Seismic Risk Assessment in the Middle East and EMME (Earthquake Model of Middle East) Project

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SUMMARY:
The present paper summarizes the activities completed within the seismic risk module of the regional program of GEM (Global Earthquake Model), EMME (Earthquake Model of Middle East). The seismic risk module encompasses the assessment of seismic risk in terms of structural damages, casualties and economic losses and also the evaluation of the effects of relevant mitigation measures. As the major component of EMME, seismic risk module includes regional loss estimation calculations based on intensity based vulnerability approach. Loss estimation results are obtained in terms of building damage and casualty distributions. As the result of the activities performed within risk module of EMME a homogenized building classification with appropriate vulnerability parameters are obtained. As the regional program of GEM, EMME also aims to adopt the GEM guidelines and criteria defined in connection with risk assessment methodologies.

Keywords: Earthquake model, Middle East Region, seismic loss estimation, vulnerability

1. INTRODUCTION

The regional program of GEM (Global Earthquake Model), EMME (Earthquake Model of Middle East) consists of two main modules: Seismic Hazard and Risk Modules. The seismic risk module encompasses the assessment of seismic risk in terms of structural damages, casualties and economic losses and also the evaluation of the effects of relevant mitigation measures. This module is coordinated by Kandilli Observatory and Earthquake Research Institute of Turkey (KOERI) with the participation of institutions from IIEES of Iran, NED University of Pakistan, Jordan University of Science and Technology of Jordan, American University of Beirut of Lebanon, Cyprus University of Technology of Cyprus, Ivane Javakhishvili Tbilisi State University of Georgia, National Academy of Sciences of Armenia, National Academy of Sciences of Azerbaijan.

This paper focuses on the Seismic Risk Assessment activities of the second module of the EMME Project. The seismic risk methodology is composed of the following components; Model definition, GIS based compilation of elements at risk (buildings, population), Vulnerability analysis of elements at risk, Estimation of risk and losses. A detailed evaluation of basic input for risk assessment in terms of vulnerability and loss assessment methodologies has been completed for the whole region. Available methodologies have been evaluated for damage estimations depending on both the hazard output and the quality of the inventories of elements at risk. As one of the major inputs for the seismic loss assessment, classification and compilation of elements exposed to hazard have been prepared. The data compiled for loss assessment is composed of the building inventory and population distribution in the relevant region in GIS environment. An intensity based loss estimation methodology is proposed for loss estimation calculations. As such, relevant vulnerability parameters have been determined for the building types defined in the building typology. The vulnerability relationships proposed by the participants are being evaluated though the loss estimation software called ELER based on the basis of the damage data from past earthquakes in the region. The next steps will involve the modification of the vulnerability relationships and the adoption of the methodology to the standards defined in GEM.

2. OBJECTIVE AND METHODOLOGY

The objective of earthquake risk assessment and loss estimation studies within EMME is to prepare a quantitative basis for the prioritization of the risk mitigation activities. Probabilistic risk assessment methodology used includes prediction of damage, for a given probability of recurrence, based on a probabilistic seismic hazard model, population distribution, and inventory and vulnerability of the built environment. All the calculations are performed by the ELER software, which has been developed by KOERI under the EU FP6 NERIES Project (Demircioğlu et al., 2009, Erdik et al. 2010). The compiled data is provided in the format required by the ELER software.

3. DESCRIPTION OF THE TASKS

An integrated approach of investigation is used to provide an accurate assessment of seismic risk assessment and loss estimations. The proposed seismic risk methodology is composed of the following components:

3.1. Engineering requirements and model definition

Engineering requirements and model definition involves the determination of the basic inputs for risk assessment in terms of hazard, vulnerability and loss assessment methodologies. Based on the characteristics of the basic available data compiled by each participant intensity based loss estimation methodology proposed by Giovinazzi et al. (2004) is used. Building taxonomy is basically based on EMS-98 classification but the building taxonomy proposed by related component of GEM will be followed. The vulnerability parameters for intensity based loss estimations calculations have also been proposed by the participants for the proposed building classification.

