ITU A|Z
VOL: 11, NO:1, 76-98, 2014-1

The seismic risk in Istanbul: An innovative assessment method

Alessandro DEMARCHI
DIST - Politecnico di Torino Viale Pier Andrea Mattioli, 39 - 10125 Torino, ITALY & ITHACA - Information Technology for Humanitarian Assistance, Cooperation and Action; via Pier Carlo Boggio, 61 - 10138 Torino, ITALY

Received: July 2013 *Final Acceptance: November 2013*

Abstract:
Over the last century, an unprecedented settlement expansion, generated by an exceptional world population growth, has made cities all around the world always more prone to disasters. Natural phenomena, such as earthquakes, could be potentially more dangerous when hit megalopolis and their neighborhoods particularly fragile. Amid the most important global cities, Istanbul is characterized by one of the highest levels of seismic risk. Within its territory, there are numerous highly vulnerable neighborhoods. Some of them are located around *İstiklal Caddesi*, famous pedestrian street, which is being visited by a great number of people (both Turkish city-users and international tourists) twenty-four hours a day, seven days a week. Part of the old and historical neighborhood of *Pera/Galata*, in the today's *Beyoğlu Belediyesi*, it is a highly attractive zone full of economic activities, acting as heart of the city. Since the importance of this area, its specific seismic risk has been assessed using two different approaches, one traditional and one proposed by the author, which have provided two different responses. The "standard method", based on generic variables applicable to the whole Istanbul Metropolitan Municipality, shows how this zone is not amongst the most risky area of the city. Whereas, "the experimental method", calibrated on more precise information and more specific variables typical of the case study area, demonstrates that the level of seismic risk is significant. Finally, a scheme of urban/district emergency evacuation system is here proposed indicating some shelter areas and classifying the streets, inside the case study area, according to their level of safety.

Keywords: *Istanbul, earthquake, risk, vulnerability, exposure.*

1. Introduction

In the last century, the number of reported natural catastrophes has vastly increased as directly consequence that today "about 25 percent world's population lives in areas at risk from natural hazard" (Murlidharan & Shah, 2003:17).

The world population's growth, and in particular the growth of the urban population which in 2010, for the first time in history, exceeded the rural population, is continuously increasing the demand for new land (United Nations, 2011). An unprecedented settlement expansion (planned and/or informal) has compromised also territories on volcanoes slopes, in proximity of seismic active fault zones (for instance, “40 of the 50 fastest-growing cities are in earthquake zones” (Murlidharan & Shah, 2003:17)), in alluvial and landslides areas. In addition to be more exposed, cities all around the world are always more vulnerable. “Each day, almost 180,000 people move to cities. While city populations grow faster than city infrastructure can adapt, migrants often encounter a lack of infrastructure, services, housing and property rights. These urban newcomers are forced to live in unsafe [and often informal] places” (Guha-Sapir et al., 2011:17).

Natural phenomena, such as earthquakes, could be potentially more dangerous when hit global cities, which are important for their economic-financial richness, the number of inhabitants, and the number of services provided. Amid the most important global cities, Istanbul is characterized by one of the highest levels of seismic risk:

- by the 2030, it could be hit by a big shock of M>7.0 (M or Mw stands for moment magnitude) with a 44±18% probability (Parsons, 2004; Kalkan et al., 2008);
- it is the economic and financial capital of Turkey, an important attractive node of population (officially, more than 13 million of people lived in Istanbul in the 2012) and national-international activities and capitals (The C.I.A.’s World Factbook, 2012; Turkish Statistical Institute, 2012);
- since the 1950, Istanbul is afflicted by an incredible urban pathology named as gecekondu (term that in Turkish literally means “built overnight”). These illegal and unplanned settlements are characterized by precarious structural and functional conditions that make dangerous the life of their inhabitants, even in ordinary situations. In particular, more than 40% of the inner city of Istanbul has been developed in unplanned way (Kundak, 2011), 93% of the buildings have been constructed in contrary to the building code (Köktürk et al., 2007), more than 50% of Istanbul inhabitants live in irregular or squatter settlements (Maritano Comoglio et al., 2000).

In this scenario, it is easy to foresee how a strong seismic shock could seriously hit the city, causing severe causalities and damages, and, with its direct and indirect effects, the whole nation.

Furthermore, all the global cities are distinguished to have some neighborhoods particularly vulnerable. They could be characterized by a high-density of residential population, economic activities, sites of important historical and cultural heritage, etc. In Istanbul, there are many such areas, one is that around *İstiklal Caddesi* which has been considered as case study area. Visited as many as three million people during the weekends, characterized by an important historical, cultural and architectonical heritage, it is also the location of several economic activities and public facilities; it is an area of vital importance, acting as the heart of the city. There, a strong earthquake could cause a great loss of lives, injuries, collapse of buildings and destruction of critical facilities (such as school, hospitals, police stations, fire stations, etc.). In turn, these consequences could trigger other secondary effects of equal gravity, such as the disruption of economic activities and services, social problems, etc. Therefore, severe damages in this zone could be exponentially larger and involve not only the whole metropolitan context.

1.1 Seismic hazard in Turkey and Istanbul

Turkey, one of the most seismically active regions of the world, is situated on the Alpine-Himalayan orogenic system that extends from Archipelago of the Azores to Southeast Asia. North Anatolian Fault Zone (NAFZ), Aegean Graben System (AGS), East Anatolian Fault (EAF) and Southeast Anatolian Thrust (SAT) are the most important faults in Turkey but much of Turkey's seismicity is due to the NAFZ, the most active fault in Europe and one of the most active in the world. At the border between the Eurasian plate and the Anatolian micro-plate, it is an arcuate right-lateral fault system long more than 1,500 km extending across all of northern Turkey, roughly parallel to the Black Sea.

According to the National Earthquake Hazard Zoning Map, published by the Turkish Ministry of Public Work and Settlements in the 1996, roughly two third of the country have been recognized under a primary seismic threat characterized by a peak ground acceleration (PGA) greater than 0.30g (see Table 1).

Table 1. *The Earthquake Zoning of Turkey according to the expected PGA with 90 percent probability of non-exceedance during 50 years (Özmen, 2003).*

Earthquake Zone	PGA	Surface Area	Population	Industry	Dams
Zone I	>= 0.40g	42%	45%	51%	46%
Zone II	0.30g - 0.39g	24%	26%	25%	23%
Zone III	0.20g - 0.29g	18%	14%	11%	14%
Zone IV	0.10g - 0.19g	12%	13%	11%	11%
Zone V	< 0.10g	4%	2%	2%	6%

Due to Istanbul's nearby location to the NAFZ, "on average, at least one medium intensity (epicentral intensity, Io=VII–VIII) earthquake has affected the city every fifty years. The average return period for high intensity (epicentral intensity, Io=VIII–IX) events has been 300 years" (Erdik, 2005:102). According to the database published by Ambraseys & Finkel (1991), the most devastating quakes occurred in the 1509, 1766 and 1894. These events caused destruction and devastation on a large scale to masonry and buildings (included the Sultan's residence known as *Topkapı Palace*), to churches and mosques (among also the former church of *Haghia Sophia*), to minarets and towers (for instance, the famous *Galata Tower*), to the main aqueduct and parts of city walls, to public buildings such as that known as *Grand Bazaar*, etc.

In the 1999, Istanbul was hit again. The İzmit or Kocaeli (M7.6 - 17,118 fatalities) and, three months later, the Düzce-Bolu (M7.2 - 894 fatalities) earthquakes, caused severe damages to some Istanbul's southwest suburbs, even if the epicenters were at 90 km southeast of Istanbul (USGS, 2012). The shakes caused a final toll of 454 people killed and 3,600 people injured (Erdik et al., 2000). Extending the statistic to the entire area hit, the count was dramatic: "329,216 housing units and 48,663 business units were damaged, 18,243 people were killed and 48,901 people were injured" (Kubat et al. 2008:280). Also the economic damage caused by the quake was enormous: US$20 billion approximately equal to the 8% of the 1999 Turkey National Gross Domestic Product (EM-DAT database, 2012; The C.I.A.'s World Factbook, 2012).

Dresen et al. (2008:58) argue that Turkey “today represents a seismic gap along a ≥100 km-long segment below the Sea of Marmara. This segment did not rupture since 1766 and [..] may have accumulated a slip deficit of 4–5m”. Istanbul’s seismic hazard is due to its location, distant just 10 km from this last unruptured section of NAFZ.

After the 1999 seismic events, scientists, authorities, and both national and international organizations started to figure out what could happen when this section of the NAFZ will break. According to Parsons et al. (2000:308), there is a “62±15% probability of strong shaking (MMI>VIII; equivalent to a peak ground acceleration of 0.34-0.65g (Wald et al., 1999)) in greater Istanbul over the next 30 yr (May 2000-2030), 50±13% over the next 22 yr, and 32±12% over the next 10 yr”. According to joint studies of the Japan International Cooperation Agency (JICA) and the Istanbul Metropolitan Municipality (IMM), an estimated quake of M7.7, the probable worst-case scenario in seventy years, could cause between 73,000 and 87,000 fatalities and between 120,000 and 135,000 injured (Gencer, 2008).

2. Seismic risk assessment

The seismic risk has been assessed following the general formula (1).

