# Chapter 20
# Vulnerability Analysis and GIS Based Seismic Risk Assessment Georgia Case

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**Abstract** The paper presents a framework for the vulnerability analysis to assess seismic risk for the Republic of Georgia. Firstly, detailed inventory map of elements at risk was created. Here elements at risk are comprised of buildings and population. The grid of 0.025° size was created to summarize building and population data into the grid cells for further analysis. The custom programming script was created that summarizes the following information for each grid cell: the total number of buildings, total area of buildings, total population, total number of buildings per each taxonomy class and total area of buildings for each taxonomy class. Secondly, seismic hazard maps were calculated based on modern approach of selecting and ranking global and regional ground motion prediction equation for region. Thirdly, on the bases of empirical data that was collected for some earthquake intensity based vulnerability study were completed for Georgian buildings. Finally, probabilistic seismic risk assessment in terms of structural damage and casualties were calculated for the territory of Georgia for 2.8 km grid cells using obtained results. This methodology gave prediction of damage and casualty for a given probability of recurrence, based on a probabilistic seismic hazard model, population distribution, inventory, and vulnerability of buildings.

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## 20.1 Introduction

Risks of natural hazards caused by natural disaster are closely related to the development process of society. Disasters pose hazard to sustainable development of the country. Out of the world populations, 75 % live in places prone of various disasters such as earthquakes, floods, hurricane, drought etc. A recent review of worldwide natural hazard losses during 2012 has identified 905 natural disasters, resulting in 96,000 deaths, $170 billion in economic losses, and $70 billion in insured losses [1].

Upward trend of disaster's intensity and frequency are observed worldwide (e.g. [2]) and are also discussed on the national level (e.g. [3, 4]). It is the result of the urbanization and rapid increase of the density of the population, global climate change and economic globalization, environmental deterioration etc. The natural disasters risk occurs when the hazardous hydro-meteorological, geological and other phenomena interact with physical, social, economic and ecological factors of vulnerable social and environmental infrastructure.

The high level of natural disasters in many countries makes necessary to work out the national programs and strategy. The main goal of these programs is to reduce the natural disasters risk and caused losses. Risk mitigation is the cornerstone of the approach to reduce the nation's vulnerability to disasters from natural hazards. Therefore, proper investigation and assessment of natural hazards and vulnerability of the element at risk to hazards is very important for an effective and proper assessment of risk. This paper issues a call for advance planning and action to reduce natural disaster risks, notably seismic risk through the investigation of vulnerability and seismic hazard for Georgia.

Georgia is prone to multiple natural hazards, the most dangerous and devastating of which are strong earthquakes. By the index of disaster risk, Georgia relates to the countries with medium and high level risk [5]. So, the natural hazard, notably seismic hazard in Georgia have to be considered as a standing negative factor in the development process of the country. Such approach implies the necessity of more active actions by all possible means to reduce the seismic risk at each level and maintain the sustainable economic development of the country. Moreover, the risk level has not been quantified so far in terms of different elements at risk and with respect to vulnerability of corresponding elements at risk.

The importance of arising problems stimulates an active investigation of vulnerability of elements at risk and seismic hazard for seismic risk reduction. The attempt has been approached within the framework of the project "EMME – Earthquake Model for Middle East Region: Hazard, Risk Assessment, Economic and Mitigation".

## 20.2 Seismotectonic and Seismicity of Georgia

Georgia, the southernmost part of Eastern Europe, occupies the western part of the South Caucasus. The main morphological units of Georgia are the mountain ranges of the Greater and Lesser Caucasus separated by the Black Sea-Rioni (Colkhis) and Kura (Mtkvari)-South Caspian intermountain troughs.

Recent geodynamics of Georgia and adjacent territories of the Black Sea-Caspian Sea region, as a whole, are determined by its position between the still-converging Eurasian and Africa-Arabian plates. The geometry of tectonic deformations in the region is largely determined by the wedge-shaped rigid Arabian block intensively intended into the relatively mobile Middle East-Caucasian region. In the first place, it influenced the configuration of main compressional structures developed to the north of the Arabain wedge (indentor) – from the Periarabicophiolite suture and main structural lines in East Anatolia to the Lesser Caucasus, on the whole, and its constituting tectonic units including the Bayburt-Karabakh and Talysh fold-thrust belts. All these structural morphological lines have clearly expressed arcuate northward-convex configuration reflecting the contours of the Arabian Block.