3.2. Comparative evaluation of building Codes

The present and past earthquake resistant design codes in the countries of the project region were comparatively evaluated for to assist in the determination of vulnerabilities associated with building stock. Code compliance levels of each building class are determined based on the seismic design provisions for each participant.

3.3. Classification and compilation of elements exposed to hazard

In urban areas, buildings, population, lifeline systems and socio-economic activities constitute the "elements at risk". Buildings and lifeline systems are generally termed "Built Environment". The physical losses to elements at risk that would result from a specified hazard level necessitate a collection of their inventories. For regional scale loss assessment, the inventories of demography and built environment in terms of building inventory have been compiled.

3.4. Vulnerability Relationships

There are two main approaches for generating structural vulnerability relationships. The first approach is based on damage data obtained from field observations after an earthquake or from experiments. The second approach is based on numerical analysis of the structure, either through detailed time-history analysis or through simplified methods. loss estimations in regional scale, the intensity based vulnerability assessment approach proposed by Giovinazzi et al. (2004) is used. The relevant parameters for each class of building have been determined by each participant. Loss estimates made using this approach are believed to be more rational.

4. SEISMIC RISK ASSESSMENT ACTIVITIES IN EMME

The activities that have been performed by participants in WP4:Risk Assessment of EMME project are summarized below.

4.1. Current Status of Risk Assessment Activities in Iran

The latest available nationwide data is from the 2006 census program. "Population" & "Building" (housing units) data sets are summarized within provinces, metropolitan areas, urban and rural settings. The statistics is presented as points within rather large geographic extents, therefore; additional spatial data namely LandScan 2008 was acquired as to distribute the values into spatial grids.. The building taxonomy comprises of adobe, masonry, reinforced concrete and steel structures considering three construction eras. Figure 4.1 shows the population distribution within the grids.