Risk (R) = Hazard (H) x Vulnerability (V) x Exposure (E) (1)

However, the evaluation has been conducted using two different methods: an accepted-standard one and a new experimental one (elaborated by the author) modeled according to the particular and specific characteristics of the area in question.

2.1 The framework of the case study area

Inside the *Beyoğlu* District, the case study area (CSA) corresponds to part of the old neighborhood of *Pera* nearby the area of *Galata*, which was already well-developed during the reign of Theodosius II (V century A.D.). It is essentially a “buffer” to *İstiklal Caddesi*, famous pedestrian street in the center of Istanbul (see Figure 1). The street links two of the most important squares of the city (*Taksim* and *Tunel Square*) and it is surrounded by late-Ottoman-era buildings (mostly from the nineteenth and early twentieth centuries) that were designed in the neo-classical, neo-gothic and art deco styles.

To better analyze the CSA, an inspection-survey was conducted by the author: almost 1,200 buildings have been cataloged in a database, recording several important information such as number of floors, urban uses and activities present, their general structural quality, any components in their external facades which could be an additional hazard in case of earthquake, the construction material used and any possible weakness. Using the data coming from this database, a detailed land-use zoning has been accomplished (seven categories have been detected: residential-Re, shopping places-Sp, leisure and catering business-Lcb, services business-Sb, facilities-Fa, touristic business-Tb and open spaces), disclosing how the CSA is a mixed-use settlement characterized by a highly level of heterogeneity. Finally, the information collected were transferred and integrated into a GIS environment.

2.2 The standard method

After the 1999 earthquakes, several studies have been done to estimate the effective seismic risk of the city. One of the most authoritative is the "Study on Disaster Mitigation/Prevention in Istanbul Including Seismic Microzonation" accomplished by the JICA in collaboration with the IMM.

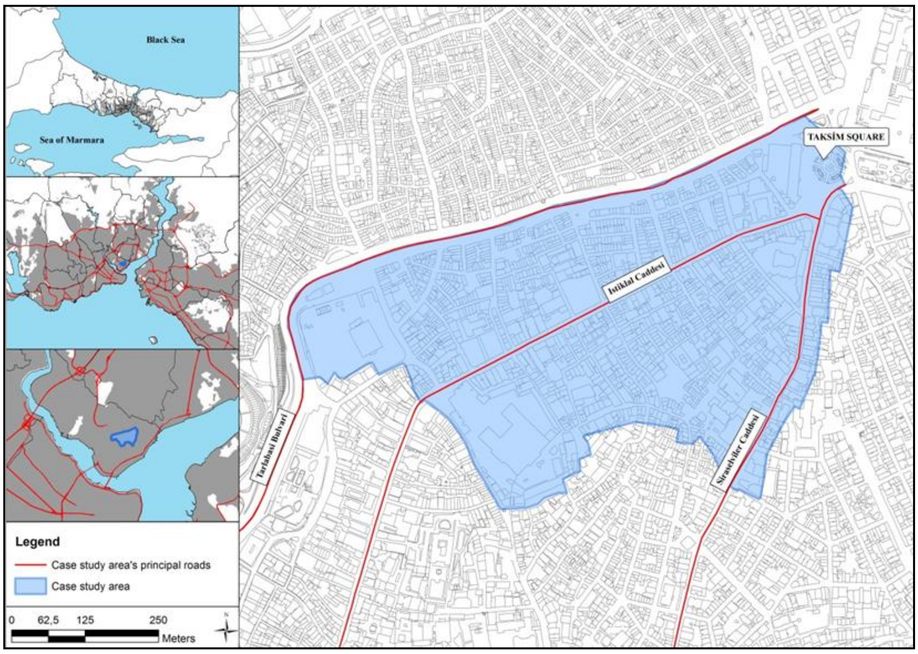

Figure 1. *The CSA (Author, 2012; using the Istanbul Municipal Technical Map, 2011).*

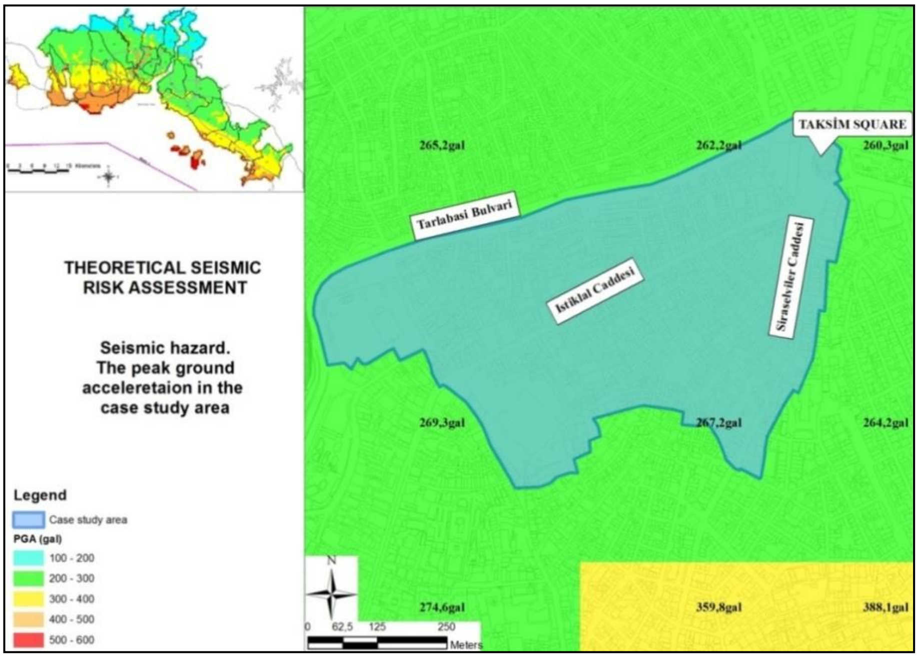

Figure 2. *Distribution of PGA in the CSA and in Istanbul (Author, 2012; data from JICA & IMM, 2002).*

Referring essentially to this study, some of most relevant aspects, characterizing the seismic hazard and the seismic vulnerability of the CSA, will be illustrated in the following paragraphs. Afterwards, in the paragraph 2.2.3, the results of an overall evaluation of the CSA's seismic risk will be depicted.

2.2.1 The seismic hazard – standard method

The seismic hazard could be assessed reckoning possible earthquake-related natural phenomena such as ground-shaking, fault rupture, soil liquefaction, etc. Considering its geomorphological characteristics, the CSA could be significantly affected only by ground-shaking.

Figure 2 shows how the CSA, at a distance between 18 and 20 kilometers from the NAFZ, is not one of the most seismically hazardous areas in Istanbul. The four cells on which it falls are all characterized by a medium-low value of Peak Ground Acceleration (PGA).

2.2.2 The seismic vulnerability – standard method

Concerning the seismic vulnerability, four sub-components have been considered here to express the most realistic overview of the CSA's predisposition to be damaged by an earthquake.

2.2.2.1 The physical vulnerability – standard method

Some factors, such as “building density”, qualities and characteristics of the urban structure, materials and techniques of construction, percentages of informal and illegal settlements are fundamental to assess the possible dimension of damage.

In Istanbul, just the fact that informal settlements constituting a relevant part of the built environment make the scenario very serious (Kundak, 2011; Köktürk et al., 2007; Maritano Comoglio et al., 2000). However, being the unplanned and squatter areas been built in the twentieth century, the historical areas, such as the CSA, are not afflicted by this phenomenon. At the meantime, with its historical compact urban fabric, the CSA has a medium-high value of density. Anyway, around 20 percent of the buildings in the CSA could be heavily damaged (JICA & IMM, 2002).

Regarding the urban structure, the quality of road networks is fundamental inasmuch an inappropriate infrastructure system could engender road blockages caused by buildings collapsed, making therefore the operations of rescue and evacuation difficult or even impossible. Considering that almost all the roads within the CSA are narrow (with widths of 6m or less), it easy to imagine the worst.

Used for temporary shelter and evacuation areas after a seismic shock, the availability of parks and open space is also crucial. Figure 3 shows that Istanbul is afflicted by a general lack of these spaces: only along the seaside they are enough, or in some case in abundance, elsewhere they are in short supply. In the CSA, as in the most of the city, not more than 25 percent of the surface is given to open spaces and parks.

2.2.2.2 The functional vulnerability – standard method

Considering that around the 30 percent of hospitals are located in the most hazardous areas of the city (the south-west neighborhoods), in the worst possible scenario, it is presumable that several hospitals go off-duty after the quake. In that case, the impossibility of rescuing the population in the phases following the earthquake could increase the number of deaths. Regarding the CSA, despite there are three hospitals, the number of hospital beds is quite scarce (Ministry of Health of Republic of Turkey, 2004) and therefore, considering that the CSA itself is not very hazardous (as shown in paragraph 2.2.1 and Figure 2), this sub-component of vulnerability results to be not very relevant.