Related tectonic activities caused moderate seismicity in the region. Three principal directions of active faults compatible with the dominant near N–S compressional stress produced by northward displacement of the Arabian plate can be distinguished in the region—one longitudinal (WNW–ESE or W–E) and two transversal (NE–SW and NW–SE).

All historical and instrumental earthquakes observed ($4.5 < Ms < 7.0$) were located along the fault systems of the Greater and Lesser Caucasus and the intermountain depressions. The maximum magnitude of observed earthquakes is $Ms = 7.0$. The moderate earthquakes reflect the regional tectonics that are largely determined by the position of the Caucasus range between the still-converging Eurasian and Africa-Arabian lithosphere plates. By this classification, the southern slopes of Greater Caucasus are characterized by thrust and thrust strike slips, while the Javakheti upland is mostly characterized by strike-slip faults [6]. Georgia is vulnerable to earthquake hazards. A seismic risk is very high here. A single large earthquake, however, can cause far more damage than the average estimate from other natural hazards. Direct losses for residential houses and infrastructure damages resulting just from the Racha earthquake (29 April 1991) in Georgia (with more than 200 deaths) was assessed in the order of 10 billion rubles (as of 1991, approximately 5.5 billion USD at commercial exchange rate and 16 billion USD at official course) [6]. So, to estimate potential losses is vital for the region. Annualized earthquake loss addresses two components of seismic risk: the probability of ground motion and the consequences of ground motion on different element at risk. Some study carried out to combine seismic hazard with the value

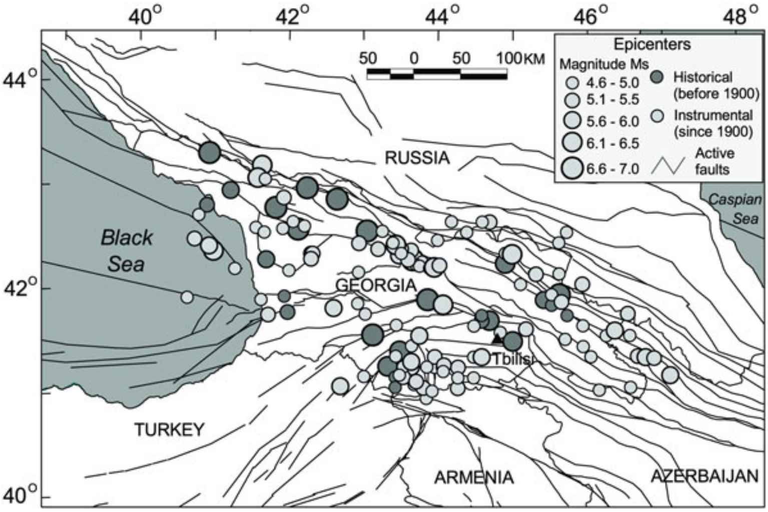


**Fig. 20.1** Seismicity and active faults of Georgia

of the building inventory in the country to provide estimations of economic losses and casualty from earthquakes in Georgia. Figure 20.1 presents seismicity with earthquake magnitude Ms more than 4.5 and active faults of Georgia.