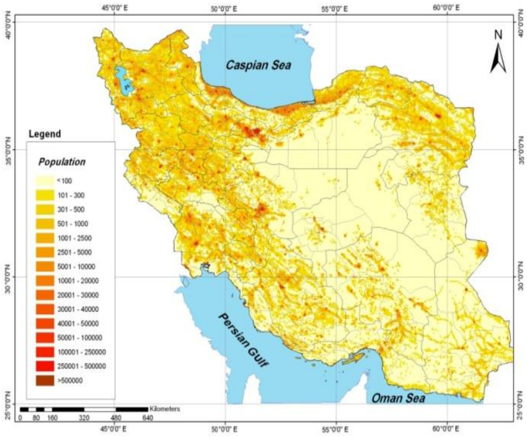

Figure 4.1. Population distribution for Iran

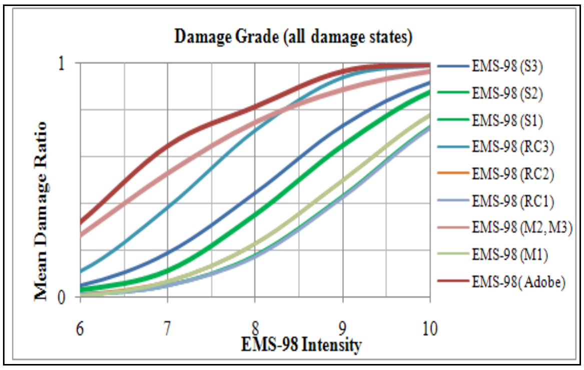

Figure 4.2. Calibrated vulnerability curves

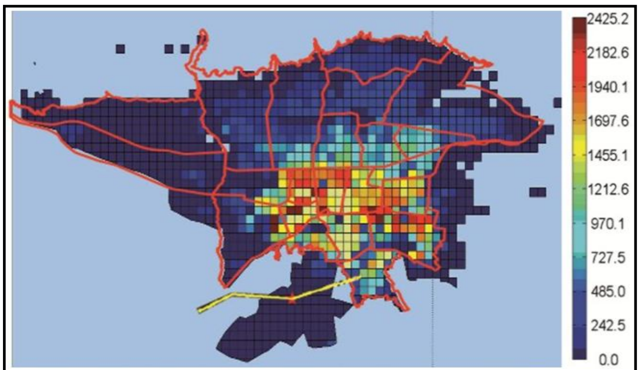

Figure 4.3. Distribution of housing damage for Tehran

Related intensity-based vulnerability functions were developed according to the EMS-98 procedure. Considering the lack of post earthquake damage data in the country, first, fragility curves were developed according to the mechanical modeling concepts, then through iteration processes, the model specific vulnerability indices were computed. Figure 4.2. shows a set of such functions for Iran. The model was implemented using the ELER software (KOERI) for Tehran considering various earthquake scenarios as to estimate the number of damaged housing units and the associated casualties. Figure 4.3 shows the distribution of damaged housing units (combined grades D4 and D5 in EMS-98 scale) for the Rey fault scenario within Tehran.

4.2. Current Status of Risk Assessment Activities in Pakistan

The latest available data on the building typology of Pakistan is the “Building and Population Census of Pakistan, 1998”. This housing data was synthesized and transformed to make it useful for acquiring estimates of seismic vulnerability. The distribution of buildings throughout the country is shown in the GIS environment.

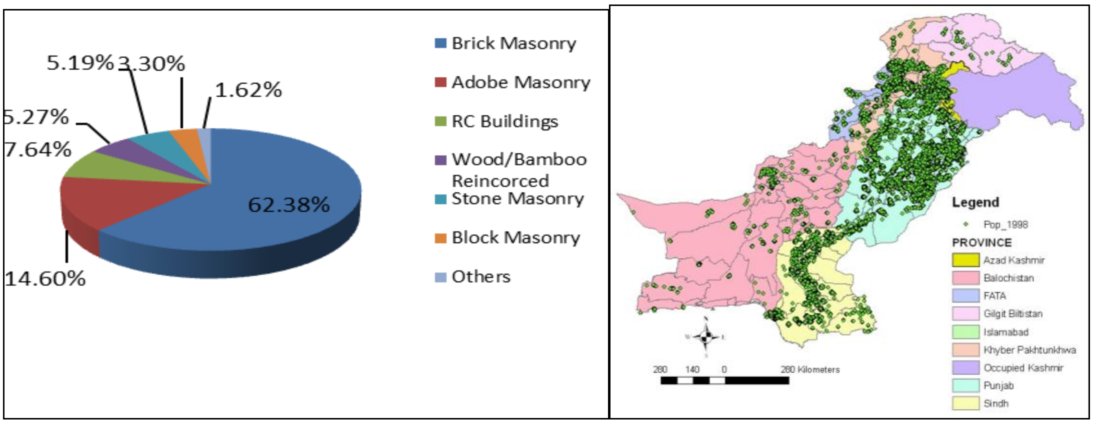

Figure 4.4. Building typologies and its distribution along Pakistan.

Intensity based fragility curves for above identified building type were developed using the post-earthquake data from Kashmir earthquake 2005. To develop the fragility curves the method suggested by Giovinazzi at al (2004) was adopted.

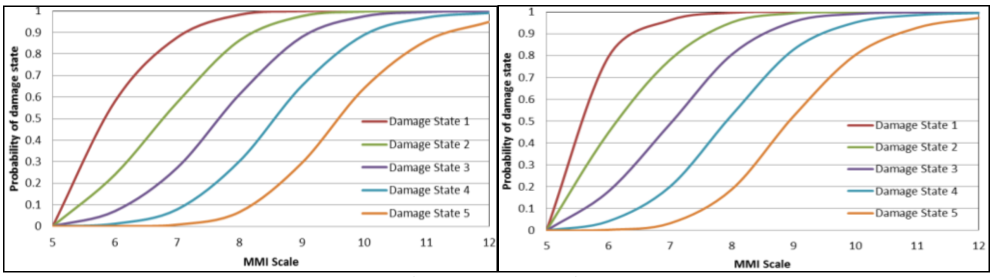

Figure 4.5. Fragility Curves for Brick and for Adobe Masonry Buildings.

