HUMANITARIAN LOGISTICS: PRE-POSITIONING OF RELIEF ITEMS IN ISTANBUL

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ABSTRACT

HUMANITARIAN LOGISTICS: PRE-POSITIONING OF RELIEF ITEMS IN ISTANBUL

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The main objective of this thesis is to study pre-positioning of relief items while considering the transportation vulnerability effect of a potential earthquake in Istanbul and suggest disaster response facility locations accordingly, utilizing the data and information about Istanbul from the JICA Report. The models developed contain 29 demand points and 29 potential disaster response facility locations and they are compared with each other with respect to several aspects such as demand and vulnerability. A final model is chosen among them and the results obtained from that model are investigated deeply. This final model includes the effects of combined transportation mean vulnerability, warehouse building vulnerability, demand intensity and distance travelled on warehouse location decision. A sensivity analysis on the number of warehouses, earthquakes impacts, demand behavior and objective function type is also provided.

Keywords: Multi-item Warehouse Location Problem; Pre-positioning Relief Items; Istanbul Earthquake; Vulnerability.

ÖZ

İNSANİ YARDIM LOJİSTİĞİ: ISTANBUL'DA İNSANİ YARDIM MALZEMELERİNİ ÖNCEDEN KONUMLANDIRMA

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Bu çalışmanın amacı, Istanbul'da gerçekleşmesi beklenen olası bir deprem için depremin neden olacağı kırılganlık etkisini de inceleyerek insani yardım unsurlarının önceden konumlandırılmasını araştırmak ve bu doğrultuda afet müdahale ve yardım merkezi konumları önermektir. Istanbul için hazırlanmış JICA raporunda yer alan bilgi ve veriler ışığında çeşitli modeller geliştirilmiştir. Bu modellerde 29 talep noktası ve 29 potansiyel afet müdahale ve yardım merkezi bulunmaktadır. Ayrıca geliştirilen modeller kırılganlık, depolanacak insani yardım unsurlarının sayısı gibi çeşitli açılardan birbirleriyle karşılaştırılmış ve çalışmanın sonunda, nihai bir model seçilerek sonuçları derinlemesine analiz edilmiştir. Bu model, ulaşım ağı kırılganlığı, depo kırılganlığı, talep ve mesafe unsurlarının müşterek etkilerini de göz önünde bulundurmaktadır. Son kısımda, afet müdahale ve yardım merkezi sayısı, deprem modelleri, talep davranışı ve hedef fonksiyonu göz önünde bulundurularak duyarlık analizi yapılmıştır.

Anahtar Kelimeler: Çok Ürünlü Depo Konumu Belirleme Problemi; İnsani Yardım Unsurlarını Önceden Konumlandırma; Istanbul Depremi; Kırılganlık

To my family

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CHAPTER 1

MOTIVATION

Among all natural disasters, earthquakes are the most frequent disasters (61%) in Turkey [1]. Turkey is settled at the boundary where the Arabian Plate and the African Plate are moving towards the Eurasian Plate. This area contains the North Anatolian Fault (NAF), which extends from east to west in the north of Turkey. Many earthquakes generated by this fault line have hit Turkey in the past years.

The Izmit Earthquake hit the north-west of Turkey with the magnitude of 7.4 at August 17, 1999. It does not only affect Izmit but also the cities of Kocaeli, Sakarya, Yalova, Istanbul, Bursa and Bolu. More than 17,000 people died and more than 45,000 people injured, and around 100,000 buildings collapsed. Turkey was not ready for such a mega disaster and therefore the effect of the earthquake was much more than its magnitude according to many authorities [2].

According to "The Study on A Disaster Prevention / Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey" prepared by Japan International Cooperation Agency in 2002 (will be called as the JICA Report thereafter) [3], local hospitals were collapsed, governmental offices were damaged and responsible staffs were themselves also victims. Most importantly, during the initial days, the environment was chaotic since there was not enough number of trained personnel, relief items, equipments, and plans to help the earthquake victims. Thus, the relief activities were not organized at the initial days. Unfortunately, the first three days was the most crucial time period to help the injured people after the disaster strikes.

After the Izmit Earthquake, many researches on NAF started and many earthquake scenarios were identified. The location of NAF lying in Marmara Sea is very crucial since the probability of having an earthquake with magnitude 7.0 or more is highly possible due to that fault line. Moreover, since the part of NAF in Marmara Sea is very close to the most populated city of Turkey, Istanbul, preparation of a disaster mitigation plan becomes a necessity.

Istanbul is located in northwestern Turkey within the Marmara Region. It is also in the north of NAF lying in Marmara Sea (see **Figure 1. 1**). The city is divided into two sides by Bosporus. Two main bridges connect each side through the Marmara Sea. It has a population of 13 million according to the 2012 data and is the largest city of Turkey [4].

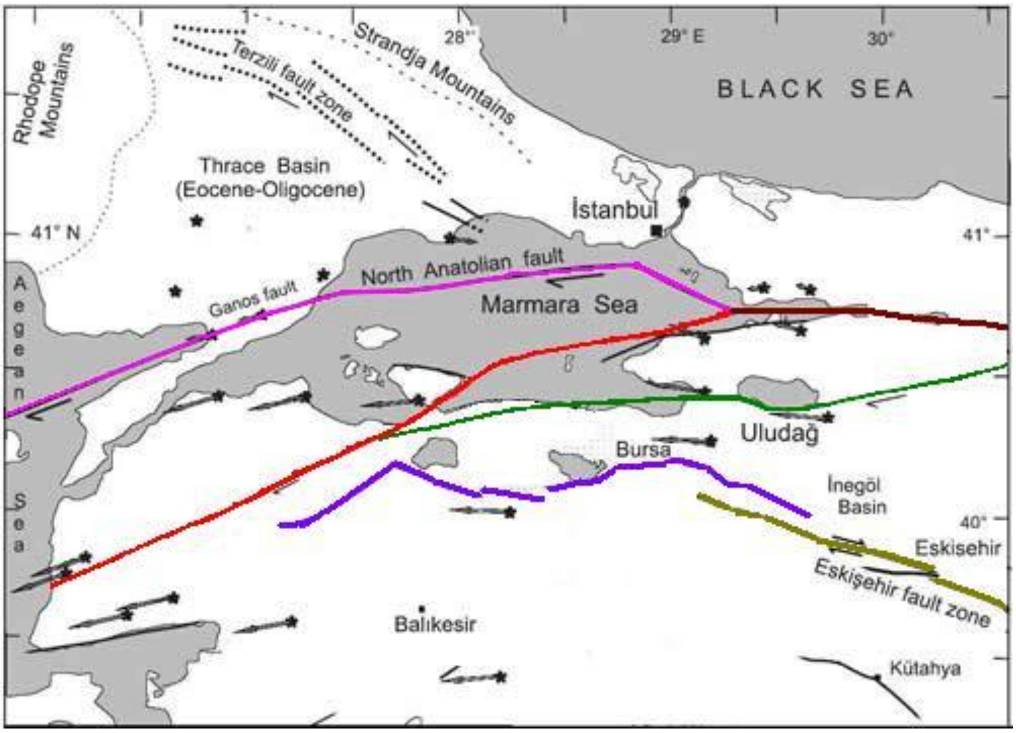


Figure 1. 1 Map of Istanbul and North Anatolian Fault

The JICA Report [3] is the most comprehensive study indicating the current status of Istanbul for a future earthquake. In order to prevent the possible damage, recommendations are provided in JICA Report [3]. Among them are the frameworks for emergency potable water and foods supply, tent villages for temporary housing and a recommended emergency road network. Although the report does not suggest a pre-positioning plan for relief items that will be needed by the affected people, it provides a good basis for data and information for preparation of such a plan. Hence, in our study we intend to have a suggestion about the pre-positioning network of Istanbul using the data given by JICA Report [3] to increase the performance of delivering relief items to earthquake victims.

In order to suggest a pre-positioning network for Istanbul, we build a five-warehouse network model such that all of the demand locations are also potential locations for warehouses. These potential warehouses will be used to supply necessary relief items according to disaster management. In our proposed model, not only the multiplication of demand and real distances is minimized but also the vulnerability is added to the objective function of the model. Thus, it is possible to consider the effect of the earthquake on the transportation means and buildings and find out how the damages on them affect the warehouse locations.

There are many studies pointing out the importance of transportation means in earthquake disaster management. For instance, Central U.S. Earthquake Consortium revised the Earthquake Vulnerability of Transportation Systems in the Central United States Report in 2000 [5] with technical support from MS Technology. In that report, it is declared that roadways suffering from the earthquakes and the bridges are the most affected components of the transportation network. They also reported that the damages in the transportation system caused from bridges and overpasses have major impacts for response sub-phase of disaster management. Hence, it can be stated that studying vulnerability of roads and bridges in our study will be beneficial for an earthquake response scenario for Istanbul.

To study the vulnerability, we need to add vulnerability terms into our model. In the literature there many studies evaluating the vulnerability of a transportation system for potential earthquake scenarios. Nojima and Sugito [6] suggest a method for evaluating the performance of highway transportation network systems combining Monte Carlo simulation method and the modified incremental assignment method (MIAM). For this purpose, the ground motion intensity, fragility relations and shape parameters of the constructions are needed to find damage rates and reliability rates. Mohaymany et al. (2006) [7] develop a method identifying the critical infrastructures based on emergency response accessibility. However, like in the previous study [6] mentioned, there are also some terms needed to be assigned, which are total damage of the infrastructure, difficulty of rescue activities, rescue potential etc. Hence, it is seen that to use those methods, there are much more information needed and that can not be gathered from JICA Report [3] which is the broadest study for Istanbul. Moreover, these data can only be obtained if a new and more detailed study for Istanbul like JICA Report [3] is held. Hence, we generate the vulnerability rates only using the data given by JICA Report [3]. In the proposed model, we weight different causes and types of vulnerability equally. For example, the transportation vulnerability is assumed to be caused from only narrow roads and bridges. So, the transportation vulnerability rate will be the average rate of the rates calculated from the data for these two causes declared in JICA Report [3]. Additionally, in our model we will give same attention to transportation vulnerability and DRF vulnerability such that the objective function will minimize the multiplication of distance, demand, transportation vulnerability and DRF vulnerability rates.

CHAPTER 2

LITERATURE REVIEW

International Federation of Red Cross and Red Crescent (IFRC) Societies define disaster as “an extreme disruption of the functioning of a society that causes widespread human, material, or environmental losses that exceed the ability of the affected society to cope using only its own resources”. Hence, not every event such as earthquakes, floods etc. can be considered as disasters. They should affect people and properties in a serious and negative way [8].

World Health Organization (WHO) also defines disaster in a similar way and associates disasters to natural hazards but also considers the preventive actions already taken place such as mitigation and preparation plans. According to WHO, only in the lack of these actions disruption becomes a disaster [9].

Duran et al. [10] classify disasters according to three dimensions such that a disaster can be natural or man-made, localized or dispersed, and slow or sudden on-set. Earthquake is a sudden on-set and natural disaster. Accordingly, Duran et al. [10] also define all of the preventive and mitigation operations held before and after the disaster as disaster management. They claim that the performance of the disaster management affects directly the disaster response outcome and may bring additional distress to helping people whenever the disaster is dispersed since the preparation and distribution of the relief items become harder. Therefore, it is stated that disaster management before and after a disaster is complicated and crucial.

Ergun et al. [11] state that disaster management can be applied through four sequential phases, which are mitigation, preparedness, response and recovery.

Assessment of vulnerability, planning of capacity of buildings, pre-positioning of relief items and training compose the mitigation and preparedness phases of the pre-disaster activities. The results of pre-disaster activities highly affect the progress of the response to a disaster.

The phase until the disaster strikes is called preparedness as mentioned before. According to Ergun et al. [11], it includes assessment, planning and training/education. After the disaster strikes, the phase is called response, which includes relief operations and logistics stages. This study focuses on the sub-phases of preparedness and response. Sub-phases of preparedness and response are given in **Table 2. 1**:

Table 2. 1 Sub-phases of Preparedness and Response Phases of a Disaster

<table>
<tr><td rowspan="3">Preparedness</td><td>Assessment</td><td>Risk Factors, Vulnerability</td></tr>
<tr><td>Planning</td><td>Infrastructure, Policy Making, Capacity Building, Pre-positioning Resources</td></tr>
<tr><td>Training/Education</td><td>Public Awareness, Education of the Response Personnel</td></tr>
<tr><td rowspan="2">Response</td><td>Relief Operations</td><td>First Phase (Medicals, food, shelter)
Second Phase (Housing, food supply chain)</td></tr>
<tr><td>Logistics Stages</td><td>Mobilization and Procurement, Long Haul, the Last Mile</td></tr>
</table>

In the preparedness phase, the assessment is performed to calculate risk factors and vulnerability. According to IFRC [8], this phase should:

- ➢ Identify the characteristics, frequency and potential severity of the hazards a community faces,

- Identify the particular geographical areas and communities that are most susceptible and vulnerable to those hazards,
- Identify the main sectors of a community (population, infrastructure, housing, services, etc.) that would be affected by a specific type of hazard and anticipate how they might be affected,
- Assess the ability of those sectors to withstand and cope with the effects of hazardous phenomena.

Planning, on the other hand, should organize the operations, assign the roles and missions, establish policies and procedures and discover the needs of the society and properties to have effective and quick action. The infrastructure improvements should be completed and the additional capacity to be used after a potential disaster should be created. The storage and pre-positioning of the relief items needed after a disaster should be evaluated so that emergency plans can be applied with agility [10].

Moreover, in the preparedness phase, the public should be educated. According to IFRC [8], the public should be educated to maintain the public awareness. Thus, the government officials and others responsible for disaster management activities should be trained in order to reduce the damage of the disaster.

The connection between the preparedness and response phases is crucial. Thomas (cited in [10], p.3, 2004) defines humanitarian logistics as a "bridge between disaster preparedness and response, between procurement and distribution and between headquarters and the field." IFRC also defines it as acquisition and delivery of requested supplies and services that are critical for living such as food, water, shelter, medicine at the right time and the right place [12].

Few days after the disaster, food, water, shelter and medical supplies are highly demanded by the affected people and the demand pattern of them can be foreseen up to a certain degree. These demands are supplied from various sources in humanitarian logistics. Governments, NGOs, national and international aid agencies and donors are the main suppliers [11].

After the disaster strikes, demand pattern becomes more complex and assessment needs to take place to see the actual requirements of the people affected. The infrastructure may deteriorate considerably such that the distribution plans may not work. At this point, pre-positioning of the relief items gains importance. According to Duran et al. [10], pre-positioning of relief items in specific locations may increase the response effectiveness by decreasing the response time. In pre-positioning, relief items are purchased in advance and held as inventory in warehouses so that after the strike of the disaster effective distribution can be obtained. Hence, this activity takes place in the preparedness phase in order to increase the effectiveness of the response phase.

The JICA Report [3] is a good example for a preparedness plan. It is prepared for a potential earthquake that is expected to hit Istanbul in near future. The plan indicates the existing social and physical condition of Istanbul such as society organizations, education status, estimation about damages, seismic damage analysis for the city, and provides recommendations for the seismic disaster prevention and mitigation. It also provides information on the vulnerable buildings and urban structures to be strengthen such as buildings, road networks, bridges and crisis management centers. However, it does not propose decisions on capacity building, pre-positioning of relief items etc. There are some recent works worth to mention that considered these issues.

Firstly, Barbarosoğlu and Arda [13] propose a stochastic multi-commodity multi-modal network flow formulation to describe a two-stage stochastic programming (SP-MCM) framework for transportation planning in disaster response. The first stage refers to the period until earthquake strikes and the second stage after the earthquake. They include vulnerability of the transportation system, some scenarios for capacity, supply and demand, and randomness of such issues. The model minimizes total first-stage transportation cost and the expected resource cost of the given earthquake scenario. The model is validated by the actual data obtained from the İzmit Earthquake with 7.4 magnitude. Avcılar district in Istanbul is the only demand region considered, hence the demand and supply points are selected for this district only. This study does not only consider the road transportation but also the air transportation.

Kutanoğlu and Mahajan [14], on the other hand, suggest inventory sharing and allocation model for a single-commodity multi-location two-echelon distribution system. There is one central warehouse with infinite capacity and a number of local warehouses, all of which serve demand locations. This study is interesting for humanitarian logistics since it proposes a two-echelon distribution system, where the central warehouse feeds all local warehouses and demand locations with infinite capacity. However, this study is needed to be extended for a capacitated central warehouse to be more realistic.

Duran et al. [15] propose a mixed integer model for CARE International in order to establish a desired configuration for pre-positioning network. The pre-positioning network configuration indicates optimal locations and inventory allocations all over the world for a given number of warehouses and capacities. The MIP model minimizes the average response time considering the replenishment times of the inventory. Number of warehouses and maximum inventory amount are the main parameters in the model. Hence, the model is considered for 1-9 warehouses and for 3 levels of allowed inventory. There is no vulnerability consideration such as the capacity decrease or road deterioration in that study.

Lastly, Görmez [16] studies disaster response and relief facility location problem for Istanbul. In the study, the average distance traveled to reach the people needing relief services and number of new facilities to be established are minimized. The model is a two-stage distribution system for Istanbul and the commodities needed are distributed to the disaster response facilities first. The facilities act as local warehouses for the demands of the districts. There are two types of models given in the study: models satisfying all demand and only some portion of demand. The vulnerability is also introduced in the study but only considering the warehouse capacity decrease. Unlike Duran et al. [15] inventory replenishment is not considered. Moreover, the average distances are taken as the linear distances between the coordinates of the already existing facilities and potential facilities.

Although, the study of Görmez [16] is the most related study to this thesis, there are many aspects of our study that individualize it. In our study, the vulnerability is considered both for transportation and disaster response facilities (DRFs) as mentioned before. Chang and Nojima consider transportation vulnerability determining the routes where the supply points are already given [17]. In many studies, the damages in DRFs are mentioned as decreasing capacity like in study of Barbarosoğlu and Arda [13] and Görmez's thesis [16]. Hence, it can be concluded that in the literature, there are not any studies to locate DRFs considering the effects of the damages in the transportation network infrastructure and the performance of the network. Thus, the damage in the infrastructure of transportation network and DRFs caused by an earthquake in Istanbul is a issue not studied yet. Hence, our thesis becomes significant considering the vulnerability for both transportation network and DRFs.

CHAPTER 3

ASSUMPTIONS AND SETTINGS

In this study, the main aim is investigating the impact of vulnerability on disaster response facility (DRF) locations for Istanbul. Unlike the previous studies in the literature, not only the DRF damage, but also the transportation mean vulnerability is considered and investigated in detail. The transportation mean vulnerability is due to two main sources, namely narrow road and bridge.

