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# SEISMIC RISK ASSESSMENT FOR RURAL AREAS

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## Özet

Ermenistan, deprem, kuraklık, sel, heyelan, toprak kayması, kuvvetli rüzgar, kar fırtınası, don ve dolu gibi doğal afetlere karşı savunmasızdır. Bu çalışmada, kırsal alanlar için hızlı ve basit bir sismik risk değerlendirme prosedürü önerilmektedir. Risk değerlendirme endeks bazlı yöntemle yapılmıştır. Ön risk değerlendirmesi, jeolojik ve sosyal veriler olmak üzere iki tür veriye dayanmaktadır. Bu model için gerekli olan jeolojik koşulları açıklayan parametreler şunlardır: sismik tehlike düzeyi, aktif faylar, heyelan, kaya düşmesi ve rezervuarlar. Sosyal koşulları tanımlayan parametreler ise şunlardır: insanların sayısı, toplam yapılı alan, öğrenci sayısı (okul varsa), sağlık hizmetleri ve güvenli hatlar. Güvenli hatların önemli bir parçası olarak yerleşim bölgelerine giden yollar değerlendirilmiştir. Tüm bu parametreler önemlerine göre sınıflandırılmış ve ilgili ağırlıklar verilmiştir.

**Anahtar Kelimeler:** sismik risk, kırsal alan, endeks bazlı yöntem

## Abstract

Armenia is vulnerable to a number of disasters due to natural hazards, such as earthquake, drought, flood, landslide, mudslide, strong wind, snowstorm, frost and hail. In this study it is proposed a fast and simple seismic risk-assessment procedure for rural areas. Risk assessment is done by index-based method. The preliminary risk assessment is based on two types of data: geological and social. The parameters describing geological conditions needed for this model are the following: seismic hazard level, active faults, landslides, reservoirs and rockfalls. The parameters describing social conditions are the following: number of people, total built area, number of pupils (if school exists), health services and lifelines. As an important part of lifelines the roads to settlement are discussed. All these parameters were classified by their importance and were given weights concerning that.

**Keywords:** seismic risk, rural area, index-based method

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# 1 Introduction

Armenia is one of the most disaster prone countries in the southern Caucasus. Armenia is vulnerable to a number of disasters caused by natural hazards, such as earthquake, drought, flood, landslide, mudslide, strong wind, snowstorm, frost and hail. All of these adverse events disrupt the routine life of a community and have a range of human and material consequences. Homes are destroyed, communities are isolated, and basic services are damaged. The methodology for risk assessment has to be evaluated in the context of specific situations. In this study a fast and simple seismic risk-assessment procedure for rural areas is proposed. Risk assessment is done by index-based method and is based on the idea of weighting discussed parameters according to their importance. Composite indexes have been used for a long time in a wide variety of disciplines to measure complex, multidimensional concepts that cannot be observed or measured directly. The preliminary risk assessment is based on two types of data: geological and social. The parameters describing geological conditions required for this model are the following: seismic hazard level, active faults, landslides, reservoirs and rockslides. The parameters describing social conditions are the following: number of people, number of houses, number of pupils (if school exists), health services and lifelines. As an important part of lifelines the roads to settlement are discussing. There are many settlements in Armenia that are far from regional centers and are situated in mountainous terrains, which is making difficulties to organize first aid. All these parameters were classified by their importance and were given weights concerning that.

# 2 Index-based method for seismic risk assessment

## 2.1 An overview of seismic risk assessment method

In this work I propose an index-based method for risk assessment. The total risk presents a relative measure of risk which is entirely adequate for comparing the risk of different settlements. The development of this index-based method provides three principal benefits. First, the direct comparison of overall seismic risk provides a systematic way to directly compare the total seismic risk across a large number of settlements. Second, a comprehensive risk value will highlight the fact, that even in regions with low seismicity, an earthquake may occur, and if it does, the other characteristics of the settlement could turn that single event into a major disaster. Third, by reevaluating this value periodically, the risk value can be used to monitor trends in risk over time.

This method has developed using the following procedure:

a) create main factors groups that contribute to earthquake disaster risk,

b) identify simple, measurable parameters to represent each of the factors in the groups (e.g., population, peak ground acceleration),

c) combine the parameters mathematically into the composite index,

**Table 2.1:** *The main factors and describing parameters*

| | Social Risk | Geological | Lifelines |
|---|---|---|---|
| **Parameters** | S1: Number of people | G1: Seismic hazard level | L1: Hospital |
| | S2: Built Area of settlement | G2: Distance to closest active fault | L2: Telecommunication |
| | S3: Number of pupils in school | G3: Landslides | L3: Distance to main highway |
| | S4: Number of children in kindergarden | G4: Rockfall | L4: Bridges, mountainside |
| | | G5: Mudflows | L5: Natural gas |
| | | G6: Reservoirs | L6: Communication |
| | | | L7: Drinking water |

**Table 2.2:** *Parameters influence definition*

| Parameter's Values | Category Description |
|---|---|
| 0 | Blank |
| 3 | Low |
| 6 | Medium |
| 10 | High |

d) interpret the numerical findings to access their reasonableness and implications and

e) present the results in a variety of easily understandable graphical forms.

