MEGACITIES AT NATURAL DISASTER RISK FOCUSING ON TRANSPORTATION ON LONDON AND ISTANBUL CASES

Funda Atun [1]

Abstract

The city is a composite of interrelated systems; each performing its own functions and each of them is strongly connected to one another. Therefore, the city can be defined as a complex system or a network in which human activities emerge from the interaction among multiple spatial, temporal, economic, social and organizational levels. When such a complex system is struck by a natural hazard, it turns into a disaster that creates serious human causality, economic and moral lost due to damages and discontinuity of functions. In this paper, London and Istanbul Megacities are introduced to reveal the advantages of complex systems and to solve the problems that lead to damage. The data gathered from various institutions, organizations and individuals are analysed to give a general framework about the situation in the case study areas in terms of identification of possible structural, functional and organizational failures.

This paper covers "disaster risk management", "complexity science" and "transportation system" research areas within a theoretical framework that enables the researcher to adopt a methodology to solve the critical problems of the transportation system in case of a natural disaster. Transportation system has been chosen as the core subject of this paper, because it is one of the sub-systems in a city, and it is broadly interdependent to other subsystems, such as water, gas, sewage, electricity, telecommunication, fuel supply, fire fighting. Moreover, transportation infrastructure often requires long repair times than other lifeline systems and having failures in the system could serve to stress pre-existing conditions of the entire city's vulnerability. Besides, it has long-term economic impacts because of long restoration times in comparison with the other lifelines. The hypothesis of this paper is that with an understanding of the complex nature of transportation system and interdependent character to its own components and to other subsystems a strong and sustainable transportation system could contribute the resilience of a city.

In particular this paper provides a way forward to handle the complex problems in a city system by focusing on transportation system on the one hand, and decisions and solutions taken by decision makers on the other hand. Thus, for engineers and urban planners the question is "what should be the methodology to solve the problems in the transportation system due to being hit by a disaster before its occurrence?" On the other hand, for decision makers, or governmental authorities, the questions of

[1] Politecnico di Milano, Milan, Italy – funda.atun@mail.polimi.it

"how to use the expert knowledge and implement it?" can be answered more easily by identifying the hidden connections in the system between vulnerable parts that affect the entire system.

Keywords: Disaster Risk Management, Transportation System, Flood Hazard, Earthquake Hazard

1. Introduction

Cities are not separated from their environment and having a problem in one of them could rapidly affect the other. Regarding to two specific examples London and Istanbul, these two cities are interconnected globally and an unexpected event in these cities could create a shock effect on the global financial market. However, their consequences could be different, as they are interconnected at different levels. For example, London is the main financial centre with Tokyo and New York. Having these three cities in three different time zones keeps financial market working 24 hours without stopping. An unexpected flooding in London could have global effects and aid could come from the all connections of London to recover the city and to keep it functioning. Besides, the economy of London is growing and they have enough resources to be used during emergency. As Istanbul is not interconnected as much as London, the aid would be less than the one offering to London, and due to competitiveness, if the recovery process takes long time, the city can be easily replaced with another developing city in the global arena. In the case of London, complex nature of the city could be an opportunity to recover immediately after a disaster, whereas in the Istanbul case complexity could lead to long term economic, structural, organizational and functional failures. So, the situation in these two cities clearly states that being complex could be either a problem or an advantage.

2. Problem definition

First of all, in case of a disaster cities stop operating as in normal conditions due to altering elements and interrupted connections among the layers, such as infrastructures and artefacts. Vulnerability analysis could help to indicate which elements are vulnerable to disasters and how they can be affected by hazards; however, how interaction affects the number of variables and consequently the number of dimensions cannot be foreseen clearly before its occurrence.

Chang and Nojima (2001) state that while much attention has been paid to understanding and predicting the performance of individual bridge structures under seismic loading, only recently researchers have begun to evaluate performance of the transportation system as a whole. There are studies focusing on the bridge damage modelling (Rojahn et al. 1997; Werner et al. 1997), the cost associated with travel times (Werner et al. 1997), network traffic flows (Werner et al. 1997; Nojima, 1997), transport cost and regional production losses (Shinozuka et al. 1998). However, the problem is that none of these studies deal with the disaster problem by considering

the relation of individual transportation problems (mainly structural) with regard to function and organization of the entire transportation system.
Secondly, one cannot be sure the reaction of humans, whether they follow orders and/or join the evacuation process properly. There are many examples to human failures. For instance, after occurrence of a hazard not shutting down the main gas valves by the operator immediately, and waiting for a while just to be sure, could lead to a big fire which would increase the death toll of the event. Moreover, not having an evacuation plan which responds to people's needs can be ended up with many failures. Furthermore, not forecasting the hazard in time could lead to un-sufficient warning lead-time, and this would be ended up with a huge traffic jam as it is seen in the Rita Hurricane.

3. Transportation system as the core subject

Transportation system has been chosen as the core subject of this paper. The reasons are:
• Transportation infrastructure often requires long repair times than other lifeline systems and having failures in the system could serve to stress pre-existing conditions of the entire city's vulnerability.
• It is one of the sub-systems of a city, and it is broadly interdependent to other subsystems, such as water, gas, sewerage, electricity, telecommunication, fuel supply, fire fighting, structurally and/or functionally (Figure 1).
• During an emergency the transportation system is one of the most important systems to keep the city system functioning and respond rapidly to emergencies. Any mistakes done on the transportation system or any other mistakes done on another subs-system affect the functions of the transportation system, and consequently could lead to increase the death toll.

