IJEGEO International Journal of Environment and Geoinformatics 3(1), 29-43 (2016)

Determination of Road Functionality for Küçükçekmece District Following a Scenario Earthquake for Istanbul

Betül Ergün Konukcu [1,*], Himmet Karaman [1], Muhammed Şahin [1]

[1] Istanbul Technical University, Faculty of Civil Engineering, Department of Geomatics Engineering, Istanbul, Turkey

Corresponding author* Tel: +90 532 6363286
E-mail: betulergun_77@hotmail.com

Received 21 October 2015
Accepted 30 December 2015

Abstract

Istanbul has been affected by earthquakes throughout its history. The closest, most recent earthquake in Istanbul occurred in the Izmit province in 1999. This earthquake results have raised the earthquake awareness and lots of scientific studies have been made for Istanbul since then. According to these studies, Istanbul is going to face a major earthquake in near future. If the Istanbul earthquake happens, the damage estimation is very high because of the building stock in Istanbul. Damage buildings cause not only losing life but also debris around roads. Besides damaged buildings debris, damage on the transportation structure decrease road functionality. In order to increase the road functionality during the response and recovery period of disaster, it is very important to reveal the road functionality against to earthquake for such a big and important megacity. Because they have critical and strategic importance role during the post-earthquake response and long-term recovery. In this study, Küçükçekmece is chosen as a study area. Within the context of this study, Road functionality in Küçükçekmece is revealed by using debris spreading distance and post-earthquake functionality of transportation structure damage. These results can be used as a base data for decision makers to develop important strategies for risk reduction.

Keywords: Road functionality, transportations structure damage, building collapse, debris spreading distance, building damage, earthquake damage analysis, building age, building code, risk analysis, remote sensing

Introduction

Istanbul is located between Asian and European continental as a bridge and divided 39 administrative regions as called district. It is very important city not only for Turkey but also for the world because of its geopolitics positon and historical frame. Besides that Istanbul has been affected by earthquakes throughout its history. Based on worldwide historical catalogues, Istanbul has suffered damage due to earthquakes repeatedly (Utsu 1990). When the historical earthquake data of Istanbul is analyzed, it is seen that Istanbul, on average, has been affected by a moderate intensity earthquake every fifty years and a high intensity earthquake every 300 year (Ambraseys and Finkel 1991). It has been proven by several scientific studies that the possibility of Istanbul facing a major earthquake in the near future is high (Ambraseys and Finkel 1991; Le Pichon et al. 2003; Parsons et al. 2000). It is estimated that damage will be extensive as a result of the anticipated earthquake due to the building stock of Istanbul (Karaman 2009).

In order to mitigate earthquake damage, lots of scientific studies has been made. “The Study on A Disaster Prevention / Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey” is one of the most important studies for Istanbul in a large scale in order to assess earthquake risk. Regarding this study, Küçükçekçekmece has the highest risk against to earthquake (Table 1) (JICA and IMM 2002). For this reason Küçükçekmece is chosen as a study area for this study. Küçükçekçekmece is the one the most populous district of Istanbul. According to the results of the 2014 Address Based Census System Registration (ADNKS) by Turkey Statistical Institute (TUIK 2014) 748.398 people has lived in Küçükçekmece.

Within the scope of this study, road functionality in Küçükçekmece after the potential Istanbul earthquake is revealed by using average debris spreading of collapsed buildings and transportation structure damage. For defining potential collapsed buildings in Küçükçekmece against to anticipated Istanbul earthquake, building damage analysis were made for buildings in Küçükçekmece.

Table 1. Building damage in Küçükçekmece

District Name	Model	Total Building Number	Heavily		Heavily + Moderately		Heavily + Moderately + Partly	
			number	%	number	%	number	%
Küçükçekmece	A	45817	4915	10.7	10325	22.5	20642	45.1
	C	45817	4299	9.4	9219	20.1	19.293	42.1

The estimation of possible building damage is very useful data to conduct risk reduction studies. There are several loss assessment tools existing worldwide in order to estimate building damage. However, most of them are proprietary, closed code, region-specific, or all above (Karaman et al. 2008b). The pioneer and the leader of these tools are HAZUS, which was developed by National Institute for Building Science (NIBS) and Federal Emergency Management Agency (FEMA) (Elnashai et al. 2008). Besides HAZUS, SELENA (Seismic Loss Estimation using a logic tree Approach) (Molina and Lindholm 2005), ESCENARIS (Strasser et al. 2008)., SIGE (Di Pasquale et al. 2004)., DBELA (Displacement-Based Loss Assessment) Pavia (Crowley et al. 2004) and ELER (Crowley et al. 2004) are the other loss estimation program that were used in a world. In this study HAZTURK was used to calculate building damage in Küçükçekmece. HAZTURK is the software that visualizes the earthquake risk and its possible damage to structures and people, considering all the aspects of a seismic risk assessment process and offering options for decision makers all in one tool (Elnashai et al. 2008). HAZTURK needs construction type, number of floor and building age for every single building in order to calculate building damage.

The building construction year (building age) in building risk analysis gives information about the construction standards regarding building codes. When the building age is produced in GIS, it is possible to classify the buildings with their building code. In this study, the building codes that came into force in Turkey are used. The first comprehensive building code in the world was enforced in London by the government after a devastating fire in London in 1666 (Holmes et al. 2008). Government control of design and construction (primarily of buildings) gradually spread throughout the World largely based on the London precedent. However, each country has its own, often unique, history and legal authorization for building code development and implementation (Meacham et al. 2005). In Turkey, following the foundation of Turkish Republic, many different rules were tried for building construction and it has been revealed as disaster regulation. (Table 2). The most recent earthquake regulation of Turkey published in 2007. This building code was the revised version of the American Earthquake Regulation (IBC) for Turkey. Currently a new building code creation is ongoing and planned to be declared in 2016 by The Republic of Turkey's Disaster and Emergency Management Presidency.