In the JICA Report [3], it is declared that narrow roads are more prone to road closure due to the collapsed buildings and road structure. The density of narrow roads is extremely high in Istanbul. Hence, while studying the transportation vulnerability, narrow road percentage will be an important factor for Istanbul. Moreover, in Istanbul the bridges are also worth to be considered for vulnerability due to Istanbul's geographic and demographic characteristics.

As well as studying the impact of transportation mean vulnerability in DRF location decisions for Istanbul, the damage in DRFs caused by an earthquake is also investigated for the integrity of the vulnerability study.

3.1 Application of the Models to the Istanbul Region

In this thesis, models are developed specifically for Istanbul. As a result, the characteristics of Istanbul shaped the assumptions used for modeling. For example, Istanbul is divided into two sides by Bosporus and these two sides are connected to each other by two east-west bridges. Because of this topographical property, in all models developed, European and Asian sides are evaluated separately, i.e. a DRF on one side is assumed not to send relief items to any district at the other side.

The JICA Report [3] is the most detailed study for the potential Istanbul Earthquake, therefore the data and knowledge except population in that report are used in this thesis. In the report, the detailed analyses are performed for 30 districts of Istanbul, which are listed with their population data in **Table 3. 1**. The population information is gathered from the last census of population for Turkey in 2012 [4]. In **Table 3. 1**, the districts are numbered and this numbering will be used consistently throughout this study thereafter. **Table 3. 1** also shows the sides of Istanbul where the districts are located. However, “Adalar” district is not considered in the models since it has a very small population. Therefore, only 29 districts are used in the models developed. These districts are located on Istanbul map in **Figure 3. 1**.

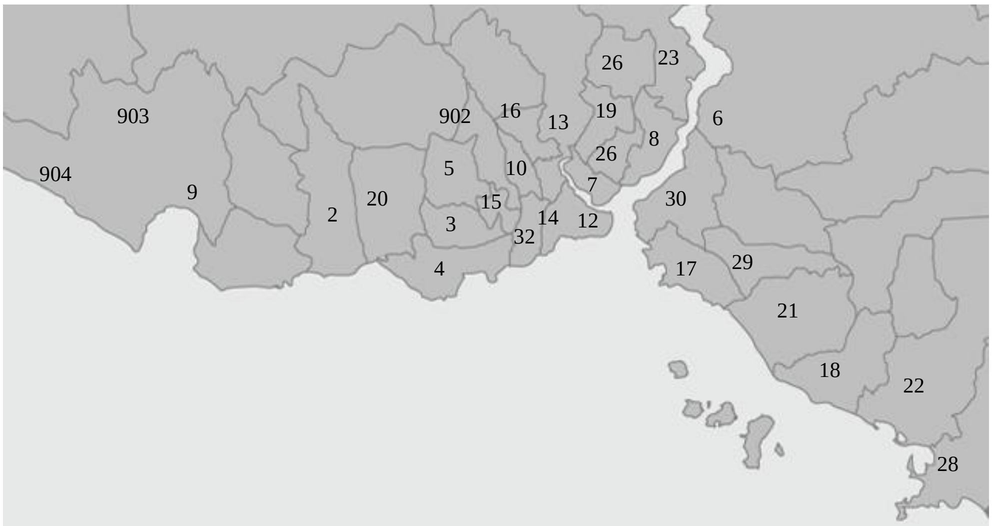


Figure 3. 1 Location of the Districts on Istanbul Map

Table 3. 1 Data of Istanbul Districts

No	District	Population	Side
1	ADALAR	14,552	-
2	AVCILAR	395,758	West
3	BAHÇELİEVLER	600,162	West
4	BAKIRKÖY	221,336	West
5	BAĞCILAR	749,024	West
6	BEYKOZ	220,364	East
7	BEYOĞLU	246,152	West
8	BEŞİKTAŞ	186,067	West
9	BÜYÜKÇEKMECE	201,077	West
10	BAYRAMPAŞA	269,774	West
12	EMİNÖNÜ	24,873	West
13	EYÜP	349,470	West
14	FATİH	403,385	West
15	GÜNGÖREN	307,573	West
16	GAZİOSMANPAŞA	980,470	West
17	KADIKÖY	916,763	East
18	KARTAL	443,293	East
19	KAĞITHANE	421,356	West
20	KÜÇÜKÇEKMECE	1,033,006	West
21	MALTEPE	460,955	East
22	PENDİK	622,200	East
23	SARIYER	258,035	West
26	ŞİŞLİ	318,217	West
28	TUZLA	197,657	East
29	ÜMRANİYE	645,238	East
30	ÜSKÜDAR	535,916	East
32	ZEYTİNBURNU	292,407	West
902	ESENLER	458,694	West
903	ÇATALCA	36,863	West
904	SİLİVRİ	137,861	West

The developed models assume that every district can have a DRF. Since, a DRF is used for storing relief items, it will be called as “warehouse” in the rest of the study. Furthermore, each district is also a demand point for relief items. Naturally, there can be many potential warehouse locations within a district, but for simplicity, warehouses are assumed to be opened in the center of the districts. While warehouse locations are chosen, the in-district relief item distribution is omitted initially. Therefore, the relief item transportation is only between the center of the districts. This restriction will be relaxed and the in-district relief item distribution will be discussed later in the thesis.

Since the center of the district is the only potential warehouse location and the demand point for each district, potential routes can be determined easily. Between every district, from a potential warehouse to a demand point, we consider two possible routes. These routes are obtained from JICA Report [3]. In this report there exists a Proposed Emergency Road Network, which suggests primary, secondary and tertiary roads to be used after an earthquake strikes Istanbul. This network is shown in **Figure 3. 2**.

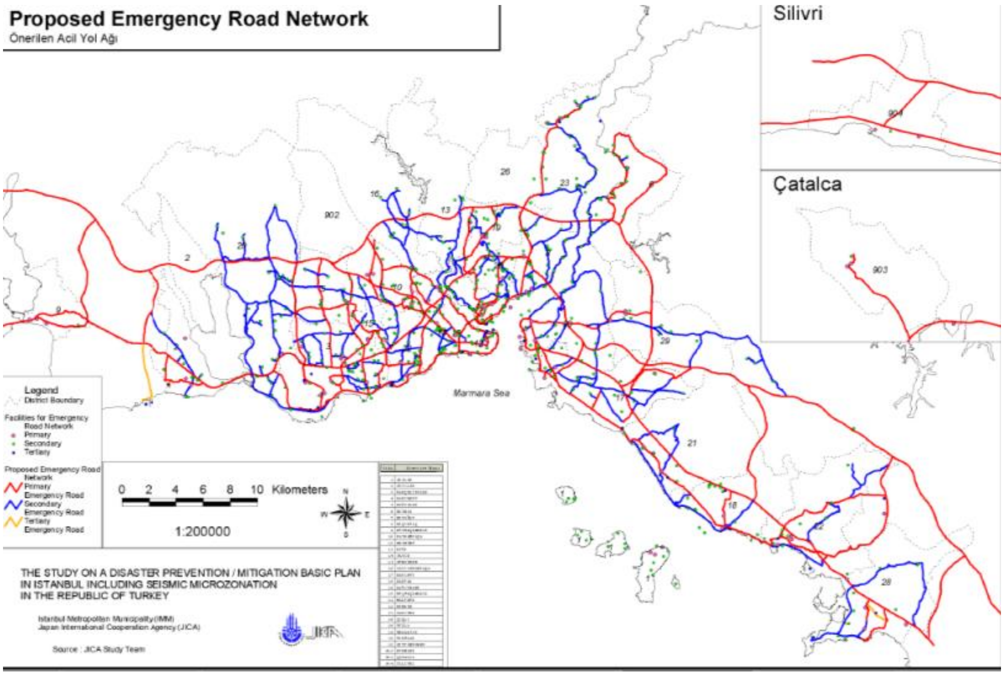


Figure 3. 2 Emergency Road Network Proposed by JICA Report [3]

According to the JICA Report [3], the length of emergency road network is composed of 455 km of primary emergency roads, 360 km of secondary emergency roads, and 3 km of tertiary emergency roads. In this network map (**Figure 3. 2**), the primary, secondary and tertiary roads are shown as red, blue and orange colors, respectively. This order is made based on the considerations below:

1) disaster damage information collection/exchange,

2) proper emergency response operations,

3) emergency goods circulation after the earthquake.

For the selected routes used in the models, not all districts in the same side of Istanbul are connected to each other, since we utilize an upper limit on distance to travel between a demand and a supply point to control response times (The connected route distances calculated are shown in APPENDIX A). For example, for the East Side the upper limit for the distances between districts is around 30 km. This limit for the West Side goes up to around 35 km. Moreover, in some cases the first route suggested stays within mentioned distance limits, however, the distance of the second route can go up to 45 km for outer districts like Büyükçekmece and Küçükçekmece.

3.2 Vulnerability

Some segments of the selected transportation routes can be partially damaged or totally destroyed by the earthquake. This transportation mean vulnerability is considered to originate from narrow roads, bridges or both. The narrow road percentages of the districts of Istanbul from the JICA Report [3] are reported in **Table 3. 2**.

Table 3. 2 Narrow Road Percentages of Istanbul Districts in JICA Report [3]

District No	Narrow Road Percentage	District No	Narrow Road Percentage
2	62.4%	**18**	52.8%
3	49.8%	**19**	62.8%
4	48.3%	**20**	68.7%
5	61.4%	**21**	62.7%
6	77.2%	**22**	75.8%
7	73.9%	**23**	78.2%
8	50.8%	**26**	63.5%
9	53.8%	**28**	68.7%
10	50.9%	**29**	67.1%
12	61.0%	**30**	65.8%
13	66.1%	**32**	47.9%
14	73.1%	**902**	76.5%
15	35.8%	**903**	N/A
16	70.7%	**904**	N/A
17	53.8%		

For Çatalca and Silivri (903 and 904), the related information could not be obtained from the JICA Report [3]. For the sake of simplicity, all of the narrow road percentages of the route segments including Çatalca and Silivri are taken as zero. This assumption is not restrictive since, Çatalca and Silivri are the most western districts of Istanbul and they are only connected to Büyükçekmece, Küçükçekmece and Avcılar, which creates a natural cluster in the west part of Istanbul. **Figure 3. 3** shows all connections in and out of Çatalca (903) and Silivri (904) Districts.

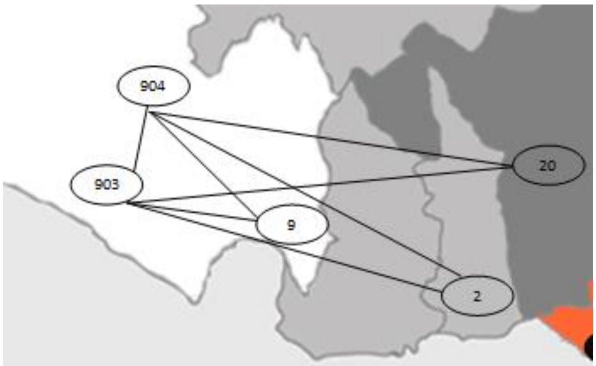


Figure 3. 3 Western Districts of Istanbul

Now we need to use the narrow road percentages of districts to calculate the vulnerability of the roads. Narrow road vulnerability rate of a route is defined as the average narrow road percentage per km. This rate is calculated for a route, which is passing through districts $D_1, D_2, \ldots, D_m$ as:

$$(R_1 + R_2 + \ldots R_m) \,/\, (\textit{total length of the route}) \tag{3.1}$$

where R_i is calculated by the multiplication of the length of the route segment passing through D_i and the narrow road percentage of D_i in the JICA Report [3]. The results are given in Appendix B.

Narrow road vulnerability rate is scaled and called as scaled narrow road vulnerability rates. The smallest scaled rate is set to 1 and the biggest one to 2. As a summary, the mean and standard deviation values of the scaled narrow road vulnerability rate of routes entering to districts are given in **Table 3. 3**.

The bridge locations in Istanbul are shown in **Figure 3. 4** which is also taken from the JICA Report [3]. The number of bridges crossed on a route is determined from this map and transformed into a number in order to calculate the bridge vulnerability rate. This rate is calculated for a route as shown in Formula (3.2).

$$\textit{Bridge Vulnerability Rate} = \frac{\textit{total number of bridges in the route}}{\textit{total length of the route}} \tag{3.2}$$

Table 3. 3 Scaled Narrow Road and Bridge Vulnerability Attributes of the Routes Entering to Districts

Dist. No	Narrow Road		Bridge		Dist. No	Narrow Road		Bridge	
	Mean	Stand. Dev.	Mean	Stand. Dev.		Mean	Stand. Dev.	Mean	Stand. Dev.
2	1.51	0.30	1.15	0.06	**18**	1.50	0.21	1.33	0.15
3	1.55	0.09	1.28	0.17	**19**	1.76	0.09	1.28	0.13
4	1.52	0.09	1.27	0.12	**20**	1.66	0.16	1.18	0.10
5	1.69	0.13	1.29	0.16	**21**	1.55	0.18	1.34	0.16
6	1.71	0.37	1.24	0.18	**22**	1.74	0.15	1.24	0.12
7	1.77	0.11	1.33	0.12	**23**	1.87	0.21	1.21	0.11
8	1.70	0.09	1.31	0.14	**26**	1.73	0.19	1.28	0.15
9	1.10	0.14	1.11	0.05	**28**	1.88	0.07	1.16	0.07
10	1.65	0.12	1.49	0.24	**29**	1.64	0.21	1.58	0.27
12	1.71	0.11	1.41	0.14	**30**	1.69	0.18	1.51	0.27
13	1.76	0.12	1.34	0.19	**32**	1.57	0.11	1.28	0.09
14	1.73	0.11	1.39	0.16	**902**	1.83	0.09	1.36	0.18
15	1.57	0.15	1.35	0.17	**903**	1.00	0.00	1.09	0.05
16	1.76	0.12	1.30	0.17	**904**	1.00	0.00	1.11	0.04
17	1.50	0.23	1.53	0.25	**Aver.**	1.61	0.142	1.30	0.145

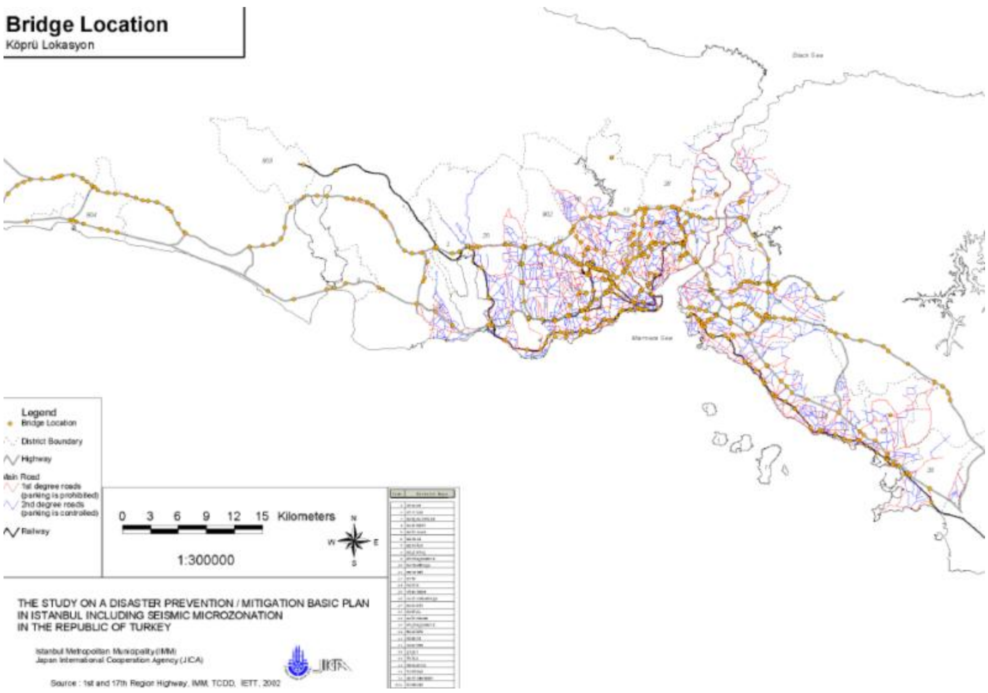


Figure 3. 4 Bridge Locations given by JICA Report [3]

Similar to narrow road vulnerability rate, bridge vulnerability rate is also mapped onto a scale of 1-2. Hence, the smallest rate becomes 1, whereas the biggest one becomes 2. The scaled bridge vulnerability rates are also given in Appendix C. Also, the mean and standard deviation values of the scaled bridge vulnerability rates of routes entering to districts are given in **Table 3. 3**.

In order to observe the effect of total transportation mean vulnerability, it is crucial to combine the narrow road vulnerability and bridge vulnerability. For this purpose, for each route the arithmetic mean of the scaled narrow road vulnerability rate and scaled bridge vulnerability rate is taken and this scaled rate is called Combined Transportation Mean Vulnerability Rate. The calculations related are given in Appendix D Note that since both rates are scaled between 1 and 2, the Combined transportation Mean Vulnerability Rate is also scaled between 1 and 2. The effects of different scales such as [2,3] and [3,4] are also considered in the later sections of this study.

The previous rates are all related to the transportation mean vulnerability. It is also important to consider warehouse building vulnerability which was considered in Görmez [16] as a decrease in capacity of warehouses. Hence, in order to cover all vulnerability issues, warehouse building vulnerability is taken into consideration in our study, too. District Building Damage Rates (the building damage percentages given in JICA Report [3]) are converted to the Warehouse Building Vulnerability Factors by scaling the West Side and East Side of the city separately and used as coefficients in the objective function, which are introduced in **Table 3. 4**. Therefore, it has the effect of increasing the transportation time just as the transportation vulnerability. Note that this scaling is between 1 and 2 for integrity of all vulnerability factors.

Table 3. 4 Warehouse Building Vulnerability Rates and Factors

Dist. No	District Building Damage Rates	Warehouse Building Vuln. Factors	Dist. No	District Building Damage Rates	Warehouse Building Vuln. Factors
2	55.5	1.83	**18**	39.0	1.93
3	57.3	1.87	**19**	25.6	1.24
4	63.9	2.00	**20**	42.1	1.57
5	39.8	1.52	**21**	34.7	1.76
6	14.9	1.00	**22**	36.0	1.81
7	38.5	1.50	**23**	13.3	1.00
8	26.0	1.25	**26**	23.9	1.21
9	50.2	1.73	**28**	40.9	2.00
10	47.0	1.67	**29**	19.9	1.19
12	48.8	1.70	**30**	21.7	1.26
13	34.9	1.43	**32**	61.2	1.9
14	55.4	1.83	**902**	36.2	1.45
15	54.6	1.82	**903**	20.6	1.14
16	25.0	1.23	**904**	27.4	1.28
17	31.6	1.64			

3.3 Relief Items

Water, medical kit and tent are the relief items considered in the study. Water is considered as one of the relief items, since loss of safe drinking water can be deadly. Six-pack bottled water (see **Figure 3. 5**) is assumed to be stocked in the warehouses and the amount of water to be stocked can be assumed as 3 dm^3 of water per person per day (half is for drinking and the other half is for food preparation and sanitation).