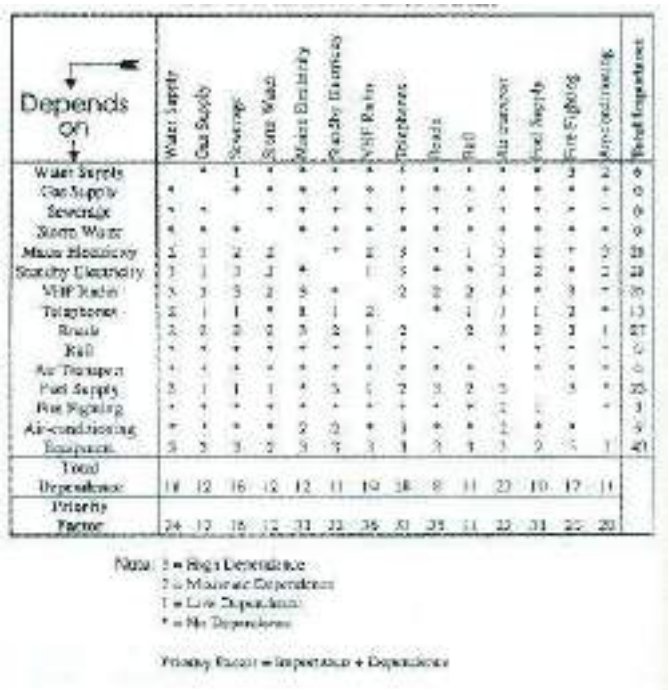

Figure 1. Interdependence matrix. Source: Paton and Johnston, 2006, p.62.

The transportation system is represented as a network of routes, railways linked by cars, trains etc. To connect the idea of networks with a study related with transportation system that is prone to natural hazards, the first step could be characterizing the structure of the transportation system, and understanding how it is spread. To be short how the transportation network works in its local and regional environment, responds to failures, and evolves depending on the needs should be understood clearly to find the short paths while improving it against natural disasters.

Last but not least, when humans are considered as one of the component, and may be the most leading one (Geoffrey West, talk in ECCS'11, 12-16 September, 2011), of a complex city system. Consequently, preparing "what if scenarios" could be the best way to deal with uncertain behaviour of human beings to simulate the actions and interactions of autonomous individual and collective entities.

4. Aim and objectives

The aim of this paper is to focus on the structural, functional and organizational connections among the elements as well as the elements itself. By achieving the defined aim this paper intends

- to consider transportation system as a whole within the entire city system by indicating nodes and edges
- to consider possible human behaviours

To have better understanding how a complex city system work and how agents react during an emergency and evacuation of people in case of an emergency, a "what if

scenario" is given as an example at the end of the paper by taking into account mega-cities, such as London and Istanbul.

5. London

Today London is ranked 28th in size by the year 2006 in the world's cities ranking. Although it is consisting of around 7.6 million population, it is not the world's largest city anymore. However, with its 300.000 employees inside the borders of the Greater London Authority, and 800.000 employees across these borders, London is one of the global centres for international banking and financial services by leading in foreign exchange turnover, trading of international bonds, trading overseas equities and fixing the gold prices. London precedes the other cities in all areas of competitiveness, and it is closely followed by New York and Tokyo in the world and by Paris, Frankfurt and Zurich in Europe (The Global Financial Centre Index, March 2009, p.7). By being one of the global centres, having an unexpected disaster could affect not only the city itself but also others that are strongly connected to London. On the other hand, increasing economy of London could help to recover and reconstruct the city in a short period. Rapid population growth, major economic transformation and rapidly changing urban environment are the three leading topics considered in mega cities.

Rapid Population Growth

After 80s by the changing economic policy, London attracted millions of population ones more in its history. As it's seen in Figure 2, London's population is increasing steadily since the late 80s and it is projected that the population increase would continue. As the industrialization has changed its shape and financial sector had gained importance more than manufacturing, the industrial and dock areas became vacant. The new coming population have settled in these old industrial new residential locations especially in the London Boroughs of Newham, Tower Hamlet, Lewisham and Southwark. For example, the population of Tower Hamlet was 140,000 in 1981, and this number has increased to 234,828 people in 2009. "The resident population of Greater London at mid-year 2009 was projected to be 7.75 million, an increase of 85,000 or 1.1% from 7.67 million in 2008. Between 2001 and 2009 London's population increased by 5.9% or more than 430,000 people" (Tfl, 2011, p.15).

Figure 2. Greater London Population, millions. Source: Tfl, 2011, p.127

Major Economic Transformation

Moreover, economic activities has transformed from manufacturing to business and financial services, construction, retail, tourism and leisure activities (Figure 3). The areas of the economic transformation overlap with the areas, which experienced the rapid population growth.

Rapidly changing urban environments

In a place where it has experienced population growth and changes on the major economic activity, it is inevitable to have major changes on the urban environment. Old docks transformed into residential buildings, commercial areas, governmental buildings and the City Airport.

