Hospital Accessibility of Istanbul Following an Earthquake

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ABSTRACT

Geographic Information System (GIS) takes major part on decision-making processes for disaster management cycle. One of the usage areas of GIS in disaster management is to create hazard scenarios and simulate the risk through the related analysis algorithms. Istanbul is one of the major earthquake prone cities of the earth and experts are expecting an earthquake with a magnitude of more than 7.0 occurring in the following 30 years with a probability between 29 and 66 % (Parsons, 2004). Managing the transportation systems with GIS is a widely used method during the normal days; however, GIS can also be used to manage the disasters and the effects of the disasters on transportation systems. Transportation networks gain importance for the accessibility to the collapsed area and for the evacuation of the dead and injured people to the emergency facilities following an earthquake. Previous experiences demonstrate that roads are vulnerable to earthquake, so efficient emergency plans and risk mitigation strategies were developed in order to decrease the impact of disasters on buildings, bridges and networks (Basöz and Kiremidjian 1996, Chang, Shinozuka et al. 2000, Werner, Taylor et al. 2000). To take substantial precautions before the earthquake and to manage the disaster in a suitable way, analyses not only for structural damage but also for the accessibility of the road network is required. In this context, this study focused on the road blockages of the Istanbul due to the bridge damages to evaluate the accessibility to hospitals. In this study, accessibility of hospitals following the expected earthquake based on the damage possibilities of bridges are determined by using HAZTURK software (Karaman et al., 2008). The analyses of this study were performed following the phases of emergency management so that the study could be beneficial to emergency managers and transportation planners to develop essential strategies and policies before, during and after an earthquake. The road network data, bridge data and hospital location data were used for the study to determine the accessibility and the blockage results. Debris of collapsed bridges leads to road blockages and reduce the road functionality after an earthquake. Therefore, emergency and rescue service cannot reach that area. In this context, firstly the bridges with the high collapse probabilities were determined by using HAZTURK software and the intersected road network data were determine to highlight the road blockages on the roads to the hospitals. This study is one of the first studies on the road blockage estimation on the accessibility to the hospitals based on bridge damage analyses for Istanbul following an earthquake. The previous road blockage study was performed on 2009 by taking into account the building debris areas as a buffer analysis on each building.

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1. INTRODUCTION

Transportation networks gain importance to reach the collapsed area and providing various facilities for causalities following an earthquake. Past experiences indicate that transportation networks are vulnerable to earthquakes and failure of their components may lead to disruption of activities and may affect the rescue and evacuation procedures in the area. (Basöz and Kiremidjian 1996, Werner, Taylor et al. 2000, K. Ertugay et al. 2016) In this context, road blockages should be determined due to accessibility of emergency facilities, including medical services, fire and police stations and shelter sites.

A number of researchers studied the transportation networks in the case of disasters. Karim and Yamazaki (2003) also developed the fragility curves for highway bridges with respect to adopting analytical approach, while this methods was used to generate fragility curves for Central and South-eastern United State bridges by Nielson (2005). Basöz and Kiremidjian (1996) have developed a risk assessment methodology that based on vulnerability for highway transportation system used against to earthquake hazard. Werner, Taylor et al. (2000) estimate how earthquake damage to highway systems can affect post-earthquake traffic flows and travel times.

Turkey is also prone to major earthquake damages and several studies are conducted mostly for the possible Istanbul earthquake. However, there are very few studies on the effect of the earthquake on the transportation system. One of them is done by JICA and IMM (2002) and the vulnerability of the bridges of Istanbul was analysed statistically based on Katayama methodology that is based on the one developed by Kubo and Katayama (1979).

Accessibility of medical services in the case of disasters was also performed (Kuwata and Takada 2004, Franchin, Lupoi et al. 2006) and these studies regarding health care accessibility conducted at not only developed countries and urban areas but also developing ones (Phillips Jr, Kinman et al. 2000, Rosero-Bixby 2004, Kalogirou and Foley 2006, Hare and Barcus 2007).