In this study, the building codes dates that have come into force in Turkey from 1940 to 2007 were taken as a reference in order to determine building age classification for Küçükçekmece. Remote sensing data (aerial photographs, satellite images and ortho photo mosaics) were obtained compatible with the date of the building codes. The literature review of studies shows that aerial photographs and satellite images were used in lots of national and international publications in order to detect collapsed buildings. These achieved over an 80% success rate for detecting collapsed buildings at local sites (Turker and San (2003);

(2004), and Kaya et al. (2005); Gupta et al. (1994) and Saraf et al. (2002)).

Table 2.Building Code and Building Age Classification

Building Code Name	***Building Code Year***	***Building Age Classification***	***Data Source***
Italian Structure Regulations	1940	Before 1982	1982 Air Photo
Temporal Structure Code for the Earthquake Zone Constructions	1944		
Structure Regulation for Turkey Earthquake Zones	1949		
Regulation for the Structures that are going to be Constructed within the Earthquake Zones	1953		
Specification for Buildings to be Built in Seismic Zones	1962		
Specification for Buildings to be Built in Seismic Zones	1968		
Specification for Buildings to be Built in Seismic Zones	1975		
Specification for Buildings to be Built in Seismic Zones	1997	1983 - 1996	1996 Ortho Photo Mosaic
		1997 – 2004	2004 Satellite Image
Specification for Buildings to be Built in Seismic Zones	2007	2004 - 2012	2013 Ortho Photo Mosaic

Building damage is the one of the highest causes of death and injures during earthquakes. Besides that, the scattered parts of collapsed buildings could create debris around the buildings and this debris could cause road blockages in the vicinity of the damaged buildings especially the narrow roads. Road blockages decrease the road functionality during the disaster time. In this part of the study, road closure in Küçükçekmece because of the debris was revealed according to the average debris spreading distance obtained from average debris spreading distance of collapsed building in Gölcük during the 1999 Kocaeli earthquake. During this part of study, Gölcük is chosen for producing average spreading distance. Because there were lots of damaged buildings during the 1999 Izmit (Kocaeli) Earthquake. According to Özmen (2000), 35.7 % of buildings in Gölcük had heavily damaged and 5025 people died in Gölcük because of the 1999 Izmit Earthquake. In order to obtain the average debris spreading distance in Gölcük, Gölcük aerial photos belonging 1994 and 1999 years were used. There are lots of literature for determining the existing and collapsed buildings during the earthquakes by using aerial photographs and remote sensing images. Fraser et al(Fraser et al. 2002). tried to define buildings by using IKONOS Satellite Image in their study in 2002 (Fraser et al. 2002). Gupta et al. studied collapsed buildings at Uttarkashi during the Uttarkashi Earthquake in their 1994 study. Remote Sensing data were used to determine changes caused by earthquakes in their studies (Gupta et al. 1994). Kaya et al. used three different data sources to estimate the proportion of Adapazarı that contained collapsed buildings in their study in 2005. One of them is SPOT HRVIR XI image, the other one is SPOT HRVIR Panchromatic image and the last one is government statistics (Kaya et al. 2005). Turker et al. used SPOT HRV images to detect earthquake-induced changes in the 1999 Kocaeli earthquake in 2003. (Turker and San 2003).

Not only the collapsed buildings debris but also the transportation structure damage will affect the road functionality during the disaster time and response and recovery period of disaster. In this part of the study, the transportation structures functionality because of the earthquake was revealed that were related to Küçükçekmece. A system, such as a highway system, is configured into a network which will consist of a large number of links and nodes (Chang and Nojima, 1998; Kameda, 2000). The disruption of any of these links (e.g. roadway) or nodes (e.g. bridge or tunnel) can disrupta section of the network, the impact of which is dependent on the redundancy in the system (Rojahn et al., 1992). Thus, a systems or network analysis of a highway system is required to be able to link structural damage of a bridge or roadway to social and economic impacts (Chang and Nojima, 1998; Werner and Taylor, 2002).

Materials and Methods

In order to determine the road functionality in Küçükçekmece, this study consists of two main part. One of them is to calculate building risk analysis and the other one is to calculate transportation structure damage.

Building attributes information (building age, number of floors, construction type) is necessary to make a building risk analysis against earthquake hazard for Istanbul. Not to obtain the building age for buildings in Küçükçekmece, the building age data were produced for every single Küçükçekmece building by using aerial photo (1982), ortho photo mosaic (1996, 2013) and satellite image (2004). In this part of the study, age of Küçükçekmece buildings were determined to according to building codes that were come into force in Turkey and produced for every single buildings in Küçükçekmece In this study, it is accepted that all buildings were constructed in accordance with the building codes in the period to which they belong.

1982 aerial photo was used to determine the buildings that were constructed before 1982. The buildings were created by digitization on ArcINFO software programme. Then this digization data were added to 1996 ortho photo mosaic in order to determine new built and demolished buildings from 1982 to 1996. Again this data were added to 2004 satellite image for defining new built and demolished buildings from 1997 to 2004. Then this data were added to 2013 ortho photo mosaic for defining new built and demolished buildings from 2005 to 2013. Thus the building age data were produced to the Geographic Information System (GIS) for Küçükçekmece buildings.