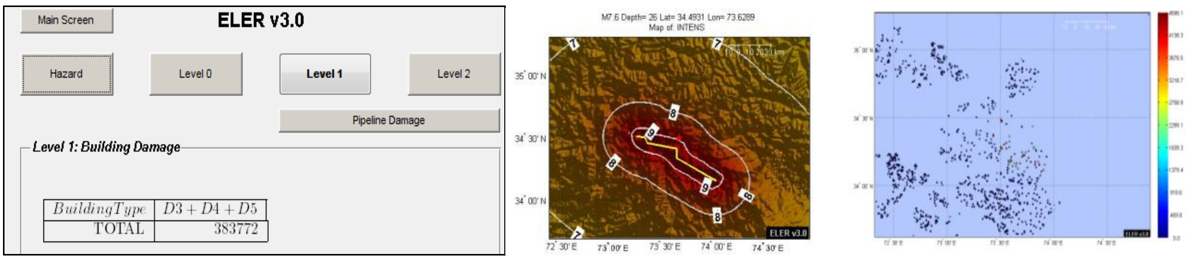

Figure 4.6. 2005 Kashmir Earthquake Building Damage Simulations and its Geospatial Distribution.

Validation of the developed model was carried out using ELER for 2005 Kashmir earthquake. Reported number of damaged buildings due to 2005 Kashmir Earthquake was 454,905 whereas simulation from ELER estimated was 383,772 damaged buildings, about 15% less.

4.3. Current Status of Risk Assessment Activities in Jordan

Statistics of the residential building stock in Jordan were obtained from the 2004 local census of housing and population. Accordingly a total of 558,588 buildings with 1.186 million housing units were found to provide accommodation for the 5.1 million populace screened in 2004. The population growth during the last 8 years was estimated, according to local authorities, to be around 1.249 million. In view of the recent construction boom, an engineering guesstimate coupled this rise in population with an increase of 77,550 buildings (total estimated number of buildings for 2012 is 636,138). Approximate calculations and field surveys revealed that the additional buildings are of the reinforced concrete skeleton type bounding a specific local type of exterior infill walls (stone-concrete walls) mainly distributed among single/twin family dwellings and multi-story multi-dwelling apartment buildings. For risk analysis, the building fabric in Jordan was categorized into 4 main typologies regarding building materials and the associated structural system. Three height categories and five construction periods (level of engineering design and earthquake resistance) were also considered in Figure 4.7.

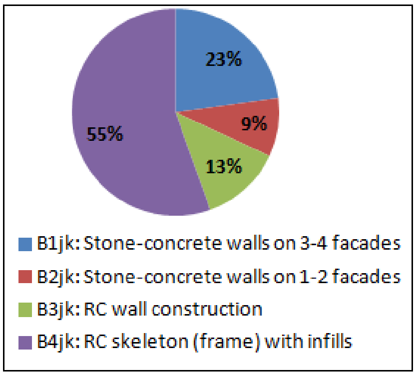

Figure 4.7. Residential building typologies in Jordan in terms of construction materials

Despite the lack of actual earthquake damage data, vulnerability of the building stock was defined using analytical vulnerability functions on one hand and vulnerability parameters (V index) developed by Giovinazzi (2004) on the other. Validation of the distribution and vulnerability of the building stock will be based on the limited earthquake damage data recorded after the Aqaba 1995 and Jericho 1927 earthquakes.

4.4. Current Status of Risk Assessment Activities in Georgia

Based on the available data, the building inventory and population distribution data in 0.025 by0.025 degree grids for the whole country (except occupied territory) have been compiled for Georgia. Current Status of Inventory Compilation in Georgia for demography is consists with the following data in GIS: population data by settlements as a point layer (on the bases of general population census of 2002 year, GEOSTAT) and settlements as a polygon layer in 1:200 000 scale. Custom Visual Basic scripts were developed to perform these tasks automatically. The inventory for buildings was created using the aerial images for the 80% of country, detailed cadastre base map layers. The building inventory has the following attribute as; material, age, number of stories for the 80% of country. Additionally archives of building for settlements for places without any information of buildings have been used. Types of buildings in Georgia according to the Seismic Design Code (DC 01.01-09) on the base of EMS-98 classification can be presented in Table 4.2. The European building taxonomy classification proposed in Giovinazzi (2004) were used for these building. The taxonomy classification was done for buildings with available data on the bases of building information and aerial photos.