Emergency management is used within various studies, including mapping of the variable hazards and risks (Giardini, Gruenthal et al. 2003, Karaman and Erden 2014), measuring the vulnerability of injured populations following hurricane evacuation (Bian and Wilmot 2017), influence of road network and population demand assumptions in evacuation model (Henry, Wood et al. 2017) and so on.

In this study, road network data, bridges having the possibility of mean damage more than 50% data and hospital location data were used in order to determine the accessibility and the blockage results. Debris of collapsed bridges leads to road blockages and reduce the road functionality after an earthquake. Therefore, emergency and rescue service cannot reach that area. In this context, debris of the collapsed bridges and its impact on road functionality for the accessibility to hospital after a possible earthquake occurs was conducted.

The main objective of this study is to analyse earthquake effects on road functionality within the emergency management phases framework. One of the main contribution of this study is

This study is one of the first studies on the road blockage estimation on the accessibility to the hospitals based on bridge damage analyses for Istanbul following an earthquake that provides background information regarding emergency management planning for decision makers and transportation planners.

2. METHOD

Geographical Information System (GIS) which helps to model, and analyse the network features through using spatial features that are substantial for the emergency management as well as HAZTURK (Elnashai et al. 2008) which is damage estimation software have been used as a tool in this study.

Within the context of this study, bridges having the possibility of mean damage more than 50% were identified and the road network was digitalized in the case of assigned distance of debris around those structures. Therefore, buffer analysis was performed due to specifying the average debris spreading distance around the buildings and bridges. As a result of the buffer analysis, road blockages and the functionality of roads after a disaster can be determined. The spatial analysis of shortest distance analysis was also performed in order to find the closest road from collapsed structures to medical services.

3. DATA COLLECTION AND STUDY AREA

Istanbul having population over 14 million located both in Asian and European continents and connected with 3 different bridges. Population density of Istanbul is illustrated in Figure 1. Istanbul has been under earthquake threat is known for many years. Istanbul and the surrounding areas have been affected destructive earthquakes in the historical period (Ambraseys and Finkel 1991). Numerous researchers studied that the possible consequences of a devastating earthquake effecting Istanbul within the near future. (Ambraseys and Finkel 1991; Le Pichon et al. 2001)

