# Seismic Risk Study for the Sustainable Development of Tbilsi City Urban Area

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**Abstract**

The international Experience of Developed countries and the Socio-Economical losses during the recent earthquakes happened in Tbilisi City underlined the importance of seismic factor consideration at all stages of governmental policy

- In governmental will, caused by social needs
- In city development concept at the realization level
- In Tbilisi City Master Plan Development at the legislation level

For integration of seismic aspects into Tbilisi City Master plan the evaluation of all city-forming factors becomes necessary in accordance with seismic hazard of territory.

Recent several years we have been working in this direction, especially on the problem of urban seismic risk reduction [1].

This gave us, the Association "Engineering Idea", the possibility, by the support of Swiss Agency for development and cooperation, UNDP, Georgian National Committee of Disaster Risk Reduction and Environment Sustainable Development, in collaboration with the M.Nodia Institute of Geophysics, the K.Zavriev Institute of Structural Mechanics and Earthquake Engineering, "Idea Design Group" LTD and Georgian Technical University, to develop the special model of seismic risk study for Tbilisi urban area [2,3].

The urban factors were ranged according to their relation with seismic effect.

According to the limitations and special requirements the urban factors' data were grouped and defined by the level of seismic vulnerability and fixed as the seismic risk.

The model of seismic risk assessment which was transformed and developed in ARC GIS System gave us possibilities for visual assessment of any urban area according to the factors separately or in complex.

The positive points of this methodology were: the opportunity of scenarios development; visualization of results; simplification of Urban factors seismic risk arrangement; creation of close links between the urban databases and city maps; strong management between city layers.

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This gave us possibility for quick testing of all urban decisions and visual analyses of their outcomes.

The seismic risk urban analysis show the diversity of urban factors nature in different environments, influence of seismic micro-zoning data on seismic risk assessment, impact of urban factors to each other during this assessment.

The special recommendations were prepared for Tbilisi Master Plan Development, for private and Institutional organizations involved into the City system and construction management, expertise, insurance and estimation.

The general outcomes were developed for urban seismic risk mitigation

## 1. Introduction

The increase of population in cities and urbanization in seismic-prone areas causes the growth of infrastructure. The goal of society is to create infrastructure that is protected from destructive earthquakes and to minimize the expected losses. The proper assessment of seismic risk is of crucial importance for sustainable economic development of cities and protection of society.

## 2. Case Study for Tbilisi Urban Area

This problem is of vital importance for Tbilisi as it is a capital of Georgia and one of the most important cities of Caucasus Region. According to the last seismological