The intensity based vulnerability parameters for the proposed building classification are determined based on the empirical data that collected for Racha earthquake (Ms = 6.9) on 29 April of 1991 and Tbilisi earthquake (Ms= 4.5) on 25 April of 2002. Also industrial types of building large panel buildings that do not have analog in European buildings were investigated. The Regional vulnerability factors were developed for these typologies. For high – rise building large panel buildings the influence of number of floors based on experts judgment have been taken into account. The proposed vulnerability parameters are given in Table 4.3.

Table 4.1. Building types for Georgia

No	Building Types
1	Steel frame with bracing or diaphragms
2	Monolithic reinforced concrete walls
3	Reinforced concrete frame:
	with bracing, reinforced concrete diaphragms or stiffening cores
	frame with brick or small block infill
	a) girder less frame with reinforced concrete diaphragms or stiffening cores
	b) frame, whose wall infill of does not influence the frame rigidity
	c) frame with bearing brick walls
4	Reinforced concrete large block walls (Industrial)
5	Three-dimensional block buildings (Industrial)
6	Large block and large panel buildings (Industrial)
7	Walls of complex structure, (brick, small block)
8	Brick or small block masonry walls strengthened by reinforcement
9	Brick or small block masonry walls without strengthening
10	Timber buildings
11	Buildings made of local materials

Table 4.2. Vulnerability parameters for building types in Georgia

Building Name	**Vulnerability**	**Δ**	**Ductility**	**"t" parameter**
MSM	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
RC2BM	0.44	2.3	2.3	8
RC2BH	0.51	2.3	2.3	8

4.5. Current Status of Risk Assessment Activities in Armenia

The building inventory for Armenia was supplied in terms of footprints in GIS environment. This database was obtained from the existing printed and digital maps as well as utilizing the data available at the Armenian Statistical Department website (www.armstat.am). A structural data in terms of construction year, purpose of usage, construction type, and number of storey for building stock is also obtained. For Armenia the available demographic data on population for 2010 is created and represents the available statistics showing the night time population distribution. Based on the available information, the data on building inventory and population distribution is presented in 0.025x0.025 degree grid for the entire country. In Armenia the main 7 types of residential buildings, presented in the following table, are found and are of main interest for seismic risk assessment. Using the availability of data, the residential building inventory is classified in several groups qualifying the structural characteristics. Also, a building taxonomy is determined and adapted from a pre-defined European building taxonomy proposed in Giovinazzi and Lagomarsino (2005). The following Table 4.4. presents the building stock in Armenia and its corresponding European classification.

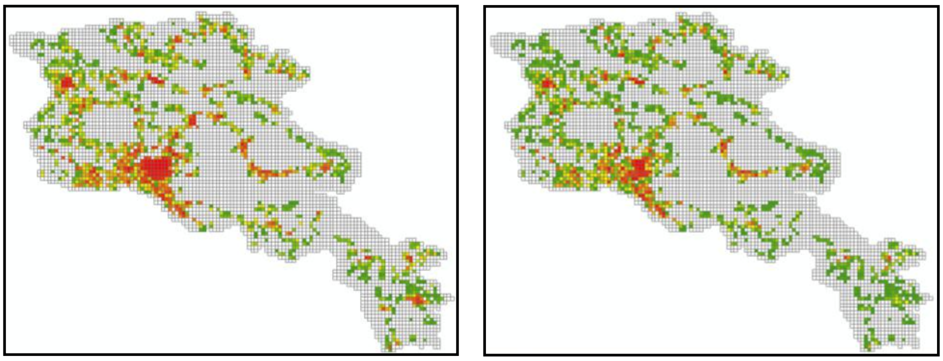

Figure 4.8. Population (left) and building (right) distributions for Armenia (0.025x0.025 degree grid)

Table4.3. Types of Buildings for Armenia

No.	Structural type	Construction year, number of stories	Corresponding European classification
1.	Masonry, individual design	Till 1958,2~4	M1, M3
2.	Masonry, Series 1-450, 1-451	1958-1970s, 1988, 4~5	M6, M7
3.	Precast RC frame	1975-1988, 9	RC2, RC3
4.	Lift slab	1970-1988, 12 and 16	RC5
5.	Frame, Badalyan and Manoukyan type	1960s~1988, 9~14	RC5, RC6
6.	Large panel	1970-till now, 5 and 9	RC6
7.	Monolith Cast-in-situ RC resisting frame	After 1988 and 1994 Medium to high-rise	RC6