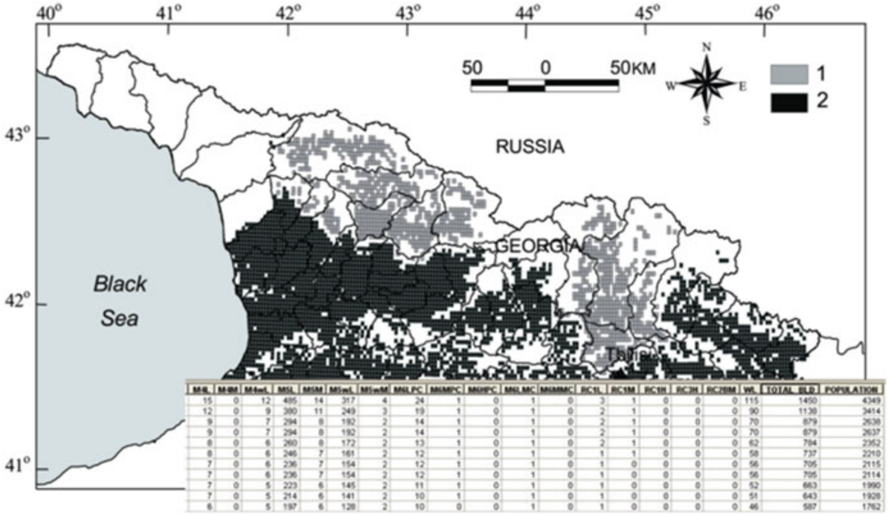
## 20.3 Inventory

In risk assessment, one important parameter is the inventory of elements at risk. In urban area, elements at risk include buildings, lifeline systems, population, socio-economic activities. Extensive and comprehensive collection of element at risk inventories is vital for estimation of losses during the earthquake.

The following GIS layers have been collected from the different sources and united in the centralized geo database: administrative division of country (regions, municipalities, election districts and precincts, cadastral zones, sectors and quarters); base topographic map layers (hydrography road network, elevation); scanned topographical and geological maps; satellite and aerial imagery; settlements and population data, and data on buildings.

The grid of 0.025° (2.8 km) size was created to summarize building and population data into the grid cells for further analysis with the seismic hazard modeling software ELER v3 [7].

Collected buildings GIS layer contains attributive data on building age, material, functionality, and number of floors. This quality and reliability of the data was not sufficient for arranging building into the predefined taxonomy classes, so we conducted additional inventory of the buildings using detailed resolution aerial



| M4L | M4M | M4wL | M5L | M5M | M5wL | M5wM | M6LPC | M6MPC | M6HPC | M6LMC | M6MMC | RC1L | RC1M | RC1H | RC3H | RC2BM | WL | TOTAL_BLD | POPULATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 0 | 12 | 495 | 14 | 317 | 4 | 24 | 1 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 115 | 1450 | 4349 |
| 12 | 0 | 9 | 380 | 11 | 249 | 3 | 19 | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 90 | 1138 | 3414 |
| 9 | 0 | 7 | 294 | 8 | 192 | 2 | 14 | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 70 | 879 | 2638 |
| 9 | 0 | 7 | 294 | 8 | 192 | 2 | 14 | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 70 | 879 | 2637 |
| 8 | 0 | 6 | 260 | 8 | 172 | 2 | 13 | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 62 | 784 | 2352 |
| 8 | 0 | 6 | 246 | 7 | 161 | 2 | 12 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 58 | 737 | 2210 |
| 7 | 0 | 6 | 236 | 7 | 154 | 2 | 12 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 56 | 705 | 2115 |
| 7 | 0 | 6 | 236 | 7 | 154 | 2 | 12 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 56 | 705 | 2114 |
| 7 | 0 | 5 | 223 | 6 | 145 | 2 | 11 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 52 | 663 | 1990 |
| 7 | 0 | 5 | 214 | 6 | 141 | 2 | 10 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 51 | 643 | 1928 |
| 6 | 0 | 5 | 197 | 6 | 128 | 2 | 10 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 46 | 587 | 1762 |

**Fig. 20.2** Databases for buildings and population in GIS for territory of Georgia

imagery, building photos (where available) and expert judgment about the known building types in different regions of Georgia. As a result, all buildings of Georgia were assigned to taxonomy classes according to Lagomarsino and Giovinazzi [8] and we obtained a GIS database of classified buildings. Population data for each grid cell was obtained from the basis of the 2007 general population census, GEOSTAT [9]. Population value from the census data was assigned to each settlement point on the GIS map. Summarizing the population into the 2.8 km grid cells using settlement points did not give correct information on population distribution, since in most cases one settlement is located in more than one grid cell, so we needed to distribute the population to the buildings or residential quarters for more exact calculation. For this purpose, the GIS layer of residential quarters (quarter polygons) was used, which models the population distribution fairly well for the whole country. Using GIS analytical tools, we automatically assigned each residential quarter to the nearest settlement point that contained population data (using settlement unique codes). Then the population of each settlement point was distributed among its quarter polygons with the proportion of polygon area (bigger quarters were assigned higher population value). The population for each grid cell was calculated by summarizing populations of each residential quarter falling into the grid cell; if the quarter was located in more than one cell, its population was distributed to the cells by area proportion. Finally, the custom programming script was created that summarizes the following information for each grid cell: the total number of buildings, total area of buildings, total population, total number of buildings per each taxonomy class and total area of buildings for each taxonomy class (Fig. 20.2). This data constituted the input for the ELER software, for further calculation of risk.