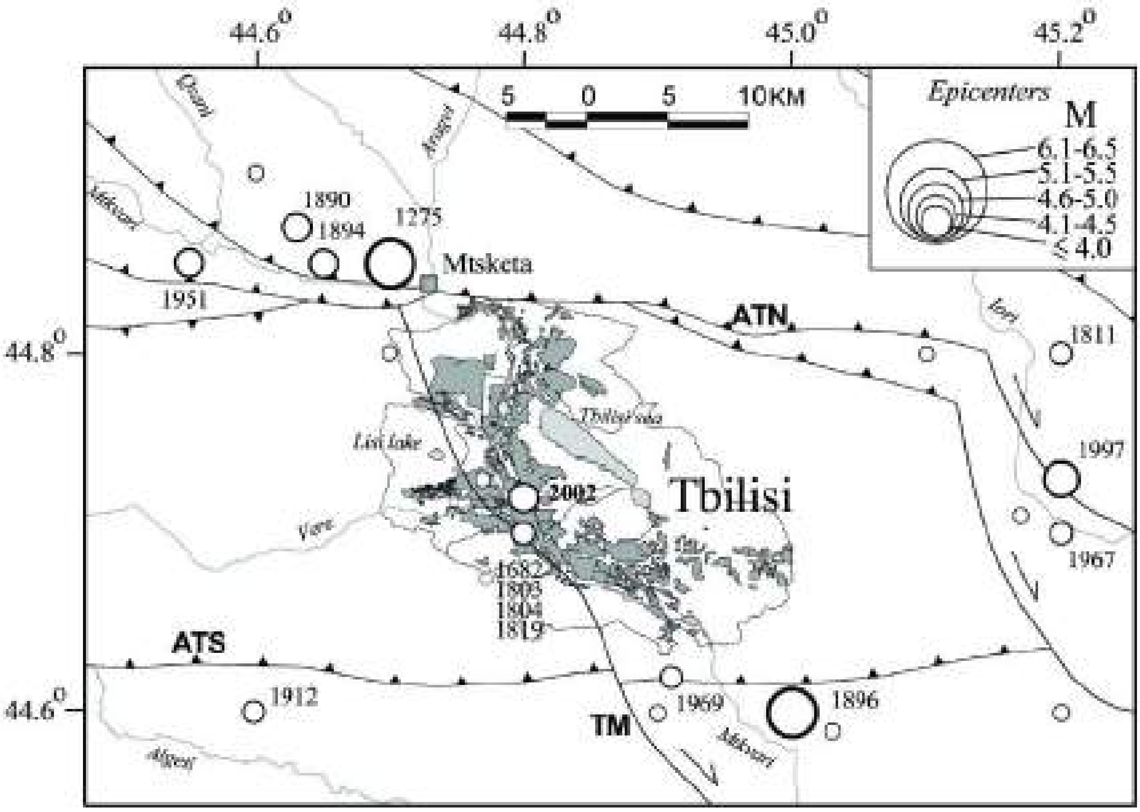


Fig. 1 ATN -The North Achara-Trialeti thrust fault; ATS - The South Achara-Trialeti thrust fault; TM - Tbilisi-Mtkvari dextral strike-slip with reverse fault.

investigations and databases new seismic foalt was developed across the river Mtkvari exactly under the City [3] (Fig.1)
New seismic building codes can’t keep up the rapid growth of the city demands. That is why the risk to be injured by the collapses, fires or floods caused by the earthquakes increased significantly.

It must be mentioned that the tourist infrastructure, governmental, nongovernmental activity, private business development concentrate the intensive construction works exactly across the river line as well as in the most densely populated historical built up environment, without the a seismic analyze during the general reconstructions of engineering and transport communications. This was confirmed by Tbilisi earthquake of 2002 years.

The new Master Plan for Tbilisi City future development (Fig.2 ) was excepted in 2009 (registration N 010.270.000.36.101.013.215, Georgia, 2009). But unfortunately the seismic hazard and risk factors were not included there again . Due to this there was significant gap in the evaluation of main transport, functional and other potential distribution units.

