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SEISMIC RISK IN THE DISTRICT/MUNICIPALITY OF DURRËS

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Abstract

After the seismic events of 2019, one of the first difficulties encountered was finding and focusing attention on the most damaged areas. It is understood that the aid of the affected population was forthcoming, but the impact of the panic and the overall chaotic circumstances left little opportunity to focus proper attention on the areas with greater damage. A document with analysis, findings and conclusions that showed in advance the areas with the highest risk and their treatment in the territory was missing. By trying to evaluate every clarifying and helpful element in damage assessment even in disaster situations, the consequences that occurred, their analysis and interpretation take on significant importance in risk assessment. This paper is focused at two main topics:

1-) Through the assessment of the seismic risk and all its affecting factors (hazard, exposure and vulnerability) to compare the results of the assessment with the results obtained based on the preliminary assessments carried out after the earthquake of 26 November and presented in the PDNA document;

2-) To establish a procedure which can be used for risk assessment on a similar scale for other municipalities/districts of the country.

This paper will not only highlight the strong and weak points for the territory of Durrës, but will give useful instructions in using the proposed methodology in other territories, without waiting for the next seismic event with possible damaging consequences.

Keywords: seismic risk, 26 November Earthquake, PDNA document, RA methodology

1. Introduction

According to the Albanian Institute of Geosciences [1], on 26th November 2019 at 03:54 local time, a devastating earthquake, with a magnitude of 6.3 on the Richter scale at a depth of 38 km, hit the country. The epicentre was about 16km from Durrës and about 35km from Tirana. As a result of the disaster, a total of 202,291 people were affected in the country, 47,263 directly, and 155,029 indirectly. The earthquake caused 51 fatalities and injured at least 913 people. Moreover, up to 17,000 people were displaced due to the loss of their homes. Overall, first responders rescued 48 people from collapsed houses. [2]. The earthquake caused extensive damage in 11 municipalities, including the two most populous, urbanized and developed municipalities (Tirana and Durrës). The worst affected municipalities were: Durrës, Tirana, Shijak, Kruja, Kamza, Kavaja, Kurbin and Lezha. Based on the PDNA report, the total effect of the disaster in the 11 municipalities amounts to 985.1 million EUR (121.21 billion ALL), of which 843.9 million EUR (103.84 billion ALL) represents the value of destroyed physical assets and 141.2 million EUR (17.37 billion ALL) refer to losses.

A similar earthquake has happened in Durrës in December 1926 [3], with a magnitude of 6.2. This shock destroyed and damaged heavily many buildings in Durrës, Kavaja and Shijak towns and surrounding villages. Many good buildings of the town suffered heavy damage; concrete buildings suffered only slight damage. In Kavaja all houses were damaged and all minarets of mosques were cut off. Based on [3] earthquakes with a magnitude of M=6.5 have a return period of 93.9 years, which is confirmed by the earthquake of 26 November 2019.

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Directly after the earthquake, a process of rapid assessment started from different team of experts, who filled out a form with a brief description of the building, its damages and the damage scale of the building (DS1÷DS5). After this process, a process of detailed assessment and retrofitting started for buildings classified with a damage scale DS4 and DS5, while for the other buildings with damage scale DS1÷DS3 the government compensated the inhabitants with a specific value based on the damage scale of the building.

This paper will be focused on risk assessment from the 26 November Earthquake, using the Event Based Method from the OpenQuake engine, and establishing a procedure which can be used for risk assessment in the future.

2. Risk Drivers

Three main risk drivers must be defined to conduct risk assessment: Hazard model (for event-based method – earthquake rapture file); Exposure model; Vulnerability model.

2.1 Hazard

The earthquake rapture file is taken from EFEHR [4]. The data on the earthquake scenario considered are given hereinafter.