To obtain the vulnerability values for building stock in Armenia the available macro-seismic data has been used to adapt the European vulnerability parameters to Armenia. Present data included the results of intensity-based macro-seismic approach available for the region of former USSR and Armenia (Sobolev, 1997; Shakhramanian, 2000) as well as the available intensity-based macro-seismic data obtained immediately after the December 7, 1988 Spitak earthquake (Der Kiureghian, 1989). Another available data is the damage ratio curves for different types of buildings (according to the MSK-64 Macro-seismic Scale), depending on shaking intensity and soil category (according to the Armenian Building Code). The obtained vulnerability indices to be used for the intensity-based macro-seismic approach are presented in the Table 4.5.

Table 4.4. Obtained vulnerability indices for building stock in Armenia

No	Building type	Vulnerability	Ductility	t parameter
1	M1_LR	0.77	2.3	8
2	M3_LR	0.65	2.3	8
3	M6_MR	0.61	2.3	8
4	M7_MR	0.41	2.3	8
5	RC_LR	0.38	2.3	8
6	RC_MR	0.43	2.3	8
7	RC_HR	0.48	2.3	8
8	RC_MN	0.21	2.3	8
9	M_C_W	0.55	2.3	8

4.6. Current Status of Risk Assessment Activities in Cyprus

The compilation of a grid based GIS database for the existing building population in Cyprus was achieved with the use of the digital building database provided by the Department of Lands and Surveys (DLS). A 1x1 km2 grid was generated for the whole of the island and the number of buildings per building category were calculated from the DLS database per grid cell. Five building categories were chosen in line with the European Building Taxonomy Classification. The four categories include the RC frames low-rise and mid-rise, with and without earthquake resistance design (ERD), whereas the fifth one includes all the traditional buildings made of adobe and stone. In addition, the building database provided in the 2011 Census of Population of Cyprus includes the number of houses and apartments per municipality/community and was used to update the DLS database. Also the population given in the Census per municipality/community was distributed into the grid cells to estimate its spatial distribution. Figure 4.9. shows the distribution of buildings (dark black) based on the DLS database, the borders of the municipalities/communities and the grid cells used (excluding the areas with no buildings or population).

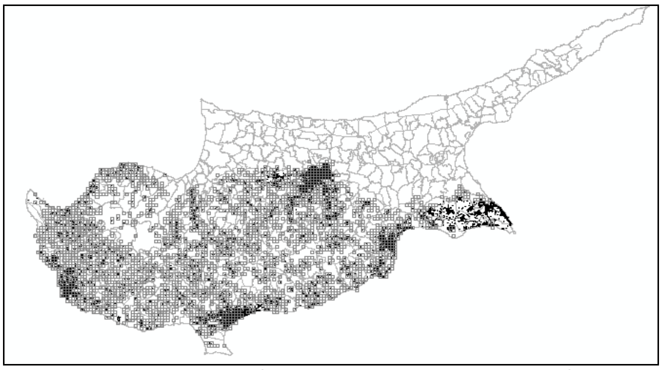

Figure 4.9. Distribution of buildings per GIS grid cell for Cyprus.

As far as the vulnerability models are concerned, empirical ones were derived based on the EMS-98 scale. These curves were used to modify the existing VQ values of the vulnerability relationships (Giovinazzi and Logomarsino, 2005) used in ELER based on the regional data. The final VQ values are given in Table 4.6 and will be used for Level 1 analysis.

Table 4.5. V-Q values for building classes in Cyprus.

Building type	V	Q
RC1L/M	0.64/0.66	2.3/2.3
RC1DCMIIL/M	0.38/0.40	2.5/2.8
M2	0.84	2.3

4.7. Current Status of Risk Assessment Activities in Lebanon

The building census was gathered from the Center of Administration and Statistics that was completed in 2004. The collected data was divided in three categories: material of construction, number of floors and date of construction per Caza, knowing that data on the Chouf area was missing in the census. On the other hand, the population distribution was collected from the Council of Development and Reconstruction that was conducted in 1994; and by interpolation it was updated to year 2005. The data that is available was then converted into a 2.5 by 2.5 kilometers grid in GIS as shown in Figure 4.10 below.