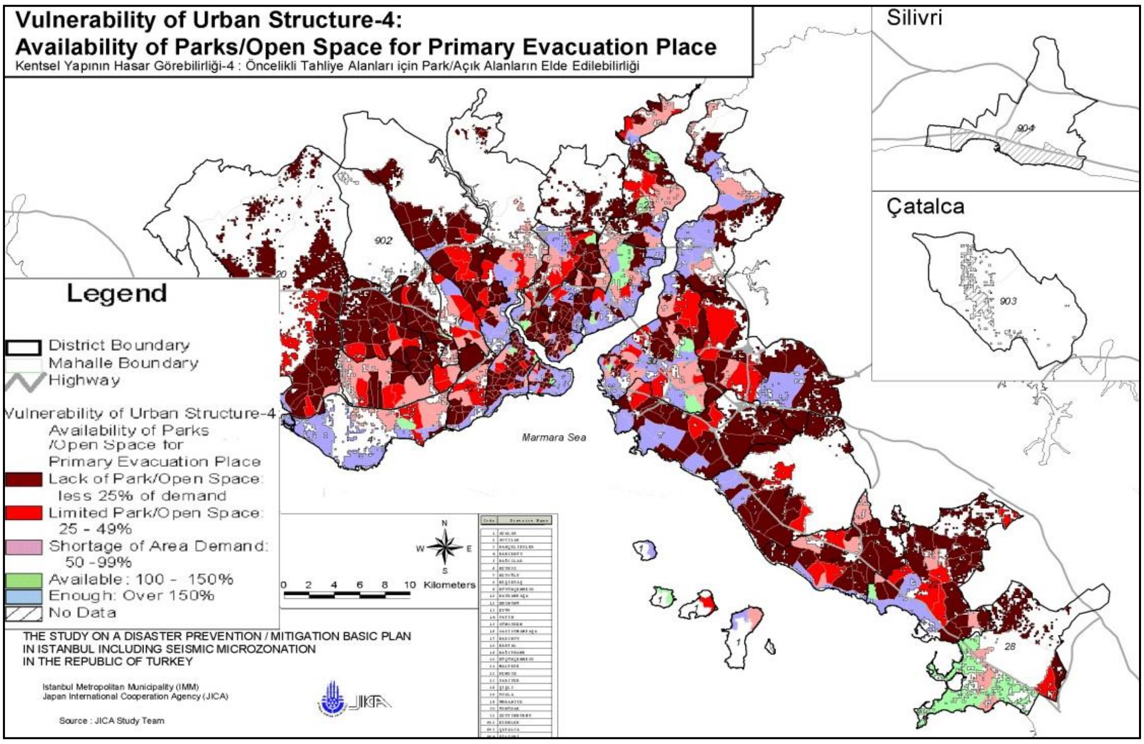

Figure 3. *Availability of parks and open spaces in Istanbul (JICA & IMM, 2002).*

2.2.2.3 The socio-demographic vulnerability – standard method

While the exposed population comprises all the resident inhabitants of a hazardous area, the principal parameter to assess demographic vulnerability is the share of young and elderly (individuals under eleven and over sixty-five years old). In the *Beyoğlu* District, the vulnerable population amounts to the 20 percent of the residents (Turkish Statistical Institute, 2012).

JICA & IMM (2002) have developed some estimates about the possible effects on Istanbul population; according to its worst-case scenario, there could be between 73,000 and 87,000 deaths plus a number of injured between 120,000 and 135,000. In this scenario, the *Beyoğlu* District will be seriously affected with a number of deaths that could reach the 1.5% of its whole residential population which in the 2011 was equal to 248,206 (JICA & IMM, 2002; Turkish Statistical Institute, 2012).

2.2.2.4 The economic vulnerability – standard method

This vulnerability is function of the physical and socio-demographic vulnerability, being the principal economic consequences of an earthquake due to collapse of buildings and/or to casualties (i.e. some businesses have to close because the owners passed away). Thus, industrial and economic activities, located in earthquake-prone places, could significantly increase the seismic risk.

Unfortunately, Istanbul's most important economic areas are located in the wrong places. The monetary losses due to building damages would be between 8 and 10 billion $, the direct industrial losses between 6 and 8 billion $ for a total physical loss estimated between 25 and 35 billion $, while between 250,000 and 300,000 could be the number of jobless (Erdik et al., 2008).

Although there are no industries located in the CSA, neighborhoods, such as those that include *İstiklal Caddesi*, contribute substantially to Istanbul's wealth. Indeed, the well-developed commercial and service sectors make this area one of the city's economic centers.

2.2.3 Seismic risk assessment – standard method

In order to have an overall evaluation of the CSA's seismic risk, it is useful refer to Kundak (2006), who used the formula (2).

Total Seismic Risk = FACTOR 1 + FACTOR 2 + FACTOR 3 + FACTOR 4 - FACTOR 5 (2)

In the formula (2), the FACTOR 1 is function of the age of the neighborhood, number of housing units, percentage of unplanned areas, vulnerable populations, land values and number of students; the FACTOR 2 is function of population density, building density and percentage of empty areas; the FACTOR 3 is function of the number of business activities and hazardous activities; the FACTOR 4 is function of spectrum acceleration response and percentage of slope areas; the FACTOR 5 is function of the number of health services and beds in hospitals.

The results of the formula (2), shown in the Figure 4, demonstrate that, after all, the CSA is not so much at risk: only one neighborhood is characterized by a medium value of seismic risk, three have a moderate and another one a low value. However, as expounded above, there are some CSA's factors which could cause many deaths and serious damages, in the event of a strong seismic shock. The most critical aspect of the CSA is its urban structure: the inadequate roads network and the general lack of open spaces could seriously endanger the local population and cause a larger death toll than expected due to the impossibility for the rescue teams to reach the area afflicted and for the local population to take refuge in safe places.

Although the urban structure constitutes a relevant problem, the building environment is not overly vulnerable. Indeed, even though most of these buildings were built during the Ottoman Empire, and therefore before the anti-seismic buildings codes came into effect, they were designed by architects from all over Europe to accommodate the middle-upper-bourgeois class in Istanbul. Being the purchaser of a certain social level, these buildings have not been designed to saving and, still today, they are pretty well resistant and of good aesthetic-architectural quality, differently form informal and illegal settlements. Indeed, the so-called *gecekondu* are often characterized by engineering deficits, lack of many urban facilities and open-green areas, and incompatible land-uses, factors that all increase urban risks not only related to natural hazards but also to ordinary situations (Kundak, 2011).

Considering in the end that the seismic *hazard* is medium-low, these are all reasons because the CSA is after all not characterized by a high level of seismic risk.

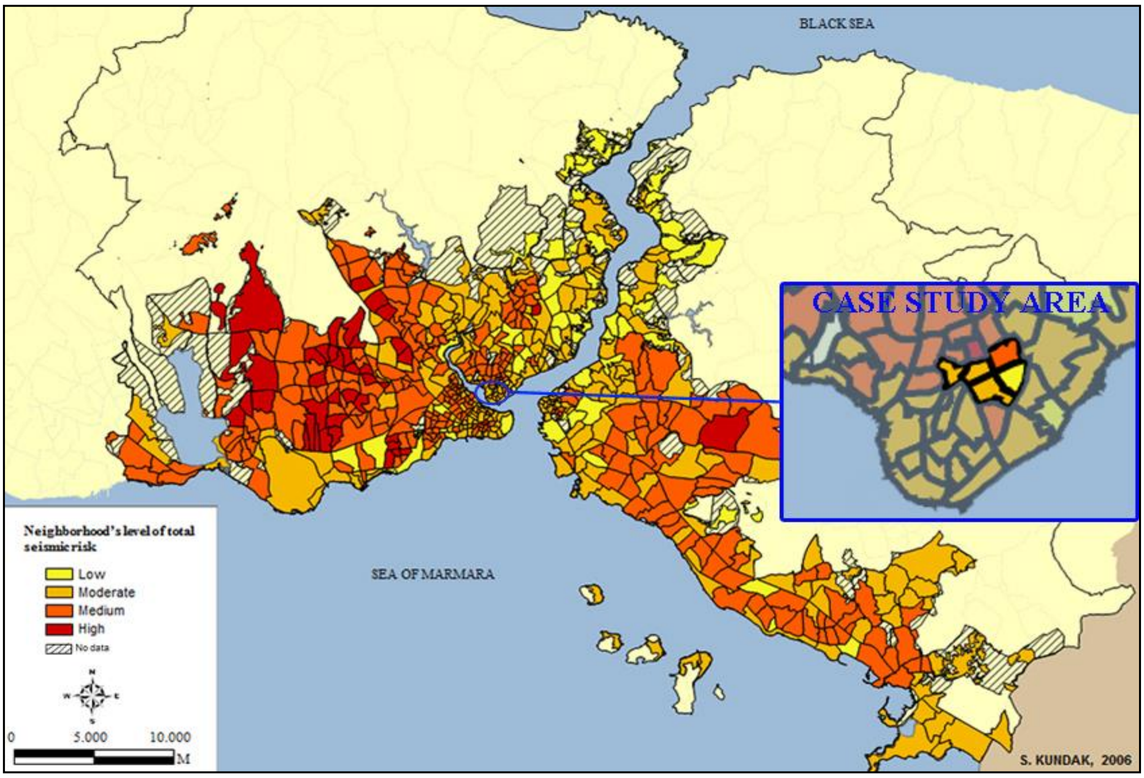

Figure 4. *Seismic risk in Istanbul (Kundak, 2006).*

2.3 The experimental method

After have assessed the seismic risk using a standard method, an experimental method has been conceived and applied on the same zone. Firstly, to accomplish this aim, the CSA has been split into twenty-eight sub-zones and the seismic risk has been assessed on this scale (sub-zones scale). Several attributes were considered in the zoning among which the road network, land-use, dimension (between 1 and 1.5 ha of surface).