Figure 3. 5 Six-Pack Water

In post-disaster sub-phase medicines play an important role for saving peoples' lives, so even though the storage of medical items is not easy as water or durable items, a medical item kit is considered in our study [18]. Personal first aid kit proposed by American Red Cross (see **Figure 3. 6**) is considered for the medical relief item. The volume of such a medical kit is around 1.4 dm^3.

Figure 3. 6 Personal First Aid Kit

For the accommodation problem tents are assumed to be the immediate solution. They are typical 4-person Turkish Red Crescent tents as shown in **Figure 3. 7**, with the storage volume of around 170 dm^3.

Figure 3. 7 Turkish Red Crescent Tent

3.4 Model Settings

The models developed include 29 demand points and 29 candidate warehouse locations. There are three main models, which are all multi item models and in all models the warehouse number and capacity are assumed as given inputs. The first model considers no vulnerability. Vulnerability is included in the other two models such that the second model has only transportation mean vulnerability concerns and the third model considering warehouse building vulnerability with transportation mean vulnerability. Moreover, all models utilize the volume of relief items as demand. The models are Mixed Integer Programming (MIP) models minimizing the multiplication of average distance and demand, where Model 2 and Model 3 have also vulnerability rates in this multiplication. Hence, it can be concluded that the models are *p* median location models.

CHAPTER 4

MODELS

When there are multi relief items to consider, the calculation of the demand for different relief items becomes crucial. There are two steps to estimate the demand used in the models. The first step is to calculate the demand amounts from the number of affected people at the most possible earthquake model in JICA Report [3] (see **Figure 4. 1**).

This earthquake model is named as Model A. This scenario originates from a section about 120 km long fault line from west of İzmit Earthquake fault to Silivri. The moment magnitude (Mw) is assumed to be 7.5. Moreover, according to the report, ground movement acceleration in Eminönü to Büyükçekmece ranges from 300 to 400 gals, whereas the largest acceleration is around 500 gals among all earthquake models proposed in the report. It also suggests that in Çatalca, and Silivri, acceleration ranges from 200 to 300 gals and the East Side of Istanbul suffers less than 300 gals, except for the seaside areas [3]. Also observing the map given in **Figure 4. 1**, it can be concluded that the sea side of western Istanbul will suffer most.

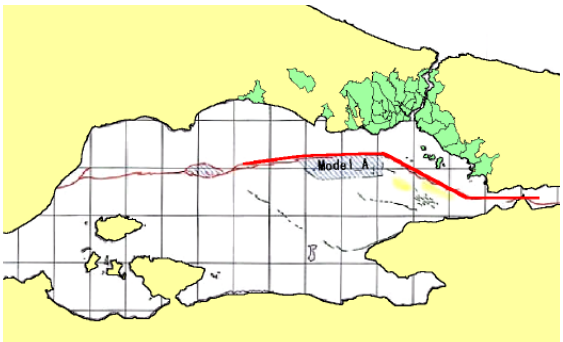


Figure 4. 1 Earthquake Position Predicted by Model A in JICA Report [3]

The demand values for tent (4-person) are calculated according to Equation (4.1) where the variables in **Table 4. 1** are used. The number of people demanding accommodation is calculated by subtracting the number of dead people (C) and the number of severely injured people (D) from the total population affected from the earthquake (B).

Moreover, since the tents are for 4 people, the number of people demanding accommodation is divided by 4 to calculate the need for accommodation. However, not all affected people will need tent since not all buildings will be severely damaged. Hence, the need for accommodation value is multiplied by the percentage of heavily damaged buildings (A) provided at JICA Report [3].

$$\#\ of\ Tents = (B\text{-}C\text{-}D)*A/4 \tag{4.1}$$

The demand for medical supply kit is assumed to originate from the number of people severely injured (D). Lastly, the demand for water is calculated using the number of people demanding accommodation *(B-C-D)* since these people will also need water. The required number of considered relief items calculated as explained are shown in **Table 4. 1**.

Table 4. 1 Number of Relief Items Required from Model A Data

Dist. No	Heavily Damaged Building (%)	Population	Death	Severely Injured	Demand for Tent	Demand for Medical Supply	Demand for Water
	A	**B**	**C**	**D**	**E**	**F**	**G**
2	14.1	395,758	6,939	10,507	52,491	10,507	378,312
3	13.1	600,162	7,368	9,746	83,522	9,746	583,048
4	18.3	221,336	3,955	6,148	33,744	6,148	211,233
5	6.6	749,024	5,727	8,565	73,106	8,565	734,732
6	1.7	220,364	366	778	8,166	778	219,219
7	8.8	246,152	3,097	5,148	22,899	5,148	237,907
8	4.1	186,067	990	2,147	11,890	2,147	182,930
9	10.5	201,077	4,417	9,615	23,474	9,615	187,046
10	12.3	269,774	4,162	6,479	30,448	6,479	259,133
12	13.9	24,873	1,146	2,016	2,649	2,016	21,711
13	7.3	349,470	2,536	4,993	29,834	4,993	341,942
14	16	403,385	6,349	8,060	53,873	8,060	388,976
15	11.8	307,573	3,388	5,610	40,755	5,610	298,575
16	3.3	980,470	2,936	5,647	60,743	5,647	971,887
17	5	916,763	4,450	7,211	71,503	7,211	905,102
18	8.2	443,293	3,170	5,693	42,357	5,693	434,430
19	3.9	421,356	1,587	3,265	26,656	3,265	416,504
20	9.4	1,033,006	9,968	13,296	106,275	13,296	1,009,742
21	6.3	460,955	2,762	5,234	39,294	5,234	452,959
22	7.1	622,200	4,359	7,562	54,925	7,562	610,279
23	1.3	258,035	336	709	8,545	709	256,991
26	3.2	318,217	1,315	2,782	18,769	2,782	314,120
28	9	197,657	2,660	5,426	19,384	5,426	189,571
29	2.3	645,238	1,415	3,068	31,878	3,068	640,756
30	2.5	535,916	1,463	2,984	28,832	2,984	531,469
32	16.6	292,407	5,642	8,269	42,610	8,269	278,496
902	6	458,694	3,172	5,450	40,732	5,450	450,072
903	2.6	36,863	71	111	1,889	111	36,681
904	4.2	137,861	1,527	3,351	9,109	3,351	132,983
Total					**1,070,352**	**159,870**	**11,676,805**

The second step is to calculate their volume. The demand will be presented in volumes within the models since volume is the main cost driver in inventory holding and transportation costs. Number of demanded relief items in **Table 4. 1** are multiplied with the volumes of the relief items, which are taken as 169.901, 1.3988 and 3 dm^3 for tent, medical supply and water, respectively. The multiplication of demand and volume are too high to be used in the models so they are given in m^3 in **Table 4. 2**:

Table 4. 2 Volume of the Relief Items Demanded (m^3)

Dist. No	Demand for Tent	Demand for Medical Supply	Demand for Water	Dist. No	Demand for Tent	Demand for Medical Supply	Demand for Water
2	8,918	15	1,135	**18**	7,196	8	1,303
3	14,190	14	1,749	**19**	4,529	5	1,250
4	5,733	9	634	**20**	18,056	19	3,029
5	12,421	12	2,204	**21**	6,676	7	1,359
6	1,387	1	658	**22**	9,332	11	1,831
7	3,890	7	714	**23**	1,452	1	771
8	2,020	3	549	**26**	3,189	4	942
9	3,988	13	561	**28**	3,293	8	569
10	5,173	9	777	**29**	5,416	4	1,922
12	450	3	65	**30**	4,899	4	1,594
13	5,069	7	1,026	**32**	7,239	12	835
14	9,153	11	1,167	**902**	6,920	8	1,350
15	6,924	8	896	**903**	321	1	110
16	10,320	8	2,916	**904**	1,548	5	399
17	12,148	10	2,715	**Total**	**181,854**	**224**	**35,030**

In all models, the capacities for each relief item type are used as the corresponding total demand volume for that relief item type in Istanbul, which are 181,854 m^3, 224 m^3 and 35,030 m^3 for tent, medical supply and water, respectively. Therefore, the total volume of relief items needed to satisfy all demand is more than 200,000 m^3.

Before introducing the model formulations, summarizing the distinctive features of the models will be useful. As illustrated in **Table 4. 3**, Model 1 has no vulnerability consideration. However, Model 2 and 3 are the vulnerability considered models. All models minimize the multiplication of vulnerability rates (if there are any), distance and demand. However, in Model 1 since there is no vulnerability it has only the multiplication of demand and distance in the objective function. Also, in all models different types of relief items are not needed to be hold in the same warehouses. This causes the fact that although in the model there is a restriction that certain number of warehouses is to be opened for each relief item type, the total number of warehouse locations for all relief items may be larger than this number. This issue is discussed later in the thesis.

Table 4. 3 Features of the Models

Distinctive Feature	No Vulnerability	Combined Transportation Mean Vulnerability	Combined Transportation Mean Vuln. + Warehouse Building Vuln. (Full Vuln.)
Models	*Model 1*	*Model 2*	*Model 3*

4.1 Model 1 –Vulnerability Not Considered

The vulnerability is not considered for this model. The calculated demand requirements are given in **Table 4. 2**. The formulation is as follows:

<u>Sets</u>

i : Set of all supply points

j : Set of all demand points

k : Set of relief items

<u>Binary Variables</u>

$x_{i,j,k}$: 1, if warehouse *i* sends relief item *k* to location *j* using route 1

$y_{i,j,k}$: 1, if warehouse *i* sends relief item *k* to location *j* using route 2

$w_{i,k}$: 1, if a warehouse is located at district *i* and keeps relief item *k*

Variable

$s_{i,j,k}$: amount of relief item *k* sent from warehouse *i* to demand point *j*

Parameters

$dx_{i,j}$: distance between warehouse *i* and demand point *j* using route 1

$dy_{i,j}$: distance between warehouse *i* and demand point *j* using route 2

$S_{j,k}$: volume of demand needed at demand point *j* for relief item *k*

$C_{i,k}$: capacity of warehouse located at supply point *i* for relief item *k*

W_k : total number of warehouses to open for relief item *k*

Objective

$$MIN \sum_j (\sum_k \sum_i (x_{i,j,k} * dx_{i,j} + y_{i,j,k} * dy_{i,j}) * S_{j,k}) \quad (4.2)$$

Constraints

$$x_{i,j,k} + y_{i,j,k} \leq 1 \quad \forall\ i, j, k \quad (4.3)$$

$$S_{j,k} *(x_{i,j,k} + y_{i,j,k} + w_{j,k}) \geq s_{i,j,k} \quad \forall\ i, j, k \quad (4.4)$$

$$S_{j,k} = \sum_i s_{i,j,k} \quad \forall\ j, k \quad (4.5)$$

$$\sum_j s_{i,j,k} \leq C_{i,k} * w_{i,k} \quad \forall\ i, k \quad (4.6)$$

$$w_{i,k} * S_{i,k} = s_{i,i,k} \quad \forall\ i, k \quad (4.7)$$

$$\sum_i w_{i,k} = W_k \quad \forall\ k \quad (4.8)$$

$$x_{i,j,k} \leq dx_{i,j} * w_{i,k} \quad \forall\ i, j, k \quad (4.9)$$

$$y_{i,j,k} \leq dy_{i,j} * w_{i,k} \quad \forall\ i, j, k \quad (4.10)$$

$$x_{i,j,k}, y_{i,j,k}, w_{i,k} \in \{0,1\}, s_{i,j,k} \geq 0 \quad \forall\ i, j, k \quad (4.11)$$

The objective function minimizes multiplication of distance and demand between all demand and supply points. Constraint set (4.3) prevent the usage of both of the alternative routes simultaneously between a pair of districts. Constraint set (4.4) and (4.5) make sure that all demand should be satisfied if a warehouse is connected to the demand location. Constraint set (4.5) also allow that different warehouses can send to the same demand point for same type of relief item, hence this gives the advantage of one demand point to be satisfied from different supply locations. Constraint set (4.6) ensure that a warehouse can only send supply up to its capacity limit to the demand locations. According to Constraint set (4.7), a warehouse satisfies the demand of the district where it is located first. Constraint set (4.8) represent the warehouse number and indicate that there are limits for warehouses for each relief item. Constraint set (4.9) and Constraint set (4.10) make sure that two districts are connected and district *i* can send supply to demand point *j* only if there is a warehouse opened in district *i*. Constraint set (4.11) define the zero-one and non-negative variables of the model.

In the distance matrix of $dx_{i,j}$ and $dy_{i,j}$, the diagonal cells are zero since if a warehouse is opened in a district, the demand of that district is assumed to be satisfied without any travel time.

4.2 Model 2 - Combined Transportation Mean Vulnerability Considered

Vulnerability considered in this model is the combined transportation mean vulnerability of the routes only. The sets, variables and constraints are same as Model 1. Only objective function is converted into:

Modified Objective

$$MIN \sum_j (\sum_k \sum_i (x_{i,j,k} * dvx_{i,j} + y_{i,j,k} * dvy_{i,j}) * S_{j,k}) \qquad (4.12)$$

Where the new parameters in the model are:

Modified Parameters

$dvx_{i,j}$: the multiplication of combined transportation mean vulnerability rate and distance between warehouse located at district i and demand point j using route 1

$dvy_{i,j}$: the multiplication of combined transportation mean vulnerability rate and distance between warehouse located at district i and demand point j using route 2

4.3 Model 3 - Warehouse Building Vulnerability Added Over Model 2

There is an additional consideration related to vulnerability in this model. In Model 3, there is also a warehouse building vulnerability which is caused by the building damage. In Görmez's study [16], warehouse building vulnerability is the only point mentioned related to vulnerability. This is reflected as a capacity decrease in the warehouses. However, in our study, the warehouses are assumed to have unlimited capacity and the warehouse building vulnerability rates are calculated and used as inflators in the objective function. They are already introduced in **Table 3. 4** and after the inflating the transportation mean vulnerability rates with warehouse building vulnerability rates, the parameters are defined as:

Modified Parameters

$dvx_{i,j}$: the multiplication of combined transportation mean vulnerability rate, warehouse building vulnerability rate and distance between warehouse located at district *i* and demand point *j* using route 1

$dvy_{i,j}$: the multiplication of combined transportation mean vulnerability rate, warehouse building vulnerability rate and distance between warehouse located at district *i* and demand point *j* using route 2

CHAPTER 5

RESULTS AND COMPARISON

There are 29 candidate warehouses and demand locations and also three types of relief items to be allocated. There are two routes between every connected district; hence, there exist 5,046 binary variables for routes and 87 binary variables for warehouse locations. As a result, there are totally 5,133 binary variables. However, the distance matrices are formed such that the cell is zero if two districts are not connected. This results in 3,450 variables to be zero certainly. Hence, the number of binary variables reduces to 885. The number of constraints, on the other hand, depends on the structure of the models.

In this thesis, vulnerability is the core topic focused on. In the later sections, the comparisons between non-vulnerable and vulnerable model results and discussions between vulnerable models are provided in order to see the effect of vulnerability in Istanbul Earthquake emergency plan. Taking the combined transportation mean vulnerability rate and warehouse building vulnerability factors into the consideration, **Table 5. 1** is formed. In this table, the vulnerability rates and factors are leveled. Level 0 means that there is almost no vulnerability, and level 3 implies the most vulnerable districts. Bakırköy and Zeytinburnu are the most vulnerable districts, whereas Çatalca is the least vulnerable. This finding is also compatible with the common idea that the South-West coast of the city will be the most affected area [3][19].

Since the warehouses are not capacitated (capacities are equal to the demand), all demand for a specific relief item at the demand location (a district) is satisfied by only one warehouse through a route determined by the model.

Table 5. 1 Vulnerability Levels of Istanbul Districts (Color Coded)

Dist. No	Vuln. Level	Dist. No	Vuln. Level
2	2	18	1
3	2	19	1
4	3	20	2
5	1	21	1
6	1	22	2
7	1	23	1
8	2	26	1
9	1	28	1
10	2	29	2
12	2	30	1
13	1	32	3
14	2	902	2
15	1	903	0
16	1	904	1
17	2		

Even though transportation vulnerability is the core topic in our thesis, the performance measures are not based on the accessibility of the routes since these types of measures are suitable for post-disaster situations [17]. However, we use two time-based performance measures to compare the results of the models [20]. Beamon and Balcik [21] also define three types of performance metrics crucial in humanitarian logistics; resources, output and flexibility. Since we assume that there is no capacity limitations in a specific area, we decide to use only the characteristics of output performance metrics in order to construct performance measures. Response time and number of items become crucial for this type of metrics. Thus, our measures are average travelling time per volume of the relief items, which is called PM1, and demand amount fulfilled by time (*t*) since the disaster hit, called PM2(*t*).

5.1 PM1 - Average Travelling Time per Volume of the Relief Items:

To calculate PM1, it is assumed that the relief items are carried by trucks with an average speed of 30 km/h since after the earthquake the chaotic environment is expected to bring bad road conditions and unorganized urban behavior. No transportation capacity limitation is considered; before the earthquake hits the region sufficient number of trucks are assumed to be prepared. To continue with the calculation, the multiplication of total distance and demand is obtained using the distances of the routes and the demand amount through these routes. Note that the total distance of a route is the distances inflated by vulnerability rates if vulnerability is considered in the model used. This calculation is then divided by the multiplication of the average speed of the trucks and total demand, and the average travelling time in hours per volume of the relief item is obtained.

5.2 PM2(*t*) – Demand Amount Fulfilled by Time *t*:

In disaster management, average travelling time is a valuable measure since it is important to deliver all relief items in a short time. However, it is not enough to measure the performance of the pre-positioning network. It is also crucial to satisfy the needs of each demand location in a very short time. As a result, another performance measure is considered in this thesis, fulfillment time of the demand at districts. When the demand locations are fulfilled for all demand, they are said to be satisfied.Satisfaction times are also considered in the thesis. An average speed of a truck is needed in this calculation also and taken as 30 km/h like in the previous measure. Taking the average speed into consideration only, expected distances that can be reach by time *t* are derived at **Table 5. 2**:

Table 5. 2 Expected Distance by Time *t*

Time (min)	Distance (km)	Time (min)	Distance (km)
15	7.5	*120*	60
30	15	*135*	67.5
45	22.5	*150*	75
60	30	*165*	82.5
75	37.5	*180*	90
90	45	*195*	97.5
105	52.5	*210*	105

Then, distances and the inflated distances of the routes chosen out by the models are investigated to find out how much demand can be satisfied at demand locations by a certain time after the disaster hit.