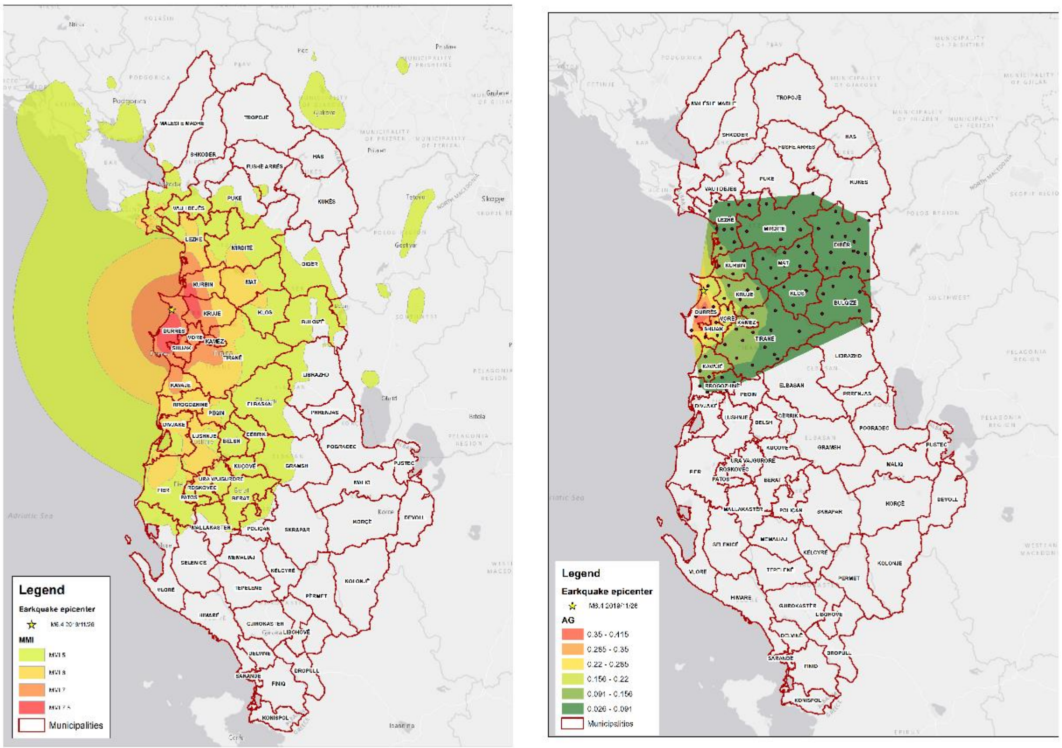

Figure 1: 26 November Earthquake ShakeMap (USGS) (left)[20]; 26 November Earthquake ground motion field (right)[21]

2.2 Exposure

The exposure model is based on the data available on the building stock taken from INSTAT [5]. The exposure model taken into account: the taxonomy model and the asset value (economic cost). The taxonomy model is based on GEM taxonomy [6] and the following main criteria have been used:

Construction period - The construction period has served as a criterion to take into account the design code, construction typology of the time and developments in the country. Three main periods have been used: a-) Before the '60s, Between the' 60s and '90s, After the years '90.

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Building height (number of stories) - Three main categories have been distinguished: a-) low-rise buildings 1÷2 floors, medium-rise buildings 3÷5 floors, high-rise buildings over 6 floors.

Main construction material - Two main categories have been distinguished: a-) masonry buildings; b-) reinforced concrete buildings.

A total of 12 taxonomies are used, which are shown in the table below.

