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Vulnerability to earthquake in Istanbul: An application of the ENSURE methodology

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Abstract:
The paper aims at introducing the reader to vulnerability to earthquake in Istanbul based on the methodology developed within the ENSURE project[1] where Istanbul has been chosen as one of the external case study areas by the courtesy of Seda Kundak who collaborated within the POLIMI project team. The result given in this paper was attained in three stages. The first stage includes the primary results attained during the ENSURE project. The second stage started regarding to the request coming from the Italian Civil Protection and Disaster and Emergency Management Presidency in Turkey (AFAD in Turkish abbreviations) for implementing the ENSURE vulnerability assessment methodology in Istanbul. The second stage helped to indicate the missing data, as not all the data are available to allow parameters to be applied. Therefore, in the last stage, the missing data set was collected during the fieldwork in Istanbul in August 2012 and the focus moved into systemic vulnerability and accessibility analysis during emergency phase after occurrence of an earthquake.

The paper starts with the description of the multi-scale vulnerability framework developed within the ENSURE project. It is followed by the brief description of the case study area Istanbul. Then, in the final part, the result achieved in three stages is given within the matrices.

Keywords: *Disaster risk management, vulnerability assessment, earthquake, accessibility, ENSURE project, Istanbul.*

1. Introduction

The introduction part includes two sub-sections: integrated multi-scale framework of ENSURE project and the case study area Istanbul including retrospective view of vulnerability.

1.1 Integrated multi-scale vulnerability framework

The main purpose of the ENSURE project is to provide an operational tool for the assessment of vulnerability to natural disasters. In Figure 1 the framework developed within the Ensure project is shown: as it can be clearly seen, it is deployed over a plane where both the spatial and the temporal dimensions are evidenced. The scales at which hazards and vulnerabilities are assessed do not necessarily correspond: as for the spatial one, some hazards may be rather localized, as landslides or volcanic eruptions, but the vulnerabilities to them may manifest at much larger scales. As for the temporal scale, the phases of "impact-emergency-recovery" that are shown on the x axe may be troubled by aftershocks or new occurrences of the extreme phenomena. Repeated occurrences may bring back systems to a stage of disruption from a situation of partial return to normalcy achieved thanks to initial successful response. Before the impact, resilience is considered as comprising the set of resources and capacities to prevent the disaster from happening. At the impact, the physical vulnerabilities play the major role; as the time from the impact passes, other forms of vulnerability gain relevance, and in particular during the emergency phase, precisely systemic vulnerabilities. Those express the response capacity (or lack of) to the impairment in crucial systems and their components provoked by the physical damage. Finally, considering the time of reconstruction and recovery, resilience gains prominence. The latter is intended as the capacity to transform reconstruction into an opportunity to build and develop a better, safer and healthier place to live (see Handmer 2003; Norris et al. 2008). As for the spatial scales, whilst it may be held that physical vulnerability is mainly local, the other forms of vulnerability and resilience must be assessed also at higher spatial levels, to include the interconnectedness of complex systems and the way agents and institutions manage risk reduction and disaster management. Each ellipsoid representing vulnerability and resilience in Figure 1 has been into a matrix comprising indicators and unit of measures so as to operationalize the proposed conceptual framework. Matrices (see Table 1) are structured by systems to be assessed (represented in the rows grouped by colours) and by parameters related to aspects describing components of the different systems. Parameters are identified by their main target (to be found in the column labelled "aspect parameter") and by the key criteria to be adopted for assessment (the column "criteria for assessment").

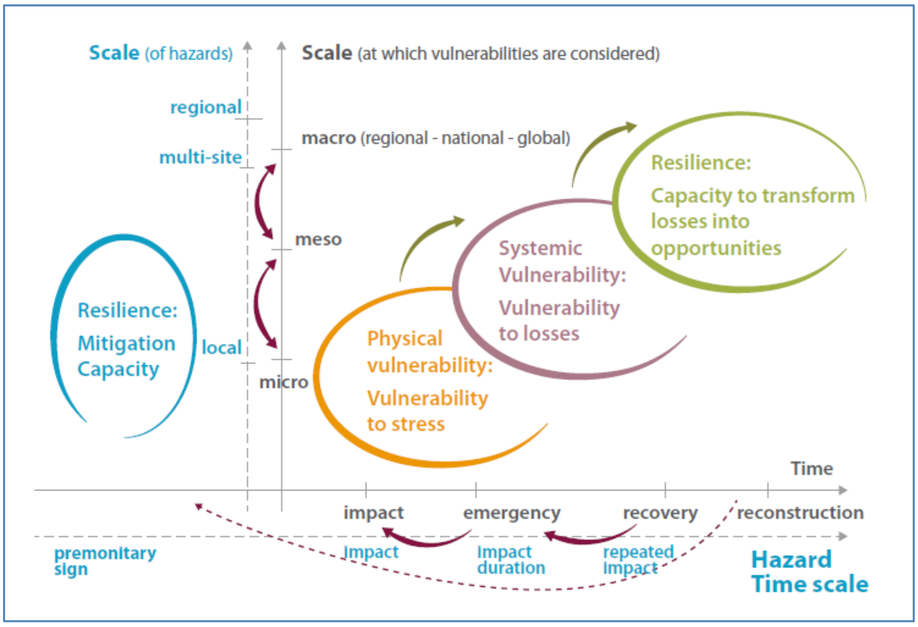

Figure 1. *General integrated multi-scale vulnerability framework developed by the ENSURE project (Source: ENSURE consortium).*

[1] ENSURE project is a specific targeted research project funded by the European Union as part of the 7th Framework Programme for research and technological development.

Table 1. *General structure of matrices of ENSURE integrated multi-scale vulnerability framework.*

System	Component	Aspect	Aspect parameter	Criteria for assessment	Comments on the case study
Natural Environment	Natural hazards	Existence and quality of mapping and monitoring	Specific parameters to permit assessment of the aspects that have been identified as relevant	Criteria may range from binary (yes/no) to degree (corresponding to judgements) or to more physical measures (for example related to time needed for ecosystems to recover)	Specific parameters to permit assessment of the aspects that have been identified as relevant.
	Enchained events	Assessment of hazards triggered by other hazards			
	Ecosystems	Fragility to hazards and to mitigation measures			
Built Environment	Residential buildings	Existence and compliance with codes and landuse planning regulations	Specific parameters translating into measurable factors to be assessed	Criteria for multiple measurement modality are provided; they also depend on the scale at which the assessment is carried out	Building codes exist for some hazards (particularly seismic) and not for others; nevertheless research in the field of resistance assessment to various types of stress has evolved in the last decades.
	Public facilities	Existence of vulnerability assessment and their consideration on mitigation strategies or in emergency plans.			
Infrastructure and Production Site	Critical facilities	Existence of strategies addressing the interdependency and the functioning of critical facilities under extreme conditions	Parameters to specify conditions at which crucial lifelines and utilities can keep functioning are provided, as well as to address the potential for na-tech	Criteria for assessment are provided; proposed criteria reflect the need to address the interaction across special scales of such facilities.	Critical facilities and production sites are clearly part of the built environment. Nevertheless a specific group of rows have been dedicated to them because of their relevance.
	Production facilities	Existence of plans and procedures to maintain production in safe conditions given the possibility of extreme event			
Social System (Agents)	People/ individuals	Weaknesses versus preparedness of individuals	Most of those are qualitative parameters to assess the general level of preparedness and recovery capacity (or lack of) to traumas and discomfort provoked by potential disasters	Criteria for evaluating the parameters are provided, taking into consideration the different spatial scales at which individuals, institutions and economic agents act	Whilst the previous groups of systems relate more to the "physical environment", clearly this one embeds the results of decades of social sciences research in the field of risk and disaster studies.
	Community and institutions	Weaknesses versus preparedness of organizations and institutions			
	Economic stakeholders	Preparedness and recovery capacity (or lack of) economic stakeholders			