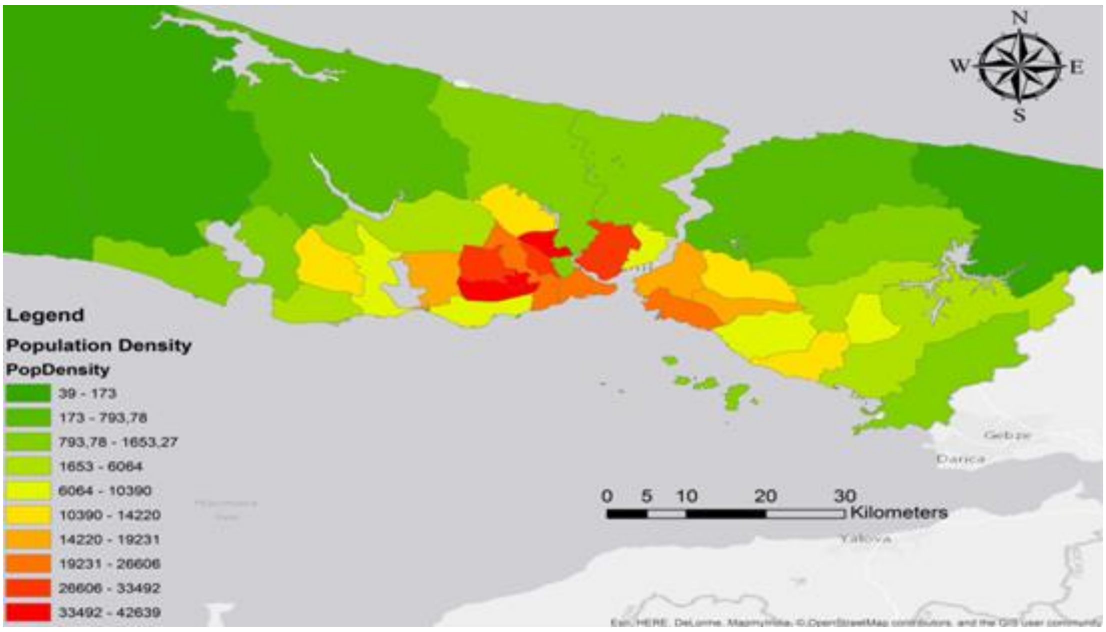

Figure 1. Population density of Istanbul

There are 293 bridges having complete, extensive, slight and no damage possibility in Istanbul. As shown in Figure 2, bridges having expected damage effects are demonstrated below. The bridge damage analysis was conducted with respect PGA demands by using HAZTURK software (Elnashai et al. 2008).

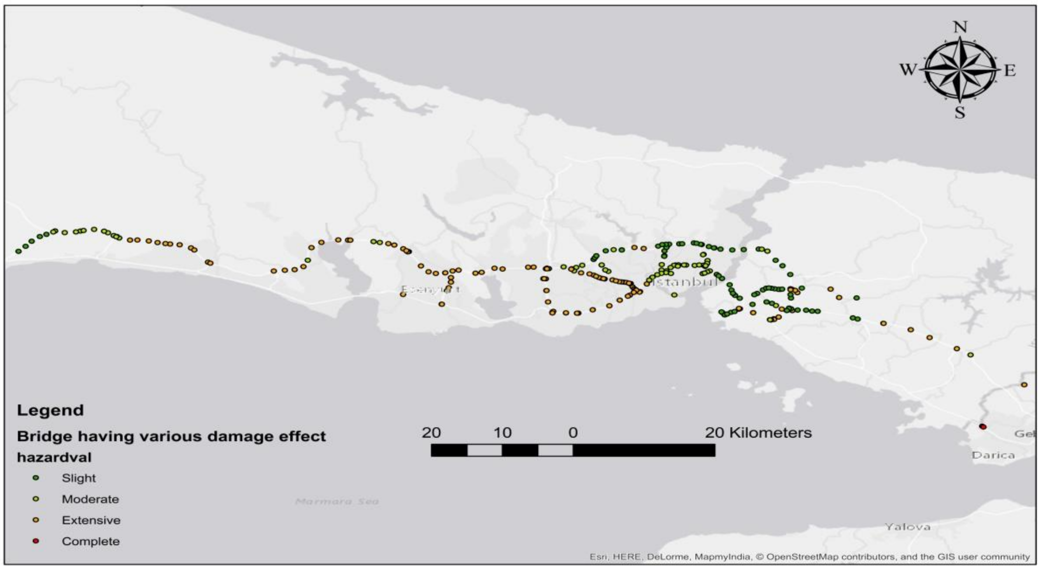

Figure 2. Bridges Having Damage Possibility Intervals

Medical service management that provides an essential facility following a disaster is one of the main parts of disaster management. Evacuated people transferred to the nearest medical facilities as well as the injured persons should be transferred to the correct medical facility based on his or her injury. The medical facilities in Istanbul are classified based on their types and specializations as given in Table 1.

Table 1. Number of Medical Services Classifications

Types of Medical Services	**Number of Services**
Mother and Child Care and Family Planning Center	38
Family Planning Center	2
Military Hospital	4
Dispensary	44
Dialysis Center	14
Hospital	58
Red Crescent	19
Private Hospital	160
Polyclinic	157
Health Center	99
Community Clinic	526
District Polyclinic	44
University Hospital	8
TOTAL	**1173**

Generally, the structural situations of the medical facilities were assessed following an earthquake. However, it is also important to assess the accessibility to the medical services both for response and recovery phases. This assessment takes into account the locations of the medical facilities, damaged assets and the connection between them as the road network. There are 1173 hospitals in Istanbul that shown in Figure 3;