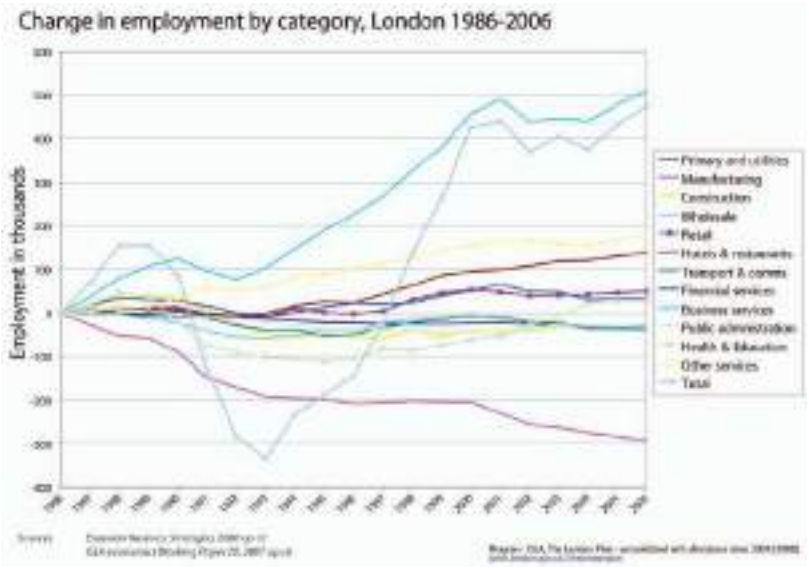

Figure 3. Change in employment by category

Source: GLA, 2007, cited in the London Plan, 2008, p.29

5.1 Changing flood hazard risk concept

Although flood hazard probability is changing due to climate change and sea level rise, the main reason of increasing flood risk in London is the *post-defence development* (Parker 1995, p.341) and increased ownership of goods and property in the floodplain (Parker et al. 1897; Green and Penning-Rowsell, 1989, cited in Parker 1995, p. 342). Consequently, the post-defence development after the construction of the Thames Barrier in the 80s, such as increasing number of population, buildings, companies and firms, and extended infrastructure in the floodplain, led to increase exposure to hazards. This means that there are more people living in the floodplain. Moreover, more businesses has been established and more infrastructure has been constructed in the area. However, not only direct damages but also indirect damages have increased due to increasing number of businesses, infrastructure and demand on traffic in the area (Parker, 1995, p.342). Having a low probability hazard could affect the area tremendously and lead to high consequences in terms of human causality and economic lost. As London is the heart of the finance and business in the UK, the effect of the economic lost in the area could be also financial.

The photo in Figure 4 was taken at the Thames Barrier. A part of the barrier is seen on the left side of the photo. On the right, there are the areas, which were developed by the construction of the barrier. The photo clearly shows the changing urban geography of London by the construction of the barrier.

Figure 4. Thames Barrier and Canary Wharf, Source: Author, August 2011

5.2 Existing risk of flooding in London

Approximately 15% of all the properties in London are in the floodplain – that is just over half a million properties, and around one million people. Approximately, 70% of them are at risk of tidal flooding, 29% of them are at risk of fluvial flooding, and 1% of them is at risk of both of them (Source: Environment Agency). As the tides in the Thames Estuary raise 60cm every hundred year, the risk of flooding in London is

increasing. There are number of reasons defined by the Environment agency to explain this fact. These are:

- *"The weather becoming stormier*
- *The south eastern corner of the British Isles tilting downwards*
- *Sea level rise*
- *London settling into its clay bed*" (EA)

The worst scenario would be a high surge that occurs at the same time with "spring" tides, which occur twice a month. Surge tides occur when low pressure comes towards British Isles by increasing the sea and creating "hump" of water, which moves the low pressure. Dangerous conditions could occur if this low depression goes through Scotland into the North Sea. Besides, strong northerly winds could increase the severity of the situation (EA).

Consequently, a severe flooding could affect first the transportation system. Underground system would stop functioning in the central London and this would affect the whole city. Moreover, a severe event could cause damage to all (sub)systems, such as water, sewer systems, electricity, gas, telephone etc. One million people can be affected directly in case of a severe flooding event in the central London. Additionally, millions of people can be affected indirectly, due to not functioning businesses, factories, and supply and chain network. The financial cost could be tremendous. Environment agency stated that it could take months to get London functioning as in normal conditions again (EA).

5.3 Tools to response to flooding

There are two types of tools to respond to flooding in London: structural and non-structural. Structural tools are the walls and embankments along the Thames and the other rivers, and indeed, the Thames Barrier and the Barking Barrier. The non-structural tools are the Flood forecasting, warning and response systems, flood plain development, insurances and the emergency management system, which is highly developed and hierarchical.

5.4 Transportation system in London

According to the report of Tfl published in 2011, the demand for travel has increased 8% more in 2009/10 than in 2000/01, as a result of 7.1% population and 5.5% occupation increase. Moreover, mode of transportation in London has shifted from car to sustainable public transport, such as walking and cycling (*5% points at the trip level*), which makes about 1 million trips. Furthermore, bus kilometres have increased with 32% and unground kilometres with 9% more in 2009/10 than in 2000/01, because of development in the docklands and DLR (Tfl, 2011, p.1). Regarding to road traffic volumes (Table 1), there were 6% fewer vehicle kilometres in London in 2009 than in 2000. Volumes of road traffic in London decreased by 3% between 2008 and 2009, having reduced by 2% between 2007 and 2008 and by 1.4%

between 2000 and 2007 (Table 1). The main reason of the steady decrease between 2008 and 2009 was economic recession in 2008. Consequently, there was an increasing shift towards public transportation modes, especially within central and inner London (Tfl, 2011, pp.2-8).

Table 1. Index of London road traffic in central, Inner and Outer London: major and minor roads, all motor vehicles. Index: year 2000=100, Source: Tfl, 2011, p.52

Year	Central London	Inner London	Outer London	Greater London - major roads	Greater London - minor roads	Greater London - all roads	Great Britain
2000	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2001	101.7	101.2	99.8	100.7	99.5	100.3	101.6
2002	98.2	99.0	100.5	100.3	99.5	100.0	104.2
2003	90.0	98.3	101.3	100.3	99.4	100.0	105.0
2004	88.8	94.6	100.6	99.4	96.8	98.5	106.7
2005	87.0	94.3	98.4	96.0	98.2	96.8	106.9
2006	86.5	96.8	98.9	97.4	98.6	97.8	108.6
2007	86.2	95.4	100.6	99.2	97.7	98.6	109.8
2008	83.8	92.7	98.9	97.4	95.2	96.6	108.9
2009	81.2	89.7	96.0	95.1	91.2	93.7	107.9

Source: Tfl. Planning.

5.5 Transportation system prone to flooding

The map of transportation system merged with 1 in 1000-year flood hazard map prepared by the Environment Agency[2]. In the Figure 5, only the flood hazard maps of London Borough of Newham and London Borough of Tower Hamlet have been merged with that part of the transportation network. In this limited area 28 tube and DLR stations, 4 railway stations, an airport and two hospitals have the risk of flooding. Having flooded stations in the tube network could affect not only that part of the city, but also all the other connected tube networks. Merging the transportation network and flood hazard map indicate the areas which has to be given the priority, such as providing evacuation plans to the hospitals that are in the middle of the floodplain. Besides, this way of combining diverse maps could also help to improve tube network and see the vulnerable parts of the network and act accordingly.