1.2 The case study area Istanbul

Istanbul is the largest city in Turkey, among the largest urban agglomerations in Europe and among the largest cities in the world with 13 483 052 inhabitants (TUIK, 2011). Today Istanbul is the primary city of Turkey by covering 5 512 kilometre square area, by having 18% of Turkey's population and 23% GDP of Turkey (IMM, 2008). However, occurrence of the recent earthquakes in 1999 (with 7.4 and 7.2 magnitudes) with the epicentre on the North Anatolian Fault (NAF) line next to Istanbul has increased the risk of having another major earthquake with an epicentre close to Istanbul due to an East to West progression of earthquakes along the NAF line[2] (USGS, cited in Gencer 2007). Apart from causing to arise extended damage, these two earthquakes also amplified the vulnerability of artefacts due to the damage given in 1999 in this region and the liability of the existing emergency system in general.

[2] Historic progression of earthquakes on the North Anatolian Fault line is given in detail by the USGS, available in http//:www.usgs.gov

In the early republican era until 50s, Istanbul lost most of its population due to the agreed mutual expulsion with Greece and shift of capital city responsibilities to Ankara. However, by the end of the 30s Istanbul leapt up by the modernization movement rooted in Ankara (Tekeli 1994, Bilsel 2004). By aiming to provide a modern appearance to Istanbul, international urban planning competitions were organized and foreign planners were invited to Turkey for preparing zoning ordinances. Henri Prost prepared the first plan of Istanbul between 1937-1951. The plan aimed to unify the city that was divided into four parts with new major roads as connections and public spaces, such as green areas and squares (Prost 1937 and 1947, cited in Bilsel 2004).

Although the Prost's master plan was effective for the city's development, it precipitated the underlying causes of today's vulnerabilities, such as **low quality housing stock in the historical centre, illegal housing, scarce green spaces and centrally located industrial activities** (see Tekeli 1994, Gencer 2007). Because of achieving the aims of the plan, the major part of the old housing stock had to be demolished during the plan's implementation process. The remained old housing stock became the houses of low-income newcomers to the city and deteriorated due to lack of maintenance. Moreover, demolishing existing housing stock for opening the boulevards and not providing sufficient houses led to housing problem in the following years. Another issue is that the plan was not implemented fully and some parts of the plan were changed in the following years. Though the plan was suggesting connecting structural pattern by large recreational areas, these areas occupied one by one by other activities in the following years. Some of them that connected the separated parts became fragmented and converted into hotel and commercial activities, a stadium and roads. Lastly, the plan proposed to increase the capacity of the existing industrial activities around the Golden Horn (see Bilsel 2004, Angel 1993). The location of industry suggested by the plan became a part of the centre as the city enlarged beyond the former districts by the 50s with increasing rate of migration from rural to urban areas (Tekeli 1994).

Underlying causes of vulnerability are rooted in not being able to forecast the future population correctly. While preparing the plan, Henry Prost's intention was to provide a modern look to an old capital city by supporting the physical structure with modern infrastructure, and establishing industrial activities for enhancing its economy, not assuring housing and infrastructure to a large number of population in Istanbul (see Bilsel 2004, Angel 1993). In the Prost's

[3] *A Disaster Prevention/Mitigation Basic Plan for Istanbul by Istanbul Metropolitan Municipality (IMM) and Japan International Cooperation Agency (JICA) – 2002.*

master plan, the old city centre was seen as the business district and industrial activities were located around the Golden Horn. Nonetheless, when it is the time to implement the plan, the policies related the economy had changed and Istanbul was chosen as the major city for the Marmara Region. Hence, it attracted population, which was not foreseen in the master plan previously.

In 1996 when Istanbul has become the first level earthquake hazard zone. Following this classification, the building codes updated in 1997. Before that, the building codes were less restrictive, as Istanbul was classified as the second level earthquake hazard zone. Meaning that the buildings constructed before 1997 gives the number of vulnerable buildings approximately. With the changes of the building codes in 1997, the newly constructed buildings became more resistant. According to the previously given numbers, 482.763 buildings were constructed before 1990 (Table 2). Therefore, more than half of the built stock was built according to a less stringent building code. Gaziosmanpasa has the largest number of the buildings and Fatih has the highest population density, 31 person/ha. In Istanbul, 37.444 buildings constructed in 1949 or before, which makes 5.2% of the total building stock. Before 70s the number of buildings of Istanbul was only 17,9% of the total stock in 2000 (JICA and IMM, 2002[3]) (Table 2).

Table 2. *Total building construction between the years 1949 and 2000 (according to building census in 2000) (JICA and IMM, 2002).*

Period	Istanbul (Total Building Stock)	
	Number of buildings constructed	Percentage of buildings constructed
1949 and before	37.444	5.2%
1950 – 1959	26.976	3.8%
1960 – 1969	63.335	8.9%
1970 – 1979	141.788	19.8%
1980 – 1989	213.220	29.8%
1990 – 2000	232.699	32.5%
Total number in 2000	715.462	

Last but not least, the 1/100 000 development plan of Istanbul City Region was approved on 13 February 2009 by the Istanbul Metropolitan Municipality (IMM). The plan proposes a polycentric model to release traffic load and to decrease population density. Besides, the plan decentralizes the increasing population to the Northern part of Istanbul by opening new housing areas and commits the third airport near to Black Sea. As for the earthquake risk, development to the North makes more sense as earthquake intensity is expected to be lower in the Northern part. However, having the natural resources, water reserves, agricultural areas and forests in the North, which are crucial for sustainability of the city, forces to look for other options. The linear development through the West to East coast of the city can be supported by considering hazard maps, avoiding settling in hazardous areas, establishing settlements according to the requirements of risk zones and by improving the building codes. Those kinds of policies make the development along the Marmara Sea reasonable both from sustainability and risk mitigation points of view.