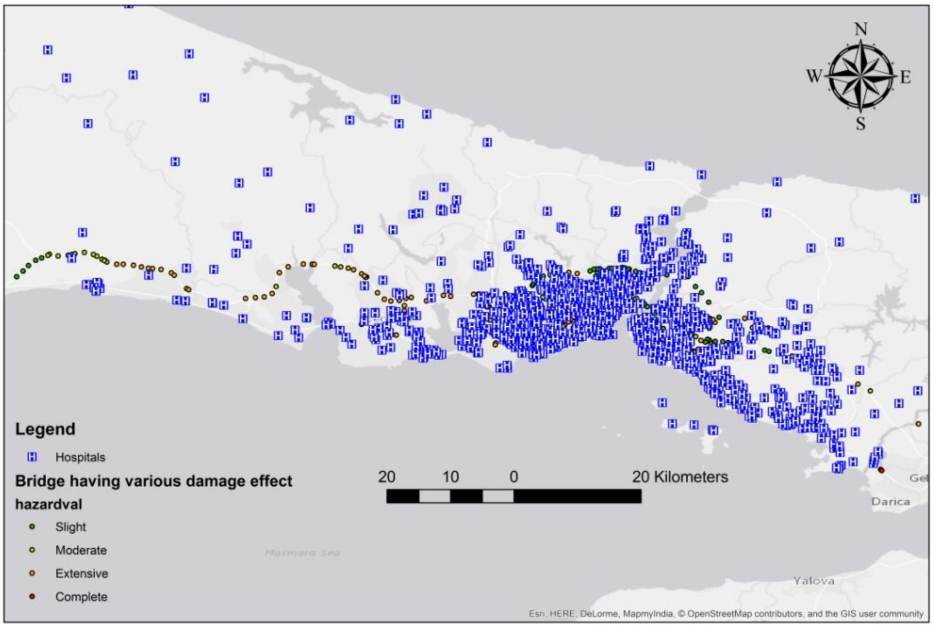

Figure 3. Medical Service Location in Istanbul

4. ROAD BLOCKAGE ESTIMATION ON THE ACCESSIBILITY TO THE HOSPITALS

Hazard map is generated through historical data emergency case due to possible disasters. Inventory, including people, nature, road and so on as well as bridges having the complete and heavy damage possibility are determined and classified in order to identify the effect of possible hazards. Based on the official reports after the 1999 Kocaeli earthquake (ERC 2000) the number of injured people in Kocaeli and Sakarya urban areas was 14297 while the population at that time in the city of Kocaeli and Sakarya was 960764 people. This shows us the ratio of injured people to the total population is 1.5%. If we extrapolate the statistics to todays Istanbul population based on the percentages and the last known official population of Istanbul as 14377018 people (TUIK 2014), the approximate number for injured people could be 215655, while the total number of bed capacity of hospitals in Istanbul is 21380 and 232 operation room number. This will show the importance of the medical services in Istanbul following an earthquake. Hazard is explained as an input ground motion parameter or a spectral response value (Karaman et al. 2008). In this research, Hazard map is simulated for Istanbul PGA demands with the help of using Boore and Atkinson (2008) ground motion estimation equation as indicated in Figure 4.