5.3 Comparison of the Models

Table 5. 3 shows the warehouse locations obtained by the models for a 5-warehouse network:

Table 5. 3 Warehouse Locations for Different Relief Items

Note	M	Tent		Medical Supply		Water	
No Vuln.	1	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE
		13	EYÜP	13	EYÜP	13	EYÜP
		17	KADIKÖY	17	KADIKÖY	17	KADIKÖY
		18	KARTAL	18	KARTAL	18	KARTAL
		20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE
No Warehouse Vuln.	2	3	BAHÇELİEVLER	3	BAHÇELİEVLER	3	BAHÇELİEVLER
		9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE
		13	EYÜP	13	EYÜP	16	GAZİOSMANPAŞA
		17	KADIKÖY	17	KADIKÖY	17	KADIKÖY
		18	KARTAL	18	KARTAL	18	KARTAL
Full Vuln.	3	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE
		16	GAZİOSMANPAŞA	13	EYÜP	16	GAZİOSMANPAŞA
		17	KADIKÖY	17	KADIKÖY	29	ÜMRANİYE
		18	KARTAL	18	KARTAL	18	KARTAL
		20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE

In **Table 5. 3**, the warehouse locations are given with the color coded vulnerability level of these locations. Note that the vulnerability levels mentioned in this section are the average of transportation mean vulnerability levels and the warehouse building vulnerability levels. When the color of the district is darker, vulnerability of the districts is higher. Models show no differences in the vulnerability levels for the districts having warehouses. When the models are compared, Gaziosmanpaşa becomes more advisable by Model 3 to be opened instead of Eyüp and Bahçelievler, respectively. Similar to these, Ümraniye may become more preferable rather than Kadıköy. There is another finding that Küçükçekmece is not preferable to be opened when only the transportation vulnerability is considered (Model 2). However, whenever the warehouse building vulnerability is also considered in the model, Küçükçekmece becomes significant to be opened.

To compare the models with respect to performance measures, we take the suggested routes and the demand sent through these routes in Model 1, 2 and 3, and calculate the performance results using the inflated distances used in Model 3. The inflationary factors used are the transportation mean and warehouse building vulnerability rates, since we want to investigate the vulnerability effect on the network and see how different allocations behave under the same vulnerability conditions.

Table 5. 4 Performance Measures for Models with 5-Warehouse

	PM1 (min)	Satisfaction Time of All Districts (min)	Satisfaction Time for Tent (min)	Satisfaction for Med. Supply (min)	Satisfaction Time for Water (min)
Model 1	33.92	128.6	128.6	128.6	128.6
Model 2	33.91	128.3	128.3	128.3	128.3
Model 3	32.69	128.3	107.2	128.3	107.2

As expected, Model 3 gives the best result for the average inflated travelling time per volume of relief items shown in **Table 5. 4** although the inflated travelling times are close to each other for all models.

Performance measure two is also investigated for these models. **Table 5. 4** shows that Model 3 is again the best for satisfying the demand of the districts in a shorter time. The significance is obtained in the satisfaction of tent and water demand and the satisfaction time for these relief items decreases by 16% with Model 3 compared to Model 1 and 2.

For all models, the delivery time distribution of the relief items through time scale is also calculated and provided in **Figure 5. 1**. In the delivery time distribution of relief items, Model 1 and Model 3 show similar behavior since the warehouse locations for these two models are also similar. On the other hand, considering only combined transportation mean vulnerability like in Model 2 gives the worst results. Hence, opening a warehouse in Bahçelievler as suggested with Model 2 is not preferable and Küçükçekmece is a better choice (as suggested by Model 1 and 3) when the distance, demand and vulnerability are considered together.

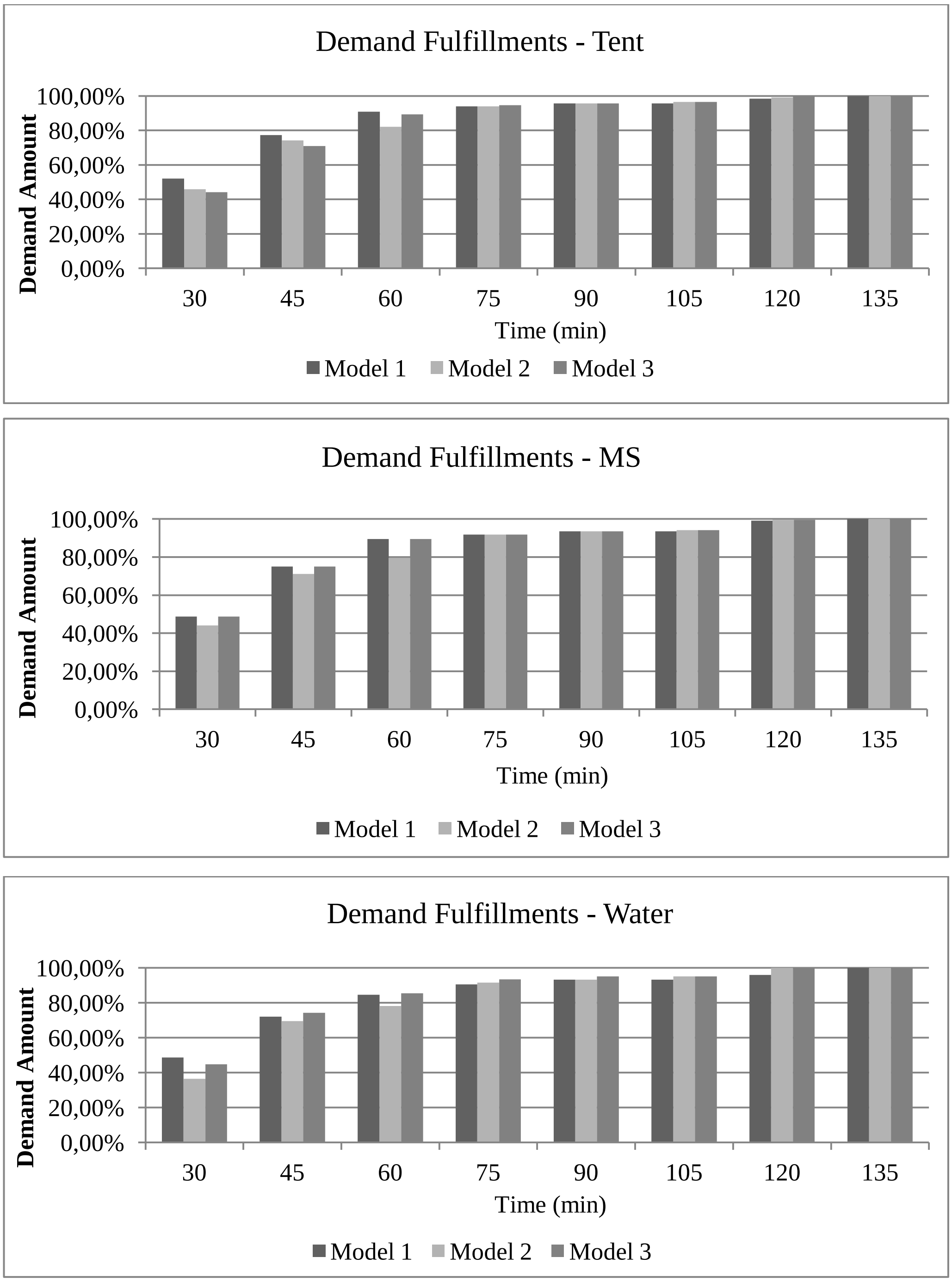
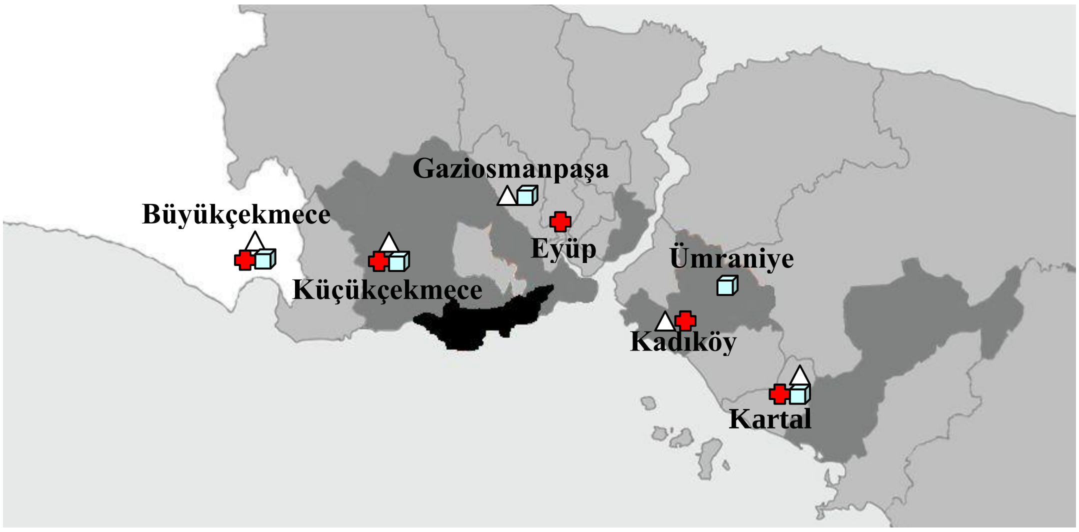


Figure 5. 1 Demand Fulfillments for All Relief Items

5.4 Five-Warehouse Pre-positioning Network

After investigating the performance measures of all models considered so far, Model 3 is the suggested model of this thesis. Therefore, various comparisons and sensitivity analysis about this model are to be held in the later sections. Before that, the result of Model 3 for five-warehouse needs to be analyzed. As indicated in **Table 5. 3.**, the warehouses are opened in Büyükçekmece, Gaziosmanpaşa, Eyüp and Küçükçekmece for West Side, in Kartal, Kadıköy and Ümraniye for East Side. In Model 3, for each relief item type at most 5 warehouses can be located and for each relief item type these locations can be different. Hence it is resulted that there are totally seven warehouse locations suggested by Model 3.

The locations are given in **Figure 5. 2,** where low vulnerability levels are colored light colors and the highest vulnerability is shown as black. It is observed that in Büyükçekmece, Küçükçekmece and Kartal, all of the item types are stored.



△ : *Tent Warehouse*

✚ : *Medical Supply Warehouse*

□ : *Water Warehouse*

Figure 5. 2 Warehouse Locations Suggested by Model 3 with Five-Warehouse

In Model 3, the capacities are unlimited, to ensure the model to give feasible solutions. Thus, the warehouse capacities are equal to the total supply sent from a warehouse to the demand locations. The supply amounts that are sent to the demand points from the warehouse locations are given in m^3 in **Table 5. 5**.

Table 5. 5 Inventory Amounts by Model 3

Districts	Tent	Medical Supply	Water	Total Amount
9	5,856	19	1,070	6,945
13	-	85	-	85
16	66,330	-	13,258	79,588
17	30,527	27	-	30,554
18	19,822	26	5,062	24,910
20	59,319	67	8,750	68,136
29	-	-	6,890	6,890

From **Table 5. 5**, it is understood that the biggest warehouse is opened in Gaziosmanpaşa. Moreover, the smallest warehouse is opened in Eyüp, which only stores medical supply. It is also found that since the West Side of the city is more crowded, the warehouses in West Side send in the amount of 154,754 m^3, whereas the ones in East Side send 62,354 m^3. If the relief items that can be sent from the same district is assumed to be kept in one warehouse, the sizes of the warehouses can be visualized as in **Figure 5. 3**.

In **Figure 5. 3**, the illustration only points out the locations of the warehouses. However, we can also visualize the volumes of the relief items stored in the warehouses, for the relief item type separately. **Figure 5. 4**, **Figure 5. 5** and **Figure 5. 6** show the warehouse locations and volumes of relief items stored in the warehouses and also reflect the assignment between warehouses and demand points. It is observed that for each relief item type five warehouses are opened; two of them in East Side and three of them in West Side since the demand and distances are larger in the West Side for all of the relief items.

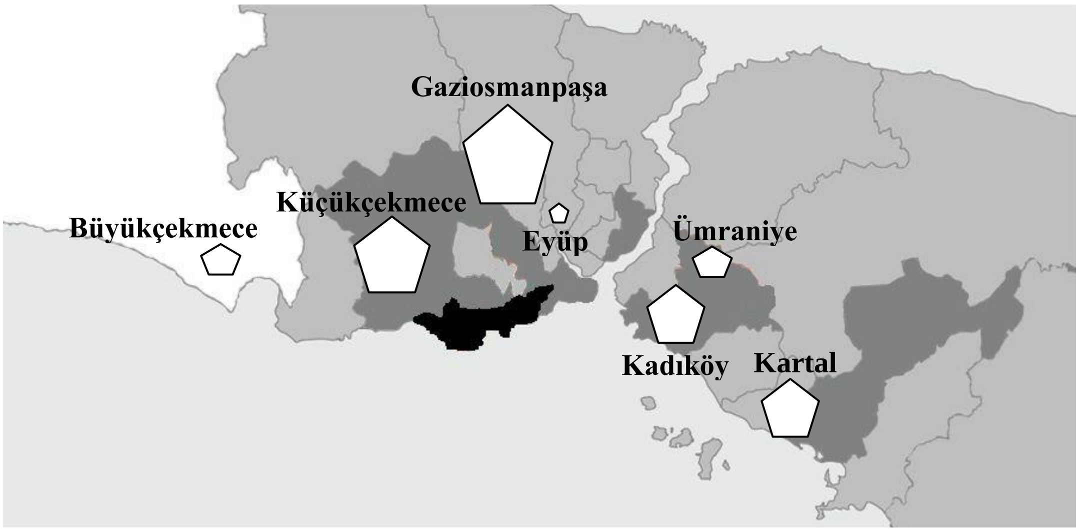


Figure 5. 3 The Sizes of the Warehouses by Model 3

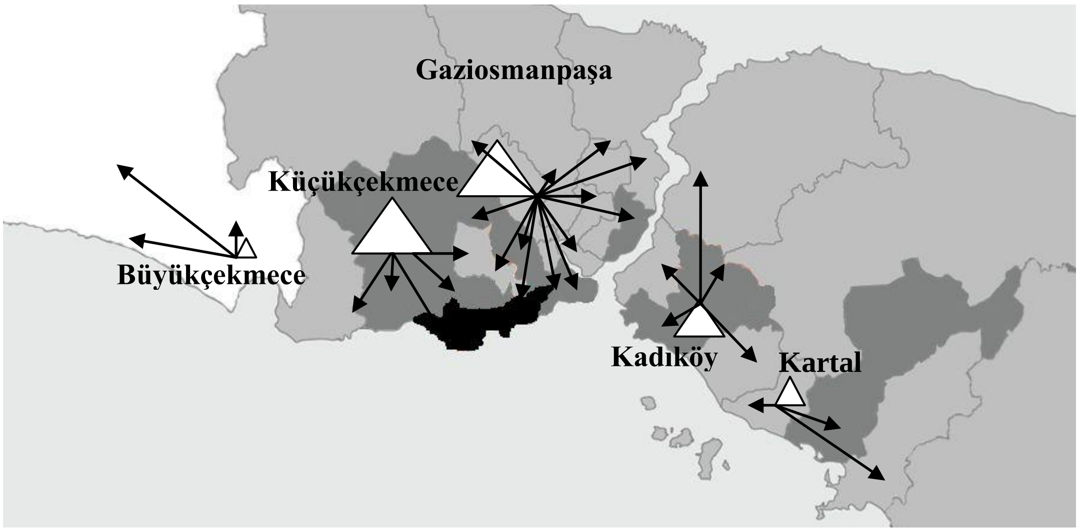


Figure 5. 4 Pre-positioning and Distribution of Tents by Model 3

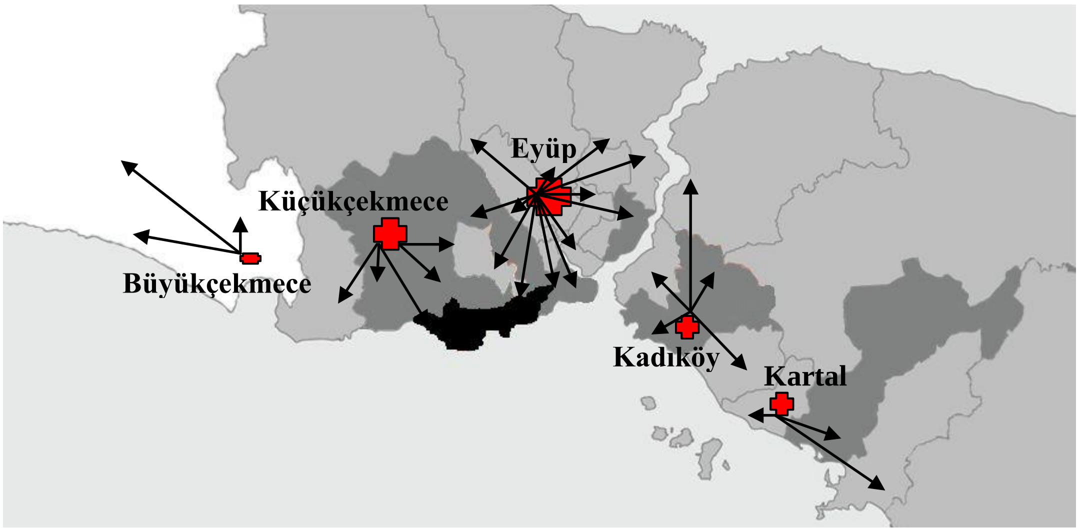


Figure 5. 5 Pre-positioning and Distribution of Medical Supply by Model 3

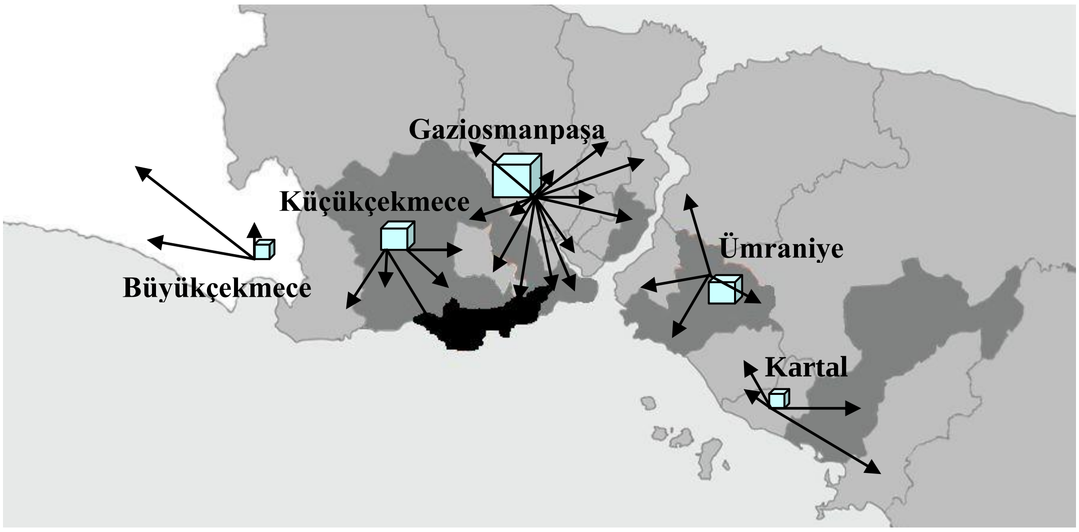


Figure 5. 6 Pre-positioning and Distribution of Water by Model 3

5.5 Final Pre-Positioning Network Configuration

Balcik and Beamon state that even though the increase in the number of warehouses in humanitarian logistics makes transportation of the relief items easy, there may be disadvantages of coordinating high number of [22]. Hence, we can consider the following question: Can we gather the relief item warehouses to decrease the warehouse number to operate. This may ease the management of these warehouses. Hence, it can be concluded that opening a warehouse in Büyükçekmece, Küçükçekmece and Kartal that stores all relief item types is feasible and also advantageous in reducing the investment cost. In Gaziosmanpaşa and Kadıköy, instead of having four separate warehouse buildings, two warehouse buildings can be constructed in order to reduce the investment cost, similarly.