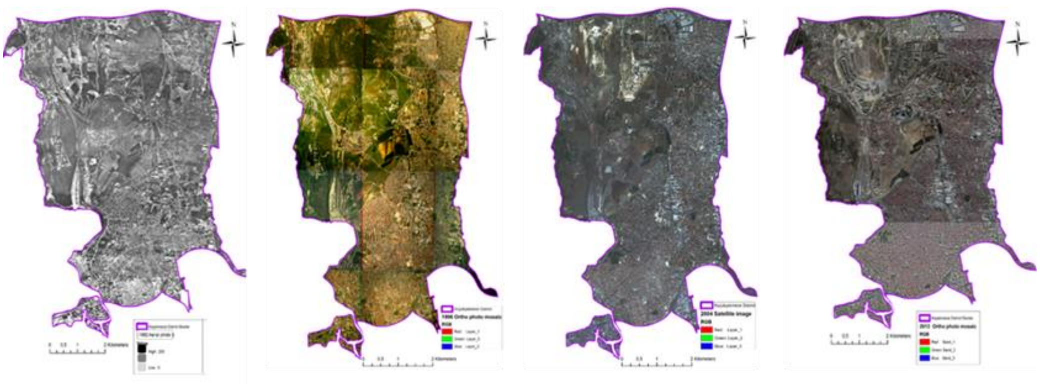

Fig. 1. Remote sensing data for using building age in Küçükçekmece

"Istanbul Structure Data" consisted of number of floors and construction type for every single building in Istanbul was obtained from Istanbul Metropolitan Municipality in order to calculate building damage. The buildings in Küçükçekmece were choosen in these dataset for this study. The dataset including building age in Küçükçekmece and the dataset including number of floors and construction type were joined for getting Küçükçekmece buildings. There are 35589 number of building in Küçükçekmece (Figure 2).

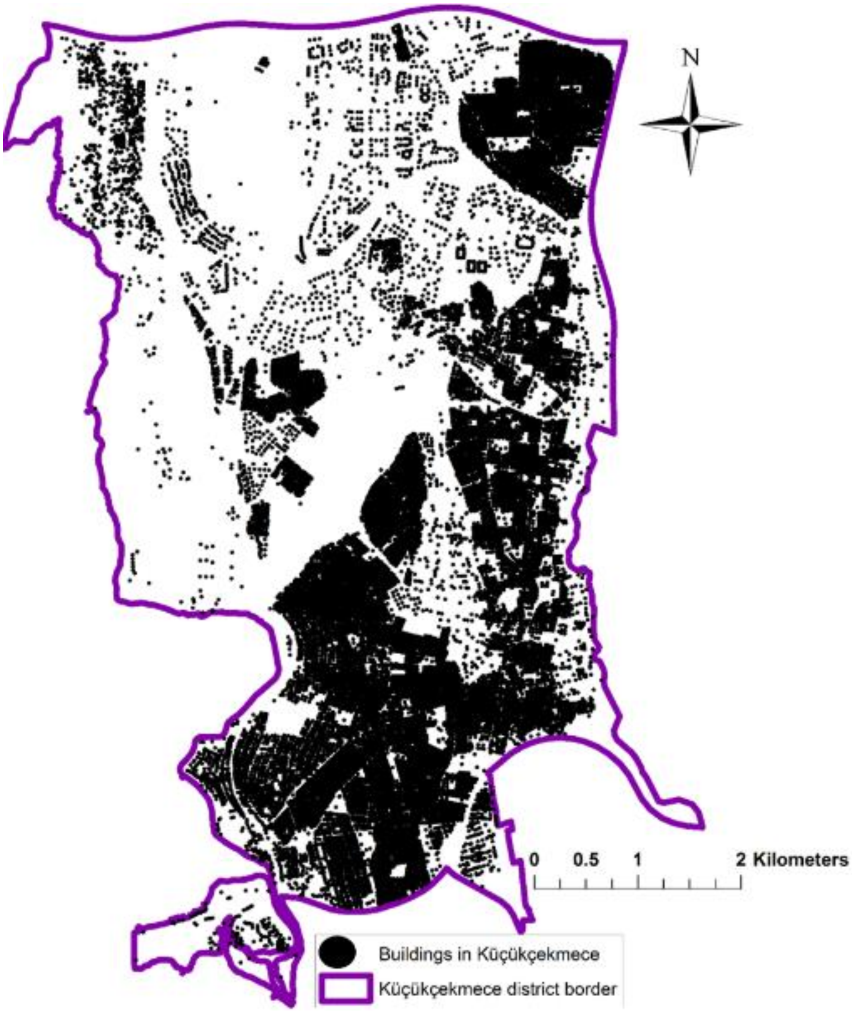

Fig. 2. Buildings in Küçükçekmece

Hazard is described as an input ground motion parameter or a spectral response value (Karaman et al. 2008a). In this study, HAZTURK software was used for the estimation of building damages in Küçükçekmece based on a scenario earthquake. Model A produced by JICA and IMM (2002) study was used as a scenario earthquake. Model A is defined as a fracture in the eastern part of the fault line and is the most anticipated model. The magnitude of this scenario earthquake was assumed as Mw 7.5 (JICA and IMM 2002). The probability of the damage to buildings is estimated by matching every building in the dataset to a fragility curve in the database by using the number of stories, construction year, structure type, and hazard values at the building location. Fragility curves used in this study were developed by using the Parameterized Fragility Method (PFM) of Jeong and Elnashai (2006). HAZTURK calculates the probability of earthquake damage on a building in four limit states based on 0.2 sec Sa and Sd demands (Karaman et al. 2008b). In this study, Boore and Atkinson (2008) ground motion estimation equation has been used to simulate the earthquake hazard map for Istanbul Sa (T=0.2 s) demands (Figure 3).

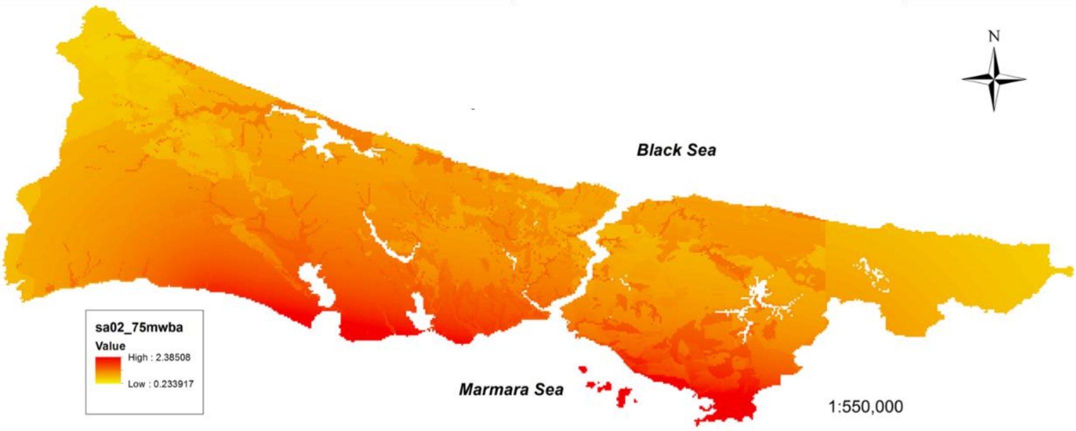

Fig 1. Earthquake hazard map for Istanbul Sa (T=0.2 s) demands.