2. Application of ENSURE methodology in Istanbul

Vulnerability is a dynamic concept that can be formed by policies and trends over time and across spatial scales (Menoni et al. 2012). Changing national economic policies have distinctive effects on Istanbul's economic, spatial and social vulnerabilities. Today Istanbul experiences the results of globalization trends on urban vulnerabilities, due to **rapid population growth, rapid urbanization, low quality/illegal housing supply** and **traffic congestion.**

Rapid population growth and urbanization: After the 50s central government left the regionalization policies[4] and focused on the economic improvement of the Istanbul region (Keskinok, 2001). As a result, the city itself and the Marmara Region developed rapidly, and Istanbul became the heart of the Turkey's economy. Consequently, the city started attracting population from the entire country, and in the 50s, the most rapid and largest population growth occurred in the Istanbul's history. In 1945, the population of Istanbul was 860.558 and this number had raised to 1.268.771 in 1955. The rate of migration from rural to urban was misinterpreted. In the following forty years, between 1950 and 1990, the average population increase is 6.3% for Istanbul, more than double that the 2.9% population increase of the rest of the country (Görgülü et al. 1993). In 1955 changes in the population per year is 5.24%, which is the highest percentage increase in Istanbul's history until today (Table 3). The second highest percentage is in 1970 with 4.12% (Table 3). Due to its new economic role, Istanbul attracted population from the rural parts of the country.

[4] At the early years of the republic, regional development policies were highly supported. It was aimed to provide a regional development by providing labour through supporting industry and agriculture with respect to the special features of regions. However, in 1950's regional policies had been left out, emphasizing mostly the Marmara Region and the development of Istanbul attracting all labour force. Consequently, this gave rise to intense migrations to Istanbul from all over Turkey (Keskinok 2001).

Table 3. *Historical populations of Istanbul and Turkey (TUIK, 2011).*

	Istanbul	Changes in the population per annum (%)	Turkey	%+Turkey	Percentage of Istanbul in Turkey's population
1927	680.857	-2,21	13.648.987	-	4.9%
1945	860.558	1.07	18.790.987	1,08	4.5%
1950	983.041	2.70	20.947.155	2.29	4.7%
1955	1.268.771	5,24	24.065.543	2.97	5.2%
1960	1.466.535	2,94	27.755.532	3.06	5.3%
1970	2.132.407	4,12	35.605.653	2.68	6%
1980	2.772.708	1,71	44.737.321	2.17	6.2%
1990	6.629.431	3,90	56.473.653	2.29	11.7%
2000	8.803.468	2,88	67.804.543	2,00	17.6%
2011	13.483.052	2,76	74.724.269	1,35	18.2%

In 1980, the proportion of Istanbul's population in the Turkey's total population increased immensely (Table 2). The percentage of Istanbul's population with respect to the entire population was 6.2%, and this number increased to 11.7% in 1990. The number of buildings grew accordingly. 29.8% of all buildings in Istanbul was constructed between 1980 and 1989 and this trend continued in the next ten-year period between 1990 and 2000 with 32.5% (Table 2). Half of the building stock of Istanbul was built after 80s, as a consequence of economic policies[5] of Turkey after 80s (JICA & IMM, 2002) (Table 2).

After the 80s, the population of urban areas became larger than rural areas, similarly to that occurred in Europe by the early 20th century, as a consequence of the mid-19th century industrialization. Decision makers and analysts were expecting a population increase because of the new job opportunities offered by the city, but its actual size was completely

[5] *Capital Markets Board and Istanbul Stock Exchange was established together with releasing interests and modernization of tax system. Free foreign trade had been disseminated, making Turkey a centre of attraction especially for the foreign capital.*

underestimated. The foreseen population for Istanbul was around 4 million in 2000, but Istanbul exceeded this level in the 80s (Tekeli 1994).

Low quality and illegal dwellings: Housing development in the peripheries was not for providing affordable houses to newcomers. As a result, newcomers moved in the emptied old urban fabric that is located in the hearth of the city. Besides, some of them built their own houses illegally and mostly situated in risky zones, because central and local governments were unable to fulfil the residential needs of large number of immigrants. Consequently, illegal houses multiplied next to industrial and central areas without following any plan. In 1966 and in 1976 the Squatter Amnesty Law legalized such illegal houses. This large housing stock that grew spontaneously without any regulation had distinctive effects on the macro-form of Istanbul. And today the same housing stock, which illegally built first but legalized afterwards, represents the largest component of buildings vulnerable to earthquakes.

Traffic congestion: During the 50s, the city, which was located only in the historical parts (Eminönü, Karaköy in the European part, Üsküdar and Kadıköy in the Asian part), expanded along the new boulevards. Macro-form of the city dispersed in the same direction of the CBD (Central Business District) (Tekeli 1994). The first bridge on the Bosporus was established in 1973 and the second bridge on Bosporus opened in 1988. Due to moving to peripheries and the comfort provided by the bridge and new roads, the car ownership increased rapidly. Istanbul faces also traffic congestion due to increased number of car ownership and road depending transportation modes by neglecting rail and sea transportation. The 1956 Zoning ordinance of Istanbul stimulated car ownership by opening large roads, boulevards, and housing development in the peripheries without investing on public transportation. The road depending transportation system leads to congestion especially in the peak hours around central business districts, and especially on the two bridges on Bosporus.

As mentioned previously, the data presented in the following parts is gathered in three stages, and demonstrates the final outcome of the application of Ensure methodology to Istanbul.

2.1 First matrix: Mitigation capacity

In the first matrix, the focus is on the capacity to mitigate vulnerabilities to natural hazards. The aspects such as natural hazard identification, inclusion of vulnerability in the land use plans etc., are evaluated in terms of their presence, absence and quality (Table 4).

Istanbul is prone to earthquake hazard, and the studies on hazard identification, mapping and monitoring have accelerated after the 1999 Marmara Earthquake. Having maps in different scales (city, neighbourhood, microzonation etc.) benefits to understand different aspects that are needed to connect the natural environment with the built environment. That serves better to understand current vulnerability, as vulnerability arises from the interaction of natural and built environment.

Overall, the assessment reveals that regarding the natural environment the mitigation capacity is high due to having good quality hazard maps including rupturing, geological and topographic studies and induced hazards, such as landslides, flood, tsunami and liquefaction.