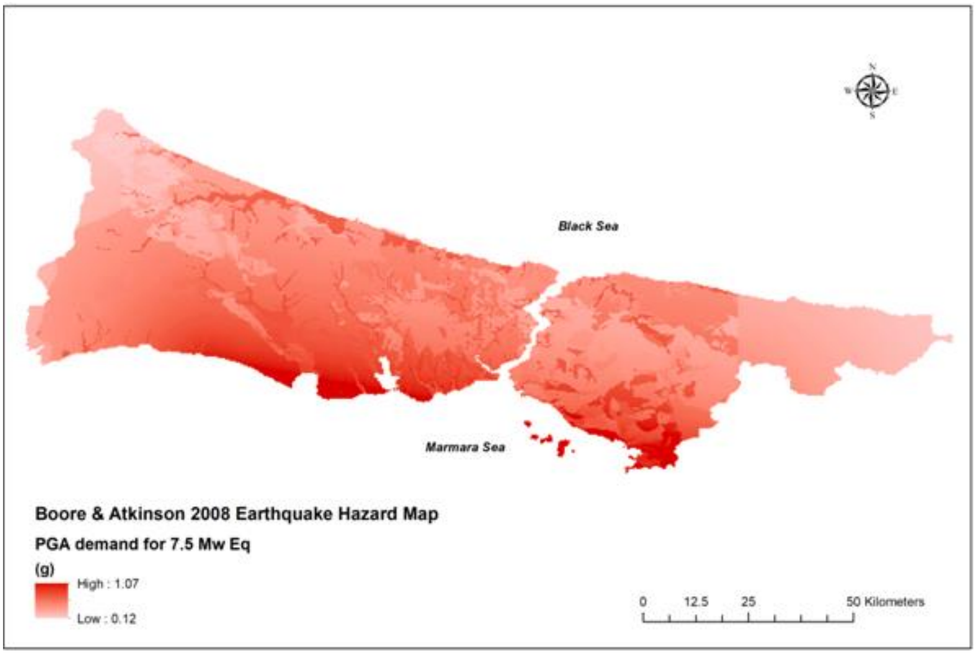

Figure 4. Hazard Map for Istanbul Earthquake for PGA demands (Boore & Atkinson, 2008)

Vulnerability function is defined by means of integration of hazard map and types of inventory in Geographical Information System (GIS). The primary benefits of GIS in this phase line in spatial information integration and dissemination (Cova 1999). Fragility curves and capacity curves are constituted the function of vulnerability. They describe the probability that a structure will reach or exceed a certain damage state for a given ground motion. An overview of existing fragility models for bridges, is made by Tsionis and Fardis (2014) while Argyroudis and Kaynia (2014) summarize existing fragility curves for different types of road segments.

HAZTURK uses the fragility curves of Nielson and DesRoches (2007a) and Nielson and DesRoches (2007b) and DesRoches et.al. (2003) to estimate the bridge damage, based on the peak ground acceleration demand typed earthquake hazard maps as shown in Figure 5.

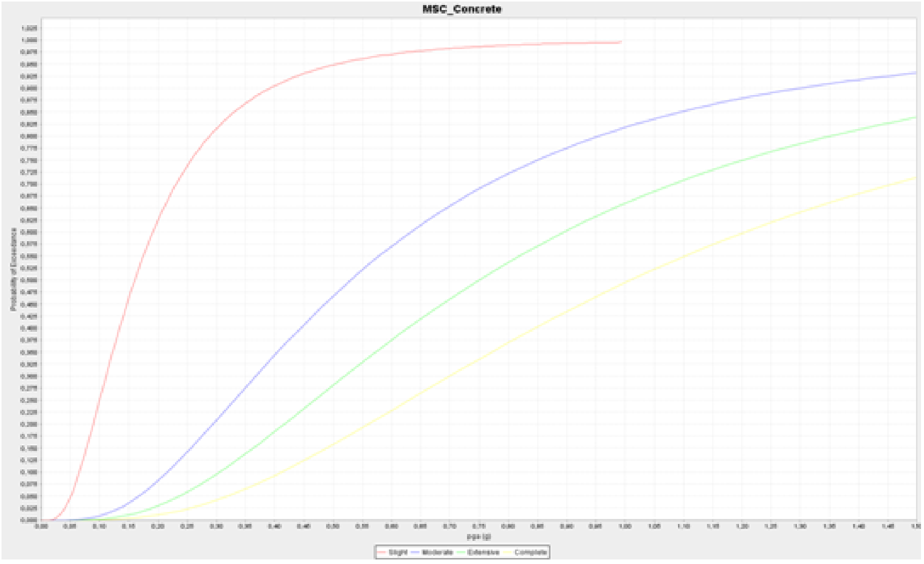

Figure 5. Fragility curves for the types of MSC_Concrete bridges

Debris of collapsed bridges leads to road blockages and reduce the road functionality after earthquake, so emergency and rescue service cannot reach that area. In this context, collapsed bridges debris distance need to be determined due to finding possible and closest roads to medical services.