In order to use building data in the HAZTURK software, the necessary reclassification and standardization process were done (Table 3). These data were classified according to the HAZUS Handbook (FEMA 2003).

Table 3. HAZUS Building Structural Type (FEMA 2003)

Description	*Label*	*Height*	*Stories*
Wood, Light Frame	W1		1 – 2
Wood, Commercial and Industrial	W2		All
Steel Moment Frame	S1L	Low-Rise	1 – 3
	S1M	Mid-Rise	4 – 7
	S1H	High-Rise	8 +
Steel Braced Frame	S2L	Low-Rise	1 – 3
	S2M	Mid-Rise	4 – 7
	S2H	High-Rise	8 +
Steel Light Frame	S3		All
Steel Frame with Cast-in-Place Concrete Shear Walls	S4L	Low-Rise	1 – 3
	S4M	Mid-Rise	4 – 7
	S4H	High-Rise	8 +
Steel Frame with Unreinforced Masonry Infill Walls	S5L	Low-Rise	1 – 3
	S5M	Mid-Rise	4 – 7
	S5H	High-Rise	8 +
Concrete Moment Frame	C1L	Low-Rise	1 – 3
	C1M	Mid-Rise	4 – 7
	C1H	High-Rise	8 +
Concrete Shear Walls	C2L	Low-Rise	1 – 3
	C2M	Mid-Rise	4 – 7
	C2H	High-Rise	8 +
Concrete Frame with Unreinforced Masonry Infill Walls	C3L	Low-Rise	1 – 3
	C3M	Mid-Rise	4 – 7
	C3H	High-Rise	8 +
Precast Concrete Tilt-Up Walls	PC1		All
Precast Concrete Frames with Concrete Shear Walls	PC2L	Low-Rise	1 – 3
	PC2M	Mid-Rise	4 – 7
	PC2H	High-Rise	8 +
Reinforced Masonry Bearing Walls with Wood or Metal	RM1L	Low-Rise	1 – 3

Deck	RM2M	Mid-Rise	8 +
Reinforced Masonry Bearing Walls with Precast Concrete	RM2L	Low-Rise	1 – 3
	RM2M	Mid-Rise	4 – 7
	RM2H	High-Rise	8 +
Unreinforced Masonry Bearing Walls	URML	Low-Rise	1 – 3
	URMM	Mid-Rise	4 – 7
Mobile Homes	MH		All

One of the reasons of losing road functionality after the earthquake is debris of building collapse. After determining the buildings that have the possibility of collapse in Küçükçekmece, it is necessary to determine how far to debris scattered from collapsed building. Debris spreading distance were calculated by studied Gölcük collapsed building. 80 collapsed buildings were chosen in Gölcük. Debris spreading lines were drawn in all directions around the collapsed buildings in Gölcük. As a result 317 debris spreading e vector in every direction were obtained (Figure 4).

Fig 4. Building Collapse Directions in Gölcük

Another reason of losing road functionality is depend on transportation structure damage. There are 16 number of transportation structures (9 Overpass Bridge, 6 Underpass Bridge, 1 viaduct) related to road in Küçükçekmece (Figure 5).