If we continue with that idea there will be no warehouses in Eyüp and Ümraniye. However, the relief items, supplied from these warehouses according to Model 3 results, should be stored in other warehouses. In order to find which warehouses need to get larger and if it is reasonable to gather the relief item warehouses, Model 3 is run for two times more.

In the first run, the warehouse in Eyüp district is closed. The objective got worse by less than 0.1% and the relief items suggested to be held in Eyüp district by Model 3 is now assigned to the warehouse in Gaziosmanpaşa. Hence, the warehouse in Gaziosmanpaşa is also suggested to keep all relief item types like Büyükçekmece, Küçükçekmece and Kartal.

In the second run, Ümraniye is omitted as a warehouse in the original Model 3. At this time, the model suggests that Üsküdar should keep the water instead of Ümraniye. However, we want to gather the relief item warehouses to ease the coordination between the warehouses. Hence, Üsküdar is also omitted and the model is run again. The objective gets worse by around 0.5% and Kadıköy and Kartal satisfy all the relief items demanded by East Side of the city.

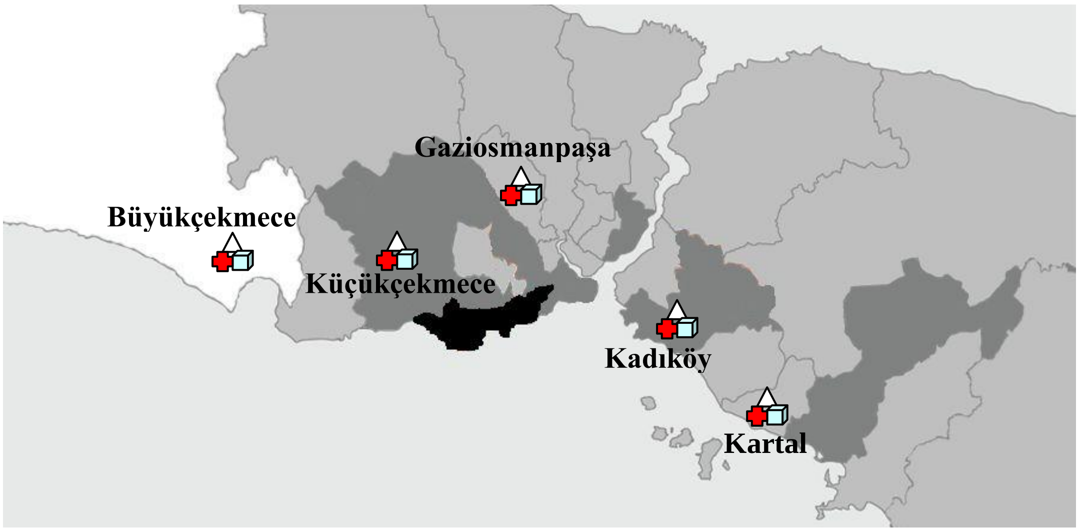
Since the omitted warehouses (Eyüp and Ümraniye) are in the different sides of the city and these sides are not connected, these runs can be applied individually. Moreover, at the end of each run the objective gets worse within a reasonable limits which is around 0.5%. Note that since there is no connection between the sides, if the districts (Eyüp, Ümraniye and Üsküdar) are omitted together the objective also increases by no more than 1%.

As a result, by gathering the relief item warehouses together for the sake of efficient coordination and good management, all warehouses store all types of relief items. The amounts of relief items that are stored and the warehouses in the final network configuration are shown in **Table 5. 6**.

Table 5. 6 Inventory Amounts by Final Network Configuration

Districts	Tent	Medical Supply	Water	Total Amount
9	5,856	19	1,070	6,945
16	66,330	85	13,258	79,673
17	30,527	27	8,248	38,802
18	19,822	26	3,704	23,552
20	59,319	67	8,750	68,136

This final network configuration constitutes from Büyükçekmece, Gaziosmanpaşa and Küçükçekmece in West Side of the city, and Kadıköy and Kartal in East Side of the city as observed from **Figure 5. 7**.



△: *Tent Warehouse*

✚: *Medical Supply Warehouse*

▢: *Water Warehouse*

Figure 5. 7 Warehouse Locations by Final Network Configuration

According to the final network configuration and **Table 5. 6**, the volumes of the warehouses and the assignments of the demand locations can also be visualized as in **Figure 5. 8**. The largest warehouse is opened in Gaziosmanpaşa and the smallest one is in Büyükçekmece; both are in the West Side of the city. The warehouses opened in Kadıköy and Kartal are moderately large compared to the warehouses in West Side.

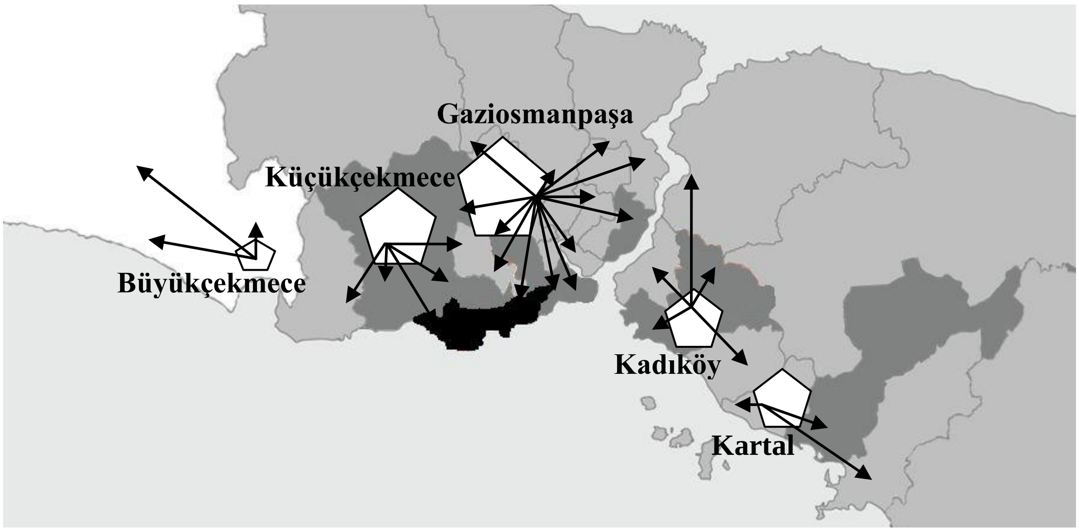


Figure 5. 8 Final Network Configuration

5.6 Literature Comparison

As mentioned before, the most similar study in the literature is Görmez's study [16]. In that study, Görmez considers no transportation mean vulnerability, which is a significant consideration in our thesis. In Görmez's study, there are various models considered such as different capacities, different warehouse numbers, different earthquake scenarios. The most similar result obtained in that study, which is comparable to Model 3, is the result of five fixed facilities model. Since, the demand pattern used in that model is parallel to the demand pattern of water in our study, water distribution is to be investigated in order to compare our study and Görmez's. Morever, in Görmez's study Büyükçekmece, Çatalca and Silivri districts are not taken into the consideration. Hence, excluding these districts Model 3 is run again and these results are referred as Model 3's modified results in **Table 5. 7**.

Table 5. 7 Comparison of Locations Chosen

Models	Districts		PM1 (min)
Results Görmez [16]	2	AVCILAR	29.76
	3	BAHÇELİEVLER	
	18	KARTAL	
	19	KAĞITHANE	
	30	ÜSKÜDAR	
Model 3 Modified	16	GAZİOSMANPAŞA	28.56
	18	KARTAL	
	19	KAĞITHANE	
	20	KÜÇÜKÇEKMECE	
	29	ÜMRANİYE	

The model of Görmez [16] opens warehouses in Avcılar, Bahçelievler and Kağıthane for West Side and in Kartal and Üsküdar for East Side, whereas Model 3's modified results suggest openning in Gaziosmanpaşa, Kağıthane and Küçükçekmece for West Side and in Kartal and Ümraniye for East Side. Comparing these two results based on the vulnerability levels of the districts there is no apparent distinction. Hence, we need to check out the performance measures.

According to **Table 5. 7** the average travelling time to fulfill all demand points by modified Model 3 is less than Görmez's relief item distribution [16]. However, one minute may not be considered as a very significant difference, hence performance measure 2 is also investigated and its results are given **Figure 5. 9**.

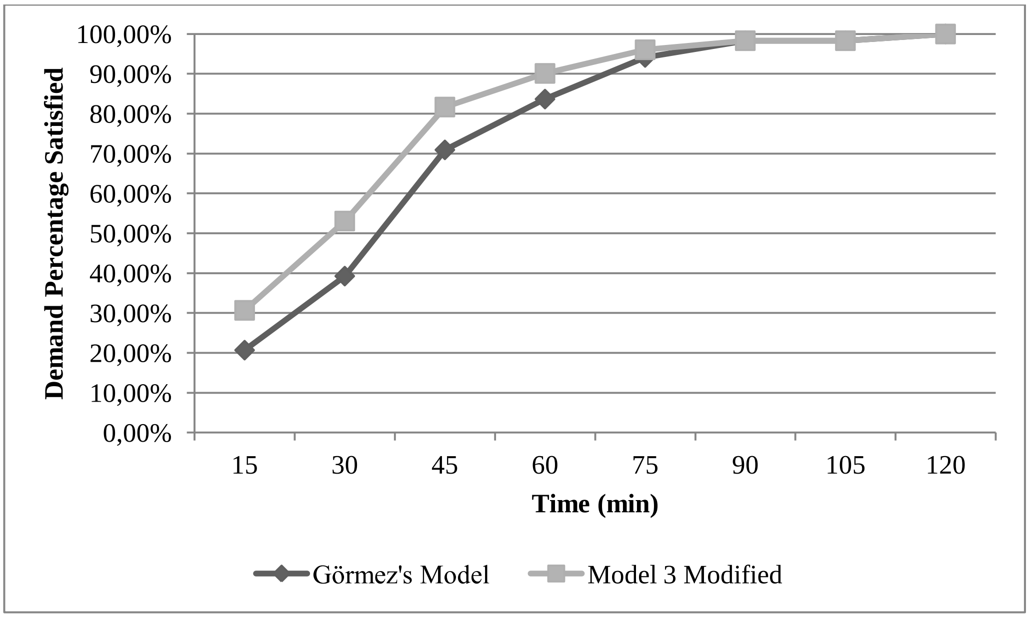


Figure 5. 9 Demand Satisfaction According to Time

As observed from **Figure 5. 9**, for the first 45 minutes modified Model 3 satisfies around 10% more demand than Görmez's network [16]. Only after 75^{th} minute, Görmez's network suggestion comes closer to pre-positioning network performance suggested by Model 3. However, both suggestions reach full satisfaction of demand points at 107.12 minutes after the disaster. Hence, these results indicate that we can achieve better results since Model 3 also considers vulnerability conditions.

There is another point worth to be mentioned. Görmez [16] results are based on existing potential facility locations given by Istanbul Metropolitan Municipality (IMM). **Figure 5. 10** illustrates these potential facilities. In that study, the potential warehouse locations are only taken as those points for 5-warehouse case. Moreover, it can be easily observed that not all districts are taken as potential warehouse locations. However, modified Model 3's results suggest having warehouses in Gaziosmanpaşa, whereas there is no potential warehouses in that district at **Figure 5. 10**. Hence, it can also be claimed that potential warehouse locations considered to be opened by IMM are not enough, and all districts should be a potential facility location.

Figure 5. 10 Potential Facility Location Provided by IMM [16]

CHAPTER 6

SENSITIVITY ANALYSIS

6.1 Warehouse Number

It is worth to mention how the number of warehouses is decided as five. For Model 3, which is the full vulnerability considered model, **Figure 6. 1** illustrates the objective function results for various warehouse numbers.

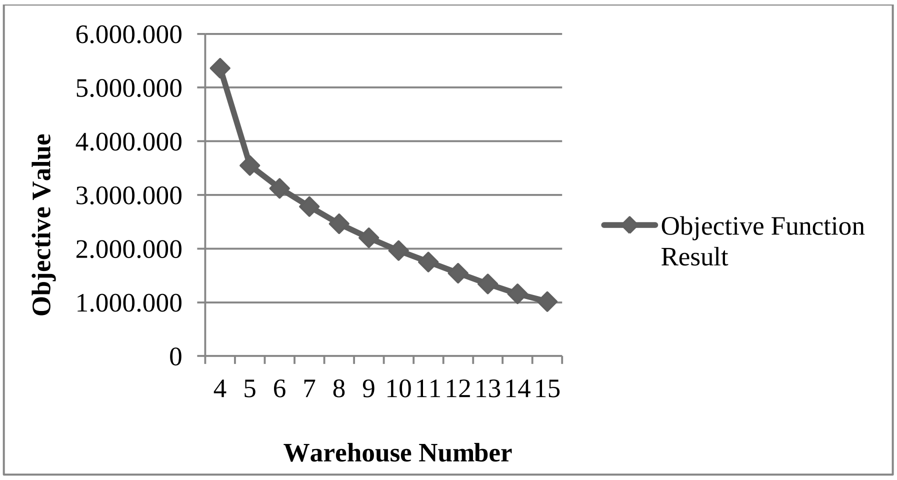
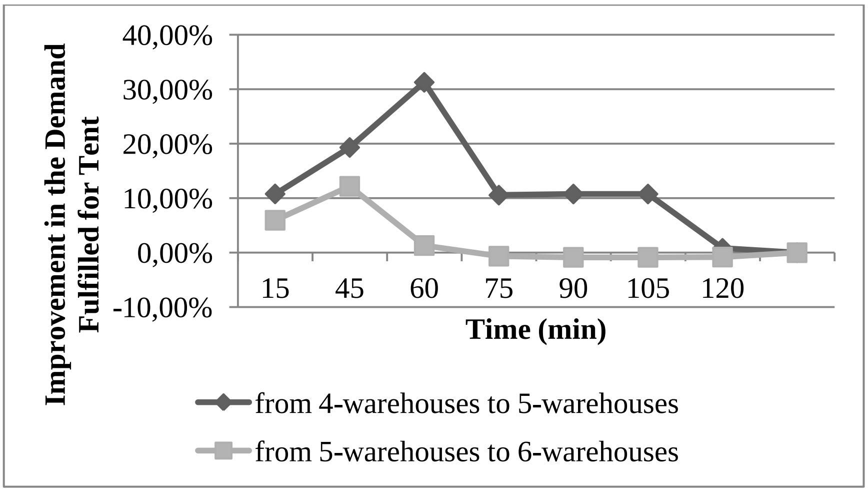
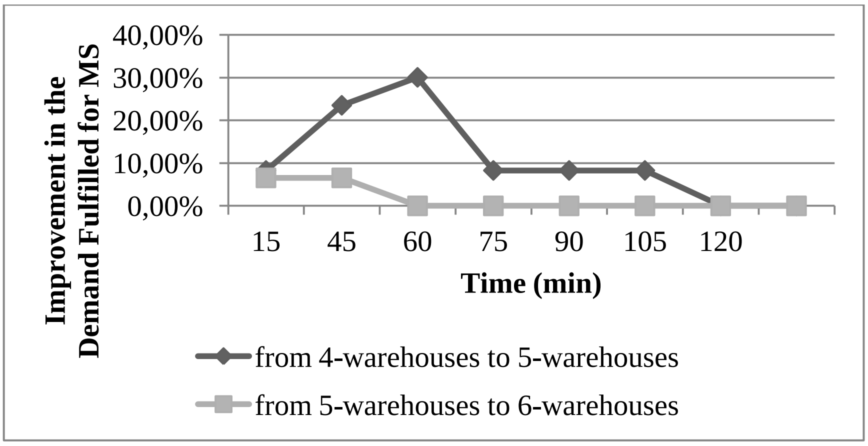


Figure 6. 1 Improvement in the Objective Function Values for Different Number of Warehouses

As observed in **Figure 6. 1**, from four warehouses to five warehouses there is more than 30% decrease in the objective function, the highest decrease among all other warehouse increments, which is generally around 10%. It is also worth to mention that since the warehouses are central we expect the number of warehouses to be not many [23]. It can be observed from **Figure 6. 2**, to open an additional warehouse has much more increase in the demand satisfied at a time *t* for all relief items when the number of warehouse is four rather than it is five. Performance measure 2 also validates the choice of five-warehouse network.





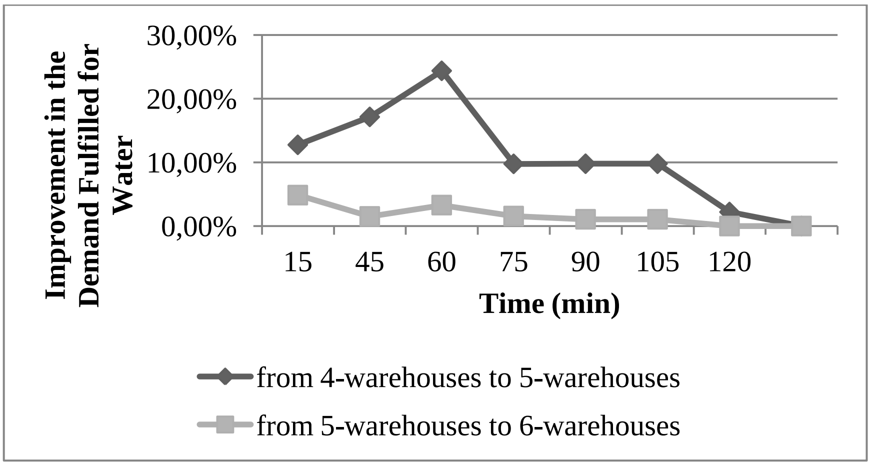


Figure 6. 2 Percentage Improvement in Performance Measure Two

6.2 In-District Distribution

In all models considered so far, warehouses are located at center locations of the districts and the demand points are also assumed to be at the center of the districts since the focus was on locating the central warehouses. However, in the actual response phase, these central warehouses should send the relief items to more local locations where the citizens can reach them easily, such as local parks, schools, hospitals etc. where the citizens come together after the earthquake hit [24]. These local locations are called sub-districts.