Table 4. *First matrix: Mitigation capacity.*

	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application or comments
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard mapsincluding map for fault rupturing at the ground surface availability	At the following scales: country level; regional and provincial; lower scales	yes/no; quality as judged with respect to international standards and updated to new knowledge and technologies	YES / In the country level there are the earthquake hazard maps and priority zones defined in those maps. In the provincial level there are hazard maps which include fault rupturing, geological maps and also topographic.
			Geological map of quaternary formation			
			Map of topographic amplification zones			
		Hazard monitoring	Availability of seismographs and accelerometers networks	binary and density	yes/no; dense/only individual sparse points	YES
		Induced/triggered hazards consideration in hazard monitoring systems	Availability of maps of landslides and estimation of their potential movement consequent to earthquakes	binary; quality	yes at appropriate scale/no; quality with resepct to international standards	YES / There are maps for induced hazards such as landslides, flood, liquefaction and tsunami hazards.
			Map of potential liquefaction zones	binary; coverage	yes/no; only spot like/covering the entire area of concern	
			Map of tsunami hazard	binary	yes/no	
			Tsunami monitoring network	binary	yes/no	
Built environment	*Exposure and vulnerability of built environment*	Is exposure and vulnerability considered and acted upon in plans?	Vulnerability assessment of exposed built stock	binary; frequency	yes/no; updated at the same rate of urban growth/not updated	YES / There are vulnerability maps for buildings, population, roads and critical facilities
			Risk maps and scenarios, including enchained events	binary	yes/no	YES
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations in amplification zones and specific building requirements	NO
	Rules and tools for risk mitigation	Inclusion of vulnerability and exposure assessments in land use plans	Building codes/rules	binary; quality	yes/no; updated according to state of the art/old	Changed two years before the Marmara Earthquake. Majority of the building stock built before 1998 and there were not considered building codes for earthquake resistance.
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	binary; judgement about the capacity to conform to the "code of practice"	N/A
			Maintenance of built stock	binary	yes/no	Maintanence degree of most of the built stock is very low
			Specific provisons for retrofitting	binary	economic incentives promoted/not promoted	There are some, but to be more specific data required in the future.
			Land use plans embedding risk mitigation and vulnerability reduction	binary/ expert quality judgement	yes/no; sectoral/comprehensive; specific/generic	NO
			Implementation capacity	binary; frequency of inspections; availability of trained personnel for inspections	yes/no; frequent/rare; yes/no and number/total of construction sites every year	YES
			Integration to other measures (insurance)	binary	yes/no	YES / But, when the scale of the city and the number of the vulnerable building stock is considered the low insurance premiums are nor realistic (Erdik, 2003)
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; each time new projects are drawn/only occasionally	YES
			Maintenance programs embedding mitigation	binary ; updating frequency	yes/no	YES
			New projects based on hazard/risk assessment	binary	yes/no	
			Level of coordination among stakeholders	degree	low/medium/high	LOW
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; each time new plants or transformation of existing ones occurs	YES
			Retrofitting measures for existing production sites	binary	yes/no	YES
			New projects based on risk assessment	binary	yes/no; special provisions for hazardous plants/generic rules	YES
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; good/poor quality	YES, to define the quality data required int he future
			Existance of emergency plans that expliclty take into account erthquakes as threat to be prepared for	binary; expert judgement on quality	yes/no; good/poor quality	YES, good quality
Social system (agents)	*People/ individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events, which largely depends on the perception and awareness of risk conditions	Risk perception/ awareness	Degree	inexistant/average/good	AVERAGE
			Individual preparedness	Regarding specific self protective measures; regarding measures included in emergency plans	low/average/high	LOW
	Community and Instituions	Evaluation of the involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees through information and education campaigns and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	Degree	low/average/high	LOW
			Education programs & media campaigns	Binary; frequency	yes/no; every two years/only occasionally	YES
				Embedded in school programs	yes/no; every two years/only occasionally	YES
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	Degree	low/average/high	AVERAGE
	Economic stakeholders	Economic capacity to mitigate of the various stakeholders; the access to financial resources for mitigation	GDP; GVA (Gross added value, measure of productivity and size of economy)	Level	rich/average/poor country	AVERAGE, Developing country
			Extent of marginalized groups	Dimension of poverty/marginalization	percentage of people living with less than x/year	Data required in the future

The built environment section in the mitigation matrix focuses not only the vulnerability of a single asset, but also its inclusion in the related plans. The study reveals that in Istanbul, although the vulnerability assessments of the buildings, population, roads and critical facilities have been prepared, the connection of these studies with the master plan needs to be considered with all aspects.

In terms of insurance, earthquake insurance became obligatory and people cannot rent or buy houses without buying the insurance first. However, the penetration of insurance is still around 40% (Çaktı, 2012). Moreover, when the scale of the city and the number of built stock are considered, the low insurance premiums are not realistic (Erdik et al. 2004; Erdik and Durukal, 2008).

The social system section in the mitigation capacity matrix aims to assess the capacity of individuals, community, institutions and economic stakeholders. As for individuals living in hazard prone areas, it is crucial to understand their ability to cope with hazardous events, which largely depends on the perception and awareness of risk and individual preparedness. Furthermore, participation in development and mitigation strategies, education programs, media campaigns, coordination and cooperation among institutions in charge of risk prevention play a significant role to assess mitigation capacity of communities and institutions. Economic stakeholders are the third part of the social system. This can be assessed by providing information on GDP, GVA and extent of marginalized groups.

For understanding the social vulnerability, a random questionnaire was conducted with 285 individuals in Istanbul in 12 neighbourhoods in August 2012. According to the data coming from the questionnaire, almost everyone knows that Istanbul is located in an earthquake prone area. That is known by the respondents mainly because of the 1999 Marmara Earthquake, and increasing concern in the media after each minor earthquake following the 1999 earthquake. 72% of the respondents experienced the 1999 Marmara Earthquake (Figure 2). 56% of the respondents said that before the occurrence of 1999 Marmara Earthquake they already knew that Istanbul is located in an earthquake prone area (Figure 3). Furthermore, 60% of the respondents expect occurrence of a major earthquake (more than 7 Mw) in Istanbul, however, 36% of them continue having the fatalistic approach (Figure 4), which is defined by Balamir (2000, 2001) as not being aware of risk, or ignoring it. Although this attitude has changed after the occurrence of 1999 Marmara Earthquake, a part of population - according to results of the questionnaire: 1/3 of the respondents - keeps the fatalistic approach. Although awareness of the earthquake risk is high, the perception of potential consequences is very low, such as people are not aware of the importance of living in

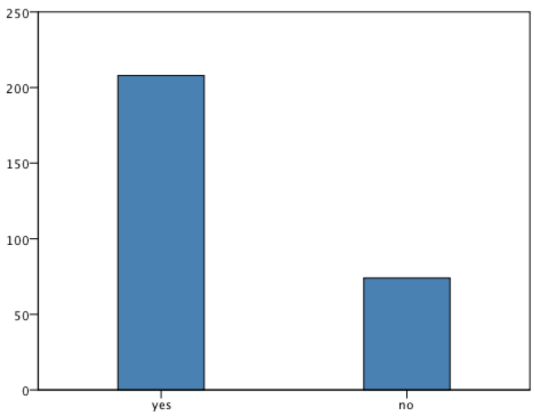

Figure 2. *Whether people experienced 1999 Marmara Earthquake, (Source: Atun, 2013).*

earthquake resistance buildings. Around half of the respondents believe that their building is resistant to seismic risk (Figure 5). However, very limited number of respondents checked their building against seismic risk or investigated the situation of building in terms of being resistance to a seismic risk when buying or renting their apartment (Figure 6).