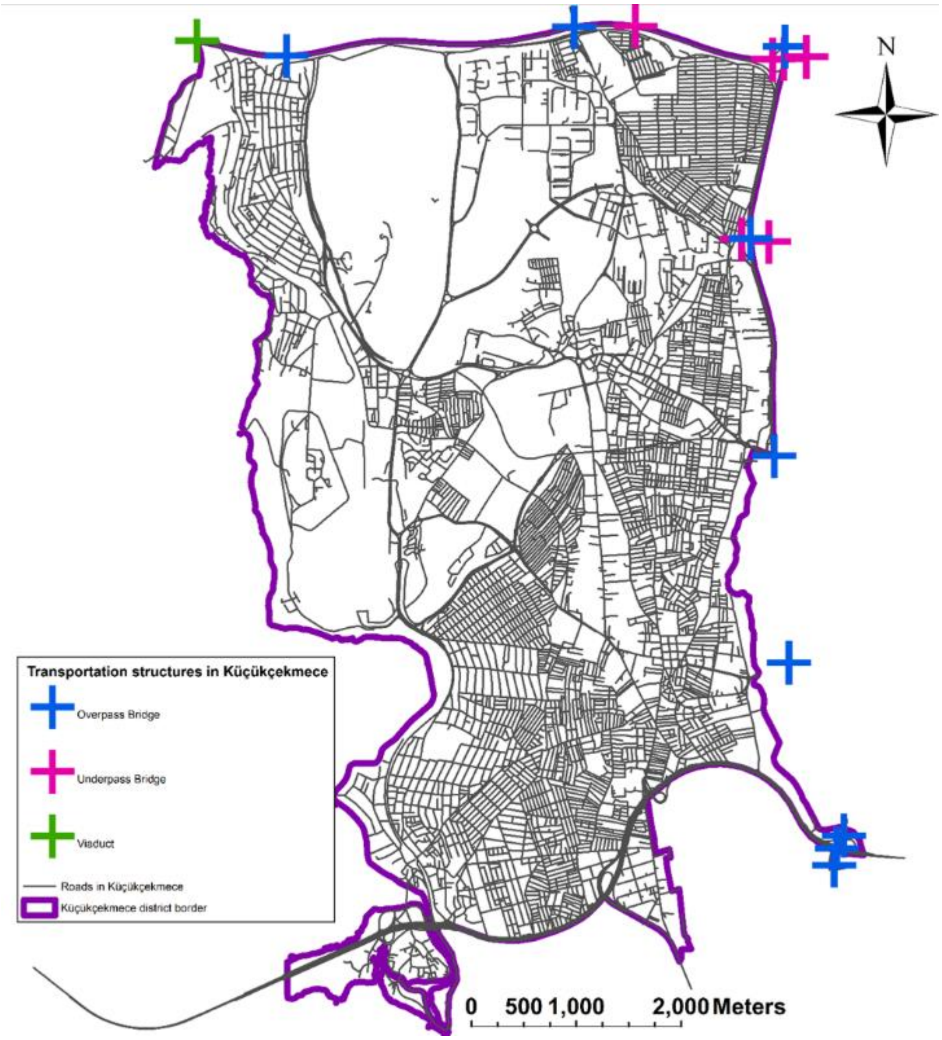

Fig 5. Transportation structure classificaiton in Küçükçekmece

The probability of damage and functionality to transportation structure is estimated by matching every single transportation structure in the dataset to a fragility curve in the database by using the transportation structure classification. This classification was made regarding to construction type, construction material, number of spans, length, deck width and the type (stringer, tee-beam, floor girder, channel beam, slab, box-beam-multiple) (Table 4). The fragilities, using by calculating transportation structures, had been developed according to construction types listed in NBI (DesRoches et al., 2003; DesRoches et al., 2006), as well as the number of spans, total length, and width)

Results

In order to reveal road functionality in Küçükçekmece because of the earthquake, debris spreading distance of potential collapse building in Küçükçekmce and transportation structure damage in Küçükçekmece were calculated then the results combined to assess together.

Firstly, in order to use in building damage analysis, building age distribution for every single building in Küçükçekmece were generated by using remote sensing data. According to GIS studies, building age distribution for Küçükçekmece buildings were given at figure 6. There are 14488 buildings that were built before 1982, 15468 buildings that were built between 1983 and 1996, 3249 buildings that were built between 1997 and 2004 and 2384 buildings that were built between 2005 and 2014 in Küçükçekmece.

Table 4.Construction Types Listed in NBI (FHWA,1995a).

Name	Abbreviation	Material	Type	Spans
Multi-Span Continuous Concrete Girderı	MSC Concrete	Concrete Continuous Prestressed Concrete Continuous	Stringer Tee-Beam Floor Girder Channel Beam	>1
Multi-Span Continuous Steel Girder	MSC Steel	Continuous Steel	Stringer Tee-Beam Floor Girder Channel Beam	>1
Multi-Span Continuous Slab	MSC Slab	Concrete Continuous Prestressed Concrete Continuous	Slab	>1
Multi- Span Simply Supported Concrete Girder	MSSS Concrete	Concrete Continuous Prestressed Concrete Continuous	Stringer Tee-Beam Floor Girder Channel Beam	>1
Multi- Span Simply Supported Steel Girder	MSSS Steel	Steel	Stringer Tee-Beam Floor Girder Channel Beam	>1
Multi-Span Simply Supprted Slab	MSSS Slab	Concrete Prestressed Concrete	Slab	>1
Multi-Span Simply Supprted Concrete Box Girder	MSSS Concrete-Box	Concrete Prestressed Concrete	Box Beam - Multiple	>1
Single – Span Concrete Girder	SS_Concrete	Concrete Prestressed Concrete Concrete Continuous Presteressed Concrete Continuous	Stringer Tee-Beam Floor Girder Channel Beam Slab Box-Beam - Multiple	<2
Single – Span Steel Girder	SS Steel	Steel Steel Continuous	Stringer Tee-Beam Floor Girder Channel Beam Slab Box-Beam - Multiple	<2

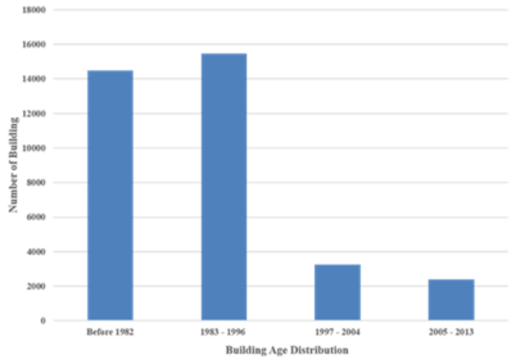

Fig 6. Building age distribution in Küçükçekmece

Building damage analysis in Küçükçekmece was made by using HAZTURK program. There are 35589 building in Küçükçekmece. 1897 buildings in Küçükçekmece have the possibility of collapse more than 30% according to Sa (Figure 7).

Within the context of this study, it is accepted that potential collapsed building in Küçükmece could cause debris around it about 17.45 m that obtained from Gölcük collapsed buildings during the 1999 Kocaeli earthquake around it. Because of this debris, the road around the potential collapsed building could lose their functionality. The length of current road in Küçükçekmece is 714743 meters. Because of the debris, 91787 meters road lose their functionality (Figure 8).