## 20.4 Seismic Hazard Assessment

Seismic hazard assessment for Georgia had been a subject for several investigations in various international and national projects that were published in international and local literature. Namely, Probabilistic Seismic Hazard Assessment (PSHA) for the Caucasus had been undertaken in the frame of the Global Seismic Hazard Assessment Program GSHAP [10]. The Seismic Hazard maps were re-calculated in 2002–2007 during operation of the International Science and Technology Centre (ISTC) project: "Caucasian Seismic Information System" ISTC A651 (CauSIN). The assessment of seismic hazard for the Caucasus, based on the Cornell approach, namely computer program SEISRISK III after Bender and Perkins [11], was used for compilation of the set of maps for macroseismic intensity and peak ground acceleration (for the 50 year exposure time and 2 %, 5 %, 10 % probability of exceeding). Similar issues were considered by several authors in individual studies [12–16]. Today in Georgia are used a normative seismic hazard map expressing the severity of impact by the peak ground acceleration and the intensity (MSK 64) for a 2 % probability of exceedence in 50 years. A generalization of this map to seismic hazard map that was calculated in the frame of the GSHAP project [10] showing considerable differences resulting from generalization. Taking into account that the GSHAP seismic hazard map for the Caucasus region is calculated for a 10 % probability of exceedence in 50 years, these differences became even larger. The Georgian normative seismic hazard map shows a lower susceptibility than the seismic hazard map recently calculated by Slejko et al. [13]. It became evident that there were gaps in seismic hazard assessment and normative seismic hazard maps needed a careful recalculation.

The methodology for the probabilistic assessment of seismic hazard includes the following steps: produce comprehensive catalogue of historical earthquakes (up to 1900) and the period of instrumental observations with uniform scale of magnitudes; produce models of seismic sources zone (SSZ) and their parameterization (estimate recurrence law, the maximum magnitude, the distribution of earthquakes depth and nature of the movement.); develop appropriate GMPE ground motion prediction equation models; develop seismic hazard curves for spectral amplitudes at each period and maps in digital format.

The new seismic catalog of Georgia: Using a complete catalog is the most important to determine seismic hazard analysis in the region. The content of work package WP1 of EMME project involved the compilation of a new earthquake catalog for the Middle East region, including Georgia. In this work, there were two main goals: (1) Drafting a new catalog of historical earthquakes of Georgia and (2) Compilation of new instrumental seismic catalog of Georgia. In the process of compiling the level of the magnitude completeness was limited to: $Ms \geq 2.9$ or $Mw \geq 4.0$.

The main principles for compiling a catalogue of historical earthquakes are considered in Varazanashvili et al. [17]. The study and detailed analysis of these original documents and researches have allowed us to create a new catalogue of historical earthquakes of Georgia from 1250 BC to 1900 AD. The method of the study is based on a multidisciplinary approach, i.e. on the joint use of methods of history and paleoseismology, archeoseismology, seismotectonics, geomorphology, etc. A new parametric catalogue of 44 historic earthquakes of Georgia has been obtained and a full "descriptor" of all the phenomena described in it.

After 1962, the seismic network in the Caucasus and in Georgia improved, but inaccurate velocity models do not give good results. To reveal the best velocity model the hypocenter parameters of the earthquake were calculated, using the HYPO-71 program [18]. More detail this work are described in Tsereteli et al. [16]. During the period 1963–2002, parameters of about 120 earthquakes were recalculated for Georgia. The difference between obtained and existing locations of individual earthquakes was sometimes more than 20 km. Thus, after the determination or specification of the basic parameters of earthquakes, we present a new catalog of historical earthquakes (pre-1900) of Georgia and the refined instrumental earthquake catalog (1900–2009) of Georgia.