The novelty of this method is not due to the seismic hazard computation (about which the evaluations and considerations exposed in the previous assessment are presumably correct), but rather to the *exposure* and *vulnerability* terms.

2.3.1 The seismic vulnerability – experimental method

Similarly to the theoretical method, four typologies of vulnerability have been used here according to the particular and specific characteristics of the CSA. Indeed, the inspection-survey completed by the author allows more detailed analysis of the CSA, so much as considering each single building in the evaluation process.

2.3.1.1 The vulnerability of the urban structure – experimental method

According to this experimental assessment method and concerning the CSA's characteristics, the vulnerability of the urban structure has been assessed using the formula (3).

Urban structure vulnerability = Physical and systemic vulnerability – Potentialities (3)

In turn, the *Physical* and *systemic vulnerability* is function of other four parameters. The first is the *Shape quality indicator*, which is a general evaluation of the shape of the CSA's buildings. This is not an indicator of engineering or architectural level, but it is an approximate evaluation based on the exterior appearance of the buildings. The *Shape quality indicator* includes four different values: *Good* (the building is in optimal condition and it does not present external problems; its structure appears strong and solid; it could be either a new building or old but recently renovated), *Sufficient* (the building's condition is pretty good but does not appear strong and solid as that in the precedent category), *Low* (the building has several problems which are easily viewed from outside, such as cracks and breaks) and *Very bad* (building's condition makes it unsafe not only in relation to a seismic shock but also in normal conditions; it shows several cracks and breaks all over its surface, and it would probably be totally destroyed after an earthquake). Each *Shape quality indicator* matches a value of *Shape vulnerability,* whose distribution in the CSA is shown in the Figure 5.

The CSA is characterized by a widespread presence of components hung on the facades of the buildings (i.e. shop signs, air-conditioners, etc.), often not sufficiently secured, which could trigger an additional hazard in case of earthquake. For this reason, a second parameter, called *Facades vulnerability*, has been introduced as part of the general CSA's *Physical and systemic vulnerability*. Obviously, not every component will trigger the same level of hazard, and thus different factors have been used for each type of element hung (see Table 2). Moreover, each facade may support more than one element, and thus a grid of values has been predisposed to determine the *Facades vulnerability* starting from specific ranges of *Vulnerability factors sum* (see Table 3).

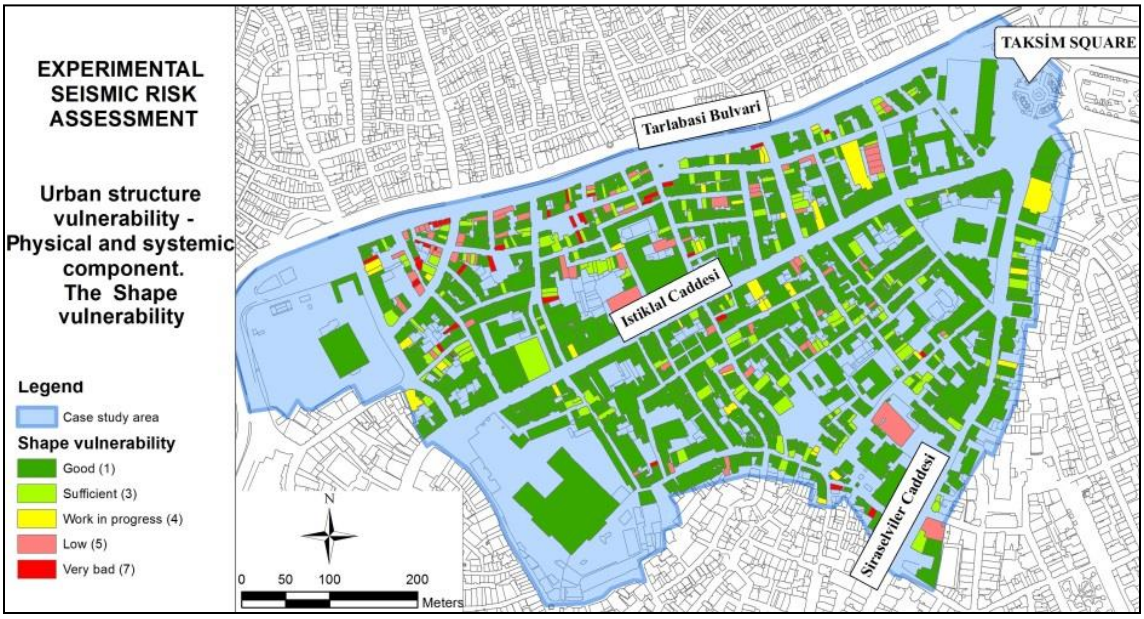

Figure 5*. The buildings' Shape vulnerability (Author, 2012).*

The third parameter regards the mobility infrastructure system, which does not consider exclusively the width of the CSA's roads, but also the "permeability" of the urban structure. This characteristic expresses the ratio between the surface of the roads and the surface area of the belonged zone. Indeed, an adequate network of capillary roads, in virtue of the existence of other alternatives, should compensate blocks of some infrastructural arteries, so as to avoid the complete isolation of neighborhoods. Vice versa, a densely built-up area, without a commensurate road network, could be affected by several problems in the aftermath of an earthquake. Therefore, the *Roads vulnerability* has been obtained correlating the percentage of share of narrow roads to the permeability of each CSA's zones (see Table 4).

Considering that most of CSA's roads (excepting *Tarlabaşı Boulevard, Sıraselviler Caddesi, İstiklal Caddesi*) have a width lower than six meters, the seismic shock will likely make the mobility system seriously blocked, cutting off rescue efforts and leaving several residential blocks completely isolated.

Table 2. *The factors used to assess the Facades vulnerability (Author, 2012).*

Typology of element hung	Vulnerability factor
Air-conditioners	2
Antennas	1
Awnings or vases of flowers	0,5
Hanging lamps or shop signs	1,5
Work in progress	3,5

Table 3. *Ranges of vulnerability factors sum used to determine the Facades vulnerability (Author, 2012).*

Vulnerabilty factors sum	Facades vulnerabilty
0 - 1	Low
1.5 - 2.5	Medium low
3 - 4	Medium
4.5 - 5.5	High
6 - 7	Very high

The last parameter considered is the *Heights of the buildings*. This vulnerability parameter may exponentially increase the physical vulnerability of a neighborhood and thus its total seismic risk. According to this construction, the highest buildings are the most vulnerable and, vice versa, the lowest are the less vulnerable.

Table 4. *Matrix of scores used to assess the Roads vulnerability (Author, 2012).*

Share of narrow roads	Permeability factor > 50%	40 - 50%	30 - 40%	20 - 30%	10 - 20%	< 10%	
0-10%	0	1	2	3	4	5	
10-20%	1	2	3	4	5	6	
20-30%	2	3	4	5	6	7	
30-40%	3	4	5	6	7	8	
40-50%	4	5	6	7	8	9	
50-60%	5	6	7	8	9	10	0-2: Low
60-70%	6	7	8	9	10	11	3-5: Medium low
70-80%	7	8	9	10	11	12	6-8: Medium
80-90%	8	9	10	11	12	13	9-11: High
90-100%	9	10	11	12	13	14	12-15: Very high

To standardize all the parameters to the CSA's sub-zones scale, a conversion of the values expressed at the building scale has been conducted making a weighted average. Indeed, the sums of values of each building have been proportioned to the volumes of the same buildings, making, in this way, the final result more realistic. This operation has allowed to calculate the CSA's *Physical and systemic vulnerability* using the formula (4).

Physical and systemic vulnerability = (Shape vulnerability + Facades vulnerability) x Roads vulnerability x Heights of the buildings (4)

Figure 6 shows the outcome of the formula (4) obtained using the so-called "Jenks natural breaks classification" which reduces the variance within the same class and maximize the variance between different classes of values. Regarding *Potentialities*, which is the second term of formula (3), it expresses the availability of green and open areas. These play a crucial role during and after disasters, providing space for evacuation, shelter and first aid. The potential value of open areas is not always the same; it depends both by the dimension of the area itself and by the typology of open space. Thus, an *Open area potentiality factor* has been considered to evaluate the presumed effective potential of the areas. In particular, green areas and squares, the most valuable spaces in a seismic event, have a factor equal to 1, because in theory the entire surface of such areas could be used as shelter location. On the other hand, car parks, by definition occupied by cars, have a factor equal to 0.5, because it has been assumed that on average these areas would be half occupied during a seismic shock. Therefore, the *Potentialities* have been assessed using the following formula (5):

$$\text{Potentialities}=\frac{\text{Open areas surface x Open areas potentiality factor}}{\text{Zone surface}} \qquad (5)$$

Finally, the results of formula (3) are shown in Figure 7, inside which is also viewable the matrix of values used to obtain the *Urban structure vulnerability* since its two terms have different ranges of values.