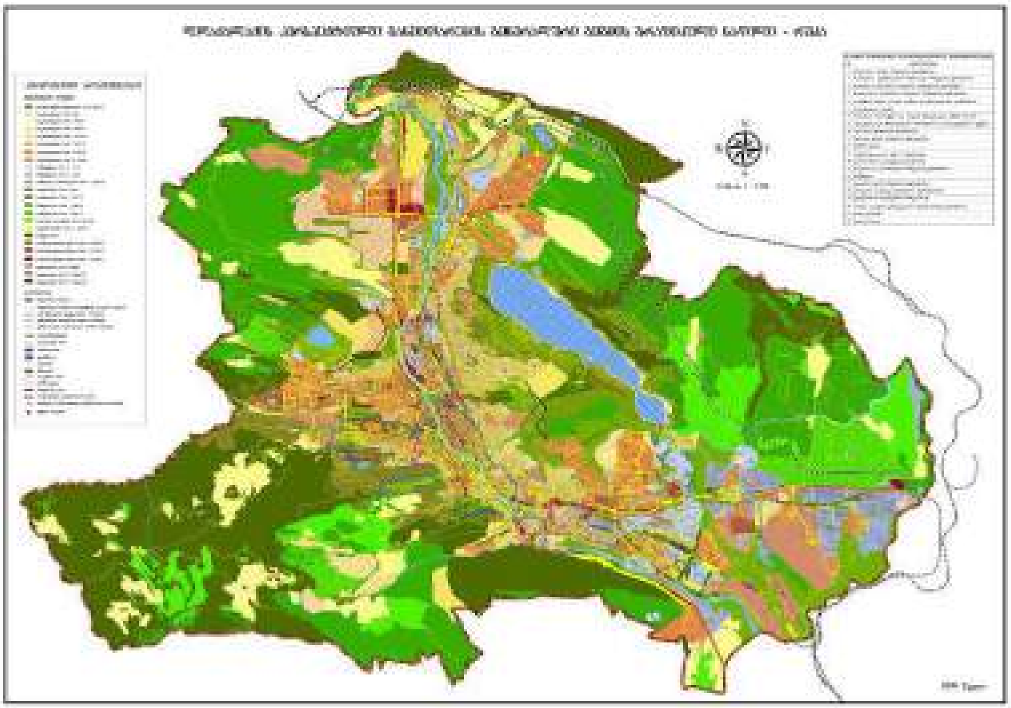

Fig. 1 ATN -The North Achara-Trialeti thrust fault; ATS - The South Achara-Trialeti thrust fault; TM - Tbilisi-Mtkvari dextral strike-slip with reverse fault.

The Municipality of Tbilisi suffered big socio-economical losses in the city after the 2002 earthquake, which provoked intensive damages in the city, especially in its historical part not only during the seismic shakes but after them too.

By the support of Swiss Agency for development and cooperation UNDP, in collaboration with the Georgian National Committee of Disaster Risk Reduction and Environment Sustainable Development, Georgian Technical University, M.Nodia Institute of Geophysics, the K.Zavriev Institute of Structural Mechanics and Earthquake Engineering, Association "Engineering Idea", "Idea Design Group" LTD, the special model of seismic risk study for Tbilisi urban area was developed.

## 3. Methodological Bases of Urban Seismic Risk Study

The scheme below shows the methodological bases and objectives of urban Seismic risk study (Fig. 3).

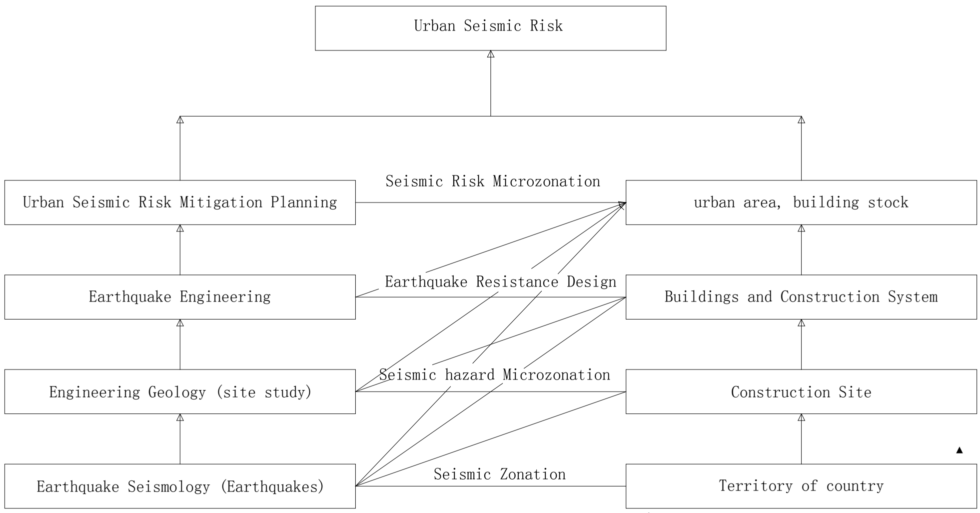


Fig. 3. The methodological bases and objectives of urban seismic risk study

For integration of seismic aspects into the Master Plan of Tbilisi City development we evaluate the seismic vulnerability of deferent city-forming factors.