Seismic Sources (SS): The identification of area SSZ was obtained on the bases of structural geology, parameters of seismicity and seismotectonics. In determining the SS, the slope of the appropriate active fault plane, the width of the dynamic influence of the fault, power of seismoactive layer are taken into account. The relationship of strong earthquakes with this fault is set based on data on the position and orientation of the earthquake sources, and the character of motion in them: the position of the hypocenter; data on direction of the first isoseismals; information about the orientation of the scattering area of forshocks and aftershocks; materials on the focal mechanism, the position of the seismogenic landslides and seismodislocations. Each SSZ was defined with the parameters: the geometry, the percentage of focal mechanism, predominant azimuth and dip angle values, activity rates, maximum magnitude, hypocenter depth distribution, lower and upper seismogenic depth values.

Ground motion prediction equation models: Data bases of strong motion are very poor for Georgian region, especially for strong earthquakes with $MS \geq 5$ that is very important from engineering point of view. Quite many works have done in the Caucasus to estimate this equation [19–21], but because of poor data the desired result were not given. Some attempt was to complete the database with the data from the tectonically similar region (Caucasus, north-west Turkey, central Italy and others) to derive more accurate ground motion prediction equation GMPE [12, 13].

To capture epistemic uncertainty in GMPE in different regions and tectonic regimes, a selection of a set of appropriate GMPEs (candidate GMPE) is required. For that, the number of selected GMPEs is kept as small as possible, but enough to capture the uncertainty. The selected GMPEs should be robust enough to cover a wide range of magnitudes, distances and frequencies. The Next Generation Attenuation project [22] developed a series of GMPEs intended for application to geographically diverse regions (including Turkey and Caucasus). Together with NGAs GMPE models by us were further considered European and regional models. From these the candidate GMPEs for shallow active crustal regions are collected and

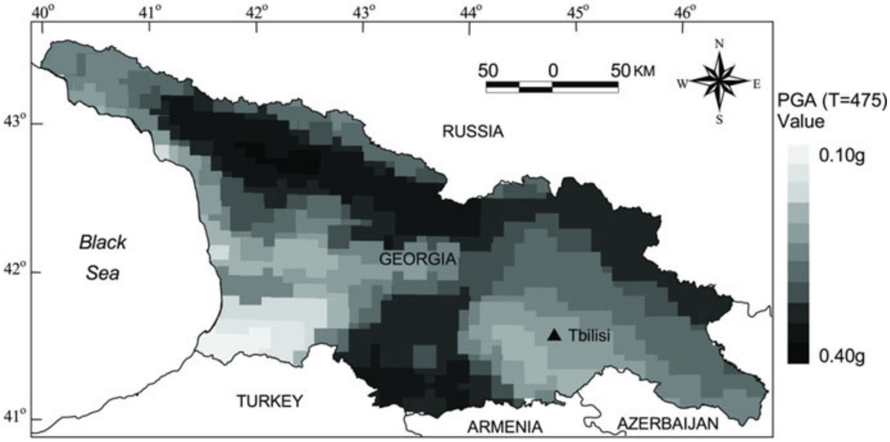


**Fig. 20.3** Seismic hazard map in terms of PGA for *10 %* probability of exceedence in 50 years for rock (Vs = 760 m/s)

they are subjected to a further elimination based on the criteria proposed in Cotton et al. [23] [24]. Accelerograms from Turkey, Iran, Georgia, Armenia, Pakistan and Jordan were collected in the EMME databases that were used for ranking and selecting candidate GMPEs using the data-driven testing procedure proposed by Scherbaum et al. [25, 26] and Kale and Akkar [27]. Proceeding from this analysis, GMPEs [28–31] were used with equal weights in the logic tree combination in the seismic hazard calculation [24].

On the basis of obtained area seismic sources, the probabilistic seismic hazard maps were calculated showing peak ground acceleration (PGA) and spectral accelerations (SA) at 0.2, 1 s periods for 10 % probability and 2 % probability in 50 years using selected GMPEs correspondingly for Rock (Vs = 760 m/s) and soil (Vs = 300 m/s). Seismic hazard (SH) calculation has been performed with two software OpenQuake [42] and EZFRISK [43]. They are used the standard methodology for probabilistic seismic hazard analysis. Both of them gave equal value of SH for Georgia. Results some of them are presented in Figs. 20.3 and 20.4.