In Model 3, warehouses send relief items only to the center of the districts as in **Figure 6. 3**. In this distribution policy, when the relief items reach the center of the demanding districts, it is assumed that the demands are satisfied for that district.

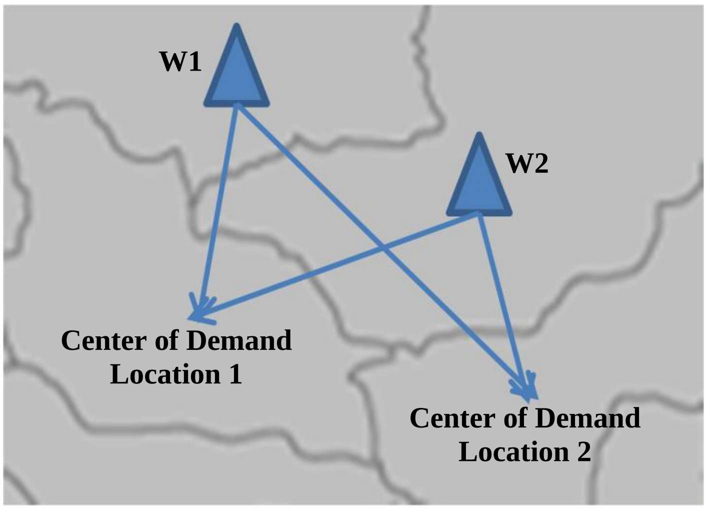


Figure 6. 3 Distribution Scheme from Central Warehouses at Model 3

However, in local distribution policy illustrated in **Figure 6. 4**, when the central warehouses send relief items to the center of the demanding district, it is not assumed that all of the demands are fulfilled for that district, since the second stage of the distribution is to be realized and the relief items are sent from the center of the demanding districts to its sub-districts. Moreover, while central warehouses send relief items to demanding districts they also send relief items to the sub-districts of its own district. Hence, with the consideration of the local distribution policy, PM1 and PM2(*t*) are expected to be larger values. The transportation of relief items from warehouses located at district centers to these sub-districts can be considered as parameters since including this in the objective function will not change the optimal central warehouse locations found by Model 3. Hence, using the warehouse locations predicted by Model 3 and these sub-districts, these two performance measures are re-calculated.

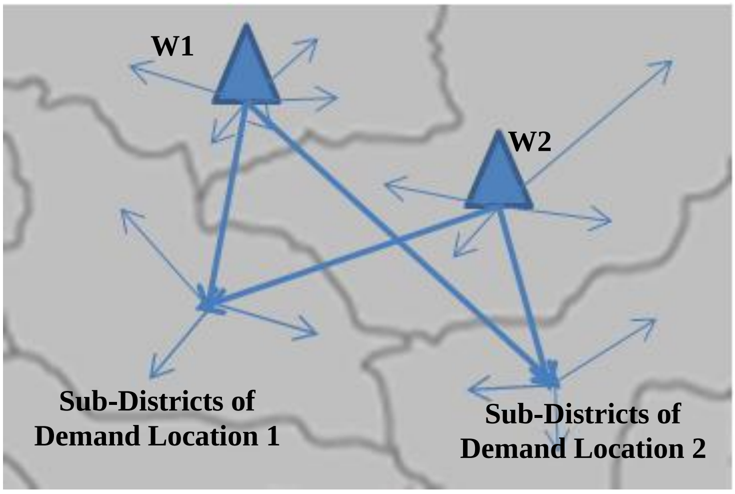


Figure 6. 4 Local Distribution Policy from Central Warehouses

The number of sub-districts considered in our study is given in **Table 6. 1**. The data on sub-districts are gathered from TÜİK 2013 population report for Istanbul, which declares the results of population census in 2012 [4] and these data are used to calculate the performance measures.

Table 6. 1 Number of Sub-Districts Within Districts

Dist. No	Number of Sub-Districts	Dist. No	Number of Sub-Districts
2	10	**18**	20
3	11	**19**	19
4	15	**20**	24
5	22	**21**	17
6	25	**22**	30
7	45	**23**	27
8	23	**26**	27
9	6	**28**	10
10	11	**29**	35
12	26	**30**	26
13	20	**32**	13
14	30	**902**	16
15	11	**903**	9
16	14	**904**	17
17	21		

Average travelling time per volume of the relief items, PM1, increases by 50% when the sub-districts are considered and when the truck speed remains at 30 km/h. Moreover, demand amount fulfilled changes for each relief item as presented in **Figure 6. 5**.

For all relief items, the warehouses can satisfy all demand locations considering the sub-districts in 175.54 min. However, when warehouses were only feeding the center of the districts this performance measure was 107.2 min for tent and water, 128.3 min for medical supply. Thus, there is more than 35% increase in the fulfillment times of the demand for all relief items.

Other models, Model 1 and 2, are also analyzed with sub-districts and as expected the similar behavior is observed as in **Figure 6. 5**. Because of the insignificance, those results will not be discussed in this thesis.

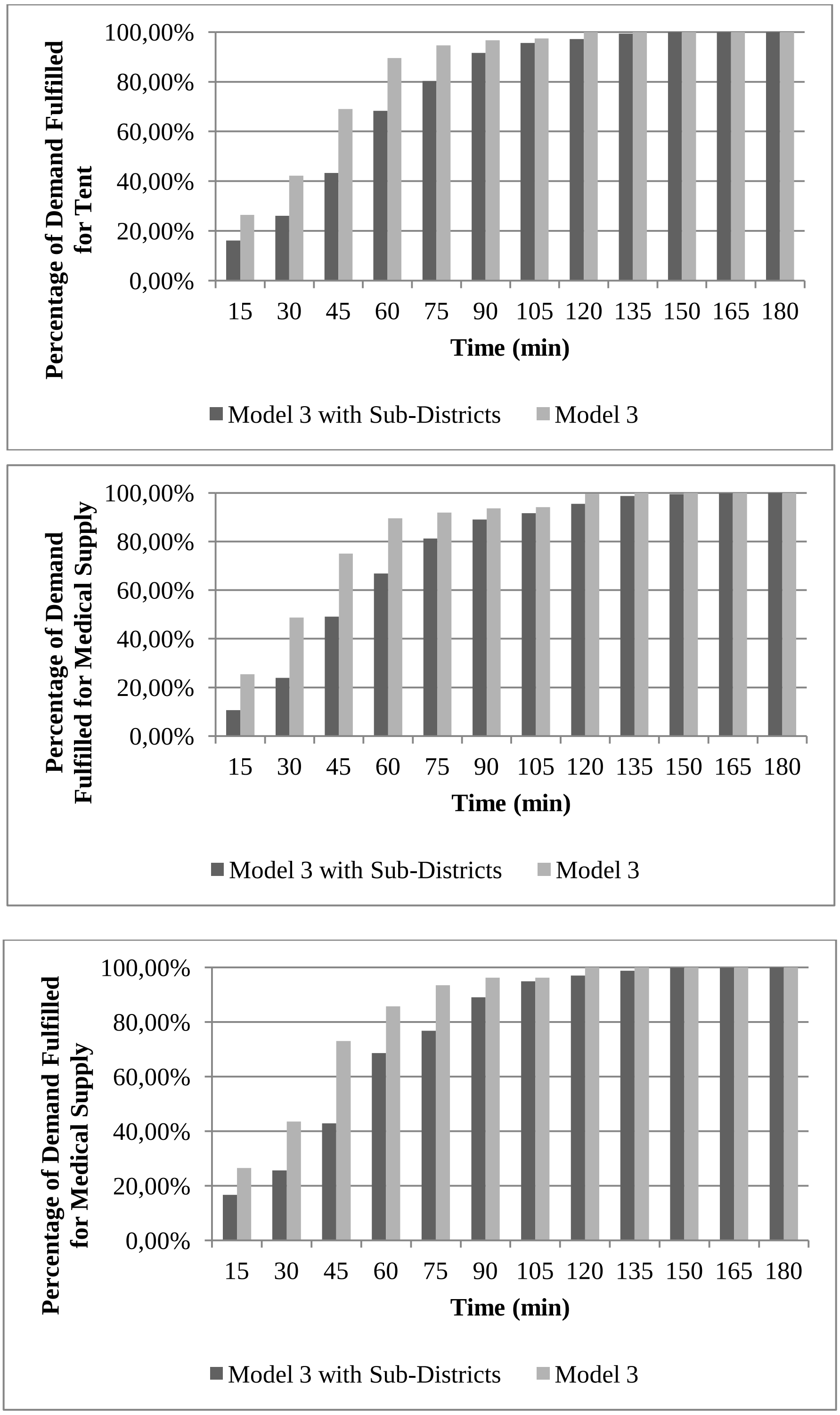


Figure 6. 5 Percentage of the Demand Fulfilled With In-District Distribution

6.3 Earthquake Impact Variability

Model 3 considers only one earthquake scenario. However, there is a possibility to include the impact of different earthquake magnitudes. For example, an earthquake may have magnitude of 4.1 or 6.1. Moreover, these different magnitudes have different impacts on the warehouse building and transportation mean vulnerability. Since different magnitudes will have various vulnerability impacts, in order to reflect this variability, Model 3 is run for several times with different vulnerability rates. Remember that the vulnerability rates used in Model 3 is scaled between 1 and 2. To observe the sensitivity with different impacts, these rates are inflated by increasing the upper limit of the scale from 2 to 20.

When the upper limit is changed from 2 to 3, the warehouse locations suggested by Model 3 changes a little. However, when the upper limit is 4 or more than 4 the model suggests same warehouse locations for all relief items which are shown in **Table 6. 2**, indicating stability. **Table 6. 2** also shows the vulnerability levels with the colors. When the vulnerability scale is very large, it is observed that model suggests Çatalca which has no vulnerability by assumption. On the other hand, the other districts are more vulnerable with larger scales compared to the scales [1, 2] and [1, 3].

What are the other differences between these different vulnerability scales? Since the warehouse locations are different, the performances also differ. **Table 6. 3** shows the average travelling time of the relief items and satisfaction time of the demands. When the scale is very large, PM1 gives the worst results. However, for the satisfaction times of the demand for each relief item type, we obtain the best with larger scales, although the differences among scales are not very significant.

Table 6. 2 Warehouse Locations Suggested by Model 3 with Different Vulnerability Scales

Vuln. Scale	Warehouses					
	Tent		Medical Supply		Water	
1-2	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE
	16	GAZİOSMANPAŞA	13	EYÜP	16	GAZİOSMANPAŞA
	17	KADIKÖY	17	KADIKÖY	29	ÜMRANİYE
	18	KARTAL	18	KARTAL	18	KARTAL
	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE
1-3	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE	16	GAZİOSMANPAŞA
	16	GAZİOSMANPAŞA	16	GAZİOSMANPAŞA	18	KARTAL
	17	KADIKÖY	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE
	18	KARTAL	22	PENDİK	29	ÜMRANİYE
	20	KÜÇÜKÇEKMECE	29	ÜMRANİYE	903	ÇATALCA
1-n, n≥4	16	GAZİOSMANPAŞA	16	GAZİOSMANPAŞA	16	GAZİOSMANPAŞA
	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE
	22	PENDİK	22	PENDİK	22	PENDİK
	29	ÜMRANİYE	29	ÜMRANİYE	29	ÜMRANİYE
	903	ÇATALCA	903	ÇATALCA	903	ÇATALCA

Table 6. 3 Performance Measure Results of Model 3 with Different Vulnerability Scales

Vuln. Scale	PM1 (min)	Satisfaction Time of All Districts (min)	Satisfaction Time for Tent (min)	Satisfaction for Med. Supply (min)	Satisfaction Time for Water (min)
1-2	32.69	128.3	107.2	128.3	107.2
1-3	32.96	110.5	110.5	110.5	107.1
1-n, n≥4	35.79	105.8	105.8	105.8	105.8

6.4 Minimizing the Maximum

In Model 3, total multiplication of demand, distance and vulnerability is minimized. However, another concern is that while minimizing the total effect, if there are very large values for some routes minimizing the maximum can be required to be investigated. Daskin et al. [25] propose a method for p-median problem by minimizing α-reliable maximum regret, which is claimed as not a useful method for many cases [26]. Hence, Model 3 is modified in a traditional way to that its objective function is changed into Function (6.9) and Constraint Set (6.10) are added to the model.

Modified Objective Function

$$MIN \quad A \tag{6.9}$$

New Constraint

$$\sum_i \sum_k (x_{i,j,k} * dvx_{i,j} + y_{i,j,k} * dvy_{i,j}) * S_{j,k} \leq A \ \forall j \tag{6.10}$$

Hence, in this new modified model, A indicates the largest value among the multiplications of demand, distance and vulnerability of all possible routes.

Table 6. 4 gives the assignments of warehouse locations with vulnerability levels as color coded according to the Model 3 and the new modified Model 3. As observed, there is no significant difference between the vulnerability levels of the suggested warehouse locations. To inquire more on modified model, two performance measures are also calculated.

Table 6. 4 Warehouse Locations Predicted by Model 3 (Min) and Modified Model 3 (MinMax)

Note	t		m		w	
Model 3 (Min)	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE
	16	GAZİOSMANPAŞA	13	EYÜP	16	GAZİOSMANPAŞA
	17	KADIKÖY	17	KADIKÖY	29	ÜMRANİYE
	18	KARTAL	18	KARTAL	18	KARTAL
	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE	20	KÜÇÜKÇEKMECE
Modified Model 3 (MinMax)	20	KÜÇÜKÇEKMECE	2	AVCILAR	5	BAĞCILAR
	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE	9	BÜYÜKÇEKMECE
	13	EYÜP	13	EYÜP	13	EYÜP
	17	KADIKÖY	17	KADIKÖY	17	KADIKÖY
	18	KARTAL	18	KARTAL	18	KARTAL

Table 6. 5 gives the performance measure results. As it is seen, Model 3 results are better than the modified model for all relief items. Moreover, it is also better with average time to travel for total demand to be satisfied. The satisfaction of demand in percentage by time is also given in **Figure 6. 6** in this sense.

Table 6. 5 Performance Measure Results of Model 3 and Modified Model 3

Model	PM1 (min)	Satisfaction Time of All Districts (min)	Satisfaction Time for Tent (min)	Satisfaction Time for Med. Supply (min)	Satisfaction Time for Water (min)
Model 3 (Min)	32.69	128.3	107.2	128.3	107.2
Modified Model 3 (MinMax)	38.08	133.9	128.6	133.9	133.9

All of these results indicate that minimizing the total multiplication of demand, distance and vulnerability is a better objective function than minimizing the maximum of the multiplication of demand, distance and vulnerability in many respects in order to obtain the potential locations for pre-positioning in Istanbul.

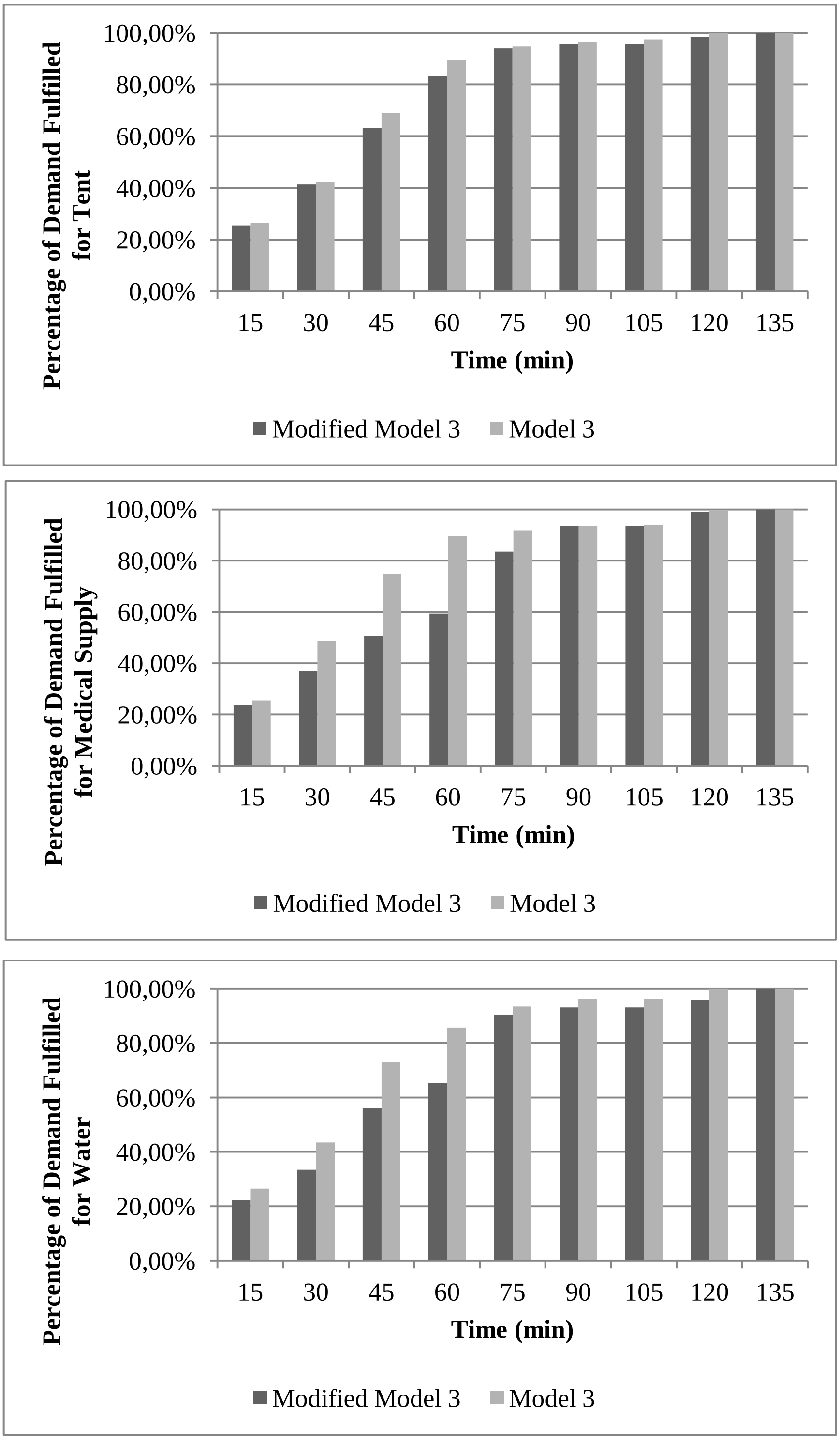


Figure 6. 6 Percentage of Demand Fulfilled for Relief Item

CHAPTER 7

THE CONCLUSION

In the thesis, emergency supply pre-positioning considering the vulnerability for an expected earthquake in Istanbul is inquired. The models are applied to Istanbul considering two sides of the city. They are connected to each other with two main bridges. Since the main point is to consider vulnerability in this thesis, each side is evaluated separately. Moreover, the number of central warehouses to open is given to the model as a parameter. Since each side of the city is evaluated separately and because of upper limit of the distances between districts, at least 2 warehouses for each side are to be opened in the model.