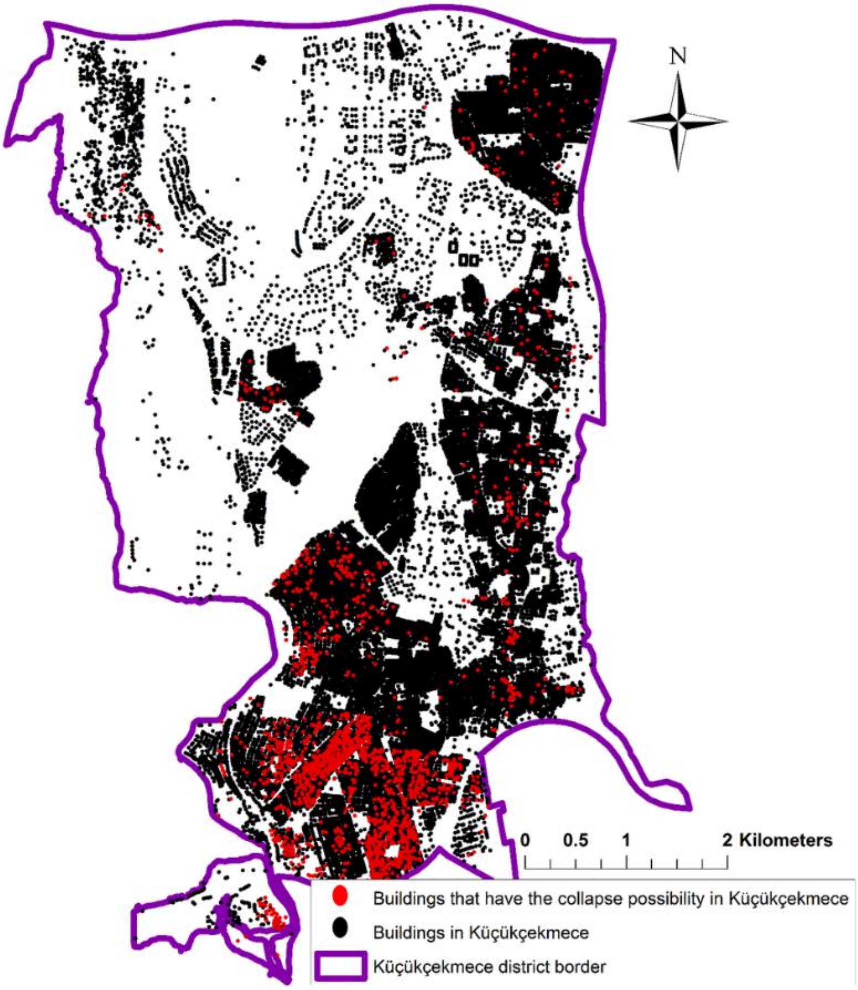

Fig 7. Buildings that have the possibility of collapse more than 30% according to Sa

Fig 8. Road blockage in Küçükçekmece

There are 9 overpass bridges, 6 underpass bridges, 1 viaduct related to road in Küçükçekmece. These transportation structures damage analyses were made by using HAZTURK program. According to this damage analysis, functionality of transportation structures was revealed (Figure 9). Regarding figure 10, there is no transportation structure that their functionality is 100. 6 of them is higher than 60. Most of them (10) is lower than 50. This shows that most of the transportation structures will not be used after a potential earthquake in Istanbul.

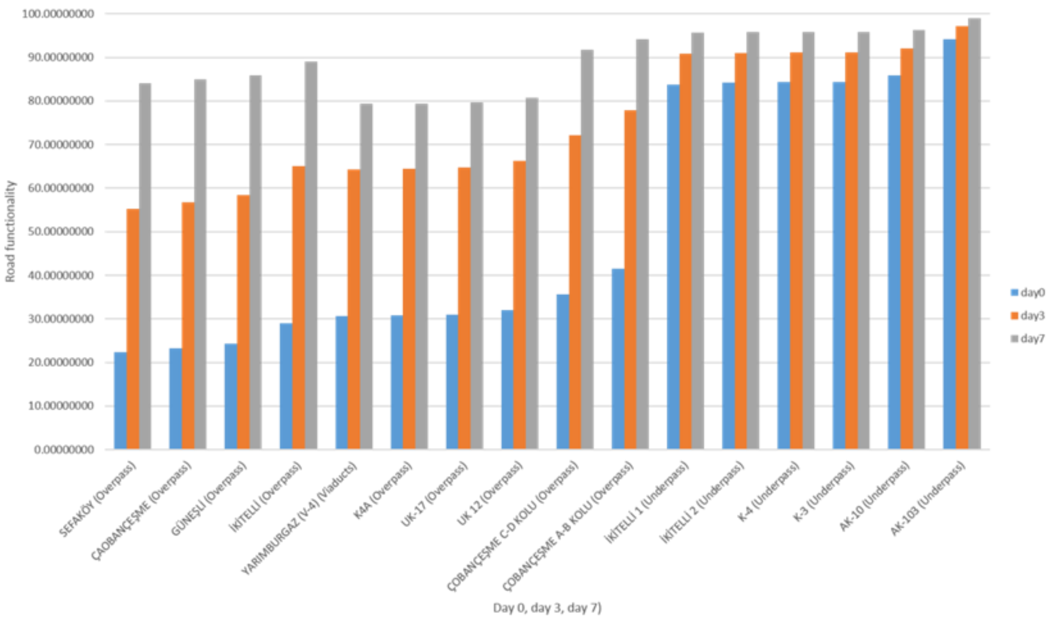

Fig 9. Transportation structure functionality in Küçükçekmece

Figure 10 shows the transportation functionality in day 0 times (the day when the earthquake occurred).