## 20.5 Vulnerability

The Vulnerability Module quantifies the vulnerability of the assets subjected to the seismic hazard. Combination of the vulnerability with the value of the affected assets gives possibility to estimate total direct losses in physical terms from earthquake (DL). Collected inventory map of element at risk allow estimation vulnerability just for buildings for the territory of Georgia. So available data just

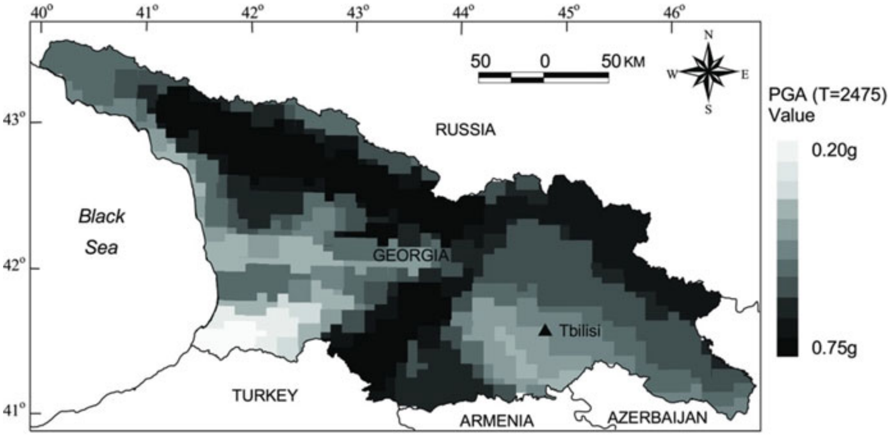


**Fig. 20.4** Seismic hazard map in terms of PGA for ***2*** % probability of exceedence in 50 years for rock (Vs = 300 m/s)

can show a picture of the consequences in terms of direct damages caused mainly on infrastructure. For any developing country, the influence of DL on national economies is important. So, the vulnerability analysis of building trough the country can works as proxy for vulnerability at a large of a country

A review of existing literature in the assessment of risk shows the big gaps in understanding of vulnerability for Georgia. There was not such clear definition of vulnerability as presented by Lagomarsino and Giovinazzi [8]. In particular, there is neither a vulnerability definition with respect to the individual element at risk for the territory of Georgia. Very often in seismic risk assessment, structural engineers use the so-called grade of sensitivity of damage [15, 32, 44, 45] or the vulnerability index [33, 34], which is defined as a relationship between the hazard intensity and the degree of loss. There were attempts to calculate the economic loss expressed in deciles using the technique presented in Dilley et al. [35], Tsereteli [36, 37], Chelidze et al. [38], but the obtained maps were very approximative due to the very limited amount of data available. The first step was done in Varazanashvili et al. [6] for the assessment of the historical and present vulnerabilities for six types of natural hazards (drought, hurricane, hail, frost, flash floods and earthquakes).

In the frame of EMME project was possible to develop intensity based vulnerability for Georgian buildings. The European building taxonomy classification proposed by Lagomarsino et al. [8] were used and taxonomy classification was done for buildings with available data on the bases of building information and aerial photos. On the bases of empirical data that was collected for Racha earthquake (Ms = 6.9) on 29 April of 1991 and Tbilisi earthquake (Ms = 4.6) on 25 April of 2002 some intensity based vulnerability study were completed. These records do not include information about the building height. For this, according to the actual observable inventory and expert opinion the following assumptions are made: simple stone are consider as mid-rise M3M; Pre code masonry reinforced

**Table 20.1** V (vulnerability), $\Delta V_r$ (regional vulnerability), Q (ductility) and t parameters for M3M, M6LPC, M6LMC, RC2PM and RC2PH buildings

| Building name | Vulnerability | $\Delta V_r$ | Ductility | t parameter |
|---|---|---|---|---|
| M3M | 0.99 | 0.25 | 2.3 | 8 |
| M6LPC | 0.72 | 0.15 | 2.3 | 8 |
| M6LMC | 0.61 | 0.12 | 2.3 | 8 |
| RC2PM | 0.59 | 0 | 2.3 | 8 |
| RC2PH | 0.66 | 0 | 2.3 | 8 |