The study was performed in Gölcük and found to be the average distance of the debris of the collapsed buildings was 17.45 m as a result of statistical process (Konukcu, 2016). In this study, buffer analysis was performed with the help of applying those values to Istanbul bridges having the effects of complete and extensive damage after an earthquake. As illustrated in Figure 6, from the centers of bridges, 17.45 m buffer zone was formed.

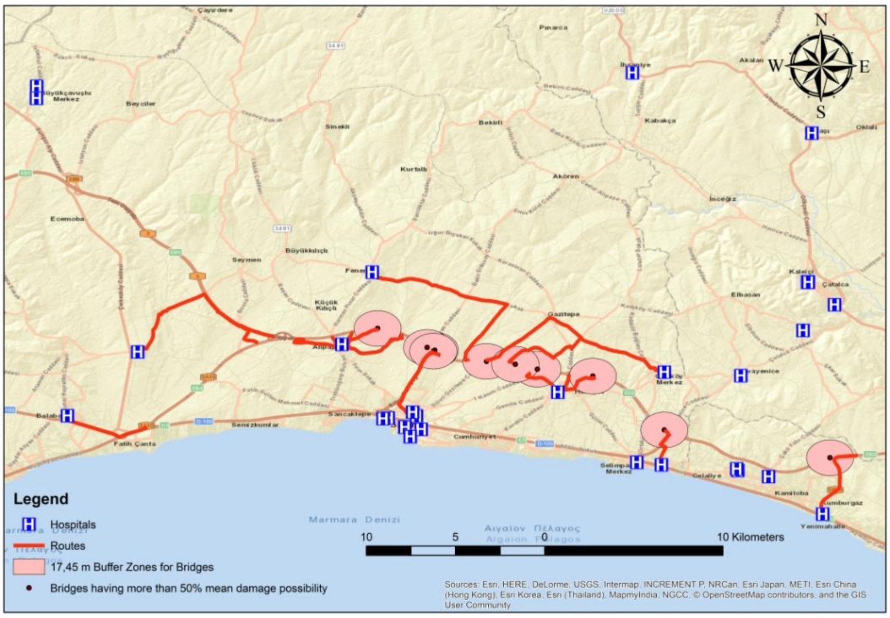

Figure 6. Buffer zones having the value of 17.45 m for bridges

As a result of this analysis, road blockages were identified after earthquake and the analysis including reaching emergency service as fast as possible can be performed. In order to access the facilities by means of using the closest roads, collapsed bridges were identified in this research. The length of road in Istanbul is 30325,21 kilometers and as a result of the road blockage analysis, approximately 13,65 km of the roads would decrease in functionality after an earthquake occurs. Possible road blockage place following an earthquake in Istanbul is illustrated figure below; (Figure 7)