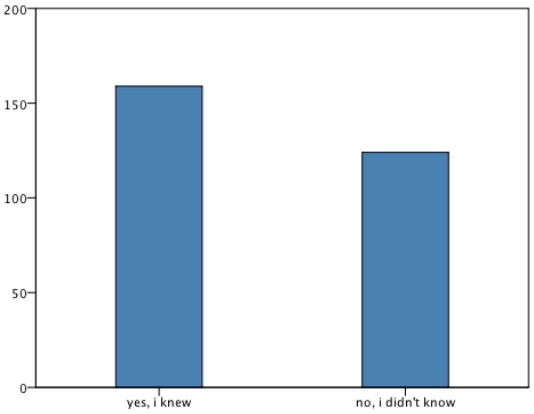

Figure 3. *Whether people knew that Istanbul is located in an earthquake prone area before the occurrence of the Marmara Earthquake (Source: Atun, 2013).*

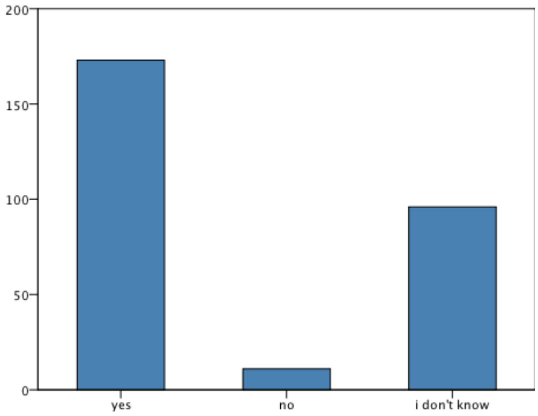

Figure 4. *Expectation of occurrence of a major earthquake (Source: Atun, 2013).*

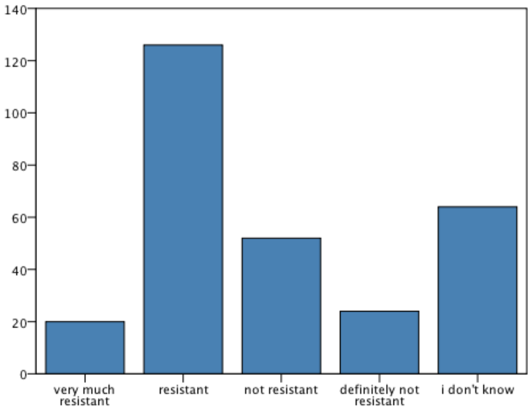

Figure 5. *Do you think that the building that you live in is resistant to an earthquake (Source: Atun, 2013).*

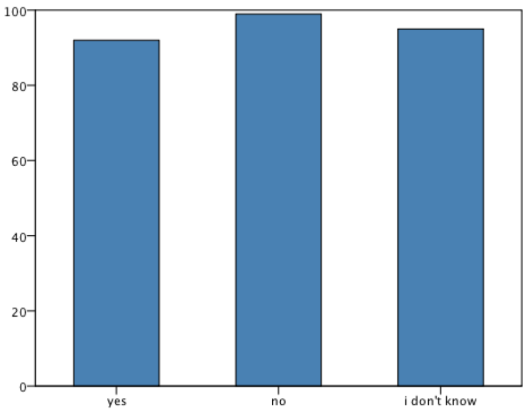

Figure 6. *Whether the building was examined against seismic risk (Source: Atun, 2013).*

2.2 Second matrix: Physical vulnerability

The physical vulnerability is assessed in the second matrix by focusing on the exposure and fragility of social systems, buildings, infrastructures and production sites where it is likely to have physical losses (Menoni et al. 2012) (Table 5).

For the structural vulnerability of buildings, parameters relate to critical features such as building materials, number of floors, relationship between built and open areas, as the urban fabric is not the simple addition of buildings, particularly in historic centres where a set of buildings sharing structural components like walls manifest rather different behaviour to shaking (Menoni et al. 2012).

Table 5. *Second matrix: Physical vulnerability.*

	Component	Aspect	Parameters	Criteria for assessment	Descriptors	Application or comments
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Average vulnerability at the municipal scale, considering settlements (rural) or urban parts	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	High vulnerability
			Vulnerability assessment of historic buildings/ monuments	Specific vulnerability indicators depending on the type of building/structure	Low-medium-high vulnerability	High vulnerability
			Vulnerability assessment of public facilities	As for residential buildings		Partly done very limited number
				Internal machinery vulnerable to shakes	Yes/No; adapted to seismic shaking/not adapted	
			Vulnerability of the urban fabric	Vulnerability assessment of structural built aggregates	On the basis of: regularity; presence of strong inclination; presence of structural disomogenity	The urban fabric is not the simple addition of buildings, particulary in historic centres where a set of buildings sharing structural components like walls manifest rather different behaviour to shaking. More studies are needed for relationship between built and open areas.
				Relationship between built and open areas	Large spaces between buidlings and open spaces availble/dense and narrow built zones	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	Vulnerability assessment of lifelines	Electricity (including nodes like power stations, transformers)	Network caracteristics (buried/aerial, existence of shut-off valves/circuit-breakers),conditions (age, degree of maintenance), network redundancy	Vulnerability of lifelines assessed by various organization especially IMM and JICA. However, to give specific details more information is needed.
				Communication (including nodes like base transceiver station)	Network caracteristics (buried/aerial), conditions (age, degree of maintenance), network redundancy	
				Gas network (including nodes like production facilities, tank farms, stations)	Network caracteristics (rigid/ductile material, existence of shut-off valves/circuit-breakers), conditions (age, degree of maintenance), network redundancy	
				Water, drinking water and sewerage network (including dams, treatment plants, pumping stations)	Network caracteristics (rigid/ductile material, existence of shut-off valves/circuit-breakers), conditions (age, degree of maintenance), network redundancy	
				Transport lines: roads, railways for instance (inc. bridges,tunnels etc.)	Network caracteristics (type of material),conditions (age, degree of maintenance), network redundancy	
			Presence of dams	Binary; assessed vulnerability to earthquakes	Yes/No; Low/Medium/High	YES, for defininig the vulnerability more data is required
			Vulnerability due to physical interaction among lifelines	Lifelines degree of connection	Low/High	HIGH
			Vulnerability due to lifeline connections physical interaction with to vulnerable buildings	Lifelines close and attached to resistant/vulnerable buildings	Yes/No	YES
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	As for public facilities	Yes/No	YES
			Potential na-tech due to stored materials, types of processes	Binary and number of workers, types of processes	Yes/No; small/large firms, processes types	YES
			Vulnerability due to dependency on lifelines	Dependance on lifelines	Low/Medium/High (existence of alternative solutions)	HIGH
Social system (agents)	*People/ individuals*	Factors that may lead to injuries and fatalities	People concentration in different zones in the hours of the day	Degree of concentration in vulnerble locations/buildings	Low/Medium/High	HIGH
			Preparedness	Previous training	Yes/No	Very small number of people have training
			Age; mobility impairment, other impairment	Difficulties to comply with evacuation orders; difficulties in escaping	Yes/No, number of people	YES
	Community and Instituions	Factors that may lead to large number of victims	Existance of emergency plan and quality	Binary; quality	Yes/No; as judged by involved institutions	YES / But not sufficient when it is compared with the population. In several cases the lack of basic SAR tools has caused the increase of victims trapped under debris. Studies show that in the first 24 hours responders are also victims.
			Availability of resources for search and rescue (lamps; cranes, special devices)	Binary; number with respect to potentially damaged areas	Yes/No; imemdiately accessible/remote; sufficient/not sufficient	

More than half of the housing stock in Istanbul is vulnerable to earthquake hazard, due to applying building codes according to the 2nd level earthquake hazard zone before 1997 and legalising squatter houses with 1966 and 1972 squatter amnesty laws. Besides, areas with low soil quality were opened to settlement after issuing the 1980s development master plan, and those areas were affected by the 1999 Marmara Earthquake, therefore, the structural components in the area need to be strengthened or reconstructed.