**Table 20.2** V (vulnerability), $\Delta V_r$ (regional vulnerability), Q (ductility) and t parameters for RC2BM and RC2BH buildings

| Building name | Vulnerability | $\Delta V_r$ | Ductility | t parameter |
|---|---|---|---|---|
| RC2BM | 0.54 | 0 | 2.3 | 8 |
| RC2BH | 0.51 | 0 | 2.3 | 8 |

concrete rc floors are considered as low rise M6LPC; MC masonry rc floors are consider as mid-rise M6LMC. Also industrial types of building like mid-rise large panel buildings RC2PM that do not have analog in European buildings were investigated. Comparison of obtained data with the data proposed by Lagomarsino and Giovinazzi [8] gave us the possibility to develop the regional vulnerability factors for these typologies. For high-rise large panel buildings RC2PH the influence of number of floors based on experts judgment have been taken into account. Obtained results are presented in Table 20.1.

The vulnerability for large block mid-rise RC2BM and high-rise RC2BH buildings were developed on the data bases of the same house in Irkutsk [33] on the bases of experts' judgment. Results are presented in Table 20.2. For building typologies three classes of height have been considered (L = low-rise, M = mid-rise, H = high-rise) differently defined in terms of floor numbers for masonry (L = 1–2, M = 3–5, $H \geq 6$) and reinforced concrete buildings (L = 1–3, M = 4–7, $H \geq 8$).

Developed regional vulnerability applied to the vulnerability classification by Lagomarsino and Giovinazzi [8] for masonry and masonry rc floors typology (M3, M4, M6). Other is not changed.

For verifying our results, we calculated the seismic risk in terms of building damage and causalities using software ELER for Racha and Tbilisi earthquakes considering the source as reverse faults using selected GMPEs. There are quite good agreements with calculated and empirical value for damage distribution. D4 + D5. D4 + D5 damage for Racha earthquake was 4,459 from empirical data. Using obtained vulnerability model, calculated D4 + D5 damage is 4,074. Empirical value of D3 damage for Racha earthquake is 11,694 and calculated D3 is 16,013. The same comparison were done for Tbilisi earthquake. The empirical value of D4 + D5 damage is 200 and the calculated value is 402. Empirical value of D3 damage for Tbilisi earthquake is 4,996 and calculated D3 is 3,157. This allows us to conclude that our estimations of vulnerability are good enough.

For estimation of casualty for Racha and Tbilisi earthquakes, we used Coburn and Spence [39], Samardjieva and Badal [40], Bramerini et al. [41]. Calculation values obtained by Coburn and Spence [39] gave the estimations that were close to empirical data. In this methodology, casualty estimations are based on the structural damage levels D4 and D5.

## 20.6 Seismic Risk

Probabilistic seismic risk assessment in terms of structural damage and casualties were calculated for the territory of Georgia for 2.8 km grid cells using obtained results. This methodology gave prediction of damage and casualty for a given probability of recurrence, based on a probabilistic seismic hazard model, population distribution, inventory and vulnerability of buildings. ELER software [7] was used for this calculation. The approach used in damage estimation is to obtain a normally distributed cumulative damage probability for each building type. The damage probability distribution is a function of each building's vulnerability and ductility parameters [8]. Figures 20.5 and 20.6 illustrate the structural damage distribution for probabilistic seismic map (in terms of PGA) for 10 % probability of exceedence in 50 years for soil and probabilistic seismic map for 2 % probability of exceedence in 50 years for soil correspondingly. Information from this calculation provides quantitative bases for the prioritization of the risk mitigation activities.