Table 1: Taxonomy model

ID	Taxonomy	Description
TAX1	MUR_HBET:2,1_YPRE:19960	Low-rise masonry building build before 1960
TAX2	MUR_HBET:5,3_YPRE:19960	Mid-rise masonry buildings build before 1960
TAX3	CR_HBET:2,1_YBET:1960÷1990	Low-rise RC building build between 1960÷1990
TAX4	CR_HBET:2,1_YPOST:1990	Low-rise RC building build after 1990
TAX5	CR_HBET:5,3_YBET:1960÷1990	Mid-rise RC building build between 1960÷1990
TAX6	CR_HBET:5,3_YPOST:1990	Mid-rise RC building build after 1990
TAX7	CR_H:>5_YBET:1960÷1990	High-rise RC building build between 1960÷1990
TAX8	CR_H:>5_YPOST:1990	High-rise RC building build after 1990
TAX9	MUR_HBET:2,1_YBET:1960÷1990	Low-rise masonry building build between 1960÷1990
TAX10	MUR_HBET:2,1_YPOST:1990	Low-rise masonry building build after 1990
TAX11	MUR_HBET:5,3_YBET:1960÷1990	Mid-rise masonry building build between 1960÷1990
TAX12	MUR_HBET:5,3_YPOST:1990	Mid-rise masonry building build after 1990

The economic cost for each taxonomy is divided into three components: structural cost, nonstructural cost, and contents cost. The economic cost for each component is calculated based on the construction area and the value for unit of area. The value for unit area is taken from [7].

The exposure model is given hereinafter.

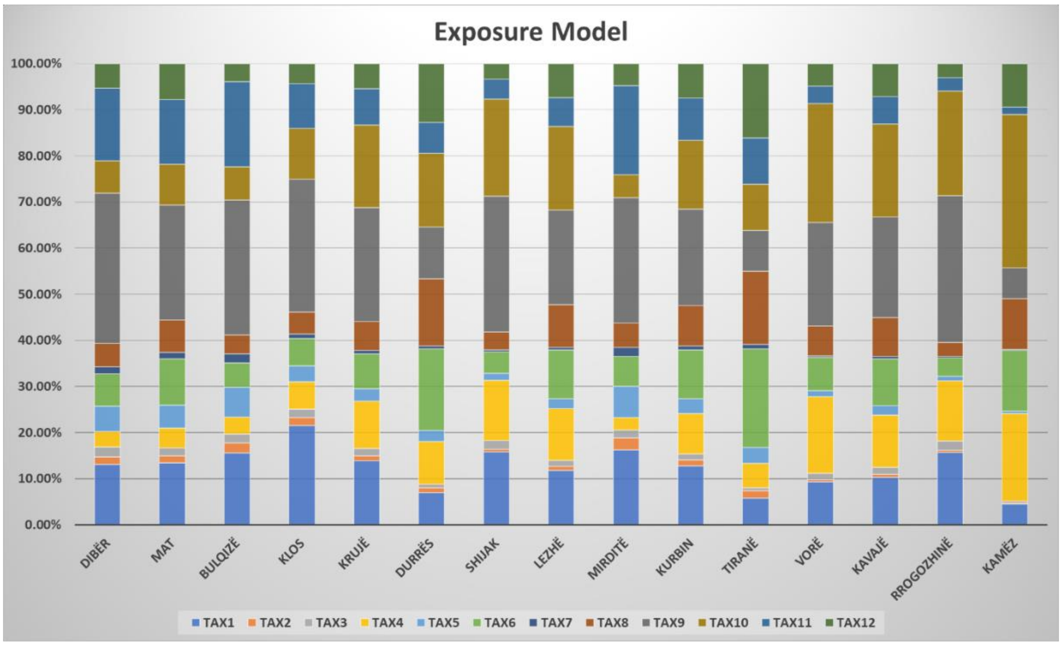

Figure 2: Exposure model

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2.3 Vulnerability

The vulnerability model is build based on fragility curves for each taxonomy and loss functions. The fragility functions are based on the knowledge of the building stock, design and construction codes [8], [9], [10], [11], [12], variety and categorization of works, references to well-known publications in neighbouring and international countries [13], [14], references to studies on specific construction typologies in our country [16], [17], data from specialized institutions and their analysis, and the PDNA reports after the 2019 earthquake.

Hazard related: 1-) National seismic hazard zoning maps, used in the design of buildings in different time periods; 2-) Seismic hazard micro-zoning maps, designed mainly for urban areas with high residential density; 3-) Maps of geological hazard and ground type; areas with significant alternation of use (lagoons, swamps, etc.).