There are many geological and economical factors affecting total risk. In this project, the main factors that have been identified as contributing to a settlements seismic risk are the following: Social, geological and lifelines. Each of these three main factors is separated into the more specific parameters that comprise it, see Table 2.1.

## 2.2 Definition of parameter's influence and their weights

There are more then fifteen parameters describing main factors. They are defined as a four-level classification system to rate a parameter's influence to total risk value. The parameters have four possible values (Table 2).

The parameters describing the main factors are considered here. Social factor: The four parameters are used to represent the Social factor.

S1: Number of people

S2: Total built area of settlement

S3: Number of pupils in school

S4: Number of children in kindergarten

The values of each parameter are defined according to their values. Geological factor: The six parameters listed below are used to represent the Geological factor. The first represents the peak ground acceleration, and the last five represent the collateral hazards of landslides, rockfalls, mudflows and reservoirs.

G1: Peak ground acceleration (in g)

G2: The distance to nearest fault (km)

G3: Are there landslides?

G4: Are there rockfalls?

G5: Are there mudflows?

G6: Is there reservoir that can affect?

Lifelines: I consider seven parameters to represent the Lifelines risk.

L1: Number of beds in hospital (if it exists)

L2: Existence of telephone station

L3: Distance to main highway

L4: Existence of bridges on the roads to the settlement

L5: Percent of natural gas supply

L6: Percent of waste system

L7: Percent of water supply

I use ArcGIS program to calculate the distance to the nearest active fault and to get seismic hazard values from the map (in this studies as a based hazard map I have used GHAP hazard map). The definition of classified value for each parameter depends on available data. There are some difficulties to define the relative values for geological hazards like landslides, rockfalls, mudflows and reservoirs. The investigations of these factors are cost, time consuming as well as different specialists required. To avoid these problems in this stage of risk assessment I consider their level of influence as Medium with corresponding relative value equal to 6, otherwise I consider the level of influence as Blank that means the relative value is equal to 0. Ie do the same for parameters describing lifelines like telecommunications and bridges (L2, L4). For the other parameters I simply divide the real values interval into three subintervals and consider the influence according Table 3.1

In next step I have defined weights for each factor. There are many alternatives for determining the weights to be used in this method such as regression, principal components analysis, subjective assessment etc. In this work I used subjective assessment to determine the values of weights for each factor according to their relative importance to seismic risk, see Table 2.3.

## 2.3 Mathematical combination and interpretation of results

Once all the indicators that will be used in the calculation have been selected, they must be combined mathematically to define the risk as a sum of different risks. I suggest a linear combination of these parameters in the following way:

$$\mathrm{Risk}_{\mathrm{Total}} = \mathrm{Risk}_{\mathrm{Social}} + \mathrm{Risk}_{\mathrm{Geological}} + \mathrm{Risk}_{\mathrm{Lifeline}} \tag{2.1}$$

**Table 2.3:** *Risk parameters and their weights*

| Main Risk Factors | Parameters | Weights |
|---|---|---|
| Social Risk | S1: Number of people | 50 |
| | S2: Total built area of settlement | 40 |
| | S3: Number of pupils in school | 30 |
| | S4: Number of children in kindergarden | 30 |
| Geological | G1: Seismic hazard level | 50 |
| | G2: Distance to nearest active fault | 30 |
| | G3: Landslides | 30 |
| | G4: Rockfalls | 30 |
| | G5: Mudflows | 30 |
| | G6: Reservoirs | 30 |
| Lifelines | L1: Hospitals | 30 |
| | L2: Telecommunication | 20 |
| | L3: Distance to main highway | 10 |
| | L4: Bridges, mountainside | 10 |
| | L5: Natural gas | 10 |
| | L6: Communication | 10 |
| | L7: Drinking water | 10 |

Where the $\text{Risk}_{\text{Social}}$, $\text{Risk}_{\text{Geological}}$ and $\text{Risk}_{\text{Lifeline}}$ are the risks of three main factors and defined as follows:

$$\text{Risk}_{\text{Social}} = \sum_i \text{Index}_{S_i} * \text{Weight}_{S_i} \tag{2.2}$$

$$\text{Risk}_{\text{Geological}} = \sum_i \text{Index}_{G_i} * \text{Weight}_{G_i} \tag{2.3}$$

$$\text{Risk}_{\text{Lifeline}} = \sum_i \text{Index}_{L_i} * \text{Weight}_{L_i} \tag{2.4}$$

Where $S_i$, $G_i$ and $L_i$ are the discussed factors and the $\text{Index}_{S_i}$, $\text{Index}_{G_i}$, $\text{Index}_{L_i}$ refer to classified values of the corresponding parameters, $\text{Weight}_{S_i}$, $\text{Weight}_{G_i}$, $\text{Weight}_{L_i}$ are the weights associated with each parameter (according to Table 2). The total risk presents a relative measure of risk which is entirely adequate for comparing the risk of different settlements. I have created a form in Excel spreadsheet to collect data and automatically calculate risk values for each group of factors and combine them in the total risk value. The results are presented using a variety of graphical forms (charts, maps) to make them as easily accessible as possible.