[2] http://www.environment-agency.gov.uk/

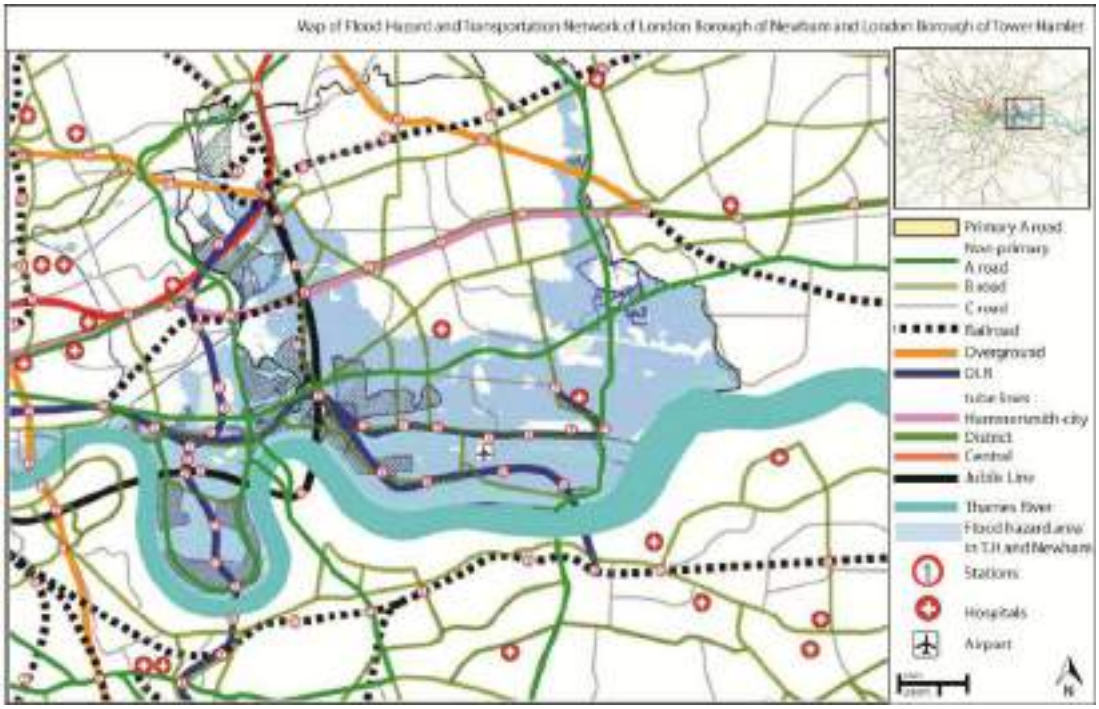

Figure 5. London borough of Newham and London Borough of Tower Hamlet: Map of flood hazard, transportation network and hospitals, Source: Author

5.6 Survey to public

Public survey carried out on the both sides of the Thames River in Lewisham and in Canary Wharf by aiming to have representative sample of people from different classes, ages, genders and backgrounds. In total carried out 61 valid questionnaires. Albeit the number of the questionnaires is not sufficient to represent the entire population in these two boroughs, the result of the questionnaires provided significant insights into the understanding of the present conditions in terms of perception and awareness of public on risk and existing information, and consequently social vulnerability. The questionnaire is made up of six parts. First there is the introduction part for understanding the respondents' profile and consists of 8 questions. The following five parts have 21 questions in total and these parts are:

- Part 1: Perception and awareness of risk condition
- Part 2: Awareness of the flood warning
- Part 3: Awareness of the access of information
- Part 4: Awareness of the information programmes
- Part 5: Population's individual preparation

During the questionnaire flood warning signs (Figure 6), which one can find in the environment agency's website, had been showed to the respondents and asked them whether they have seen them before or not. Correspondingly, 82% of the respondents said no and they do not know the meanings of the signs, and 18% answered yes. They have seen them mainly in the driving exam. Moreover, one person said that he

had seen it while driving on the county, and another one said that he had seen them abroad.

Figure 6. Flood warning signs (Source: Environment Agency)

Furthermore, the respondents had been asked whether they know what to do during an emergency, and if do they have a plan. The vast majority of the respondents (%87) said that they do not know what to do during an emergency. The other 13% said that they would call emergency line to learn what to do and to get some help. Besides, 59 respondents (97%) said that they have never informed about any evacuation plan by the authorities, 2 people (3%) said that they had informed by their workplaces (Figure 7).

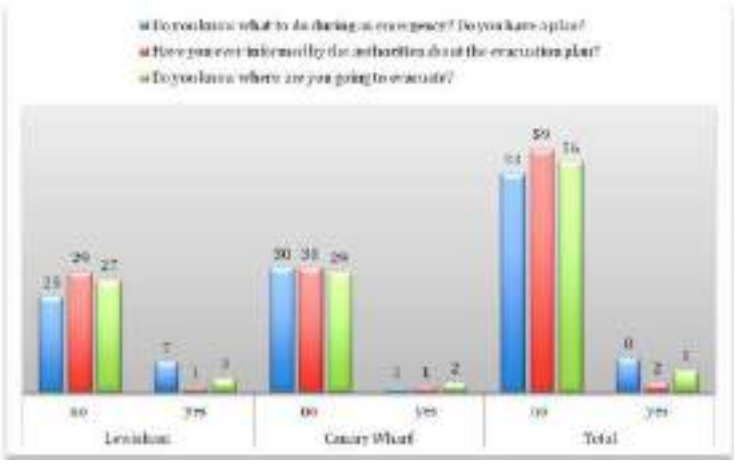

Figure 7. Preparedness to emergencies (Source: Author)

Another result of the survey is that people do not know where to go if they need to evacuate. The vast majority of responses (92%) were negative and they said that they do not know where to evacuate if they need to do so. Others who are in the 8% said that they would go to the Borough's main building to ask help, some of them said that they would go to other family members' homes that are living outside London. Regarding to the evacuation vehicle, the answers can be grouped into four: their own car, neighbour's/friend's car, public bus/train/boat, and a vehicle provided by the government. Mainly the respondents (46%) chose their own car for evacuation. Moreover, 29% said that they would use public bus/train/boat. This is followed by the vehicle provided by the government (15%) (Figure 8).