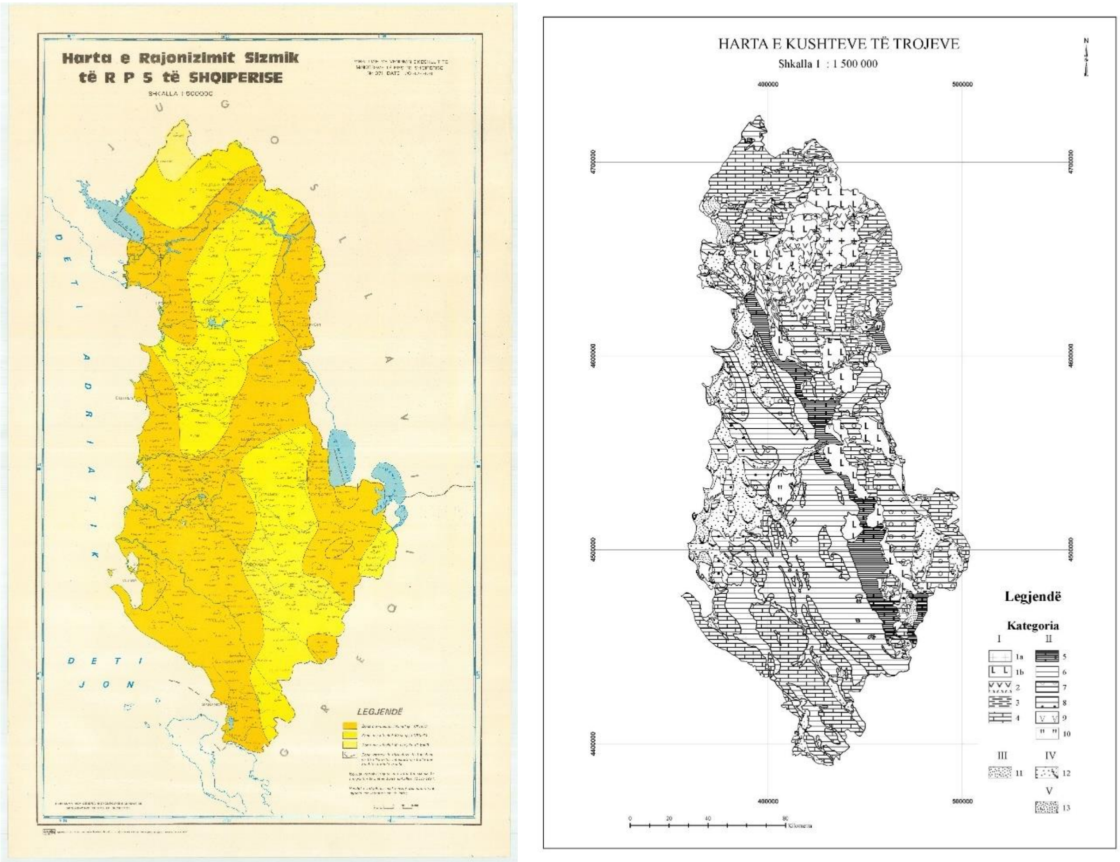

Figure 3: Official seismic intensity map (left)[20]; Soil category map (right)[21]