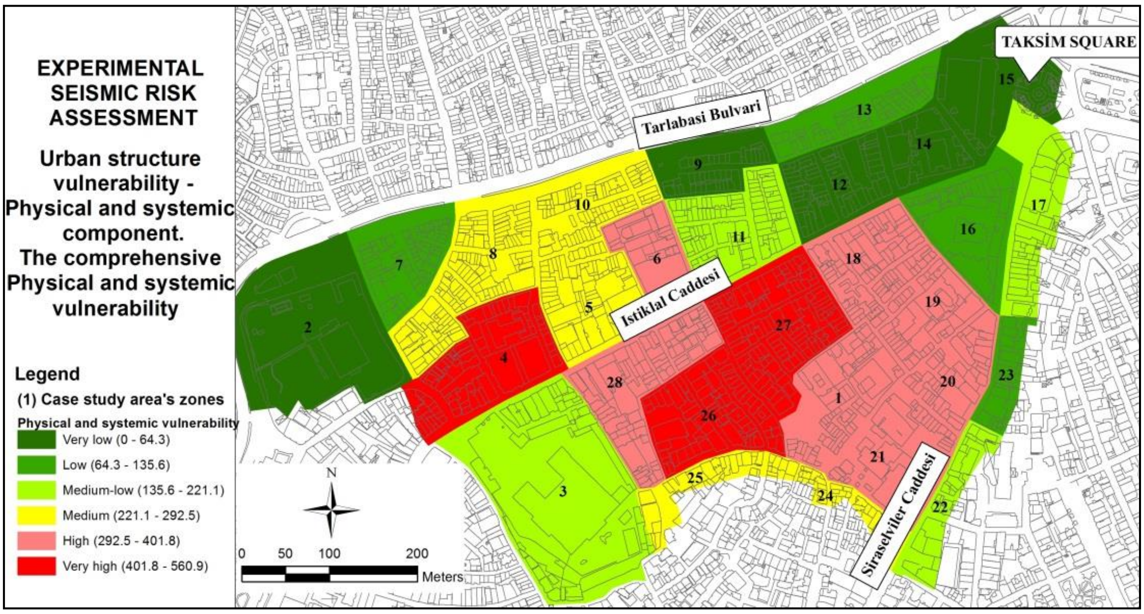

Figure 6. *The physical and systemic vulnerability of the CSA (Author, 2012).*

2.3.1.2 The functional vulnerability – experimental method

Among the facilities normally located in a neighborhood, emergency facilities (such as police stations, fire stations, hospitals, etc.) are particularly important during and after a disaster. Their mere presence might be an advantage but, however, their locations and the morphology of the surrounding areas sometimes hamper their maximal efficiency. Paradoxically, an area with several excellent emergencies structures could be more vulnerable than another less-well-equipped but in a better location.

Regarding the CSA, there are some important emergency facilities located at the sides of *Sıraselviler Caddesi.* Looking to the Figure 7, except the sub-zones 16 and 17, the road is surrounded by sub-zones with medium-high values of *Urban structure vulnerability* (sub-zones 19, 20, 21, 22, 23 and 24). In addition, with only one lane in each direction, it is a critical infrastructure even in normal situations when is often clogged by traffic jams. It is quite probable that an earthquake and the consequent collapse of buildings would further worsen the already poor level of service blocking parts of the road. Therefore, the CSA is highly vulnerable in this respect, inasmuch its few emergency facilities are all located where the CSA is vulnerable.

2.3.1.3 The socio-demographic vulnerability – experimental method

Peculiarity of this experimental method is how the *Socio-demographic vulnerability* and the exposure are viewed. Usually, only the residents are considered as exposed population and, among them, the dimension of "fragile" population (i.e. percentage of elderly and children) is used to express the vulnerability. Instead, in this case the exposed population includes also the whole city-users (who daily visit the CSA), and the assessment of the vulnerability is switched to a new concept which consider the knowledge of the CSA's urban system as an important factor. This setting is essential because, besides an adequate risk preparedness culture, during and after seismic shocks, it could be crucial the decision of where and how to find refuge (i.e. which road take). The result of this choice depends, to a certain extent, on chance and luck, but the individual knowledge of the area is a fundamental factor able to make the difference between the safety and the bereavement. It exponentially decreases or increases the vulnerability and thus the total risk.

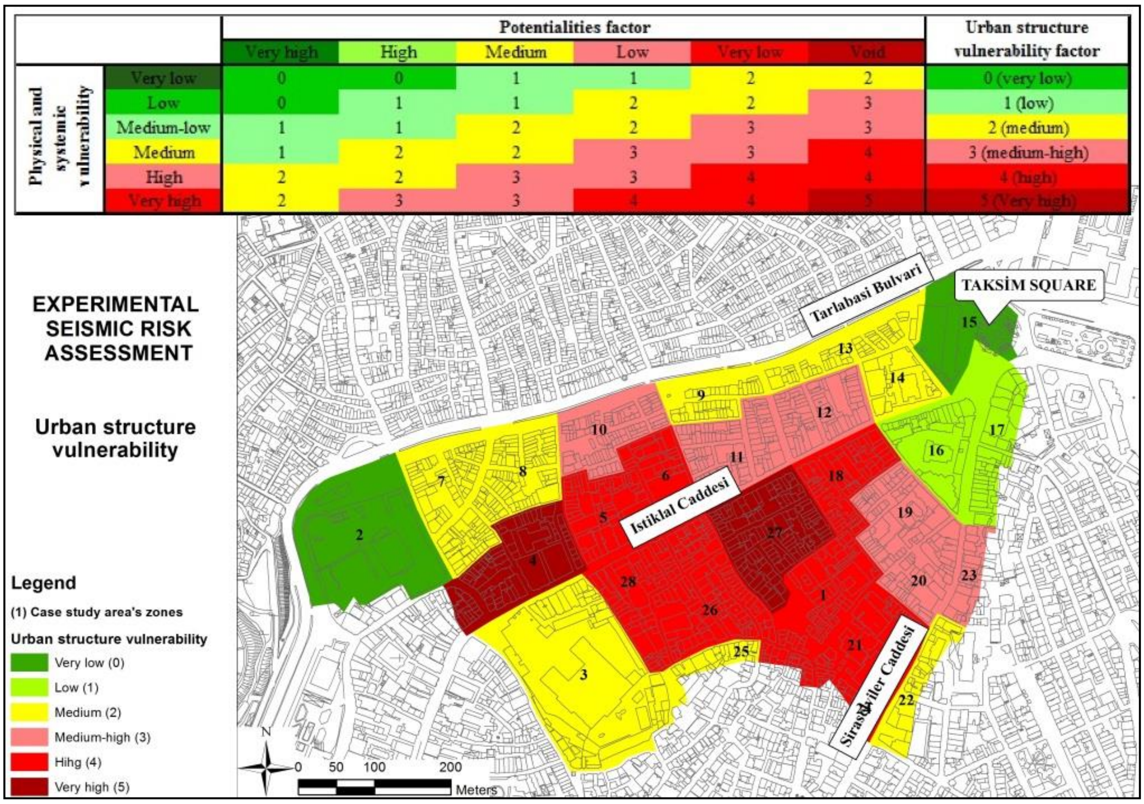

***Figure* 7.** *The Urban structure vulnerability of the CSA (Author, 2012).*

As the several types of activities located in the CSA are not characterized by common timetables, different types of city-users frequent the CSA in different times of the day. In virtue of these considerations, the exposed population has been split into eight different categories, which are strictly related to the categories of CSA's land-use above described (see paragraph 2.1):

1 *Residents:* people who live or domicile within the CSA.

2 *Offices workers and customers:* people who work and/or come to use the functions provided by the offices within the CSA.

3 Services workers and customers: people who come to the CSA to use or provide all those activities categorized as services business.

4 *Facilities workers and customers:* users, clients and personnel of public or private facilities.

5 *Restoration workers and customers:* workers and the clients of the several Turkish and international restaurants, fast food and cafés located in the CSA.

6 *Night life workers and customers:* workers and the clients of the CSA's bars and clubs, especially located in the streets running parallel to or crossing *İstiklal Caddesi.*

7 *Shopping workers and customers:* people who work or shop in the retailers of the CSA, which is one of the most important city's shopping areas.

8 *Tourists: İstiklal Caddesi* and the historical neighborhoods of *Galata* and *Pera* are principal attractions of Istanbul, one of the most visited cities in the world. Considering that, a great number of accommodation structures are located within and near the CSA, tourists come to the CSA for two different reasons: there are *Tourist-visitors* and *Tourist-sleepers.*

As noted above, depending on the time of day, it is possible to find more or less people, belonged to one category rather than another one. Thus, the concept of *exposure*, changing throughout the day and in relation to the day typology (weekday vs. weekend), is a dynamic parameter (see Table 5).