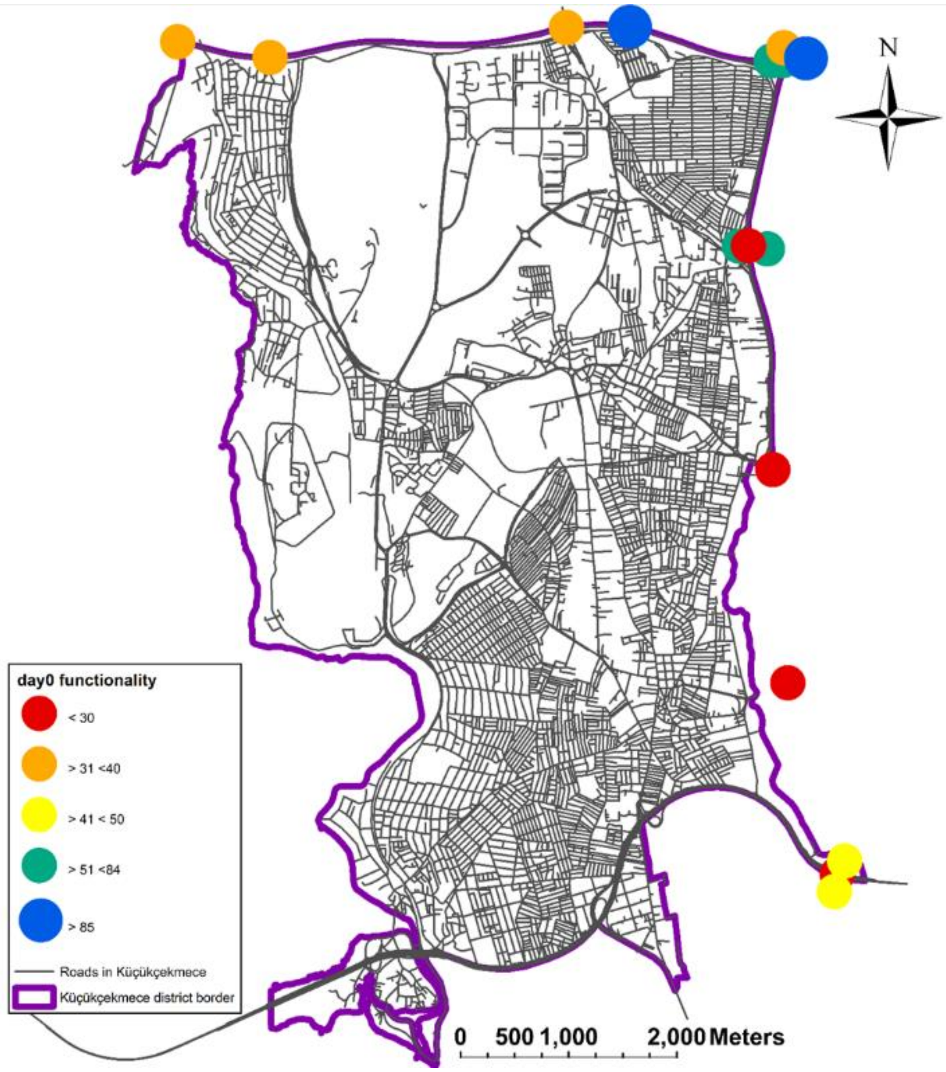

Fig 10. Transportation structure distribuiton according to functionality in Küçükçekmece

Discussion and Conclusion

Road functionality in Küçükçekmece is revealed with figure 11 by using debris spreading of collapsed building in Küçükçekmece and related post-earthquake functionality of transportation structures damage.

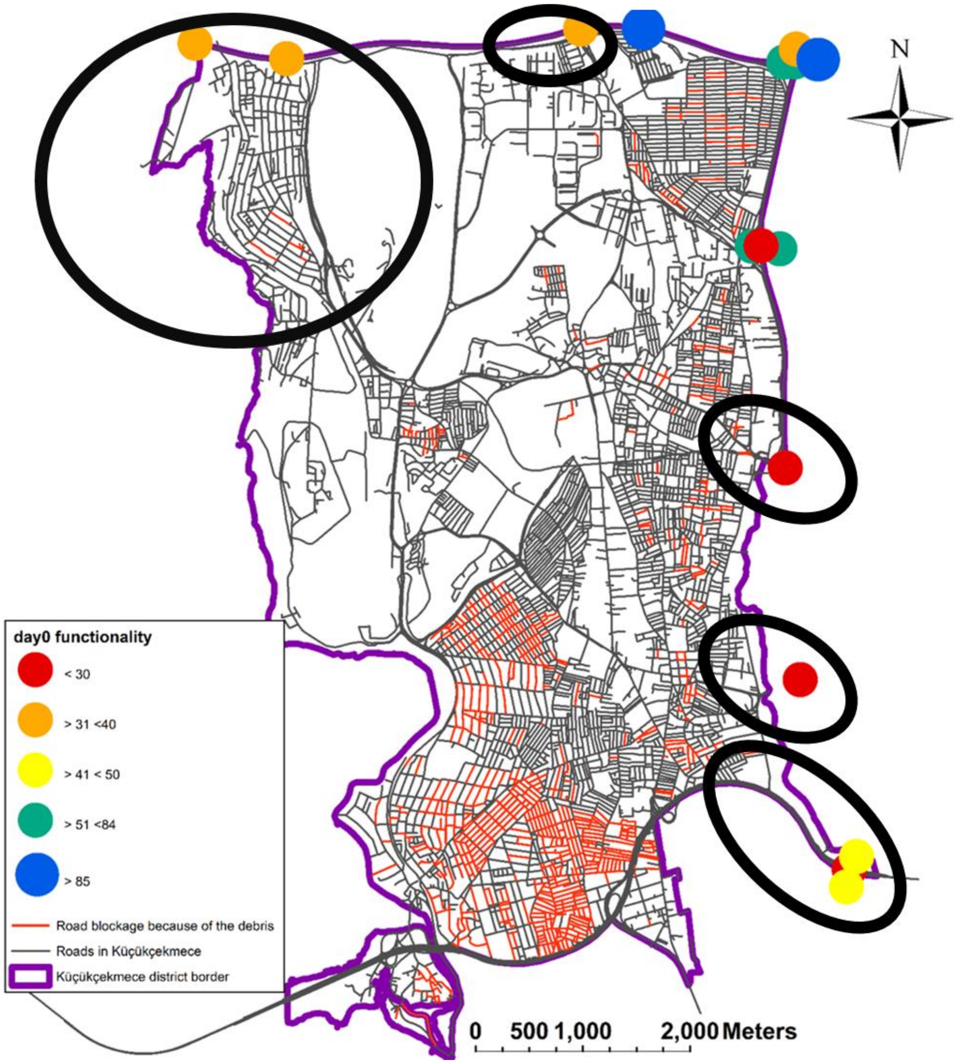

Fig 11. Road functionality according to building collapse direction and transportation structure damage

This figure shows that most roads in Küçükçekmece district lose their functionality during the potential earthquake because of the collapsed buildings debris. Also most of transportation structures functionality is lower than 50. Due to the this stiuation, search and rescue activities, fire fighting and the temporary shelters accessibility is getting lower. For this reason the necessary activities during the response and recovery time are impractical.