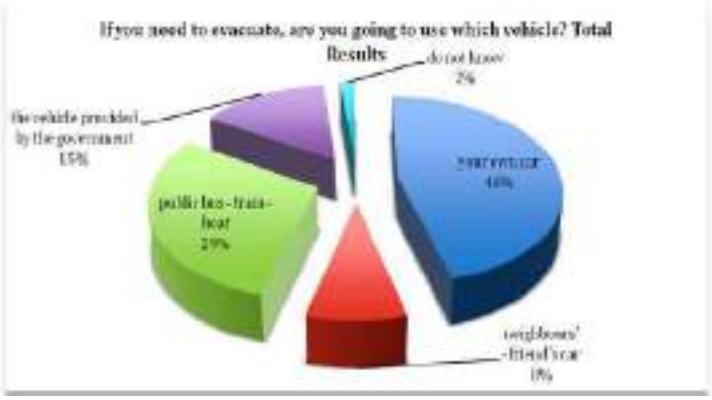

Figure 8. Modes of transportation for evacuation (Source: Author)

According to the insights coming from this survey, although there is information available online about emergency responses and flood warnings, it is not reasonable to expect all people know what to do during an emergency and follow those websites to gather information. Not sharing the information face to face with people especially make elder people more vulnerable, as most of them do not know how to use internet and most dramatically not able to read messages coming to their mobile phones. So, all possible reactions coming from public shall be considered in every phase of disaster management.

6. Istanbul

By the foundation of the Turkish Republic in 1923, during the 30s and the 40s, the city had been enlarged beyond the former districts to provide room for the growing population. The most rapid and recognizable population growth is seen in the 50s with a high migration rate from rural to urban. Today Istanbul is the primary city of Turkey by covering 5 512 km and by having 13% of Turkey's population (12 573 836) and 23% GDP of Turkey (IMM, 2008[3]). In 1945 the population of Istanbul was 1 078 000, due to the given dominant economic role to Istanbul this number had reached to 1 533 000 during the 50s. According to the census in 2000, the population of the city has reached more than 10 million and today it is 12 573 836 (SIS, 2008).

6.1 Changing vulnerabilities

Vulnerability is a dynamic concept that can be formed by policies and trends over time and across spatial scales (Menoni et al. 2012). The changes on the vulnerability due to dynamic structure of cities are seen clearly both in London and Istanbul megacities. Like London, Istanbul has also experienced the global trends in urban vulnerabilities, such as rapid population growth, rapid urbanization, major economic transformation, and increasing gap between socio-economic classes. Additionally,

[3] http://www.ibb.gov.tr/en-US/Pages/Home_Page.aspx

Istanbul has experienced also increased illegal housing supply starting by the 50s. After the 50s central government had left the regional policies and focused on the economic improvement of the Istanbul region. As a result, the city itself and the Marmara region had developed rapidly. Furthermore, by aiming to modernize the city, Henry Prost has prepared a plan for Istanbul between 1936 and 1950. By this plan, a part of the existing housing stock had demolished by aiming to open new roads, and industrial facilities located in the centre of the city.

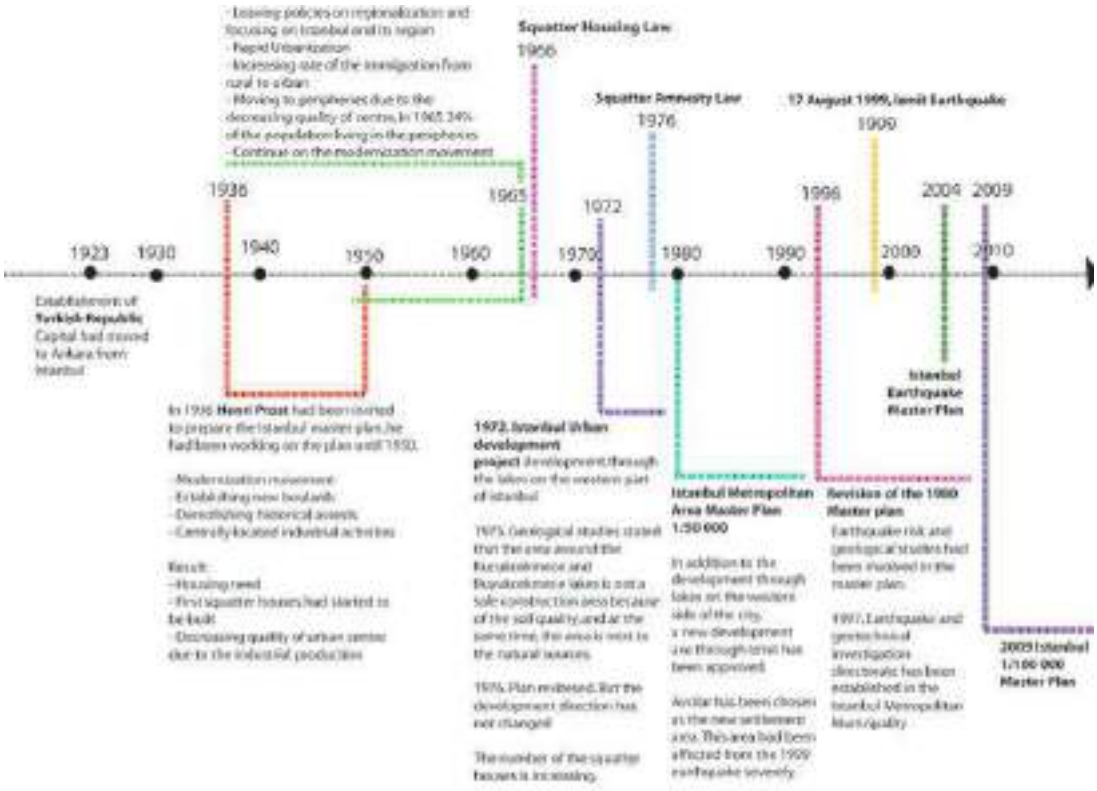

Figure 9. Retrospective view of changing vulnerability of Istanbul (Sources: Compiled from data in Tekeli, 1994; Keskinok, 2001; Şengezer, 1993; Türksoy, 1993; Görgülü et al. 1993; Angel, 1993; Gencer, 2007; Gedikli, 2001)