Although the strengthening and reconstruction works of both public and individual buildings continue all over the city, repairing/rebuilding sufficient number of vulnerable artefacts is impossible, due to the large number of the vulnerable building stock and economic deficiencies of individuals.

Density of the built area is very high according to the ratio between built and open areas, especially in the centrally located areas. The open areas are scarce and not sufficient when the density of the population is considered.

Vulnerability assessment of lifelines, including nodes and edges, should be done by considering network characteristics, condition of the lifelines (age, degree of monitoring etc.) and network redundancy. In Istanbul, vulnerability of lifelines was assessed by various organizations, such as JICA&IMM and various universities. Currently an early warning system is being established for providing warning to critical facilities (such as gas, electricity etc.) (Çaktı, 2012).

In addition to preparedness level and mobility impairment of individuals, the difference between day and night populations increases the vulnerability of the social system as well. The disaster risk and emergency plans are prepared by considering the night population (as the census data provides information on night population). However, if a major event occurs during the day, some areas where transportation nodes and central activities are concentrated will be affected severely because of the excessive population in the area. In Istanbul there are some major transportation nodes and central hubs such as Eminönü and Karaköy, where an additional emergency plan should be prepared by considering the day population as well.

2.3 Third matrix: Systemic vulnerability

As the damage can be propagated through highly connected systems, effects of interdependencies on accessibility and redundancy of systems are evaluated within the third matrix (Table 6). As for exposure and built environment, the assessment should be done by focusing on rapid post seismic building usability assessment, number and quality of temporary shelters, accessibility to work sites and services from temporary shelters and vulnerability of strategic public facilities. Regarding to infrastructure and production sites, the assessment in the matrix considers the factors that make critical infrastructures stop functioning and may lead to halting production. In the social system regarding systemic vulnerability coping capacity during crisis and the factors that may hamper effective crises management are also included in the matrix due ti their increasing importance. During an emergency, critical facilities gain importance and accessibility to these nodes from damaged areas in limited time is vital.

In the case of Istanbul, during the daily routine, transportation is one of the biggest challenges; travel time is approximately 1 hour between residential locations and central business districts. During an emergency, many roads will be blocked, so accessibility, which is already not provided, would decrease tremendously. Regarding critical facilities, hospitals with highest capacity are located mainly in the Western part of Istanbul, which is vulnerable in terms of infrastructure and buildings as well. In case of a disaster, accessibility to vulnerable areas would be very problematic.

Table 6. *Third matrix: Systemic vulnerability.*

Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Availability of rapid post seismic buildings usability assessment	Forms pre-prepared and shared among all teams	Yes/No	YES
				Information computerized	Yes/No	YES
				Rapid damage assessment map obtained in few weeks	Yes/No	NO
			Quality of temporary shelters (first emergency)	With heating or conditioning; sanitation; density	Yes/No; a>1/50 people/ a < 1/50 people; d < 1tent per family/d > 20 persons/tent	In the recent Van Earthquake in 2011, there were some difficulties to establish temporary camps immediately. The first reason was the difficult winter conditions. The second reaons was that people did not want to leave their home and they wanted to build a tent in front of their home. In the case of Istanbul there would be difficulties to provide sufficinet conditions, especially, if the earthquake hit in winter due to the large number of potential affected people.
			Accessibility to work sites and services from temporary shelters	On foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Vulnerability of strategic public facilities	Functional vulnerability of services due to physical damage to facilities	Yes/No	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Redundancy in lifelines systems	Degree	Low/High	LOW
			Degree of interdependance among lifelines	Degree	Low/Medium/High	HIGH
			Availability of emergency devices	Binary (generators; tanks, etc)	Yes/No	YES
			Continuity plan for lifelines, individually and in a coordinated fashion	Binary and quality	Yes/No; considers also induced hazards/ does not	YES, induced hazards are also considered
			Degree of dependance of critical public facilities from lifelines	Degree	Low/Medium/High	LOW
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	Degree	Low/Medium/High	LOW
			Accessibility to the plant and to markets	Redundancy; quality of roads; usability; expected increase in travel time	Redundant/not redundant; open/close roads; t.inc < 30 min/ t.inc > 30 min	Not redundant
			Contingency plan for na-tech	Binary	Yes/No; considers all potential threats/does not	During the Marmara Earthquake Tupras Oil Refinery had affected by the shock and exploded. It took several days to extinguish the fire in the refinery. Data is needed in future to understand what did change after 1999 Marmara Earthquake.
			Business continuity plan	Binary	Yes/No	YES (for the quality, data required in the future)

In Figure 7, four different maps (building vulnerability, vulnerability of infrastructure, road network, emergency road network, ports, critical facilities, such as hospitals, fire brigade, police) were combined to understand potential problems that may emerge due to infrastructure's vulnerability. Combination of the data coming from diverse sources shows the most vulnerable parts of the system and critical facilities, such as hospitals, with risk of being without access in case of an event. Hospitals with highest bed capacity are located mainly in the Western part of Istanbul, which is vulnerable in terms of infrastructure and buildings as well. In case of a disaster, accessibility to these areas would be very problematic. Besides, hospitals would also have problems related with infrastructure such as disruption to water and electricity (Figure 7).

Moreover, fire would be the second hazardous issue following the earthquake itself. "Istanbul fire brigade is capable to extinguish maximum 100 fires at the same time in different locations. According to the scenario earthquakes, it is probable to have 17000 fires due to vulnerability of gas pipelines and boxes. If 10% of this expectation becomes real, this makes 1700 fires at the same time"[6]. As firefighting equipment is not sufficient in

[6] The information is provided by Mahmut Baş, the Head of the Earthquake Department in Istanbul Metropolitan Municipality, in 17 August 2012, at the conference for the memory of Marmara Earthquake at Istanbul University, Istanbul, Turkey.

case of a tremendous earthquake, there would be the need to search additional resources such as water tanks, swimming pools etc.

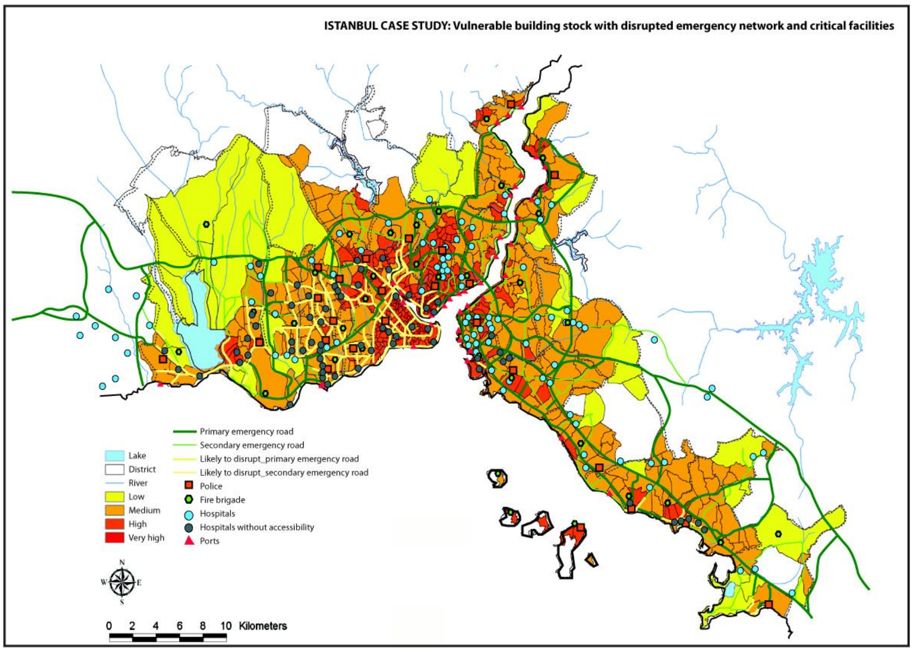

Figure 7. *Vulnerable building stock with disrupted emergency road network and critical facilities (Source: Atun, 2013).*