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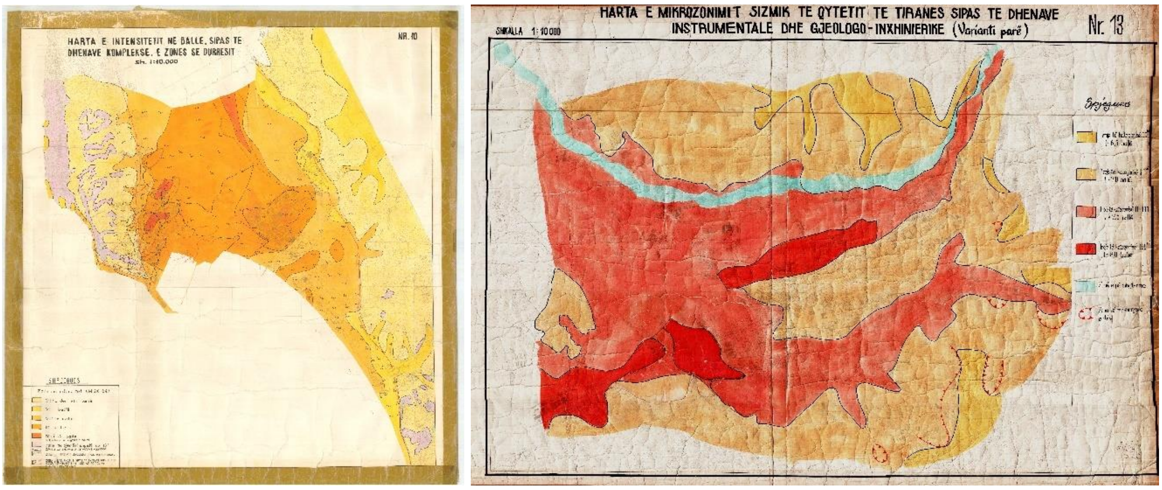

Figure 4: Seismic hazard micro-zoning maps, Durrës (left)[22], Tirana (right)[23]

Related to the exposure: 1-) The importance of the works, their function and the respective categorizations; 2-) Construction intensity and density of use; 3-) Categorization based on the construction period, height / extent of the buildings and construction typology;

Related to vulnerability: In addition to the factors listed above (related to hazard and exposure), other factors directly or indirectly related to vulnerability are: 1-) Design codes; 2-) Workmanship and tradition of implementation; 3-) Norms and experience in structural assessment and retrofitting; 4-) Typified construction models; 5-) Statistics of damages and losses after dangerous previous events; 6-) The spread of severely damaged buildings in the territory and the distinction of the most affected areas.

The fragility functions used for risk assessment are given hereinafter.

Table 2: Fragility functions

Taxonomy	DS1		DS2		DS3		DS4		DS5	
	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
TAX1	0.124	0.247	0.177	0.247	0.231	0.247	0.295	0.247	0.393	0.247
TAX2	0.152	0.369	0.217	0.369	0.284	0.369	0.362	0.369	0.483	0.369
TAX3	0.191	0.267	0.273	0.267	0.432	0.267	0.682	0.267	0.909	0.267
TAX4	0.140	0.228	0.200	0.228	0.317	0.228	0.501	0.317	0.668	0.317
TAX5	0.143	0.295	0.205	0.295	0.324	0.295	0.511	0.295	0.682	0.295
TAX6	0.169	0.305	0.242	0.305	0.383	0.305	0.605	0.383	0.807	0.383
TAX7	0.148	0.284	0.211	0.284	0.335	0.284	0.529	0.284	0.705	0.284
TAX8	0.193	0.277	0.276	0.277	0.437	0.277	0.690	0.277	0.920	0.277
TAX9	0.130	0.224	0.186	0.224	0.243	0.224	0.310	0.224	0.414	0.224
TAX10	0.143	0.229	0.205	0.229	0.268	0.229	0.342	0.229	0.456	0.229
TAX11	0.160	0.336	0.229	0.336	0.299	0.336	0.381	0.336	0.508	0.336
TAX12	0.176	0.279	0.252	0.279	0.329	0.279	0.420	0.279	0.560	0.279

The loss functions for structural, non-structural and contents losses are taken from [18] and are given hereinafter.

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Table 3: Loss functions

Damage State	Structural	Nonstructural	Contents
DS1	2%	2%	1%
DS2	10%	10%	5%
DS3	50%	50%	25%
DS4	75%	75%	37.5%
DS5	100%	100%	50%

2.4 Scenario Building

All the data given above are used as input in the OpenQuake [19] engine for the calculation of the risk assessment.