This enable us to develop the special model of relative seismic risk R, which becomes the indicator of seismic hazard influence on the urban factors' seismic vulnerability [3]. (fig. 4)

$$R_j = \frac{\sum_{i \in S} f_i\left(k_{i,j}\right)}{\sum_{i=1}^{n} f_i\left(k_{ij}^{\max}\right)}$$

Fig.4 The Formula of relative seismic risk R identification

In Fig 4. $R_j$ - value of relative seismic risk of the site; *f* – value of a function or modifier which define risk; *s* - number of factors which define risk of one element; *n*- number of factors which define risk; *j* – index of a site.

The main regions of Tbilisi City were investigated in this work empowering us to fix the significance of urban factors influence on urban seismic risk reduction across the large territory that gives the possibility of efficient construction and planning management for sustainable development of the city.

According to the limitations and special requirements the urban factors' data were grouped and defined by the level of seismic vulnerability.

According to the limitations and special requirements the urban factors' data were grouped and defined by the level of seismic vulnerability (Table 1).

Table 1. Vulnerability Evaluation for Functional Factor

| Code | Usage of Object | Level of seismic Vulnerability |
|---|---|---|
| A | Unusable objects (Open Spaces, parks, playgrounds) | 1 |
| B | Not very usable objects (2-3 story, 1-4 multifamily apartments) | 2 |
| C | Very usable objects (Banks, 4-8 multifamily residential, small commercial and office apartments.) | 3 |
| D | Highly usable objects (big banks, hotels, schools, fire and police stations, railway and bus stations, theatres, industries, high-rise residential and commercial buildings) | 4 |

In Table 2 is presented the vulnerability evaluation for city roads

Table 2. Vulnerability evaluation for city roads

| | Type of the Roads/ The level of vulnerability | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| A | The Roads of City Significance and main trunk highways | >45 | 30-45 | 10-20 | 10>X |
| B | The Regional Roads | >30 | 25-30 | 25-15 | 15> X |
| C | Local Roads | >30 | 25-30 | 25-15 | 15> X |
| D | The Roads of trunk communication between cities | >65 | 45-65 | 30-40 | 20-30 |

Table 3. Vulnerability evaluation for historical heritage

| Code | Usage of Object | Level of seismic Vulnerability |
|---|---|---|
| A | New building Stocks | 1 |
| B | All Buildings in Historical Area (Old Quarters) | 2 |
| C | The Monuments of Local Importance | 3 |
| D | The Monuments of National Importance | 4 |

As a result, it became possible to unite all urban factors in one system and assess the relative seismic risk for any urban area as a whole or separately, for each factor (Table 4).

Table 4. Vulnerability level of Building type and other factors

| | | Weight Coefficient | Width of the Roads m | | | |
|---|---|---|---|---|---|---|
| A | The Roads of City Significance and main trunk highways | 3 | >45 | 30-45 | 10-20 | 10>X |
| B | The Regional Roads | 2 | >30 | 25-30 | 25-15 | 15> X |
| C | Local Roads | 2 | >30 | 25-30 | 25-15 | 15> X |
| D | The Roads of trunk communication between cities | 1 | >65 | 45-65 | 30-40 | 20-30 |
| | The level of vulnerability | | 1 | 2 | 3 | 4 |

The model of risk assessment was transformed and further developed in ARC GIS System.

This gave us possibilities for visual assessment of any urban area according to the factors separately or in complex.

The positive point of GIS methodology is its capacity to develop various scenarios, visualize results, simplify urban factors seismic risk arrangement, create close links between the urban databases and city maps, rank the data and strong management between city layers represented various urban factors. This gives us possibility for quick testing of all urban decisions and visual analyses of its outcomes.