By the 50s, the city started attracting population from the entire country. Existing residents of Istanbul moved to the peripheries of the city, as the housing stock in the city centre were deteriorated. Moreover, new immigrated population 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 on risky zones, because central and local governments were unable to fulfil the residential needs of large number of immigrants. By the 80s, by the new regionalization policies, industry started to move to Kocaeli and Adapazarı in the eastern part and to Küçükçekmece in the western part of the region, which are the areas prone to earthquake hazard more than the other parts of the city. As a result of these trends, the city become more vulnerable to hazards, because of the low quality dwellings, increased density and the industrial production in between residential areas. To have more detailed information on retrospective view of changing vulnerabilities please see Figure 9.

6.2 Changing hazard concept

Before the 1999 Marmara Earthquake, Istanbul was accepted as the second priority earthquake hazard zone. After the event it has became the first priority earthquake zone, because now it is expected another major event with the probability of 62% within the next 30 years in the Marmara Region, as a result of the tension created by this earthquake on the fault line (Figure 10).

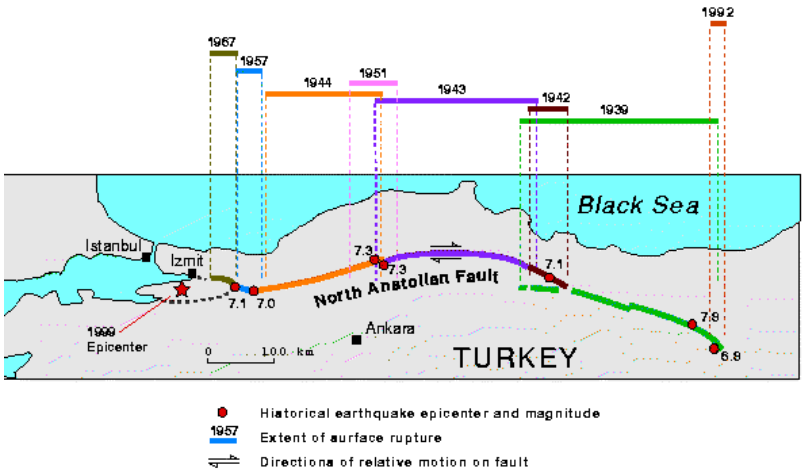

Figure 10. Historic progression of earthquakes on North Anatolian Fault line, Source: http://neic.usgs.gov/neis/eq_depot/1999/eq_990817/T990817000138.html

6.3 Existing risk of earthquake

In the IMM and JICA research (JICA and IBB, 2002), four earthquake scenarios were prepared, and they were compared to estimate the damage due to their distribution of peak ground acceleration (PGA), the damage distribution pattern and damage amount.

Building damage

Building hazard estimation was calculated for every type of the building included in the building census year 2000 by the JICA and IMM team (JICA and IBB, 2002). Building damaged is examined into three main topics; heavily, moderately, partly and four models (A, B, C and D) had prepared. According to model A, the total number of the damaged buildings is 252.000, which makes 35% of the total building stock. In addition, 1.116.000 households would be affected by the event. In the model C, the damage distribution is almost the same as that of model A. The total number of the damaged buildings is 300.000, 38% of the building stock and affected number of households is 1.300.000. In the models, southern west coast of the Istanbul is the most affected area due to the location of the epicentre. The less affected areas are located along the Bosporus and northern part of the Istanbul.

Human casualties

Human casualties are defined considering with collapsed buildings and have been done according to the night-time. These scenarios just give a framework to understand the growth of the event. Model A is estimated 73.000 deaths and 120.000 severely injured. According to model C the number of deaths is 87.000 and the number of severely injured is 135.000. In both of the models islands have the biggest ratio of death, which is 8.4% according to model A and 9.3%.according to model C.

6.4 Earthquake risk and transportation system

To have better understanding on the existing situation Figure 11 is prepared by combining 4 different maps: the map of existing road network, vulnerable buildings, vulnerable infrastructure and medical capacity. When these maps merged in one map, south-western part is indicated as the most vulnerable part of the city, because of having narrow roads, the vulnerable and aged infrastructure, and vulnerable housing supply.