3. Risk assessment

The economic cost is calculated using the OpenQuake engine and the results obtained are compared with the economic cost given in PDNA report. The economic cost for each municipality is given hereinafter.

Table 4: Economic cost

Municipality	PDNA report	Risk Assessment
Bulqizë	€ -	€ 834,327
Dibër	€ -	€ 1,014,573
Mat	€ -	€ 2,629,347
Klos	€ -	€ 1,305,829
Durrës	€ 220,780,000	€ 336,252,343
Shijak	€ 52,910,000	€ 56,171,318
Krujë	€ 73,010,000	€ 39,039,273
Kurbin	€ 25,390,000	€ 15,750,854
Lezhë	€ 22,180,000	€ 11,112,220
Mirditë	€ 4,420,000	€ 1,252,069
Kavajë	€ 28,620,000	€ 19,034,778
Rrogozhinë	€ -	€ 5,824,497
Kamëz	€ 14,490,000	€ 55,091,351
Tiranë	€ 214,330,000	€ 153,967,205
Vorë	€ 40,160,000	€ 33,172,853
Total	€ 696,290,000	€ 732,452,837

As it can be seen from the table above, the results taken from the risk assessment analysis are comparable with the values given in the PDNA report.

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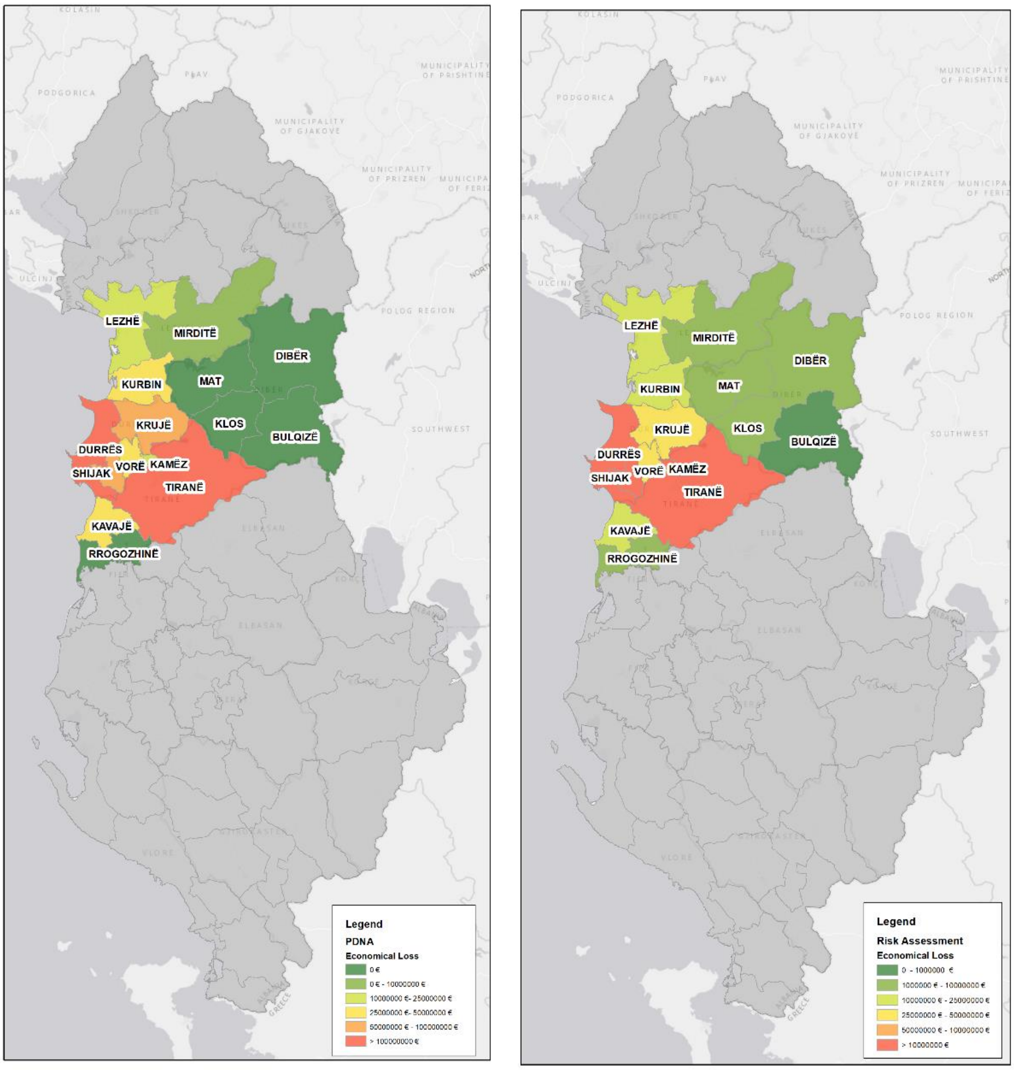