All models in the study consider three relief items needed after earthquake, which are tent, medical supply and water. All assumptions are held as same for these relief items among different models. The models are compatible to each other with respect to two main performance measures: PM1 – average traveling time per volume of the relief items and PM2(t) – demand amount fulfilled by time t. Moreover, the vulnerability levels of the districts are also discussed during the comparisons.

After the comparisons, Model 3 stands out as a final model in this thesis. This model especially concerns combined transportation mean vulnerability and warehouse building vulnerability. Hence, it includes narrow road and bridge percentages of the districts. The multiplication of combined transportation mean vulnerability, distance and demand is the objective function of the model. Moreover, warehouse building vulnerability is considered by inflating this multiplication in the objective function.

In the thesis, the comparisons with the most similar study in the literature are also performed. Our findings show that our model gives better warehouse locations in performance measures when the vulnerability is considered.

As the last chapter of this thesis, sensitivity analyses considering the warehouse number, in-district distribution policy of relief items, earthquake impacts, and objective function types are taken place.

Several warehouse numbers are considered in Model 3 and changes in the objective function values and improvements in the performance measure results are analyzed for different warehouse numbers. Model 3 gives the best results when the warehouse number to open is five.

Additionally, although the model focuses on the central warehouse locations, local distribution of the relief items from center of demand points to sub-districts are also worth consideration. We calculated more than 35% increase in the satisfaction time when the in-district distribution is taken into consideration; the relief items are sent to the sub-districts.

Moreover, the vulnerability rates are taken in different ranges in Model 3, thus the change in the earthquake impact is investigated through vulnerability levels. It is observed that the scale of the vulnerability rates affect the results of Model 3. However, when upper limit of the scale is larger than 3, the model suggests same warehouse locations, which are Gaziosmanpaşa, Küçükçekmece and Çatalca for West Side and Ümraniye and Pendik for East Side of the city. Hence, for given demand and distance the model becomes robust for different vulnerability rates.

Lastly, the objective function type is changed. In Model 3, the total multiplication of demand, distance and vulnerability is minimized. Besides that, the minimization of the maximum value of the multiplication of demand, distance and vulnerability of the routes is also studied.

Therefore, this thesis focuses on vulnerability and usage of vulnerability in the location models for a reasonable and feasible emergency supply pre-positioning in Istanbul. However, it does not address the question of how many warehouses to open are optimal for Istanbul since the pre-positioning warehouses act as distributors with unlimited capacity. But, sensitivity analysis is taken place about such issues to touch the fringes.

Moreover, the study in this thesis is based on the data and information of the JICA Report [3] which was prepared in 2001. There are updates in the number of districts, status of the bridges and buildings, which can affect the results of the study. Therefore, it is highly recommended that this study should be repeated with the updated data and information. Moreover, the future studies should also cover districts such as Çatalca and Silivri which were not applicable for vulnerability data.

Finally, it can also be noted that only land transportation is highlighted since the vulnerability is the main concern. However, it may also be useful to consider sea transportation for heavy relief items such as tent and air transportation for light relief items such as medical supply [27]. These types of transportation may not be affected by vulnerability, moreover they can decrease the burden of land transportation.

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APPENDIX A

THE ROUTE PROPERTIES

Table A.1 Distances of the Routes

Districts	From	To	Distance (km)
West Sıde of Istanbul			
AVCILAR	**2**		
Bahçelievler	2	3	**29.3**
Bahçelievler	2	3	**24.1**
Bakırköy	2	4	**16.5**
Bakırköy	2	4	**22.9**
Bağcılar	2	5	**24.4**
Bağcılar	2	5	**23.1**
Büyükçekmece	2	9	**15.1**
Büyükçekmece	2	9	**18.5**
Küçükçekmece	2	20	**14.4**
Küçükçekmece	2	20	**29.4**
Zeytinburnu	2	32	**24.6**
Zeytinburnu	2	32	**27.4**
BAHCELIEVLER	**3**		
Avcılar	3	2	**17.3**
Avcılar	3	2	**29.1**
Bakırköy	3	4	**9.2**
Bakırköy	3	4	**8.8**
Bağcılar	3	5	**7.6**
Bağcılar	3	5	**7.1**
Beyoğlu	3	7	**21.3**
Beyoğlu	3	7	**20**
Bayrampaşa	3	10	**17.8**
Bayrampaşa	3	10	**15.5**
Eminönü	3	12	**17.5**
Eminönü	3	12	**23**
Fatih	3	14	**21.5**
Fatih	3	14	**14.3**
Güngören	3	15	**6.1**
Güngören	3	15	**10**
Gaziosmanpaşa	3	16	**17.2**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Gaziosmanpaşa	3	16	**20.6**
Küçükçekmece	3	20	**5.9**
Küçükçekmece	3	20	**8.6**
Zeytinburnu	3	32	**16.2**
Zeytinburnu	3	32	**11.4**
Esenler	3	902	**14.8**
Esenler	3	902	**11.5**
BAKIRKOY	**4**		
Avcılar	4	2	**16.2**
Avcılar	4	2	**15.4**
Bahçelievler	4	3	**8.1**
Bahçelievler	4	3	**10**
Bağcılar	4	5	**13.5**
Bağcılar	4	5	**15.3**
Beyoğlu	4	7	**18.5**
Beyoğlu	4	7	**21**
Bayrampaşa	4	10	**18.2**
Bayrampaşa	4	10	**16.5**
Eminönü	4	12	**11.8**
Eminönü	4	12	**16.5**
Fatih	4	14	**15.3**
Fatih	4	14	**15.2**
Güngören	4	15	**11.6**
Güngören	4	15	**9.9**
Küçükçekmece	4	20	**8.6**
Küçükçekmece	4	20	**9.8**
Zeytinburnu	4	32	**8.6**
Zeytinburnu	4	32	**9.7**
BAGCILAR	**5**		
Avcılar	5	2	**22**
Avcılar	5	2	**24.3**
Bahçelievler	5	3	**8.7**
Bahçelievler	5	3	**6.9**
Bakırköy	5	4	**13.8**
Bakırköy	5	4	**13.1**
Bayrampaşa	5	10	**15.7**
Bayrampaşa	5	10	**13.7**
Eminönü	5	12	**18**
Eminönü	5	12	**23.2**
Fatih	5	14	**16.7**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Fatih	5	14	**21.9**
Güngören	5	15	**6.6**
Güngören	5	15	**15.8**
Gaziosmanpaşa	5	16	**12.3**
Gaziosmanpaşa	5	16	**14.8**
Küçükçekmece	5	20	**8.8**
Küçükçekmece	5	20	**11.1**
Zeytinburnu	5	32	**20.7**
Zeytinburnu	5	32	**18.3**
Esenler	5	902	**10**
Esenler	5	902	**7.1**
BEYOGLU	**7**		
Bahçelievler	7	3	**19.8**
Bahçelievler	7	3	**22.4**
Bakırköy	7	4	**20.4**
Bakırköy	7	4	**18.8**
Bağcılar	7	5	**19.7**
Bağcılar	7	5	**24.2**
Beşiktaş	7	8	**10.9**
Beşiktaş	7	8	**9.4**
Bayrampaşa	7	10	**10.7**
Bayrampaşa	7	10	**11.5**
Eminönü	7	12	**6.4**
Eminönü	7	12	**12.2**
Eyüp	7	13	**6.8**
Eyüp	7	13	**6.7**
Fatih	7	14	**5.2**
Fatih	7	14	**9.7**
Güngören	7	15	**13.8**
Güngören	7	15	**13.2**
Gaziosmanpaşa	7	16	**16**
Gaziosmanpaşa	7	16	**13.1**
Kağıthane	7	19	**5.7**
Kağıthane	7	19	**7.9**
Sarıyer	7	23	**25.6**
Sarıyer	7	23	**25.9**
Şişli	7	26	**16**
Şişli	7	26	**16.3**
Zeytinburnu	7	32	**13.4**
Zeytinburnu	7	32	**17**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Esenler	7	902	**16.7**
Esenler	7	902	**19.9**
BESIKTAS		**8**	
Beyoğlu	8	7	**11.6**
Beyoğlu	8	7	**8.5**
Bayrampaşa	8	10	**15.6**
Bayrampaşa	8	10	**23.3**
Eminönü	8	12	**17.1**
Eminönü	8	12	**12.9**
Eyüp	8	13	**11.7**
Eyüp	8	13	**16.9**
Fatih	8	14	**14.6**
Fatih	8	14	**11.6**
Güngören	8	15	**18.7**
Güngören	8	15	**25.6**
Gaziosmanpaşa	8	16	**20.7**
Gaziosmanpaşa	8	16	**21.2**
Kağıthane	8	19	**7.9**
Kağıthane	8	19	**10.9**
Sarıyer	8	23	**13.6**
Sarıyer	8	23	**17.5**
Şişli	8	26	**9.3**
Şişli	8	26	**15.1**
Zeytinburnu	8	32	**21.9**
Zeytinburnu	8	32	**19.9**
BUYUKCEKMECE		**9**	
Avcılar	9	2	**15.1**
Avcılar	9	2	**18.4**
Küçükçekmece	9	20	**23.3**
Küçükçekmece	9	20	**35.4**
Çatalca	9	903	**19.5**
Çatalca	9	903	**34.3**
Silivri	9	904	**31.1**
Silivri	9	904	**44.3**
BAYRAMPASA		**10**	
Bahçelievler	10	3	**19.9**
Bahçelievler	10	3	**16.1**
Bakırköy	10	4	**16.6**
Bakırköy	10	4	**19.1**
Bağcılar	10	5	**12.5**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Bağcılar	10	5	**15**
Beyoğlu	10	7	**11.5**
Beyoğlu	10	7	**16.2**
Beşiktaş	10	8	**15.8**
Beşiktaş	10	8	**21.4**
Eminönü	10	12	**8.2**
Eminönü	10	12	**9.1**
Eyüp	10	13	**5.5**
Eyüp	10	13	**6**
Fatih	10	14	**6.4**
Fatih	10	14	**6.9**
Güngören	10	15	**7.5**
Güngören	10	15	**10.6**
Gaziosmanpaşa	10	16	**4.8**
Gaziosmanpaşa	10	16	**5.5**
Kağıthane	10	19	**11.9**
Kağıthane	10	19	**15.1**
Küçükçekmece	10	20	**20**
Küçükçekmece	10	20	**23.2**
Sarıyer	10	23	**31.4**
Sarıyer	10	23	**30.7**
Şişli	10	26	**21.8**
Şişli	10	26	**21.1**
Zeytinburnu	10	32	**10.3**
Zeytinburnu	10	32	**13.7**
Esenler	10	902	**6.4**
Esenler	10	902	**9.5**
EMINONU	**12**		
Bahçelievler	12	3	**17**
Bahçelievler	12	3	**18.5**
Bakırköy	12	4	**15.4**
Bakırköy	12	4	**17.5**
Bağcılar	12	5	**16.6**
Bağcılar	12	5	**20.3**
Beyoğlu	12	7	**5.4**
Beyoğlu	12	7	**12.5**
Beşiktaş	12	8	**16.8**
Beşiktaş	12	8	**13.3**
Bayrampaşa	12	10	**7.7**
Bayrampaşa	12	10	**8.5**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Eyüp	12	13	**6**
Eyüp	12	13	**6.4**
Fatih	12	14	**2.2**
Fatih	12	14	**2.4**
Güngören	12	15	**9.2**
Güngören	12	15	**14.9**
Gaziosmanpaşa	12	16	**12.8**
Gaziosmanpaşa	12	16	**11.7**
Kağıthane	12	19	**12.9**
Kağıthane	12	19	**10.3**
Sarıyer	12	23	**31.7**
Sarıyer	12	23	**30.6**
Şişli	12	26	**22.1**
Şişli	12	26	**22**
Zeytinburnu	12	32	**10.1**
Zeytinburnu	12	32	**10.3**
Esenler	12	902	**13.7**
Esenler	12	902	**13.6**
EYUP	**13**		
Bahçelievler	13	3	**14.6**
Bahçelievler	13	3	**21.9**
Bakırköy	13	4	**15.2**
Bakırköy	13	4	**16.7**
Bağcılar	13	5	**14.5**
Bağcılar	13	5	**14.9**
Beyoğlu	13	7	**7.9**
Beyoğlu	13	7	**11**
Beşiktaş	13	8	**12.1**
Beşiktaş	13	8	**15.6**
Bayrampaşa	13	10	**5.6**
Bayrampaşa	13	10	**5**
Eminönü	13	12	**7.1**
Eminönü	13	12	**6.9**
Fatih	13	14	**4**
Fatih	13	14	**5.6**
Güngören	13	15	**8.6**
Güngören	13	15	**12.7**
Gaziosmanpaşa	13	16	**6.5**
Gaziosmanpaşa	13	16	**10.6**
Kağıthane	13	19	**9.2**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Kağıthane	13	19	**8.3**
Sarıyer	13	23	**27**
Sarıyer	13	23	**26.4**
Şişli	13	26	**16.9**
Şişli	13	26	**17.4**
Zeytinburnu	13	32	**11.3**
Zeytinburnu	13	32	**9**
Esenler	13	902	**11.5**
Esenler	13	902	**11.4**
FATIH	**14**		
Bahçelievler	14	3	**15.4**
Bahçelievler	14	3	**20.1**
Bakırköy	14	4	**15.9**
Bakırköy	14	4	**15.1**
Bağcılar	14	5	**15.1**
Bağcılar	14	5	**18.8**
Beyoğlu	14	7	**4.6**
Beyoğlu	14	7	**10.9**
Beşiktaş	14	8	**15.1**
Beşiktaş	14	8	**13.4**
Bayrampaşa	14	10	**6.1**
Bayrampaşa	14	10	**6.3**
Eminönü	14	12	**3.1**
Eminönü	14	12	**2.4**
Eyüp	14	13	**5.3**
Eyüp	14	13	**4.9**
Güngören	14	15	**9.3**
Güngören	14	15	**13.3**
Gaziosmanpaşa	14	16	**11.2**
Gaziosmanpaşa	14	16	**9.1**
Kağıthane	14	19	**11.3**
Kağıthane	14	19	**10**
Sarıyer	14	23	**30**
Sarıyer	14	23	**29.9**
Şişli	14	26	**20.5**
Şişli	14	26	**20.4**
Zeytinburnu	14	32	**9.7**
Zeytinburnu	14	32	**11.6**
Esenler	14	902	**12**
Esenler	14	902	**12**

Table A.1 (continued)