Table 5. *Estimated percentages of presence of each category of CSA's city-users during a weekday (Author, 2012).*

	WEEKDAYS TIME											
Categories of population exposed	**0:00**	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	**7:00**	**8:00**	**9:00**	**10:00**	**11:00**
RESIDENTS	100%	100%	100%	100%	100%	100%	100%	75%	50%	20%	5%	5%
OFFICES W. & C.	0%	0%	0%	0%	0%	0%	0%	10%	50%	100%	100%	100%
SERVICES W. & C.	0%	0%	0%	0%	0%	0%	0%	10%	50%	100%	100%	100%
FACILITIES W. & C.	10%	10%	10%	10%	10%	10%	10%	20%	50%	100%	100%	100%
RESTORATION W. & C.	0%	0%	0%	0%	0%	5%	5%	20%	30%	30%	10%	10%
NIGHTLIFE W.& C.	50%	50%	30%	15%	5%	0%	0%	0%	0%	0%	0%	0%
SHOPPING W. & C.	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	20%	30%
TOURISTS_visitors	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	10%	10%
TOURISTS_sleepers	75%	75%	75%	75%	75%	75%	75%	75%	55%	40%	20%	10%
	12:00	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
RESIDENTS	10%	25%	25%	10%	10%	25%	50%	80%	90%	100%	100%	100%
OFFICES W. & C.	100%	100%	100%	100%	100%	100%	75%	50%	20%	0%	0%	0%
SERVICES W. & C.	100%	100%	100%	100%	90%	80%	70%	30%	10%	10%	10%	10%
FACILITIES W. & C.	100%	100%	100%	100%	75%	50%	20%	10%	10%	10%	10%	10%
RESTORATION W. & C.	50%	90%	90%	25%	25%	25%	30%	75%	75%	50%	25%	5%
NIGHTLIFE W.& C.	0%	0%	0%	0%	0%	0%	0%	0%	15%	25%	40%	50%
SHOPPING W. & C.	30%	30%	30%	40%	50%	50%	75%	75%	60%	40%	20%	0%
TOURISTS_visitors	10%	20%	20%	55%	75%	75%	75%	75%	55%	55%	40%	20%
TOURISTS_sleepers	0%	0%	0%	0%	0%	0%	20%	20%	40%	40%	40%	55%

Since the number of people who visit the CSA is unknown, the values of exposure are expressed in percentage terms (basic units equal to 5 percent) proportionated to their maximum amount of presence. Obviously, these estimates are results of personal considerations which, however, have been objectified during the preliminary phases of survey/study of the CSA.

First of all, the time-intervals characterized by the maximum amount of each category have been detected; these are the values equal to 100 percent (in Table 5, the time-intervals highlighted in green). For example, the maximum number of people (100%), belonging to the *Office workers and customers'* category, is between 9 a.m. and 5 p.m. during weekdays. In other times of the day, for example after 6 p.m., many offices are presumably closed, so the number of people belonging to this category is likely halved (50%).

Forasmuch as, the previous percentages represent exclusively the presence of each category during the day in relation of their absolute maximum value, a comprehensive value is needed. Being percentages of different values, obviously, it is not possible just sum them together. One manner to assess the weight of each category is the production of some statistical surveys, but, due to shortage of means, another method was chosen for this study: the measure of each category, called *Coefficient of presence*, have been estimated in relation to surface of the CSA's urban functions from which each category is "attracted" to the area (see Table 6).

Table 6*. Coefficient of presence, Knowledge factor and Demographic vulnerability factor (Author, 2012).*

Categories of population exposed	Land-use category	Surface (mq)	Coefficient of presence	Knowledge factor
RESIDENTS	Re	41.273	0,064	0,95
OFFICES W. & C.	Sb	94.769	0,148	0,7
SERVICES W. & C.	Sb	75.996	0,118	0,4
FACILITIES W. & C.	Fa	96.226	0,150	0,8
RESTORATION W. & C.	Lcb	83.418	0,130	0,4
NIGHTLIFE W.& C.	Lcb	66.043	0,103	0,4
SHOPPING W. & C.	Sp	124.728	0,194	0,5
TOURISTS_visitors	Tb	59.086	0,046	0
TOURISTS_sleepers	Tb		0,046	0,05

Afterwards, the *Coefficient of presence* (see Table 6), multiplied by the *Estimated percentages of presence* (see Table 5), provides the CSA's estimated *Exposed population*, expressed for each category, and the *Total exposed population*, expressed for the whole (see Figure 8). The changes in the dimension of the *Exposed population* are well represented by Figure 9, whose photos (taken from the rooftop of a shopping mall located in *İstiklal Caddesi*) show the influx of people into *İstiklal Caddesi.*

After have assessed the size of the *Exposed population*, it is possible to assess the *Socio-demographic vulnerability*. For this purpose, a parameter called Knowledge factor has been introduced to evaluate the knowledge of the CSA's urban system. The categories of *Exposed population* are obviously characterized by different degrees of familiarity with the CSA. In particular, as shown in Table 6, the range of *Knowledge factor* could differ between 1 ("expert knowers") and 0 ("not knowers at all").

Table 7 shows that, due to the obvious reason that they spend the most of the week in the CSA, *Residents* have been recognized as the most knowledgeable and their *Knowledge factor* is the highest. At the other end, *Tourists,* particularly foreigners who do not speak Turkish, are the least knowledgeable about the CSA. However, it is possible to differentiate between *Tourists_visitors* who, during their permanence in the city, come sporadically in the CSA, and the *Tourists_sleepers* who come or cross the area at least every day to sleep in their accommodations and, therefore, likely know the area a little bit.

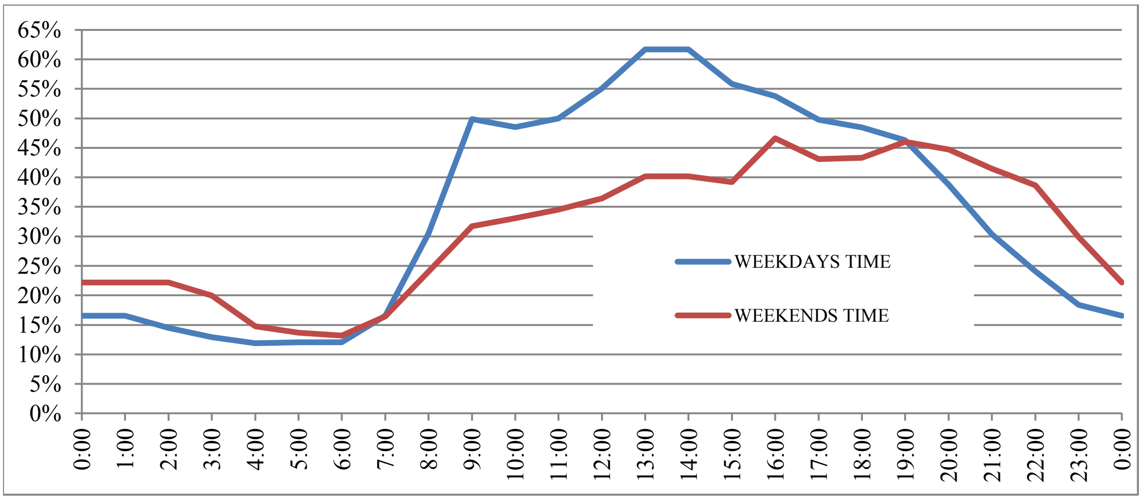

Figure 8. *Trend of CSA's Total exposed population during the day (Author, 2012).*

Figure 9. *People walking in İstiklal Caddesi during a weekday; March 14, 2012 (Author, 2012).*

The second highest *Knowledge factor* has been assigned to *Facilities workers and customers*. Indeed, the people of this category, to which belong educational and religious institutions, share the same high level of CSA's knowledge thanks to their frequent presence.

The categories of *Restoration workers and customers* and *Nightlife workers and customers* are characterized by the same assumption: in both cases, regular customers could be very familiar with the places but they may not know the CSA very well. Vice versa, in the case of *Shopping workers and customers*, the customers usually have a good knowledge of the CSA's urban system thanks to their periodic frequentation.

***Table 7.** Socio-demographic vulnerability and scores assigned (Author, 2012).*

TIME-INTERVAL	WEEK DAY		WEEKEND	
	SOCIO-DEMOGRAPHIC VULNERABILITY	SCORES OF VULNERABILITY	SOCIO-DEMOGRAPHIC VULNERABILITY	SCORES OF VULNERABILITY
0:00	6,99%	1	11,14%	2
1:00	6,99%	1	11,14%	2
2:00	5,76%	1	11,14%	2
3:00	4,83%	1	9,61%	1
4:00	4,21%	1	6,52%	1
5:00	4,29%	1	5,70%	1
6:00	4,29%	1	5,39%	1
7:00	6,84%	1	7,13%	1
8:00	12,18%	2	9,89%	1
9:00	19,41%	2	12,74%	2
10:00	18,61%	2	13,31%	2
11:00	19,15%	2	13,84%	2
12:00	21,85%	3	14,75%	2
13:00	25,48%	3	17,16%	2
14:00	25,48%	3	17,16%	2
15:00	22,94%	3	17,83%	2
16:00	23,38%	3	23,00%	3
17:00	21,96%	3	22,17%	3
18:00	23,02%	3	23,79%	3
19:00	22,38%	3	25,33%	3
20:00	19,08%	2	24,03%	3
21:00	14,95%	2	22,66%	3
22:00	11,29%	2	20,65%	3
23:00	8,14%	1	15,81%	2

0-10%: score of vulnerability = 1
10-20%: score of vulnerability = 2
20-30%: score of vulnerability = 3
30-40%: score of vulnerability = 4
<40%: score of vulnerability = 5

Finally the moderately high value of *Office workers and customers* is due to the predominant presence of workers (who should know quite well the CSA's urban systems and probably also some emergency procedures for their workplace) in respect of the customers (who visit the offices less regularly and therefore are presumed to be unfamiliar with the CSA's urban system). A similar argumentation applies also for the *Services worker and customers*. However, this category is characterized by a ratio between workers and customers more imbalanced in favor to the second one. This is the reason because its Knowledge factor has a value lower than the previous one.

