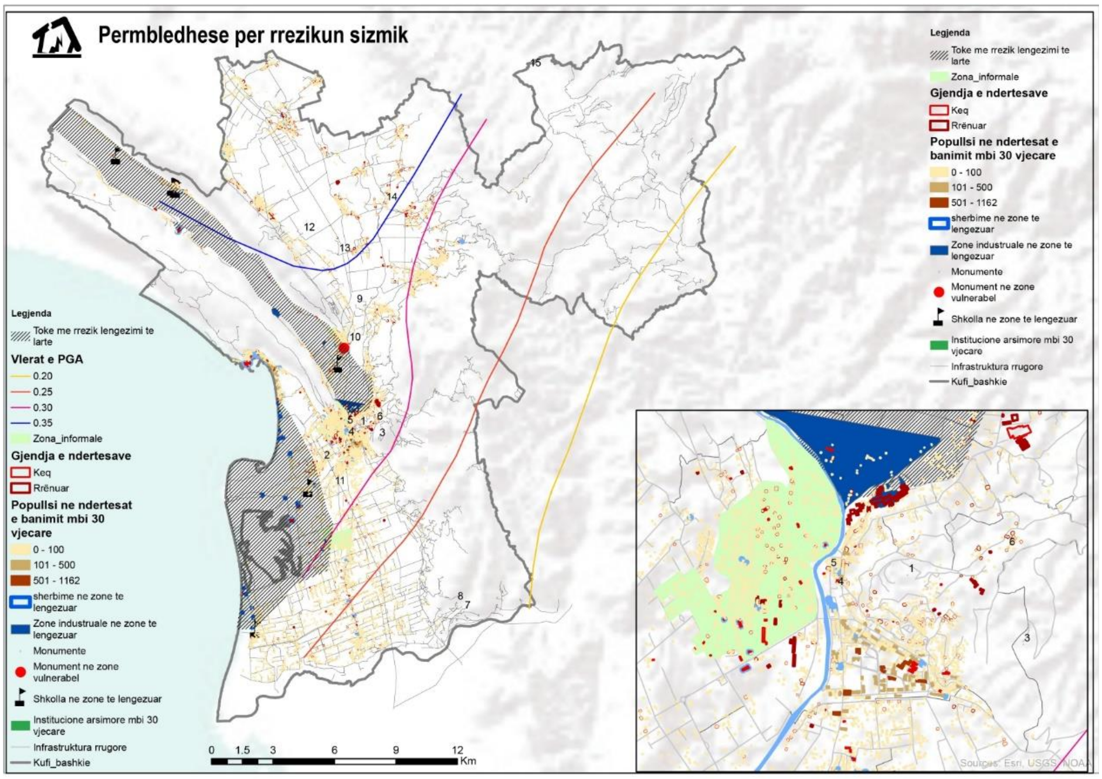

Figure 9. The vulnerability and exposure map for the Lezhë municipality [10]

3.3 Seismic Risk Index Evaluation

Based on the aforementioned risk indicators an indexing process was performed for the multi-risk approach. The results are summarized in Tables 2 to 4 in terms of seismic hazard, exposure and vulnerability. The analysis was performed considering buildings older than 30 years, soil liquefaction, and buildings in informal settlements. The final representative value of each risk element identified in Section 2 was generated as a mean value for all corresponding indicators.

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Table 2 – Hazard Index for Seismic Event (adapted from Co-Plan, 2020)

	SEISMIC HAZARD (probability/ frequency)						
	Normal Frequency	Fatality Frequency	Duration	Probability of Occurrence	Spatial Distribution	Hazard Exposure	
	1.00	3.00	3.00	1.00	1.00	3.00	2.00
Damage of buildings > 30 years	1.00	3.00	3.00	1.00	1.00	3.00	
Liquefaction	1.00	3.00	3.00	1.00	1.00	3.00	
Damages in informal settlements	1.00	3.00	3.00	1.00	1.00	3.00	

Table 3 – Vulnerability Index for Seismic Event (adapted from)

	SEISMIC VULNERABILITY												
	The dependency on social help	Lonely elderly people	Age of population	Persons with disabilities	Mean distance from municipality	Mean distance from administrative unit	Services	Employment rate	Distance to work outside residential unit	Percentage of youth population	Lack of sanitary systems in housed apartment	Agricultural workers	
	1.00	1.00	1.67	1.33	1.67	1.00							1.28
Damage of buildings > 30 years	1.00	1.00	2.00	1.00	2.00	1.00	n/a	n/a	n/a	n/a	n/a	n/a	
Liquefaction	1.00	1.00	1.00	2.00	2.00	1.00	n/a	n/a	n/a	n/a	n/a	n/a	
Damages in informal settlements	1.00	1.00	2.00	1.00	1.00	1.00	n/a	n/a	n/a	n/a	n/a	n/a	

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Table 4 – Exposure Index for Seismic Event (adapted from [10])

THE HAZARD	EXPOSURE												
	Number of Objects	Infrastructure	Service Objects	Industrial Area in the Hazard Area	Population	Natural Monuments	Protected Areas	Forest Area	Agricultural Area	Educational Institutions	Cultural Monuments	Building with cultural relevance	
SEISMIC	1.67	0.33	1.67	1.00	1.67	-	0.33	-	0.67	1.67	1.67	2.00	1.06
Damage of buildings > 30 years	2.00	-	2.00	1.00	2.00	-	-	-	-	3.00	3.00	2.00	
Liquefaction	2.00	1.00	2.00	-	2.00	-	1.00	-	2.00	1.00	1.00	2.00	
Damages in informal areas	1.00	-	1.00	2.00	1.00	-	-	-	-	1.00	1.00	1.00	

The final risk index was generated by multiplying the results of each risk element as shown in Equation (1) and for the case of Lezhë corresponds to a value of **2.7** which corresponds to moderate levels of risk. Table 5 presents a summary of the indices for each element of risk and, for each type of hazard, to illustrate how seismic risk is positioned among other hazards.

Table 5 – Risk Index for different Hazards (adapted from [10])

Event	Hazard	Exposure	Vulnerability	Risk
Flooding	1.50	1.28	1.79	3.43
Geo-Hazards	1.67	0.79	1.83	2.42
Earthquake	2.00	1.06	1.28	2.7
Meteorological	2.17	0.92	2.06	4.08
Wildfire	2.17	2.33	1.83	4.63
Pandemic	2.60	0.58	1.90	2.88
Climate Change	1.92	1.17	1.51	3.37

4. Conclusions

The seismic risk of Lezhë municipality was assessed as a part of multi-risk assessment study for decision-making purposes showed that the municipality has moderate level of risk due to a combination of moderate hazard levels with low to moderate exposure and vulnerability. Compared to other hazardous events, seismic risk index has the second lowest value, while more frequent events like wildfires and flooding have almost a double value compared to risk. A risk analysis presented in this study could serve as a starting point for detailed risk assessment which would take into consideration several factors like construction technology, building design codes, informal settlements, and other planning aspects. The results might reveal higher levels of seismic risk that require major mitigation measures.

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