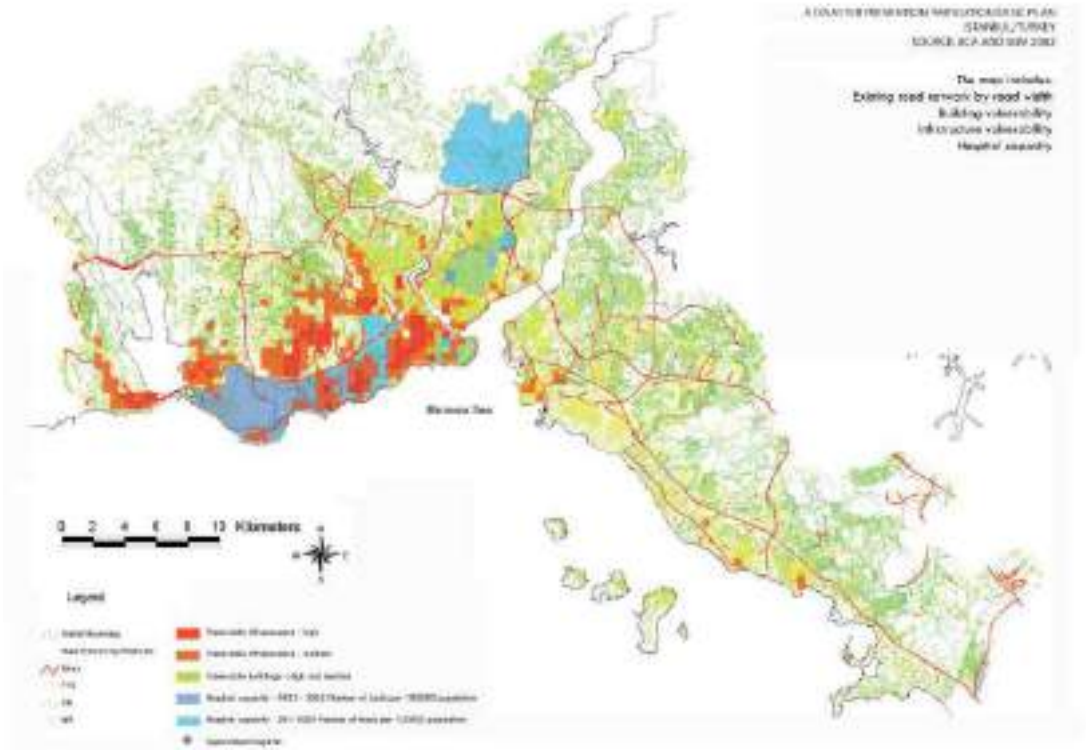

Figure 11. Vulnerability of infrastructure, buildings and medical facilities, (Produced by the author by combining the maps in the JICA and IBB, 2002 report)

As the main hospitals are located in this part of the city, it would be needed to reach that part from the other parts. However, due to vulnerability of the infrastructure and artefacts, it could be difficult to reach there during an emergency. Moreover, medical supply in the other part of the city would not be sufficient for the entire city.

7. “What if Scenario” – Evacuation

A “What if Scenario” can be defined as a simulation which aims to investigate the possible behaviour of a complex system (Golfarelli and Rizzi, 2008, p.1). Experiences, such as 2005 Katrina and Rita Hurricanes and most recently 2011 Tohoku earthquake and Tsunami, show that there are domains of people acting differently especially during evacuation phases. The unforeseen behaviour of people affects the emergency procedure negatively. In the first part of this paper, not being able to forecast human behaviour was indicated as one of the problems. Preparing a “what if scenario” provides a simplified representation to understand the way that people react and their effect on the transportation system. An evacuation starts by giving the decision of evacuation and ends when all these people turned back to their families and homes. In the scenario (Figure 12), it is expected that not all the people follow the evacuation order properly, the reasons and possible human reactions schematized by asking some questions whether they have received the evacuation warning, and whether they follow the rules etc.

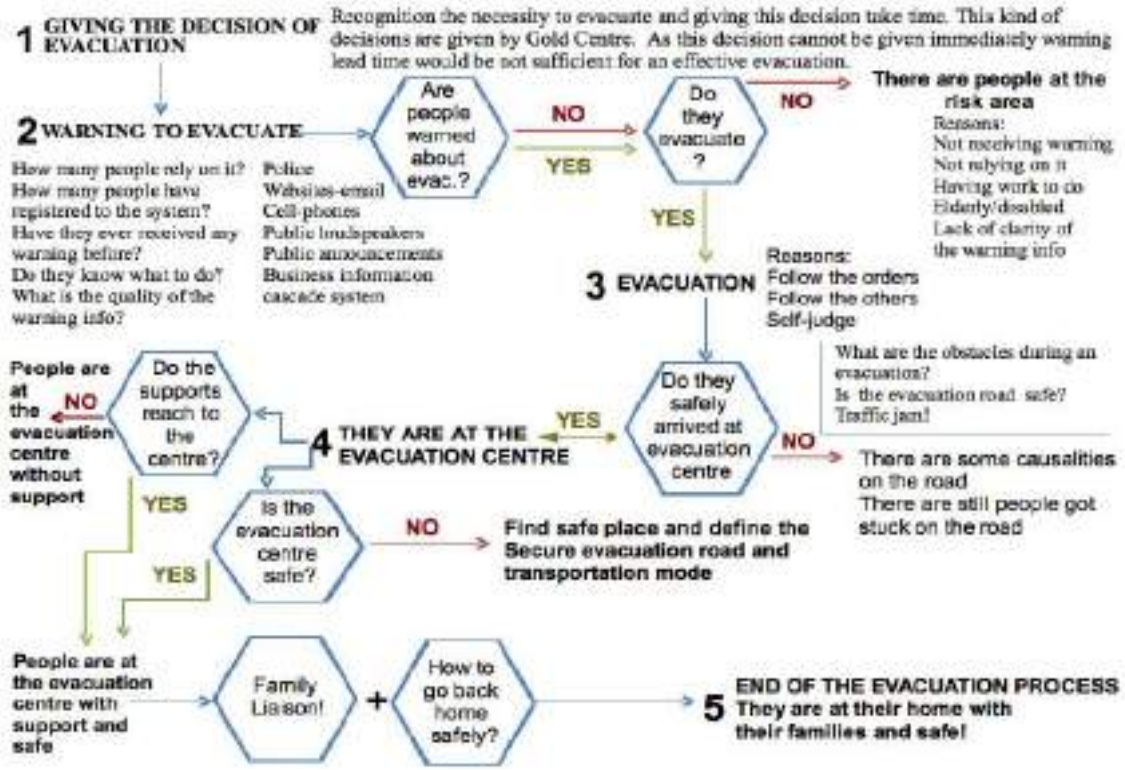

Figure 12. A scenario for evacuation, Source: Author

8. Conclusion

In the beginning of the paper two problems have been identified, the first problem was not considering the entire city while providing policies or tools for solving the existing problem. For this reason, both for London and Istanbul different maps have merged to identify the most vulnerable part of the city in case of a disaster. The

second problem was being unable to forecast the human behaviour. To have more simplified picture on this issue, a survey has been conducted in London to gather some insights and several real cases (such as Rita and Katrina Hurricanes in 2005, Northridge Earthquake in 1994 and Tohoku Earthquake and Tsunami in 2011) have studied to achieve a scenario on evacuation and possible behavioural domains of people.