Determined these factors, the Socio-demographic vulnerability of each category has been obtained using the formula (6).

Socio-demographic vulnerability = (1 - Knowledge factor) x Exposed population (6)

Afterwards, summing together the values of *Socio-demographic vulnerability* of each category, a generic rate of *Socio-demographic vulnerability* is achieved for each time-interval. To make these values better interpretable, they have been correlated by a scale of scores, which values range from 1 to 5 (see Table 7).

The overall findings express how the CSA's *Socio-demographic vulnerability* (variable in function of the day and the week) is basically high during the afternoon-evening and low during the night-early morning (see Table 7). However, the *Socio-demographic vulnerability* is influenced also by the personal condition factor (i.e. age, gender, etc.), even though, as explained above, the knowledge of the urban system could be crucial. Thereafter, the overall findings do not mean that people are surely more vulnerable in those time-intervals, but they show how vulnerability changes and when the CSA could be potential more vulnerable.

Finally, since the *Urban structure vulnerability factor* has been evaluated for each CSA's zones, it is necessary to convert the scale of the *Socio-demographic vulnerability.* As was done to calculate the *Total exposed population*, the coefficients of presences have been estimated in relation to the surface of the activities, located inside each CSA's zone, from which each category of *Exposed population* is attracted.

2.3.1.4 The economic fragility of the CSA – experimental method

Even though, the CSA is not the location of industrial activities, an earthquake in the area would cause a severe economic damage. As described above, the CSA is predominantly devoted to commercial and service activities, therefore, physical damages to buildings housing these activities, would trigger indirect economic effects. First of all, the owners, especially those of small and medium businesses, may not have funds to restore and restart operations or, worse, the owners themselves could lose their lives in the disaster. Some CSA's businesses, such as shops, offices, small service business, could stop temporarily or permanently their activity. This negative scenario could trigger further consequences due to the loss of employment and to a general diminishing of wealth.

There is also a psychological factor which contributes to the economic risk. Assuming that the CSA will be severely damaged, customers, visitors and tourists would presumably stop coming to the area in the weeks and months after the disaster, as the tragedy happened would remain alive in their memory. This is a concrete scenario already occurred in the November 2003, when some terrorist attacks hit two synagogues, a British bank and the British Consulate in Istanbul (which is located within the CSA). Most people consider these events the most devastating in the recent Turkish history: "the Turkish 9/11". These attacks had immediate negative consequences, both in the financial transactions and in the decline of the tourist flows (Christofis et al., 2010; Iatridis, 2011; Mazilu, 2007; Republic of Turkey, Ministry of Culture and Tourism, 2012). A similar or worse scenario could transpire also after the occurrence of the expected seismic event.

2.3.2 Seismic risk assessment of the CSA – experimental method

As previously described, the seismic hazard has a medium or medium-low value and it is not so much differentiated inside the CSA (see Paragraph 2.2.1 and Figure 2). Being a sort of constant parameter, invariable within the CSA, this term has been omitted in the CSA's risk assessment. Therefore, to simplify the calculation procedures, the final evaluation of the CSA's seismic risk might be referable to the values of *Total vulnerability* using the formula (7).

Total vulnerability = Urban structure vulnerability + Scores of Socio-demographic vulnerability (7)

Since the *Socio-demographic vulnerability* is a dynamic parameter, which could change during the day and in relation to the day typology, the *Total vulnerability* and the seismic risk are expressed also in a dynamic way although the *Urban structure vulnerability* is a static parameter.

In the weekdays, according to Figure 10, the CSA has a maximum peak of vulnerability essentially in the daytime and a minimum peak in the night. In particular, the most vulnerable CSA's zones are those located in the center while the external ones are the less vulnerable thanks to a good availability of open spaces. Instead, in the weekends, the dynamic is opposite, or better "delayed". Indeed, the maximum level of seismic risk is in the afternoon and in the evening. Later in the night, it starts to decrease until to reach its minimum peak in the late morning/early afternoon.

Figure 10. *Some relevant examples of Total vulnerability during a weekday (Author, 2012).*

3. Concluding remarks and contribution of the research

In the light of these analyses, the methods used have provided two different responses. According to the works of JICA & IMM (2002) and of Kundak (2006), the five CSA's neighborhoods have a medium or medium-low seismic risk whereas the experimental method shows as the situation is significantly worst (medium-high seismic risk). Indeed, considering only generic variables, applicable to the whole urban context, there are other zones inside the IMM with higher values of risk (i.e. the south neighborhoods located nearby the NAFZ and characterized also by a high ratio of unplanned buildings), but, however, it is a too large simplification and therefore not very realistic for the CSA. Instead, using the experimental method, a bigger scale has been used and thus more precise information and more specific variables have been considered. This is the case of the Socio-demographic vulnerability which makes the seismic risk assessment much more realistic because, at different hours of the day, the CSA is more or less crowded by a variety of people who differently know the CSA's urban system. In addition, this vulnerability component has been calibrated on the "real exposed population" of the area and not on the "theoretical one".

After the 1999 earthquakes, that have severely struck also Istanbul, the IMM has undertaken some preparatory measures among which the formulation of an Earthquake Master Plan for Istanbul (EMPI) and the elaboration of a Pilot Project for the regeneration of *Zeytinburnu* district. However, despite what has been done, after almost fifteen years since the 1999 earthquakes, Istanbul is still a *City-at-(great)Risk*. Indeed, a real comprehensive mitigation program, at the great urban scale, and not only focusing on hot spot points, was never started. At the meantime, in other important zone of the city, such as the CSA and especially along *İstiklal Caddesi*, the principal pedestrian street in Istanbul, solutions and actions were not undertaken and even contemplated.

Therefore, the development of an urban/district emergency evacuation system is recommended to minimize human casualties from aftershocks and from secondary disasters and to efficiently coordinate and arrange operation teams and emergency goods (JICA & IMM, 2002). Following the suggestions prefigured in the work of JICA & IMM (2002) and following the Italian Civil Protection Department's Guidelines (2012), an example of emergency evacuation system is here proposed (see Figure 11) detecting three typologies of shelter areas:

1. Primary evacuation areas (PEA): these are places of first shelter for the population where they will receive the first information about the event and the first relief supplies.
2. Tent villages areas (TVA): after the temporary permanence in the PEA, people who are in need of shelter could find an accommodation in these areas where temporary tent cities would be assembled.
3. Rescuers and resources collecting areas (CA): these are areas that will be filled with the rescuers and the resources useful to overcome the emergency.

Considering the size of the roads and the CSA's morphology, as consequence of a seismic shock, some buildings could be seriously damaged or even completely destroyed covering parts of the road network and blocking some CSA's blocks and streets. Therefore, in addition to the shelter areas, a pedestrian evacuation route system is also suggested (see Figure 11). This system has been elaborated supposing which will be the dimension of the debris coming from the CSA's buildings, according to the *Urban structure vulnerability* (see paragraph 2.3.1.1). Obviously, it should be implemented and improved, including engineering and structural evaluations. Anyhow, all the roads within the CSA have been classified in three categories according to their safety:

- Dangerous: route extremely dangerous during and after a seismic shock.

- Unsafe: relevant portions of the path are dangerous and insecure.
- Safe: the path is safe and secure from falling debris and from components of facades.

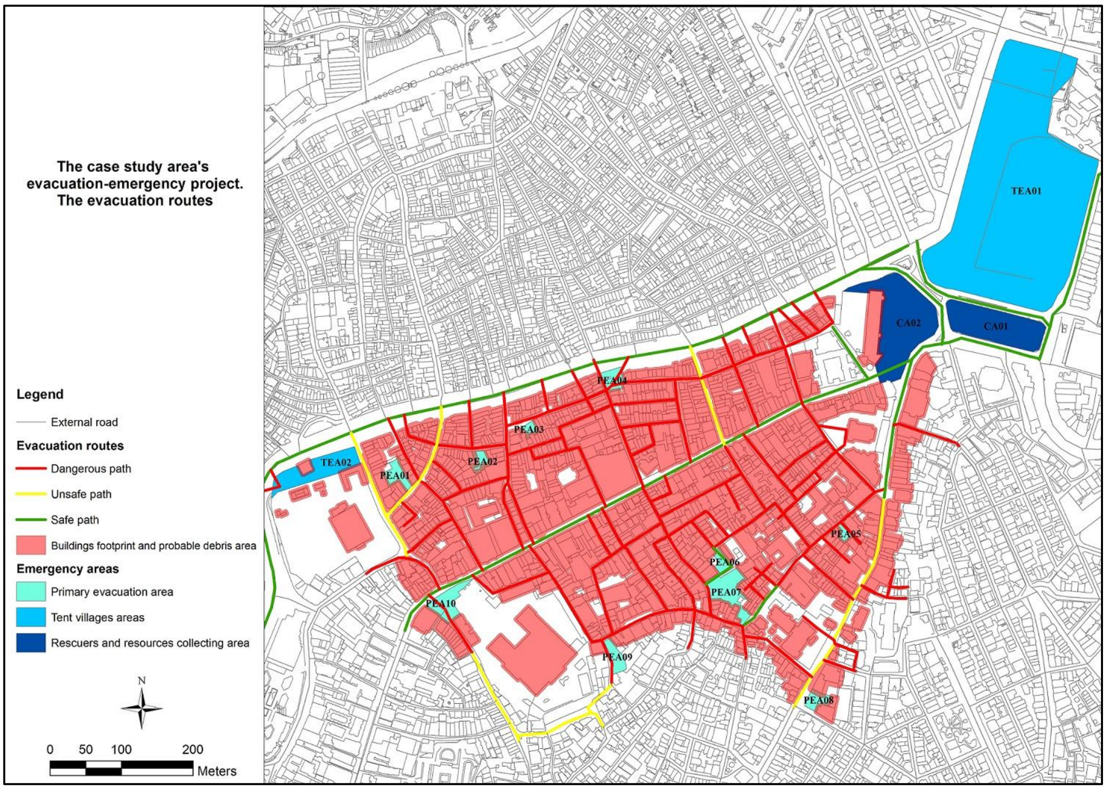

Figure 11. *The evacuation-emergency project proposed for the CSA (Author, 2012).*