Figure 5: Economic cost PDNA report (left), Risk Assessment (right)

The economic cost for each taxonomy is given hereinafter.

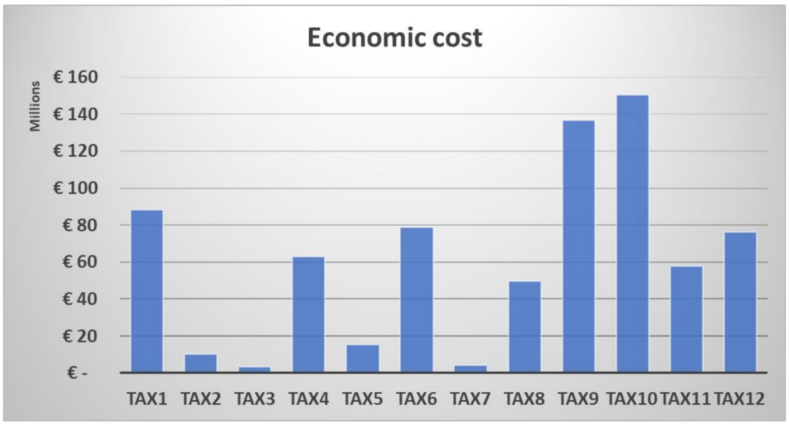

Figure 6: Economic cost for each taxonomy

Based on the chart above, the most damaged building typologies are the low-rise masonry buildings build in each of the considered construction periods, and midrise reinforce concrete buildings build after 1990.

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Referring to the distribution of damages in buildings according to the damage scale (DS), it is observed that the simulation of the scenario and the data collected in the field in some cases coincide. For administrative unit of Durrës (city), the comparative results are satisfactory, while for Shijak and Krujë administrative units, the results differ significantly. The distribution of damages for each case are given hereinafter.