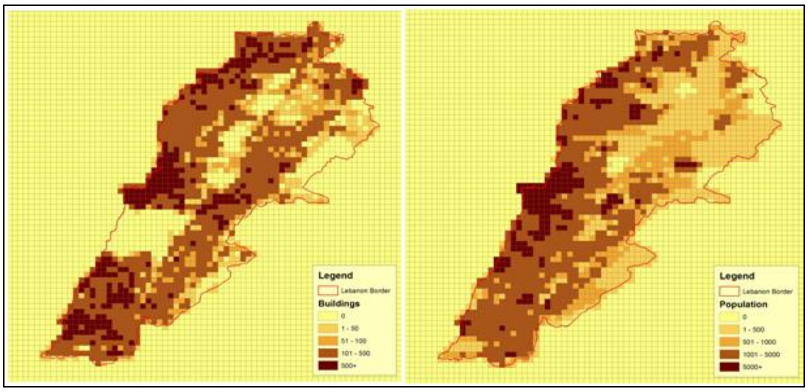

Figure 4.10. GIS Maps for Buildings and Population Distribution-Lebanon

Some assumptions based on experience in real estate in Lebanon were applied to the original building data in order to develop an inventory that matches with the EMS-98 building categories and that takes into account the building types that are available in Lebanon. The data was aggregated accordingly to the following eight building typologies: stone buildings, masonry buildings with RC floors, RC frame without ERD (Earthquake Resistant Design), low rise and built before 1960, RC frame without ERD, low rise and built after 1960, RC frame without ERD, medium rise and built before 1960, RC frame without ERD, medium rise and built after 1960, shear walls with moderate ERD and shear walls with high ERD. Vulnerability parameters for each building category were consequently derived from Giovinazzi and Lagomarsino's vulnerability tables as shown in Table 4.7. below.

Table 4.6. Building categories and their corresponding vulnerabilities-Lebanon

Building Type	Vulnerability Parameters
M3 (simple stone)	0.650
M6 (U-masonry-r.c floors)	0.790
RC1_LR_1 (frame in r.c without ERD)	0.644
RC1_LR_2 (frame in r.c without ERD)	0.490
RC1_MR_1 (frame in r.c without ERD)	0.800
RC1_MR_2 (frame in r.c without ERD)	0.644
RC5 (shear walls-moderate ERD)	0.384
RC6 (shear walls-high ERD)	0.047

4.8. Current Status of Risk Assessment Activities in Turkey

The grid based building inventory for Turkey has been prepared in the study of Demircioglu et al., (2010). The TUIK building census data contained information in excel, the grid based Landscan population data, building inventory census at villages, population census of TUIK, Admistrative boundaries of Turkey, and grid based Landscan population (2005) datasets were utilized to composed the grid based building inventory dataset for Turkey. According to the European Building Taxonomy, the building classification has been done according to construction type, number of stories, construction date, and use of building. The distribution of the building inventory distribution for Turkey are compiled in grid based GIS format. The details of the process is presented in the study of (Demircioğlu et al., 2012) performed for the prioritization study in Turkey.

5. CONCLUSION

As summarized above the risk module of EMME aims to estimate the building damage and casualty loss through intensity based methodology in regional scale. The compiled databases for both inventory and population distribution is based on the most recent datasets available in the region in GIS environment. On the other hand an attempt has been performed to homogenise the building classification in the region. As for the intensity based vulnerability parameters, a set of vulnerability and ductility indexes have been proposed by introducing some regional factors in order to consider the regional differences in seismic response characteristics of the building types in a specific region. It should be emphasized that the features of the compiled database, its attributes, proposed vulnerability parameters will be evaluated in detail through a verification and validation process. Additionally as a regional application of GEM, EMME will follow all the guidelines and criteria proposed by GEM's relevant global components and necessary modification will be done in order to comply the specifications in GEM.

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