Finally, since “the evacuation location should be easily recognized and understood by the residents and citizens within the community [providing] guides and signs along the selected routes and in the selected evacuation locations” (JICA & IMM, 2002), some divulgation solutions have been conceived such as the installation of informative totems along the principal and more frequented roads and squares of the CSA, the positioning of direction signals indicating the closest shelter area, the modification of the street signals describing the grade of safety of the routes, the distribution of free illustrated and informative brochures in the city's entrance terminals; this last action aim to divulgate useful information particularly to foreign tourists which usually are not aware of Istanbul’s risk.

References

Ambraseyes, N. N., & Finkle, C. F. (1991), Long-term seismicity of Istanbul and of the Marmara Sea region. **Terra Nova**, *3*, 527-539. doi: 10.1111/j.1365-3121.1991.tb00188.x.

Ambraseys, N. N., & Finkle, C. F. (1995), **The Seismicity of Turkey and Adjacent Areas. A Historical Review, 1500-1800**. Istanbul, Turkey: Muhittin Salih EREN.

Christofis, N., Kollias, C., Papadamou, S., & Stagiannis, A. (2010), **Terrorism and Capital Markets: The Effects of the Istanbul Bombings**. Economics of Security Working Paper 31, Berlin: Economics of Security.

Dresen, G., Bohnhoff, M., Aktar, M., & Eyidogan, H. (2008), Drilling the North Anatolian Fault. **Scientific Drilling Journal**, July 2008(6), 58-59. doi: 10.2204/iodp.sd.6.10.2008.

Durukal, E., Erdik, M., & Uçkan, E. (2008), Earthquake risk to industry in Istanbul and its management. **Natural Hazards,** *Vol. 44, No. 2*, 199-212. doi 10.1007/s11069-007-9119-0.

Erdik, M. (2005), Earthquake Risk, Earthquake Rapid Response System, and Early Warning System in Istanbul. **Macalester International***, Vol. 15, Article 12* (Available at: http://digitalcommons.macalester.edu/macintl/vol15/iss1/1), 99-124.

Erdik, M., Durukal, E., Biro, Y., & Birgören, G. (2000), İstanbul'da Binalar için Deprem Riski ve Risk Azaltımına Yönelik Somut bir Öneri. **İkinci İstanbul ve Deprem Sempozyumu, TMMOB İnşaat Mühendisleri Odası İstanbul Şubesi, 27 Mayıs 2000, İstanbul Teknik Üniversitesi Maçka Kampusü,** (pp. 131-149). Istanbul.

Gencer, E. A. (2008), **Natural Disasters, Vulnerability, and Sustainable Development: Examining the Interplay, Global Trends, and Local Practices in Istanbul.** Saarbrücken: VDM Verlag. ISBN/ISNN: 9783836475105.

Guha-Sapir, D., Vos, F., Below, R. & Ponserre, S. (2011), **Annual Disaster Statistical Review 2010. The numbers and trends.** Centre for Research on the Epidemiology of Disasters (CRED), available on: http://www.undp.org.cu/crmi/docs/cred-annualdisstats2.

Iatridis, G. (2011), Terrorist attacks and company financial numbers: Evidence on earnings management and value relevance from Madrid, London and Istanbul. **Research in International Business and Finance***, 26*(2), 204-220.

Japan International Cooperation Agency (JICA), & Istanbul Metropolitan Municipality (IMM). (2002), **A Disaster Prevention/Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey.** Finalr report - Main report.

Kalkan, E., Gülkan, P., Yilmaz Öztürk, N., & Çelebı, M. (2008), Seismic Hazard in the Istanbul Metropolitan Area: A Preliminary Re-Evaluation. **Journal of Earthquake Engineering, Volume 12, Supplement 2,** 151-164. doi:10.1080/13632460802013925.

Köktürk, E., Köktürk, E., Özlüdemir, M., & Çelik, R. (2007), An Investigation on to 'Squat and The Exemption of Unauthorized Buildings-Gecekondu' in Turkey. **FIG Com3 Workshop, on "Spatial Information Management toward Legalizing Informal Urban Development", 28-31 March 2007.** Greece: UN/ECE-Committee on Housing&Land Management-UN/ECE Working Party on Land Administration, International Federation of Surveyors, Technical Chamber of Greece, Hellenic Association of Rural and Surveying Engineers (HARSE).

Kubat, A., Eyüboĝlu, E., Ertekin, Ö., & Sari, F. (2008), Earthquake as a Fact of Istanbul: Risk-based Strategy and an Action Plan for the Vulnerable Zeytinburnu Area. In T. Kidokoro, J. Okata, S. Matsumura, & N. Shima, **Vulnerable Cities: Realities, Innovations and Strategies. XII** (pp. 275-298. ISBN: 978-4-431-78149-3). Hicom, Japan: Springer.

Kundak, S. (2006), **Istanbul'da Deprem Risk Parametrelerinin Değerlendirilmesine Yönelik Bir Model Önerisi (A Model on the Evaluation of Earthquake Risk Parameters in Istanbul).** Thesis in Urban and Regional Planning (Advisor: Prof. Dr. Handan Turkoglu), Istanbul Technical University, Institute of Science, Istanbul.

Kundak, S. (2011), **Evaluation of Istanbul Confronting with Hazards.** ENSURE Final Workshop 9-12 May 2011, Orleans Paris, France.

Maritano Comoglio, N., Vitale, L., Turgut, H., Erkut, G., Gülersoy, N. Z., & Piccini, A. (2000), **Housing and urban policies for low-income people in the central areas of Istanbul and Sao Paolo.** Torino: AGAT Editrice. ISBN: 8882020061.

Mazilu, M. (2007), Opportunities and Threats for Romania as a Tourist Destination after the World Economic Crisis. **Proceedings of the 5th WSEAS International Conference on Economy and Management Transformation**. Volume I. ISBN:978-960-474-240-0.

Ministry of Health, Republic of Turkey. (2004), Database of Health Services in Turkey.

Murlidharan, T., & Shah, H. (2003), **Economic Consequences of Catastrophes Triggered by Natural Hazards.** Stanford University, Department of Civil and Environmental Engineering. The John A. Blume Earthquake Engineering Center. Report No. 143, March 2003. Availabe at: https://blume.stanford.edu/sites/default/files/TR143_Murlidharan.pdf.

Özmen, B. (2003), Earthquake Risk Reduction Studies at General Directorate of Disaster Affairs. **Forum on Regional Initiative for Disaster Risk Management, 02-04 March 2003**. Tehran.

Parsons, T. (2004), Recalculated probability of M≥7 earthquakes beneath the Sea of Marmara, Turkey. **Journal of Geophysical Research**, *109, B05304, doi:10.1029/2003JB002667*.

Parsons, T., Barka, A., Toda, S., Stein, R. S., & Dieterich, J. H. (2000), Influence of the 17 August 1999 İzmit Earthquake on Seismic Hazard in Istanbul. In *The* **1999 Izmit and Duzce Earthquakes: Preliminary results** (pp. 295-310). Istanbul: İstanbul Technical University.

Turkish Statistical Institute. (2012), **Addressed Based Population Registration System 2011**. *Population Census Results.* Available on: http://www.turkstat.gov.tr/PreTablo.do?tb_id=39&ust_id=11;.

United Nations. (2011), **World Population Prospects: The 2010 Revision, Highlights and Advance Tables**. Working Paper No. ESA/P/WP.220, Department of Economic and Social Affairs, Population Division - DESA.

Wald, D. J., Quitoriano, V., Heaton, T. H., & Kanamori, H. (1999), Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California. **Earthquake Spectra**, *Volume 15, Issue 3*, 557-564. doi: http://dx.doi.org/10.1193/1.1586058.

Website consulted

EM-DAT database (consulted on: April 10, 2012): http://www.emdat.be/

Protezione Civile /Italian Civil Protection (Consulted on: Jun 26, 2012): http://www.protezionecivile.gov.it/cms/attach/liguria_linee_guida.pdf;

Republic of Turkey, Ministry of Culture and Tourism (Consulted on: March 22, 2012): http://www.kultur.gov.tr/EN,36568/number-of-arriving-departing-foreigners-and-citizens.html

The C.I.A.'s World Factbook (Consulted on: March 22, 2012): https://www.cia.gov/library/publications/the-world-factbook/geos/tu.html

United States Geological Survey – USGS (consulted on: January 26, 2012): http://www.usgs.gov