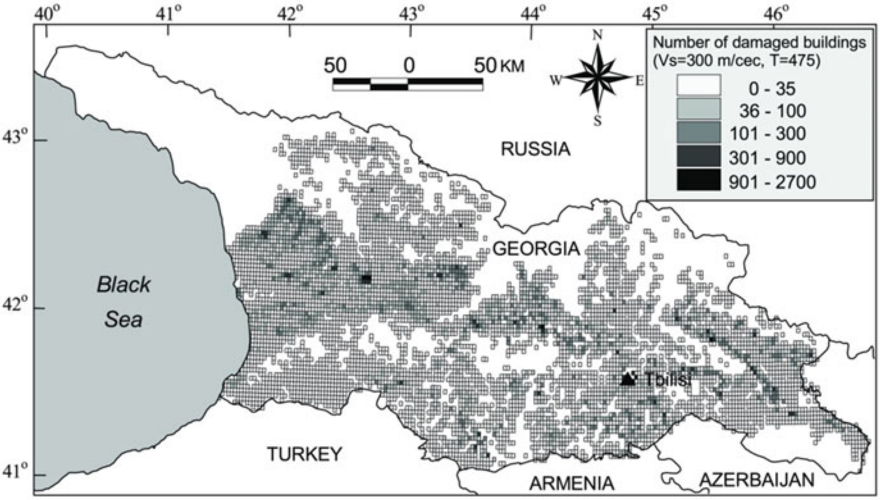


**Fig. 20.5** Structural damage distribution for probabilistic seismic map (in terms of PGA) for *10 %* probability of exceedence in 50 years for soil

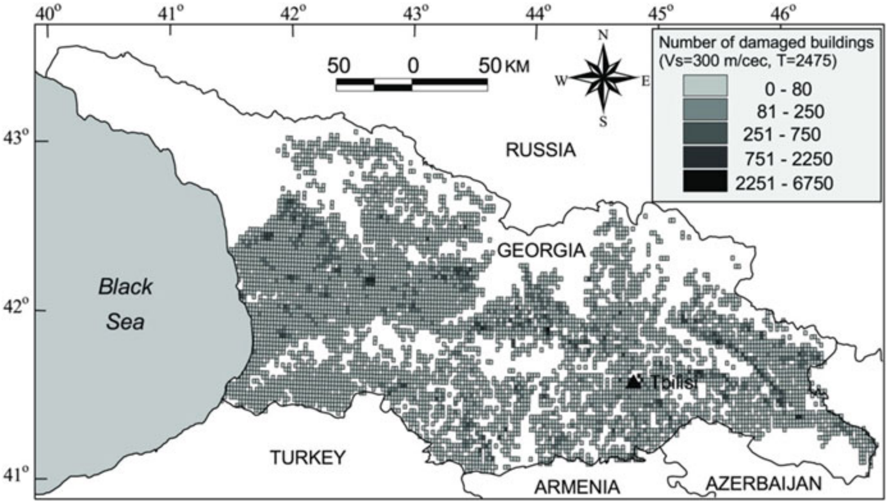


**Fig. 20.6** Structural damage distribution for probabilistic seismic map (in terms of PGA) for *2 %* probability of exceedence in 50 years for soil

## 20.7 Conclusions

The compilation of inventory maps, seismic hazard and vulnerability are definitely the pre-requisite for solution of the final task-risk management and reduction vulnerability of the country. The review of international and local literature according to risk assessment for Georgia, however, clearly showed lack of knowledge in vulnerability and seismic hazard assessment. Due to this, some attempts were made to fill these gaps towards an enhanced risk management in Georgia:

- Inventory map of element at risk (building and population) was created in GIS for the territory of Georgia except occupied regions (Abkhazia and South Ossetia).
- New probabilistic seismic hazard map in terms of PG and SA (at period 0.2 and 1 s) were calculated using modern approaches developed in the frame of EMME project.
- Intensity based vulnerability for the buildings that can be considered as proxy for vulnerability at large were developed in Georgia.
- Finally, an attempt was made to assess probabilistic seismic risks emerging in terms of structural damage and casualties for the territory of Georgia.

On the basis of these results it is possible to create a system indicating earthquake vulnerability and risk for Georgia and its particular regions/communities also. This will enable the managing agencies to carry out the effective policy of advance planning and action to reduce seismic risk through the development of resilient cities. The major obstacle in disaster management in Georgia is the absence of active and powerful national agencies that will work in systematic manner for assessing archiving, mapping, monitoring, predicting managing of all catastrophic events. GIS Mapping of seismic risk in Georgia can be considered as the early warning tool for long-term disaster preparedness of national and local authorities The presented work can contribute to a reduction of disaster losses in Georgia and will foster future efforts of harmonization of risk management strategies in the country.

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