In terms of economy, Istanbul is the primary city of Turkey by having 18% of Turkey's population and 23% GDP of Turkey (IMM, 2008), and the city locates in the Marmara Region that possesses 30% of Turkey's total population. Having disruption in this region could affect the entire country, as Marmara Region is the primary region in Turkey's economy.

The last sub-section in Table 6 is about social vulnerabilities. In Istanbul, although interest of public is still very low, community preparedness is improving by establishing protocols between stakeholders and by providing training courses to public. Thinking and planning before an emergency could increase the probability of taking the right decision during an emergency, as people behave instantly in most of the cases.

2.4 Fourth matrix: Resilience response capacity

Resilience response capacity is assessed in the fourth matrix (Table 7) by considering capacity to recover, to reduce pre-event vulnerabilities, availability of tools and skilled workers to recover physical structure, critical infrastructures and production sites, resilience of people, transparency, reliability and reliability of institutions in charge of reconstruction, and capacity and willingness of stakeholders to invest in affected areas.

In terms of bouncing back to the previous situation and making the system functioning as soon as possible, it is crucial to transfer some of the facilities relevant for the settlement temporarily. Existence of reconstruction plans including the resources and skilled workers could help to response to situation and start to reconstructing rapidly to turn back to normal conditions as soon as possible. During the fieldwork in 2012, the author did not encounter any plans related with immediate reconstruction after the event.

Table 7. *Fourth matrix: Resilience response capacity.*

System Component		Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments from case studies
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Temporary transferability of facilities relevant for the settlement/city community life and economy	Binary; type of relocation	Yes/No; temporary/permanent	NO
			Existance of plans for reconstruction in case of severe destruction scenarios	Binary	Yes/No	NO
			Reconstruction plans considers lessons learnt from earthquake (including amplification zones)	Binary and quality	Yes/No; seismic zonation map made available for reconstruction/not available	YES
			Existance of skilled workers/firms for repairs and reconstruction (example historic sites)	Binary; quality	Yes/No; availability with respect to expected need	YES (but not sufficient when it is compared with the need)
			Level of sharing among stakeholders of reconstruction plans	Degree	High/low; only formal/substantial	NO
			Level of integration of physical reconstruction with community healing processes	Degree	High/low; room for interpreting in the new/restored setting the meaning of the destruction	NO
			Relevance of potentially affected settlements in geographic/economic terms	Level of importance	Central/peripheral	Central
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	Binary	Yes/No	YES
			In site devices for quick survey of damaged parts	Binary	Yes/No	YES
			Availability of spare materials for fast repairs	Binary; time needed to bring on site spare materials	yes/no; t < 1 day/ several days	Detailed data required in the future
			Availability of personnel for repairs	Location and number of technicians	On site/in distant areas; number of available technicians with respect to expected need	Detailed data required in the future
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	Degree; number of different stakeholders to be coordinated in repair efforts	Yes/Partial/No; one main stakeholder/several stakeholders	Detailed data required in the future
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	Binary	Applicable/Not applicable	not applicable (detailed data required in the future)
			Existance of funds for fast repairs	Binary	Yes/No	Detailed data required in the future
			Existance of inspection and guiding personnel for correct repairs	Binary	Yes/No/Forecasted in the recovery plans	YES
			Economic sectors	Diversified or concentrated on few sectors	Few/Many different economic sectors in the area	MANY
Social system (agents)	*People/ individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	Binary	Yes/No	YES, in both Marmara and recent Van Earthquake children and adults supported by the volunteer doctors.
			Availability of private resources to resettle/repair	Binary; support by public agencies; rapidity of compensation process	Yes/No; available/not available; rapid/slow	YES
			Access to insurance	Binary and coverage	Yes/No; percentage of coverage	YES
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Areas vitality	Aging population; low fertility rates	Young population
			Local condition of aged population	Binary	Autonomous/not autonomous; relatively healthy/not healthy	Percentage of aged population for each neighbourhood is known. However, their exact location is not very clear.
			Employment rate	Degree	High/medium/low	MEDIUM
			Annual population growth rate (over the last five years)	Degree	High/medium/low/negative	MEDIUM
			Immigration index	Degree	High/medium/low/negative	HIGH
			Social networking	Degree	High/medium/low/negative	HIGH
			Conflict among social/ethnic groups	Degree	High/medium/low	MEDIUM
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	Degree	High/medium/low (from sociological surveys when available)	LOW
			Transparency in funds allocation	Existance of public information and independent control mechanisms	Yes/No	Data required in the future
			Long term vision	Existance of strategic development/land use plans	Yes/No	YES
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	Binary and coverage	Yes/no;percentage	YES / But the percentage is low
			Construction industry	Level of development and modernization	High/average/low	HIGH

Having computerized systems of infrastructures and in site devices for quick survey for damaged parts increase the resilience of the infrastructure system. However, for better analysis more data is needed regarding availability of spare materials, number of personnel for repairs, present protocols to proceed with repairs, temporary transferability of production in case of need, existence of funds for fast repairs etc. (for more information please see Table 7).

As for the last part of the resilience matrix, in both 1999 Marmara and 2011 Van Earthquakes children and adults were supported by the volunteer psychiatrists and medical doctors, and civil society supported the disaster victims by providing resources. Although Istanbul has the highest unemployment rate among the country, it can be still considered as in the medium level. Medium employment and high immigration rates affect the social system's resilience negatively as they have not sufficient resources to recover from the disaster. Those people who already have low living standards would choose to return to their home city after a disaster. Low-level trust to institutions is another issue that affects resilience negatively. On the other hand, having a relatively high percentage of young population is an asset in terms of society's resilience. Moreover, highly connected social network and medium level conflict among ethnic groups affect resilience positively. Having available insurance funds and presence of highly developed construction industry increase the resilience of economic stakeholders. When these issues are considered all together, it can be said that in the case of Istanbul social system's resilience is higher when it is compared with the structural and infrastructural system's resilience.

3. Conclusion

The 1999 Marmara Earthquake has had remarkable effects on the legal and organizational systems in Turkey. Before the event, the focus of activities was on disaster management only, such as providing humanitarian aid and shelter etc. The importance of disaster risk management was understood after the occurrence of 1999 Marmara Earthquake. Following the event, authorities with collaborating universities and research centres analysed technical and organizational deficiencies in the system, the risk was assessed and decisions were made to mitigate the present earthquake risk by strengthening the public buildings and preparing emergency plans.