References

Ambraseys N, Finkel C (1991) Long-term seismicity of Istanbul and of the Marmara Sea region Terra Nova 3:527-539

Le Pichon X, Chamot-Rooke N, Rangin C, Sengör A (2003) The North Anatolian fault in the Sea of Marmara Journal of Geophysical Research: Solid Earth (1978–2012) 108

Parsons T, Toda S, Stein RS, Barka A, Dieterich JH (2000) Heightened odds of large earthquakes near Istanbul: An interaction-based probability calculation Science 288:661-665

Holmes W, Kircher C, Petak W, Youssef N (2008) Seismic performance objectives for tall buildings: A report for the tall buildings initiative, PEER 2008/101 Berkeley (CA): Pacific Earthquake Engineering Research Center

Meacham B, Bowen R, Traw J, Moore A (2005) Performance-based building regulation: current situation and future needs Building Research & Information 33:91-106 doi:10.1080/0961321042000322780

Karaman H, Şahin M, Elnashai AS (2008a) Earthquake loss assessment features of maeviz-istanbul (hazturk) Journal of Earthquake Engineering 12:175-186

Karaman H, Şahin M, Elnashai AS, Pineda O (2008b) Loss assessment study for the zeytinburnu district of istanbul using maeviz-istanbul (hazturk) Journal of Earthquake Engineering 12:187-198

JICA, IMM (2002) The Study on A Disaster Prevention / Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey. Pacific Consultants International, OYO Corporation, Istanbul

Jeong S-H, Elnashai AS (2006) New three-dimensional damage index for RC buildings with planar irregularities Journal of Structural Engineering 132:1482-1490

FEMA H-M (2003) MR3 Technical Manual Multi-hazard Loss Estimation Methodology Earthquake Model

Elnashai AS et al. (2008) Overview and applications of Maeviz-Hazturk 2007 Journal of Earthquake Engineering 12:100-108

Crowley H, Pinho R, Bommer J (2004) A Probabilistic Displacement-based Vulnerability Assessment Procedure for Earthquake Loss Estimation Bulletin of Earthquake Engineering 2:173-219 doi:10.1007/s10518-004-2290-8

Di Pasquale G, Ferlito R, Orsini G, Papa F, Pizza A, Van Dyck J, Veneziano D (2004) Seismic scenario tools for emergency planning and management.

Erdik M, Cagnan Z, Zulfikar C, Sesetyan K, Demircioglu M, Durukal E, Kariptas C Development of rapid earthquake loss assessment methodologies for Euro-Med region. In: Proc. 14th World Conference on Earthquake Engineering, 2008.

IMM DvZIM- (2009) İstanbul Olası Deprem Kayıpları. İstanbul

Molina S, Lindholm C (2005) A logic tree extension of the capacity spectrum method developped to estimate seismic risk in Oslo, Norway Journal of Earthquake Engineering 09:877-897 doi:doi:10.1142/S1363246905002201

Strasser FO et al. (2008) A Comparative Study of European Earthquake Loss Estimation Tools for a Scenario in Istanbul Journal of Earthquake Engineering 12:246-256 doi:10.1080/13632460802014188

Özmen B (2000) 17 Ağustos 1999 İzmit Körfezi Depremi'nin Hasar Durumu (Rakamsal Verilerle). Afet İşleri Genel Müdürlüğü, Deprem Araştırma Dairesi, Ankara.

Fraser C, Baltsavias E, Gruen A (2002) Processing of Ikonos imagery for submetre 3D positioning and building extraction ISPRS Journal of Photogrammetry and Remote Sensing 56:177-194

Gupta R, Saraf A, Saxena P, Chander R (1994) IRS detection of surface effects of the Uttarkashi earthquake of 20 October 1991, Himalaya International Journal of Remote Sensing 15:2153-2156

Kaya Ş, Curran P, Llewellyn G (2005) Post-earthquake building collapse: a comparison of government statistics and estimates derived from SPOT HRVIR data International Journal of Remote Sensing 26:2731-2740

Turker M, San B (2003) SPOT HRV data analysis for detecting earthquake-induced changes in Izmit, Turkey International Journal of Remote Sensing 24:2439-2450

Chang, S. E. and Nojima, N. (1998). "Measuring Lifeline System Performance: Highway Transportation Systems in Recent Earthquakes." 6th US National Conference on Earthquake Engineering, Seattle, WA. EERI.

Kameda, H. (2000). "Engineering Management of Lifeline Systems Under Earthquake Risk." 12th World Conference on Eartquake Engineering, Auckland, New Zealand. New Zealand Society for Earthquake Engineering.

Rojahn, C., Scawthorn, C., Khater, M., and Ballantyne, D. B. (1992). "Transportation Lifeline Losses in Large Eastern Earthquakes." Lifeline Earthquake Engineering in the Central and Eastern US, New York, NY, USA. ASCE, p 87–101.

Werner, S. D. and Taylor, C. E. (2002). "Component Vulnerability Modeling Issues for Analysis of Seismic Risks to

Transportation Lifeline Systems.” Acceptable Risk Processes: Lifelines and Natural Hazards, Monograph No. 21, S. D. Werner and C. E. Taylor, eds., Technical Council on Lifeline Earthquake Engineering, ASCE, Reston VA USA.

FHWA (1995a). Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation’s Bridges, Vol. FHWA-PD-96-001. Office of Engineering Bridge Devision, Federal Highway Administration, McLean, VA.

TUIK (2014) 2014 Address Based Census System Registration (ADNKS). Turkey Statistical Institute. http://tuikapp.tuik.gov.tr/adnksdagitapp/adnks.zul. Accessed August 2015 2015

DesRoches, R., J. E. Padgett, A. S. Elnashai, Y. S. Kim, and D. Reed. "MAE Center transportation test bed." In Proceedings of the 8th US National Conference on Earthquake Engineering, San Francisco, California. 2006.

DesRoches, Reginald, Roberto T. Leon, and Shirley Dyke. "Response modification of bridges." Mid-America Earthquake Center CD Release 03-08 (2003).