# 3 Results

Settlements analysis was done to explore the challenges associated with this process and to illustrate its feasibility and usefulness of the results (Figure 3.1). I have chosen some settlements in Armavir region. Region was chosen because its territory is valley, and there is no geological hazards such landslides, mudflows but at the same time all settlements are very close to active faults. On the contrary, Vayoc Dzor region is mountainous and with active faults. There exist additional hazards such as landslides, mudflows, settlements are in mountains and located far from regional centers which bring a high value of geological risks. In Armenia the settlements in general have the same infrastructure. Based on this I suggest classify the results into two groups: settlements with risk value that is above the medium level and

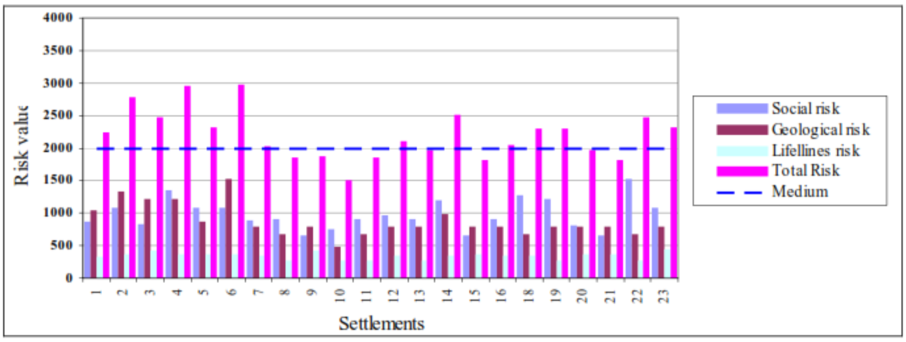


**Figure 3.1:** *Diagram of risk values for some settlements in two regions of Armenia*

settlements with risk value that is below the medium value, (see Figure 3.1). The first six settlements in illustrated Figure 3.1 are located in Vayoc Dzor region, and the others in Armavir region. As it's evident from this chart that the geological risk level is high in Vayoc Dzor which is not a result of only seismic hazard values. I can see in the Figure 3.2, the hazard level in two selected regions almost is the same (0.3g-0.4g) but the seismic risk is high in Vayoc Dzor region. The reason is the following: there are different collateral geological hazards, settlements are in mountains and the roads to settlements pass over bridges. After possible earthquake some settlements can be trapped in mountains which will make difficulties for first aid from out. But on the other hand the settlements in the Armavir region are larger. They have more population with corresponding consequences that bring to high risk from social aspects.

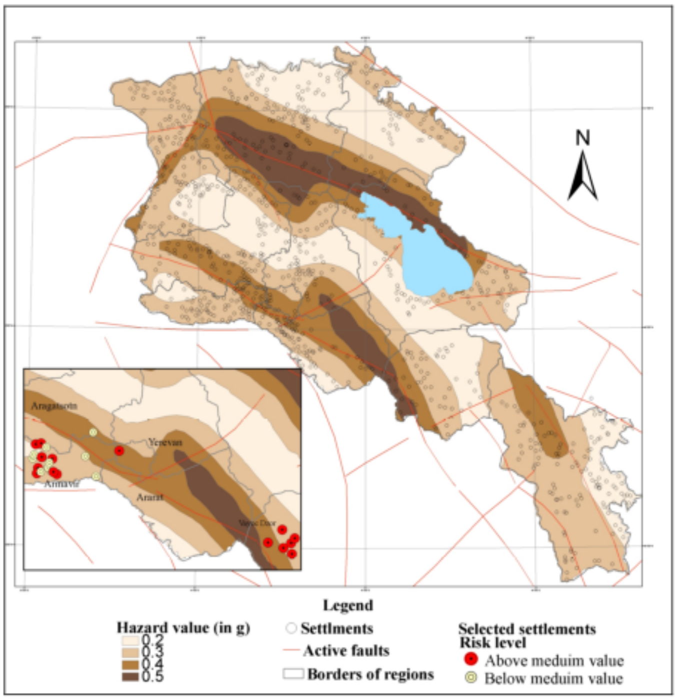


**Figure 3.2:** *Seismic risk values for selected settlements*

# 4 Conclusion

The Republic of Armenia (RA) is one of the most active regions in the world, which territory almost totally is located in the seismic zone with the highest level of seismic hazard, see Figure 3.2. As a consequence of this seismic risk is high for rural areas in whole Armenia. The total risk value places a settlement into one of two categories, helping determine which settlements most urgently need further investigations and show the most vulnerable factors that bring to high risk. It is shown that more vulnerable are the mountainous villages as a result of geographical location, geological conditions, poor developed communications and insufficient health services.

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