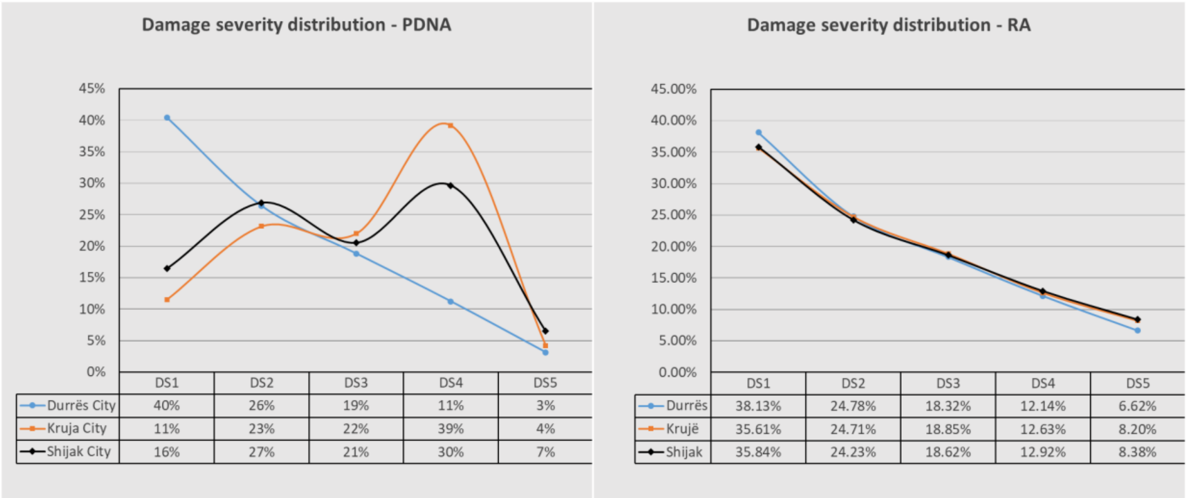

Figure 7: Damage distribution (PDNA report left, Risk Assessment right)

As it can be seen above according to Risk Assessment the damage distribution is similar in all three administrative units, while according to PDNA report, the damage distribution for the administrative unit of Durrës is similar to the damage distribution of the Risk Assessment, while for the administrative units of Kruja and Shijak, the damage distribution differs significantly, having the number of buildings with damage scale DS4 higher that the number of lower damage scales (DS1÷DS3).

4. Recommendations for future risk assessment

The earthquake of November 26, today's studies on seismic risk and the findings of this risk analysis show that the "design earthquake" is higher than the one predicted in the current seismic map.

In areas with dense construction and in areas with weak soil properties, the data on soil conditions needs to be prepared/updated on a smaller scale with focus on the seismic amplification factor.

We advise that either the next census take into account the completion of a series of technical data for buildings or a special project starts for completing the database of buildings with technical data, suitable for the construction of the taxonomy;

Academic institutions, the national civil defense agency and experts in the field need to be involved and undertake research projects to build fragility and vulnerability models for building stock and critical infrastructure. The accuracy of these models directly affects the accuracy of seismic risk calculations;

The typologies that are the most damaged by the earthquake, reported and found by the risk analysis in this paper, require increased attention for their evaluation and rehabilitation.

5. Conclusions

Seismic hazard: The November 26 earthquake added data to seismic models and reinforced previous studies (betim muco ref) that similar seismic events occur with 100-year return periods. As a result, the earthquake that occurred can be considered a "service earthquake" according to the provisions of the Eurocode and meanwhile coincides with the maximum seismic action provided in ktp-n2-89.

Due to the extremely poor ground conditions in some areas of Durrës, their impact on the seismic risk assessment is significant and must therefore be kept in mind.

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Exposure: The exposure model - prepared with data available from census2001, census2011 and other data collected in local institutions and in the field - is not comprehensive and needs further improvement by enriching it by structuring it according to known taxonomies for building stock, critical infrastructure and cultural heritage.

Vulnerability: for fragility and vulnerability models, there are few studies conducted at the territorial scale. Their drafting is based on: Durrës earthquake data, design codes and recent studies. The fragility and vulnerability model are of key importance in the preparation of seismic risk analysis, and it needs to be prioritized by experts in the field and state bodies.

Seismic risk: The comparison between the seismic risk scenario presented in this paper with the data obtained from the rapid assessments in the field (presented in PDNA) shows that the results on a macro scale are comparable. Meanwhile, some of the specific findings obtained from this risk analysis are presented below:

1-) The administrative unit with the most losses is the administrative unit of …

2-) The most damaged buildings are buildings with 1-2 storeys

3-) The taxonomies with the most losses are low rise masonry buildings build in each considered construction period

4-) Referring to the distribution of damages in buildings according to the degree of damage (DS), it is observed that the simulation of the scenario and the data collected in the field in few cases coincide. For administrative unit of Durrës (city), the comparative results are satisfactory, while for Shijak and Kruje administrative units, the results differ significantly.

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