The methodology to solve the problems in transportation system in case of a disaster should consider hidden connections between elements of the city. The relation between vulnerable buildings and vulnerable parts of the roads has to be studied before concentrating on a single part of the transportation system. The fact that reaction of people could contribute into the resilience of a structural system either negatively or positively should also be considered in all kind of emergency plan. Moreover, having information on hazard and emergencies in the online platform does not mean that people know about the existence of this information, or even if they know that it exists, they might be not interested in acquiring this information. There is a need to have face-to-face interaction with public to provide them the information on hazard and emergency. On the other hand, if decision makers, or governmental authorities, have the simplified and completed picture of the situation in case of a disaster, it can be more effective for them to use the expert knowledge and implement it. The reaction of a complex city system to a disaster depends on the initial conditions. The initial condition includes both vulnerabilities and strengths of a city. Having small changes in the initial conditions would affect the results tremendously.

Acknowledgements The author acknowledges and thanks with gratitude to the members of the Flood Hazard Research Centre at Middlesex University for their excellent help and support during the author's research period in London. Moreover, the author is grateful to Prof. Scira Menoni for her support in all the time of the research.

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.

Chang, S.E. and Nojima, N., 2001. Disasters and transport system Performance: the Kobe 1995 earthquake in comparative perspective. Transportation Research Part A: Policy and Practice, 35(6), pp. 475-494.
EA, Environment Agency, the booklet of the Thames Barrier and associated tidal defences.

Gedikli, B., 2001. Adapazarı'nda, Doğu Marmara depreminin sonuçlarının kentleşme ve planlama süreçleri çerçevesinde değerlendirilmesi. Journal of the Chamber of City Planners Union of Chambers of Turkish Engineers and Architects (TMMOB),

2001/3, pp.54-64.

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.

GLA, Greater London Authority, 2007. Employment projections for London by sector and borough. GLAEconomics, Working Paper 20. [online] Available at: http://www.london.gov.uk/mayor/economic_unit/docs/wp_20_employment.pdf

Golfarelli, M. and Rizzi, S., 2008. UML-Based modelling for what-if analysis. DaWak 2008, LNCS 5182, pp.1-12.

Görgülü, Z., Görgülü, T. and Ramazanoğulları, S., 1993. Bir dünya kenti olarak İstanbul'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.

Green, C.H. and Penning Rowsell, E.C., 1989. Flooding and the quantification of "intangibles." Journal of the Institution of Water and Environmental Management 3(1), pp.27-30.

IMM, Istanbul Metropolitan Municipality, 2008 [online]
http://www.ibb.gov.tr/en-US/Pages/Home_Page.aspx

Japon Uluslar arası İşbirliği Ajansı (JICA) ve İstanbul Büyükşehir Belediyesi (İBB), 2002. Türkiye Cumhuriyeti, İstanbul İli Sismik Mikro-Bölgeleme Dahil Afet Önleme/Azaltma Temel Planı Çalışması, İstanbul.

Keskinok, C., 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. and Tapsell, S., 2012. Assessing multifaceted vulnerability and resilience in order to design risk-mitigation strategies." Nat. Hazards, published online 21 March 2012.

Nojima, N., 1997. Performance based prioritization in upgrading seismic reliability of road network. Proceedings of the 24th JSCE Earthquake engineering symposium

Parker, D.J., 1995 Floodplain development policy in England and Whales. Applied Geography, 15(4), pp. 341-363.

Parker, D.J., Green, C.H. and Thompson, P.M., 1987. Urban floods protection benefits: a project appraisal guide. Aldershot: Gower.

Paton, D. and Johnston, D., 2006. Disaster Resilience. An integrated approach.

Springfield, Illionis, USA: Charles C Thomas Publisher.

Rojahn, C., Mayes, R.L. and Nutt, R.V., 1997. Recommendations for improved AASHTO Bridge design specifications. NCEER Bulletin 11(3), pp.1-5

Şengezer, B.S., 1993. İstanbul metropolünde deprem tehlikesi ve bir deprem senaryosu. Journal of the Chamber of City Planners Union of Chambers of Turkish Engineers and Architects (TMMOB), 1993/1-4, pp.30-37.

Shinozuka, M., Moore, J., Gordon, P., Richardson, H.W., Chang, S. and Cho, S.-B., 1998. An integrated model of highway networks and the spatial metropolitan economy: towards a general model of how earthquake losses affect the economy. NCEER Bulletin 12 (1), pp.8-15.

SIS, State Institute of Statistics in Turkey: The census of Population, 2002, 2007, 2008.

Tekeli, İ., 1994. The Development of the Istanbul metropolitan area: Urban administration and planning. Istanbul: IULA-EMME and YTU.

Tfl, Transport for London, 2011. Annual Report and Statement of Accounts 2010/2011. [online] Available at: http://www.tfl.gov.uk/assets/downloads/corporate/tfl-annual-report-2010-11-final-interactive.pdf

The Global Financial Centre Index, March 2009. [online] Available at: http://www.romandie.com/news/pdf/PDF_Classement_GFCI_des_places_financis__ZH_5_GE_6_ROM_200320120403.pdf

The London Plan, 2008. The London Plan: Spatial Development Strategy for Greater London. [online] Available at: http://www.london.gov.uk/thelondonplan/docs/londonplan08.pdf

Türksoy, C., 1993. İstanbul için bir planlama ve yönetim örgütlenmesi. Journal of the Chamber of City Planners Union of Chambers of Turkish Engineers and Architects (TMMOB), 1993/1-4, pp.10-11.

Werner, S.D., Dickenson, S.E. and Taylor, C.E., 1997. Seismic risk reduction at ports: Case studies and acceptable risk evaluations. Journal of Waterway Port Coastal and Ocean Engineering, 123(6), pp.337-346.