## 4. Impact of Urban Factors to the Evaluation of Seismic Risk across the Territory of Tbilisi

Below is presented relative urban seismic risk according the various factors separately or in complex

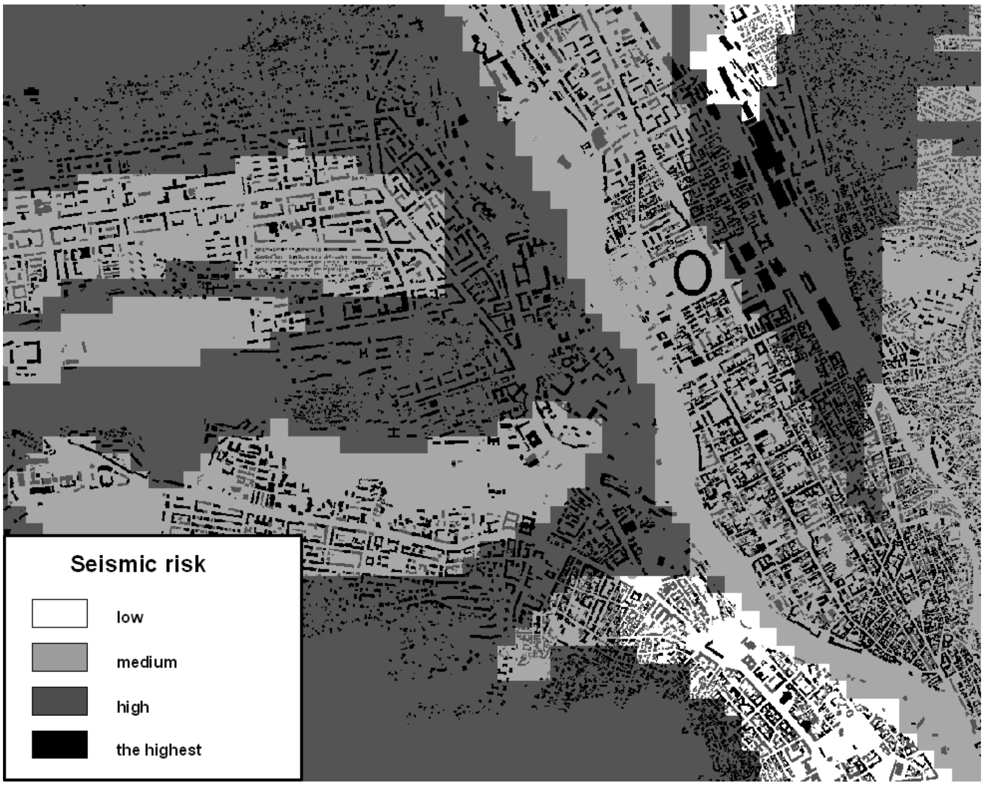


Figure 5. The seismic vulnerability of Building type, functionality, building density and seismic hazard