Turkey succeeded to move from being a "humanitarian community"[7] to "disaster risk management community" in terms of organizational and legal point of views that should be supported by the policies regarding to the spatial pattern as well. To diminish direct and indirect hazards, structural mitigation measures are taken especially in public facilities such as hospitals, schools and governmental buildings etc. However, as given previously, more than half of the housing stock of Istanbul is vulnerable to earthquake in different levels. As the number is very large, the government or municipalities cannot provide sufficient funding and most of the people cannot afford the cost of strengthening their houses.

Last but not least, according to the disaster risk report published by the UNDP (2004), to integrate disaster risk management and development plans, the basic data regarding present disaster risk shall be collected and after this, planning policies shall be used as a tool to set up a bridge between development and disaster risk management. Turkey is successful in collecting basic data on existing disaster risk, but more efforts need to be taken to achieve development plans that embed risk mitigation concerns.

[7] While disaster management communities are focusing on the pre-disaster activities, humanitarian communities stress the post-disaster activities (Balamir, 2001). Disaster risk management community identifies societies where there is a profound knowledge of disaster and risk. These communities know the importance of assessing risk and reducing it before the disaster, because they are also aware of chain effects and how a catastrophe can be destructive and costly after it occurred.

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References

Angel, A. (1993), Henri Prost ve İstanbul'un ilk nazım planı. **Journal of the Chamber of City Planners Union of Chambers of Turkish Engineers and Architects** (TMMOB), 1993/1-4, pp.6-9.

Atun, F. (2013), **Enhancing resilience of transportation system in case of disasters.** PhD thesis, Faculty of Architecture and Urban Planning, Politecnico di Milano, Milan, Italy.

Balamir, M. (2001), Disaster Policies and Social Organisation, unpublished paper presented at **the Disasters and Social Crisis sessions of the European Sociological Association Conference**, Helsinki 27 August-3 September, Finland.

Balamir, M. (2000), Is Turkey in the Process of Restructuring its Earthquake Strategy?, **Mimarlık** 295: 44-47 (in Turkish).

Bilsel, F.C. (2004), Shaping a modern city out of an ancient capital: Henri Prost's Plan for the historical peninsula of Istanbul. IPHS 2004-Barcelona

Çaktı, E. (2012), Assesment of Earthquake Risk in Istanbul. In **"Cities at Risk: Understanding, Perceiving and Responding" international PhD seminar**. November, 2012, Politecnico di Milano, Italy.

Erdik, M., Demircioglu M., Sesetyan K., Durukal E., Siyahi B. (2004), Earthquake hazard in Marmara Region, **Turkey.** 24(8): 605-631

Erdik, M., Durukal E. (2008), Earthquake risk and its mitigation in Istanbul. **Natural Hazards**, 44: 181-197.

Gencer E. (2007), Vulnerability in Hazard-prone megacities: an overview of global trends and the case of the Istanbul Metropolitan Area. Munich-Re Summer Academy for Social Vulnerability.

Görgülü Z., Görgülü T., Ramazanoğulları S. (1993), Bir dünya kenti olarak Istanbul'un değişen kimliği. **Journal of the Chamber of City Planners Union of Chambers of Turkish Engineers and Architects (TMMOB)**, 1993/1-4, pp.12-14.

Handmer, J. (2003), We are all vulnerable, in **Australian Journal of Emergency Management**, vol. 18:3, August.

IMM, Istanbul Metropolitan Municipality, (2008), Available at: http://www.ibb.gov.tr/en-US/Pages/Home_Page.aspx**.**

JICA and IMM, Japon Uluslar arası Isbirliği Ajansı (JICA) ve Istanbul Büyükşehir Belediyesi (IBB) Türkiye Cumhuriyeti (2002), Istanbul Ili Sismik Mikro-Bölgeleme Dahil Afet Önleme/Azaltma Temel Planı Çalışması, Istanbul

Keskinok Ç. (2001), 17 Ağustos Depremi, Kentleşme ve Planlama Sorunları Üzerine Düşünceler. **Journal of the Chamber of City Planners Union of Chambers of Turkish Engineers and Architects (TMMOB),** 2001/3, pp.33-39.

Menoni S., Molinari D., Parker D., Ballio F., Tapsell S. (2012), Assessing multifaceted vulnerability and resilience in order to design risk-mitigation strategies. **Nat. Hazards**, published online 21 March 2012.

Norris F., Stevens S., Pfefferbaum B., Wyche K., Pfefferbaum R. (2008), Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness, in **Americal Journal of Community Psychology,** vol. 41.

Prost, H. (1937), “Memoire Descriptif du Plan Directeur de la Rive Eupèeenne d’Istanbul”, Les Transformations d’Istanbul, Plans Directeurs, Vol.3, unpublished reports.

Prost, H. (1947), “Communivation de Henri Prost, 17 Septembre 1947 à l’Institut de France”, Les Transformations d’Istanbul, unpublished reports.

Tekeli, I. (1994), The development of the Istanbul Metropolitan Area: urban administration and planning. Istanbul: IULA-EMME and YTU.

TUIK (2011), **Turkey’s statistical yearbook**. Turkish Statistical Institute.

United Nations Development Programme UNDP (2004), Reducing Disaster Risk: A Challenge for Development. UNDP: New York.

İstanbul’da depreme karşı hasar görebilirliğin tespiti: ENSURE metodolojisinin uygulanması

Bu makale ENSURE projesi kapsamında depreme dayalı hasar görebilirliğin tespiti için geliştirilen metodolojinin İstanbul’a uygulanmasını içermektedir. İstanbul çalışma alanı projeye Seda Kundak’ın Politecnico di Milano ekibine misafir araştırmacı olarak katılması ile ikincil proje alanlarından biri olarak dahil olmuştur. Bu makalede sunulan sonuçlar üç aşamada elde edilmişlerdir. İlk aşama proje süresince elde edilen birincil sonuçları içermektedir. İkinci aşama ise Italya Sivil Savunma ve AFAD’ın ENSURE projesinin daha kapsamlı anlatılabilmesi için projenin İstanbul’a uygulanmasını talep etmeleri ile geliştirilmiştir. İkinci aşama hangi verilerin eksik olduğunun tespit edilmesine yardımcı olmuştur. Üçüncü aşamada ise tespit edilen eksik veriler ağustos 2012’de İstanbul’da yürütülen alan çalışması ile tamamlanmıştır. Son aşamada elde edilen verilerin de yardımı ile çalışmanın odak noktası hasar görebilirliğin sistemde yarattığı etkilerin tespitine ve deprem olması durumunda acil durum sırasında ulaşılabilirliğin analizine doğru kaymıştır. Makale ENSURE projesi sırasında geliştirilen metodolojinin ana hatları ile anlatılması ile başlamaktadır. Bunu İstanbul çalışma alanının kısa anlatımı takip etmektedir. Makalenin son kısmında ise üç aşamada elde edilen sonuçlar ENSURE metodolojisi kapsamında geliştirilen tablolarda sunulmaktadırlar.