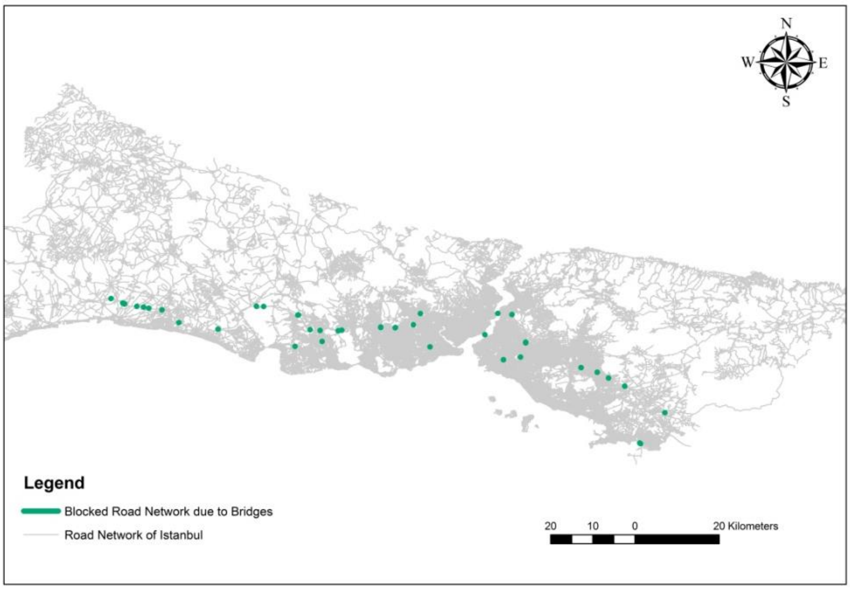

Figure 7. Representation of Possible Road Blockages in Istanbul

Figure 8 represents the distribution of population and buildings and substructures having expected complete damage possibilities in Istanbul. People would be affected by the road blockages during response. It is estimated that the road blockages due to debris of both buildings and bridges would affect approximately 2 million people around non-functional roads.

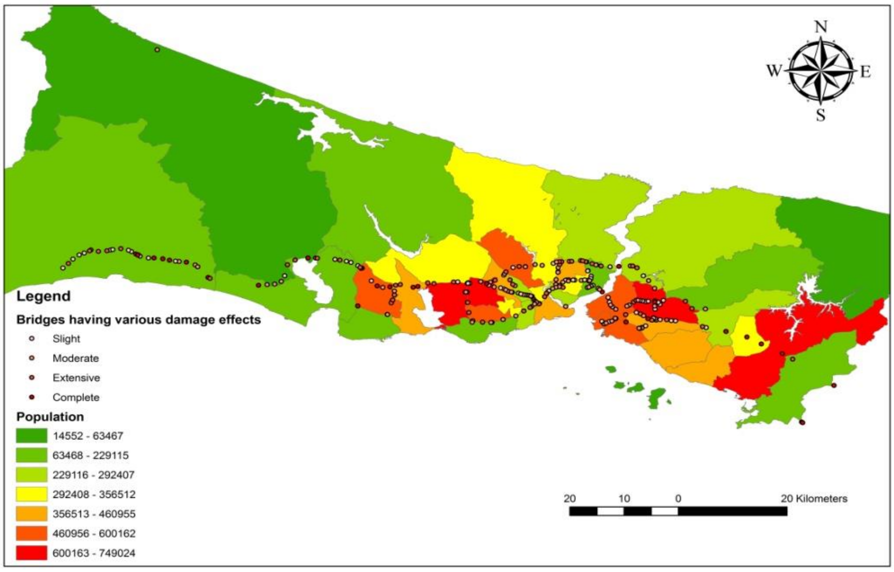

Figure 8. Distribution of Population and Bridges Having Expected Various Damage Possibilities

5. CONCLUSION

This study investigates the road blockages in Istanbul following a possible earthquake. Within the context of the study, average spreading distance of debris of collapsed bridges having various damage possibilities as well as the possible closest distances from those structures to medical services were analysed after possible Istanbul earthquake. Collapsed bridges decrease the road functionality, so the emergency facilities could not reach that area and the effects of hazards of earthquake could increase due to late response.

In this regard, numerous precautions must be taken by government and individuals to avoid the hazards of earthquake. The results presented in this paper can be used as an input for decision-making processes for the emergency management phases of the city of Istanbul. People should be educated about how to reach the assembly areas where individuals gather after evacuating following an earthquake.

The analyses of the study could be useful for decision makers and emergency managers to analyse the road blockage estimation on the accessibility to the hospitals after possible Istanbul earthquake in order to take strategic precautions against the disaster hazards during preparedness and mitigation phases. The outcomes of this study would be possible to extrapolate to other analyses for different disasters.

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