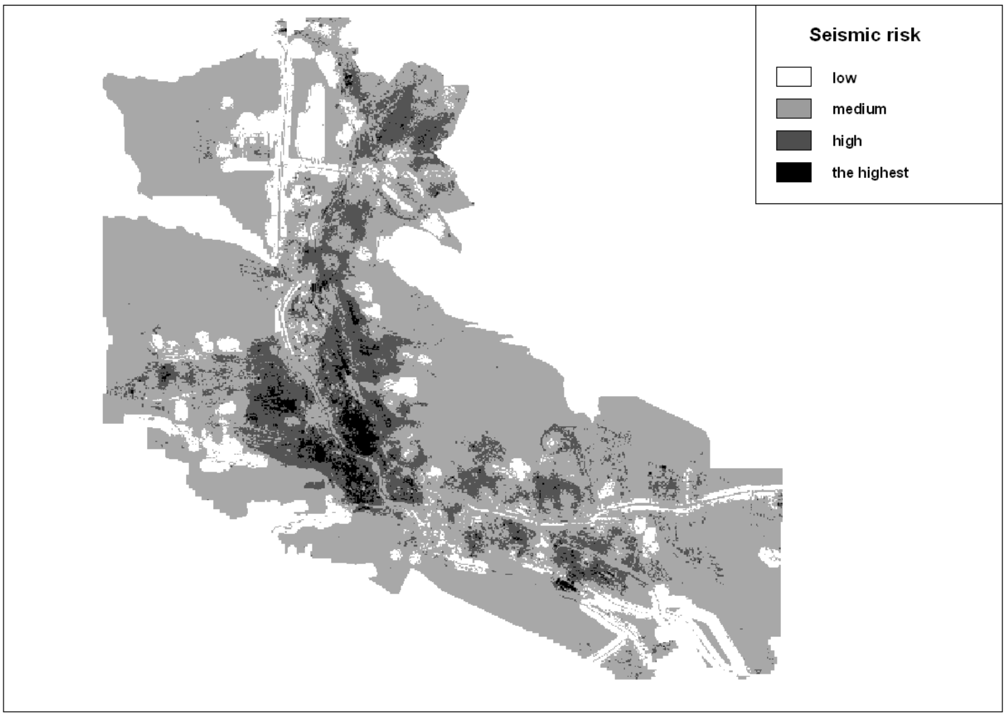


Figure 6. The seismic vulnerability of building type, functionality, building density, population density, roads and seismic hazard

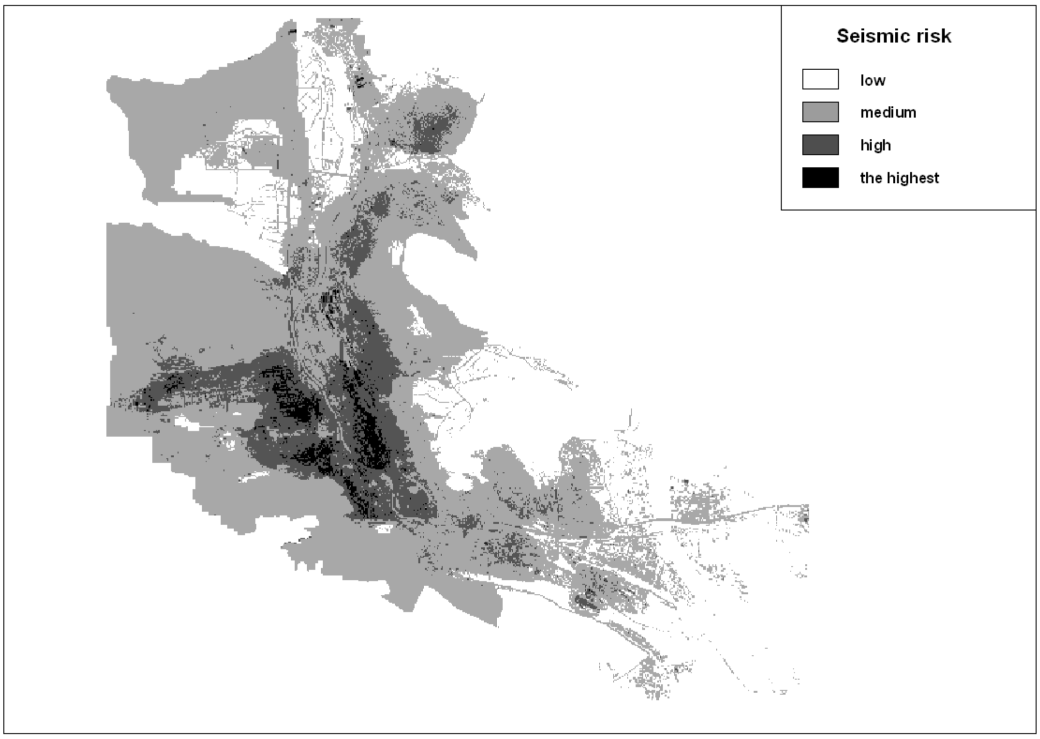


Figure 7. The seismic vulnerability of building type, functionality, building density, population density, road, distance from safe area  and seismic hazard

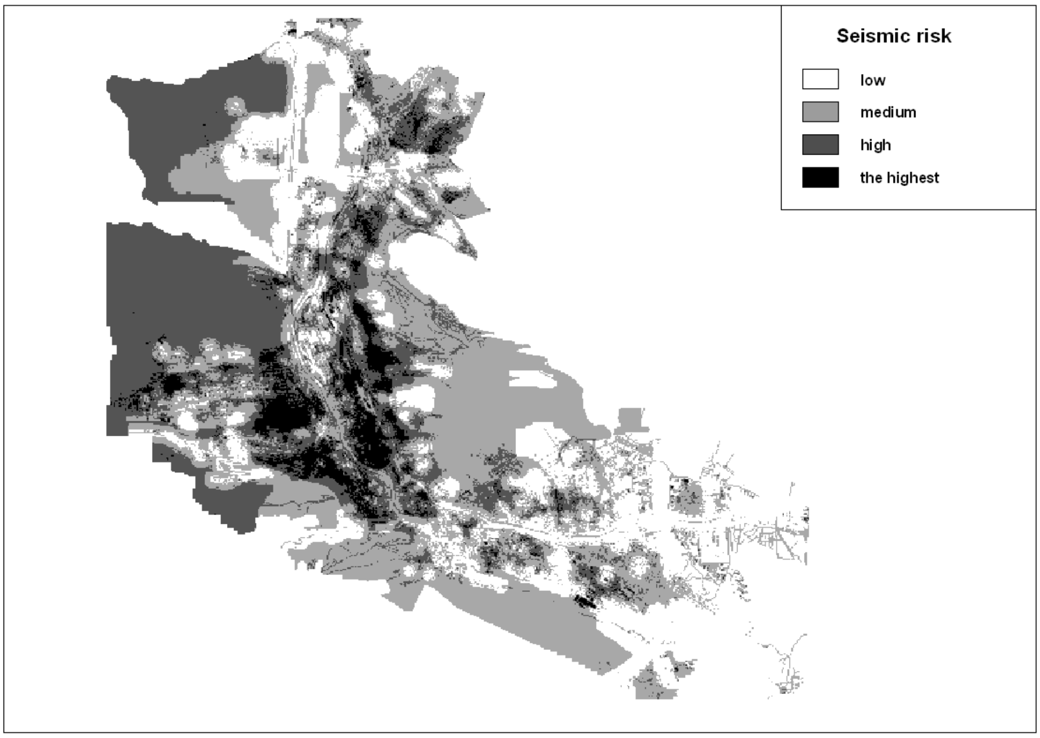


Figure 8. The seismic vulnerability of building type, functionality, building density, population density, road, distance from safe areas, cultural heritage  and seismic hazard

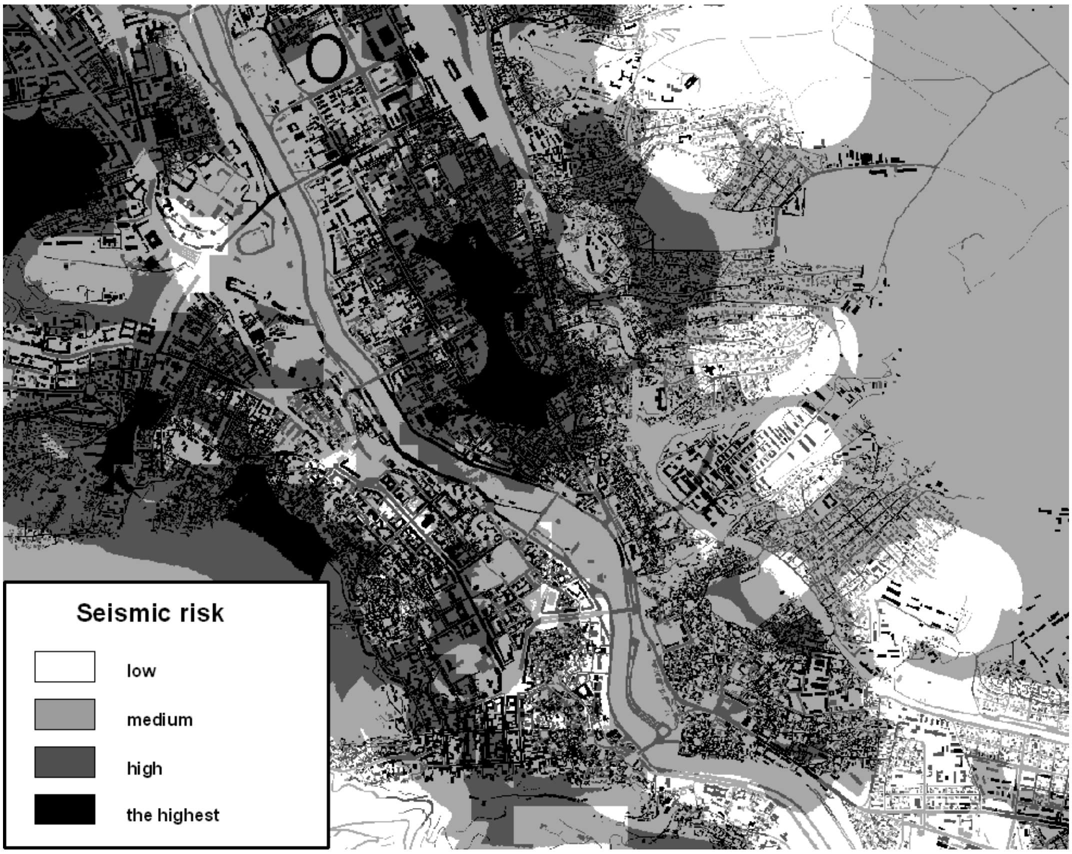


Figure 9. Relative seismic risk without seismic hazard will be added.

## 5. Results

Seismic risk analysis shows the diversity of urban factors nature in different environments, influence of seismic micro-zoning data on seismic risk assessment, impact of urban factors to each other during this assessment.

Thus, the urban seismic risk study results must become the natural undetached part of Tbilisi City Master Plan Development.

This should give the governmental, private and non-governmental bodies possibility to manage correctly their work and financial activity.

The urban seismic risk assessment creates good basement for bank and insurance system to be involved into sustainable development of City.

The protection and regulation of the social and functional processes in the cities located in seismic prone areas can be realized by urban planning and seismic risk testing.

The concentration and location of urban functions is based on the usual social relations between the inhabitants, their general demands, their work , their ways to relaxation.

## 6. Conclutions

In order to regulate the seismic risk in the process of the designing and planning it is desirable to follow the recommendations given below:

- To consider the seismic intensity of the site during the general plan development.
- To Organize the main transport distribution areas as potential logistic points during the strong earthquakes
- To Create special life lines for replacement in the case of damages on the main lifeline roads
- To protect the areas of high seismic risk, by the regulation of building stock and population density
- To define the directions of safe City development by the way of functional zoning
- To carry out the demolition of heavy damaged buildings in time.
- The disposition of the buildings of public significance and responsible buildings in convenient territories.
- Making of parks, green recreational areas in seismic hazard areas.
- Building of underground garages and parking-lots in order to unload heavy traffic in the center of the city
- Organization of the movement system in the region – creation of new passages instead of damped buildings by partial opening of ground-floors and deadlocks, which will significantly facilitate the evacuation of population and other salvage operations during the earthquakes, other disasters and their secondary element (fire, flood, landslide etc.).
- The positive influence of basements on the earthquake resistance of the buildings in case of regulation of underground waters, can be used as additional territories, that will safe historical buildings from high rising during the reconstruction process.

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