Districts	From	To	Distance (km)
GUNGOREN	**15**		
Bahçelievler	15	3	**6.3**
Bahçelievler	15	3	**9.2**
Bakırköy	15	4	**11.5**
Bakırköy	15	4	**9.6**
Bağcılar	15	5	**7**
Bağcılar	15	5	**14.6**
Beyoğlu	15	7	**18.4**
Beyoğlu	15	7	**12.2**
Bayrampaşa	15	10	**6.2**
Bayrampaşa	15	10	**5.4**
Eminönü	15	12	**8.7**
Eminönü	15	12	**14.1**
Eyüp	15	13	**12.8**
Eyüp	15	13	**8.6**
Fatih	15	14	**8**
Fatih	15	14	**12.6**
Gaziosmanpaşa	15	16	**10.4**
Gaziosmanpaşa	15	16	**9.8**
Kağıthane	15	19	**18.7**
Kağıthane	15	19	**16.9**
Küçükçekmece	15	20	**12.1**
Küçükçekmece	15	20	**10.2**
Zeytinburnu	15	32	**4.8**
Zeytinburnu	15	32	**12.4**
Esenler	15	902	**11.2**
Esenler	15	902	**11.5**
GAZIOSMANPASA	**16**		
Bağcılar	16	5	**13.5**
Bağcılar	16	5	**14.7**
Beyoğlu	16	7	**16.8**
Beyoğlu	16	7	**18.3**
Beşiktaş	16	8	**22.5**
Beşiktaş	16	8	**19.2**
Bayrampaşa	16	10	**7.1**
Bayrampaşa	16	10	**5.4**
Eminönü	16	12	**14.1**
Eminönü	16	12	**11.5**
Eyüp	16	13	**12.8**
Eyüp	16	13	**7.9**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Fatih	16	14	**12.5**
Fatih	16	14	**9.2**
Güngören	16	15	**11.5**
Güngören	16	15	**11.8**
Kağıthane	16	19	**12.1**
Kağıthane	16	19	**10.9**
Sarıyer	16	23	**25.6**
Sarıyer	16	23	**28.8**
Şişli	16	26	**16.1**
Şişli	16	26	**14.2**
Zeytinburnu	16	32	**14**
Zeytinburnu	16	32	**18.8**
Esenler	16	902	**7.6**
Esenler	16	902	**8.3**
KAGITHANE	**19**		
Bağcılar	19	5	**20.4**
Bağcılar	19	5	**20**
Beyoğlu	19	7	**7**
Beyoğlu	19	7	**9**
Beşiktaş	19	8	**8.3**
Beşiktaş	19	8	**7.6**
Bayrampaşa	19	10	**11.4**
Bayrampaşa	19	10	**14.7**
Eminönü	19	12	**13**
Eminönü	19	12	**10.3**
Eyüp	19	13	**7.5**
Eyüp	19	13	**9**
Fatih	19	14	**10.4**
Fatih	19	14	**9.8**
Güngören	19	15	**14.4**
Güngören	19	15	**22.7**
Gaziosmanpaşa	19	16	**11.8**
Gaziosmanpaşa	19	16	**16.5**
Sarıyer	19	23	**20.1**
Sarıyer	19	23	**20.3**
Şişli	19	26	**7.5**
Şişli	19	26	**7.4**
Zeytinburnu	19	32	**17.7**
Zeytinburnu	19	32	**21**
Esenler	19	902	**17.4**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Esenler	19	902	**15.9**
KUCUKCEKMECE	**20**		
Avcılar	20	2	**12.2**
Avcılar	20	2	**30.2**
Bahçelievler	20	3	**9.7**
Bahçelievler	20	3	**6.4**
Bakırköy	20	4	**9.3**
Bakırköy	20	4	**14.8**
Bağcılar	20	5	**8.8**
Bağcılar	20	5	**8.3**
Büyükçekmece	20	9	**21.6**
Büyükçekmece	20	9	**36**
Bayrampaşa	20	10	**21.6**
Bayrampaşa	20	10	**23.6**
Güngören	20	15	**21.8**
Güngören	20	15	**15.1**
Gaziosmanpaşa	20	16	**18.4**
Gaziosmanpaşa	20	16	**20.6**
Zeytinburnu	20	32	**17.4**
Zeytinburnu	20	32	**21.7**
Esenler	20	902	**16.1**
Esenler	20	902	**16.9**
SARIYER	**23**		
Beyoğlu	23	7	**26.5**
Beyoğlu	23	7	**29.1**
Beşiktaş	23	8	**21.7**
Beşiktaş	23	8	**22.9**
Bayrampaşa	23	10	**30.2**
Bayrampaşa	23	10	**32**
Eminönü	23	12	**31.8**
Eminönü	23	12	**27.3**
Eyüp	23	13	**26.3**
Eyüp	23	13	**26**
Fatih	23	14	**29.1**
Fatih	23	14	**27.5**
Gaziosmanpaşa	23	16	**25.5**
Gaziosmanpaşa	23	16	**33.8**
Kağıthane	23	19	**19.1**
Kağıthane	23	19	**19.2**
Şişli	23	26	**16.1**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Şişli	23	26	**21.7**
Esenler	23	902	**29.6**
Esenler	23	902	**35.4**
SISLI	**26**		
Beyoğlu	26	7	**17.3**
Beyoğlu	26	7	**16.8**
Beşiktaş	26	8	**12.4**
Beşiktaş	26	8	**16.1**
Bayrampaşa	26	10	**21**
Bayrampaşa	26	10	**20.6**
Eminönü	26	12	**22.5**
Eminönü	26	12	**19.6**
Eyüp	26	13	**17.1**
Eyüp	26	13	**15**
Fatih	26	14	**19.9**
Fatih	26	14	**20.2**
Gaziosmanpaşa	26	16	**16.3**
Gaziosmanpaşa	26	16	**19.2**
Kağıthane	26	19	**7**
Kağıthane	26	19	**9**
Sarıyer	26	23	**16.6**
Sarıyer	26	23	**22.5**
Esenler	26	902	**20.3**
Esenler	26	902	**26.9**
ZEYTINBURNU	**32**		
Avcılar	32	2	**24.8**
Avcılar	32	2	**36.9**
Bahçelievler	32	3	**12.3**
Bahçelievler	32	3	**9.5**
Bakırköy	32	4	**8.7**
Bakırköy	32	4	**16.6**
Bağcılar	32	5	**20**
Bağcılar	32	5	**17.6**
Beyoğlu	32	7	**11.7**
Beyoğlu	32	7	**15**
Beşiktaş	32	8	**19.2**
Beşiktaş	32	8	**19.5**
Bayrampaşa	32	10	**10.2**
Bayrampaşa	32	10	**9.3**
Eminönü	32	12	**8.2**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Eminönü	32	12	**8.9**
Eyüp	32	13	**8.7**
Eyüp	32	13	**12.7**
Fatih	32	14	**8.5**
Fatih	32	14	**8**
Güngören	32	15	**4.7**
Güngören	32	15	**17.3**
Gaziosmanpaşa	32	16	**13.5**
Gaziosmanpaşa	32	16	**15.2**
Kağıthane	32	19	**15.4**
Kağıthane	32	19	**17.8**
Küçükçekmece	32	20	**17.1**
Küçükçekmece	32	20	**19.2**
Esenler	32	902	**14.3**
Esenler	32	902	**16.1**
ESENLER	**902**		
Bahçelievler	902	3	**14**
Bahçelievler	902	3	**12.1**
Bağcılar	902	5	**5.2**
Bağcılar	902	5	**6.6**
Beyoğlu	902	7	**17.5**
Beyoğlu	902	7	**20.8**
Bayrampaşa	902	10	**7**
Bayrampaşa	902	10	**8.7**
Eminönü	902	12	**13.3**
Eminönü	902	12	**15.7**
Eyüp	902	13	**12**
Eyüp	902	13	**13.2**
Fatih	902	14	**11.7**
Fatih	902	14	**12.9**
Güngören	902	15	**10.8**
Güngören	902	15	**8**
Gaziosmanpaşa	902	16	**7.2**
Gaziosmanpaşa	902	16	**9**
Kağıthane	902	19	**16.7**
Kağıthane	902	19	**17.9**
Küçükçekmece	902	20	**14.1**
Küçükçekmece	902	20	**14.8**
Sarıyer	902	23	**29.7**
Sarıyer	902	23	**36.7**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Şişli	902	26	**20.1**
Şişli	902	26	**27.1**
Zeytinburnu	902	32	**13.3**
Zeytinburnu	902	32	**18**
CATALCA	**903**		
Avcılar	903	2	**35.6**
Avcılar	903	2	**33.7**
Büyükçekmece	903	9	**21.2**
Büyükçekmece	903	9	**32.9**
Silivri	903	904	**34.3**
Silivri	903	904	**40.6**
SILIVRI	**904**		
Büyükçekmece	904	9	**31.8**
Büyükçekmece	904	9	**45.7**
Çatalca	904	903	**33.6**
Çatalca	904	903	**40.5**
East Sıde of Istanbul			
BEYKOZ	**6**		
Kadıköy	6	17	**26.1**
Kadıköy	6	17	**31**
Ümraniye	6	29	**19.9**
Ümraniye	6	29	**21.8**
Üsküdar	6	30	**24.8**
Üsküdar	6	30	**23.8**
KADIKOY	**17**		
Beykoz	17	6	**26**
Beykoz	17	6	**30.3**
Kartal	17	18	**24.1**
Kartal	17	18	**18.8**
Maltepe	17	21	**12.2**
Maltepe	17	21	**20.2**
Ümraniye	17	29	**9.9**
Ümraniye	17	29	**10.5**
Üsküdar	17	30	**7.4**
Üsküdar	17	30	**13.4**
KARTAL	**18**		
Kadıköy	18	17	**15.5**
Kadıköy	18	17	**24.4**
Maltepe	18	21	**13.2**
Maltepe	18	21	**15.1**

Table A.1 (continued)

Districts	From To	Distance (km)	Districts
Tuzla	18	28	**20.1**
Tuzla	18	28	**21.5**
Pendik	18	22	**5.8**
Pendik	18	22	**7.2**
Ümraniye	18	29	**25.6**
Ümraniye	18	29	**22.5**
Üsküdar	18	30	**19.9**
Üsküdar	18	30	**29**
MALTEPE	**21**		
Kadıköy	21	17	**11.4**
Kadıköy	21	17	**19.6**
Kartal	21	18	**16**
Kartal	21	18	**15.3**
Pendik	21	22	**17.7**
Pendik	21	22	**17.3**
Ümraniye	21	29	**18.4**
Ümraniye	21	29	**22.8**
Üsküdar	21	30	**15.8**
Üsküdar	21	30	**26.5**
PENDIK	**22**		
Maltepe	22	21	**18**
Maltepe	22	21	**18.1**
Tuzla	22	28	**14.2**
Tuzla	22	28	**16.7**
TUZLA	**28**		
Kartal	28	18	**20.8**
Kartal	28	18	**21.7**
Pendik	28	22	**16.2**
Pendik	28	22	**17.1**
UMRANIYE	**29**		
Beykoz	29	6	**20.6**
Beykoz	29	6	**21.5**
Kadıköy	29	17	**9.1**
Kadıköy	29	17	**10**
Kartal	29	18	**25.5**
Kartal	29	18	**24.3**
Maltepe	29	21	**17.8**
Maltepe	29	21	**21.7**
Üsküdar	29	30	**5.4**
Üsküdar	29	30	**8.6**

Table A.1 (continued)

Districts	From	To	Distance (km)
USKUDAR	**30**		
Beykoz	30	6	**25.3**
Beykoz	30	6	**23.6**
Kadıköy	30	17	**9.3**
Kadıköy	30	17	**11.9**
Kartal	30	18	**24.9**
Kartal	30	18	**29**
Maltepe	30	21	**18.3**
Maltepe	30	21	**25.2**
Ümraniye	30	29	**5.8**
Ümraniye	30	29	**8.1**

APPENDIX B

THE CALCULATION AND RESULTS FOR NARROW ROAD VULNERABILITY RATE

Appendix B includes the calculation results of narrow road vulnerability rates of the routes. The third column of the table shows the final result of the narrow road vulnerability rates of the route. Each route has segments beginning from one district and ending in another one. When all routes are considered, it is concluded that one route can have at most five road segments, which means that there are at most six districts linked to that route. For example, From Avcılar to Bahçelievler there are two possible routes. The narrow road vulnerability rate is given as 0.623 for the first route. This value is calculated from the narrow road percentage of the districts linked to the route. There are 2 road segments for this route. The first segment is from district 2 to district 20. The second segment is from district 20 to district 3. Hence, the values for distrct 2, 20 and 3 are used. The narrow road vulnerability rates of the route is calculated as:

$$((0.624*15.2) + (0.687*9.2) + (0.498*4.9)) + (15.2+9.2+4.9)$$

Hence, it can be concluded the for the rest of the calculations of the narrow road vulnerability rate of the route i, the following formula is used:

((NR1*Length of route i in district 1) + … + (NR6*Length of route i in district 6)) / the length of the route

where NRj is the narrow road vulnerability rate given in JICA Report j= {1, 2, 3, 4, 5, 6}

Also note that narrow road vulnerability rate is also similar to narrow road percentage per kilometer.

Table B. 1 Narrow Road Vulnerability Rates

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
2														
2	3	**0.623**	2	15.2	20	9.2	3	4.9						
2	3	**0.532**	2	8.1	4	13.9	3	2.1						
2	4	**0.552**	2	8.1	4	8.4								
2	4	**0.533**	2	8.1	4	14.8								
2	5	**0.642**	2	15.2	20	7.3	5	1.9						
2	5	**0.635**	2	8.1	4	2.8	20	10.6	5	1.6				
2	9	**0.378**	2	5	9	4.8								
2	9	**0.295**	2	4.6	9	4.8								
2	20	**0.612**	2	8.1	4	2.8	20	3.5						
2	20	**0.654**	2	15.2	20	14.2								
2	32	**0.529**	2	8.1	4	13.7	32	2.8						
2	32	**0.547**	2	8.1	4	13.5	20	3	32	2.8				
3														
3	2	**0.599**	3	2.9	20	5.1	4	2.8	2	6.5				
3	2	**0.627**	3	4.1	20	9.7	2	15.3						
3	4	**0.488**	3	3.2	4	6								
3	4	**0.489**	3	3.8	4	5								
3	5	**0.551**	3	4.1	5	3.5								
3	5	**0.554**	3	3.7	5	3.4								
3	7	**0.572**	3	3.8	4	5.8	32	2.8	14	6.2	7	2.2		
3	7	**0.58**	3	7	32	4.8	14	2	7	5.9				
3	10	**0.622**	3	4.1	5	6.9	902	5.2	10	1.6				
3	10	**0.521**	3	6.5	902	1.4	32	3.6	10	4				
3	12	**0.554**	3	3.8	4	4.9	32	2.8	14	3.6	12	2.4		
3	12	**0.586**	3	4.1	5	6.9	902	1.5	10	6.5	14	2.6	12	1.4
3	14	**0.584**	3	4.1	5	6.9	902	1.5	10	6.5	14	2.5		
3	14	**0.538**	3	7	32	4.5	14	2.8						
3	15	**0.461**	3	4.5	15	1.6								
3	15	**0.454**	3	5.6	4	1.4	15	3						
3	16	**0.627**	3	4.1	5	6.9	902	2.1	16	4.1				
3	16	**0.567**	3	6.5	902	1.4	32	3.6	10	4	16	5.1		
3	20	**0.62**	3	2.1	20	3.8								
3	20	**0.575**	3	5.1	20	3.5								
3	32	**0.485**	3	3.2	4	10.3	32	2.7						
3	32	**0.487**	3	3.8	4	4.9	32	2.7						

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
3	902	**0.621**	3	4.1	5	6.9	902	3.8						
3	902	**0.594**	3	6	5	2.4	902	3.1						
4														
4	2	**0.556**	4	7.8	2	8.4								
4	2	**0.553**	4	7.8	2	7.6								
4	3	**0.487**	4	6	3	2.1								
4	3	**0.486**	4	7.7	3	2.3								
4	5	**0.521**	4	6	3	4	5	3.5						
4	5	**0.517**	4	7.7	3	4.1	5	3.5						
4	7	**0.533**	4	9.4	32	3.9	14	2.4	7	2.3				
4	7	**0.565**	4	8.1	32	4.6	13	2	7	6				
4	10	**0.486**	4	6.7	32	8.2	10	3.3						
4	10	**0.487**	4	8	32	5.2	10	3.3						
4	12	**0.528**	4	6.7	32	2.9	14	2.2						
4	12	**0.529**	4	9.5	32	3.9	14	3.1						
4	14	**0.575**	4	6.7	32	2.9	14	5.7						
4	14	**0.513**	4	9.4	32	3.9	14	1.9						
4	15	**0.472**	4	8.8	32	1.8	15	1						
4	15	**0.472**	4	5	3	3.6	15	1.3						
4	20	**0.547**	4	5.9	20	2.7								
4	20	**0.61**	4	3.7	20	6.1								
4	32	**0.482**	4	6.7	32	1.9								
4	32	**0.483**	4	8.5	32	1.2								
5														
5	2	**0.558**	5	3.8	3	3.9	4	6.5	2	7.8				
5	2	**0.639**	5	3	20	6.3	2	15						
5	3	**0.549**	5	3.8	3	4.9								
5	3	**0.553**	5	3.3	3	3.6								
5	4	**0.523**	5	3.8	3	3.9	4	6.1						
5	4	**0.519**	5	3.2	3	3.8	4	6.1						
5	10	**0.556**	5	7	10	8.7								
5	10	**0.566**	5	7.4	10	6.3								
5	12	**0.595**	5	7	10	6.8	14	3.2	12	1				
5	12	**0.551**	5	3.8	3	11.2	32	4	14	3.2	12	1		
5	14	**0.592**	5	7	10	6.8	14	2.9						
5	14	**0.546**	5	3.8	3	11.2	32	4	14	2.9				
5	15	**0.486**	5	3.3	15	3.3								
5	15	**0.538**	5	6.5	10	4.8	32	3.7	15	0.8				

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
5	16	**0.661**	5	7.3	902	2	16	3						
5	16	**0.669**	5	7.3	902	2	16	5.5						
5	20	**0.675**	5	1.5	20	7.3								
5	20	**0.677**	5	1.5	20	9.6								
5	32	**0.508**	5	3.6	3	4.2	4	11.1	32	1.8				
5	32	**0.545**	5	6.6	10	10.7	32	1						
5	902	**0.655**	5	7.3	902	2.7								
5	902	**0.682**	5	3.9	902	3.2								
7														
7	3	**0.574**	7	5.2	13	2	32	3.7	3	8.9				
7	3	**0.575**	7	2.7	14	6.1	32	2.8	4	5.9	3	4.5		
7	4	**0.565**	7	5.2	13	2	32	3.7	4	9.5				
7	4	**0.6**	7	2.7	14	6.1	32	2.8	4	7.2				
7	5	**0.646**	7	5.2	13	2	10	4	902	3.2	5	5		
7	5	**0.681**	7	4.3	13	7.4	16	4.6	902	2	5	5.9		
7	8	**0.608**	7	1	26	6.8	8	3.1						
7	8	**0.592**	7	3.4	8	6								
7	10	**0.649**	7	5.2	13	2	10	3.5						
7	10	**0.518**	7	2.7	14	2.7	10	3.9						
7	12	**0.617**	7	2.7	12	3.2								
7	12	**0.684**	7	5.2	13	2.8	14	2.8	12	1				
7	13	**0.721**	7	5.2	13	1.6								
7	13	**0.672**	7	2.7	14	2.75	13	0.75						
7	14	**0.665**	7	2.7	14	2								
7	14	**0.683**	7	5.2	13	2	14	2						
7	15	**0.582**	7	5.2	13	2.1	32	5.35	15	0.65				
7	15	**0.59**	7	2.7	14	4.4	32	4.9	15	0.65				
7	16	**0.674**	7	2.7	19	5.6	13	3.6	16	4.1				
7	16	**0.681**	7	2.7	13	1.6	16	8.3						
7	19	**0.666**	7	1.8	26	2	19	1.9						
7	19	**0.65**	7	1.5	26	1.5	19	4.9						
7	23	**0.72**	7	3	19	6.2	26	3.4	23	13				
7	23	**0.721**	7	3	26	9.9	23	13						
7	26	**0.639**	7	1	19	6.5	26	8.5						
7	26	**0.641**	7	1	26	15.3								
7	32	**0.628**	7	2.7	14	6.1	32	4.1						
7	32	**0.577**	7	5.2	13	2.8	32	8.6						
7	902	**0.689**	7	5.2	13	2.8	10	3.6	902	5.2				

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
7	902	**0.707**	7	4.3	13	7.4	16	4.6	902	3.6				
8														
8	7	**0.626**	8	2.5	26	7	7	2.1						
8	7	**0.584**	8	5.7	7	2.8								
8	10	**0.575**	8	3.1	26	7.1	13	1.9	10	3.2				
8	10	**0.601**	8	5.2	19	4	13	3.5	16	5.8	10	4.8		
8	12	**0.619**	8	3.1	26	7.1	13	3	14	2.6	12	1		
8	12	**0.583**	8	5.7	7	3.2	12	3.7						
8	13	**0.588**	8	3.1	26	7	13	1.3						
8	13	**0.616**	8	3.1	26	5.2	19	4.8	13	3.8				
8	14	**0.608**	8	3.1	26	7.1	13	3	14	1.1				
8	14	**0.605**	8	5.7	7	3.2	14	2.4						
8	15	**0.544**	8	3.1	26	7	13	2	32	5	15	1.2		
8	15	**0.588**	8	3.1	26	4.9	13	11.4	32	5	15	1.2		
8	16	**0.568**	8	3.1	26	7	13	1.9	10	7	16	1.3		
8	16	**0.606**	8	7.6	19	6.1	13	3.1	16	4.4				
8	19	**0.584**	8	3.1	26	3.3	19	1.5						
8	19	**0.567**	8	5.5	19	5.4								
8	23	**0.681**	8	5	23	8.6								
8	23	**0.735**	8	3	23	14.5								
8	26	**0.552**	8	6.1	26	3.2								
8	26	**0.57**	8	7.7	26	7.4								
8	32	**0.567**	8	3.1	26	5	7	2	14	2.9	32	8.5		
8	32	**0.606**	8	5.7	7	3.6	14	6.2	32	4.1				
9														
9	2	**0.385**	9	5	2	5								
9	2	**0.35**	9	5	2	6								
9	20	**0.485**	9	5	2	7.1	20	6.1						
9	20	**0.454**	9	5	2	5.7	20	14.3						
9	903		9	2.1	903	7.1								
9	903		9	5	903	7.1								
9	904		9	2.1	904	4.5								
9	904		9	2.1	904	10.7								
10														
10	3	**0.545**	10	7.5	5	7.4	3	5						
10	3	**0.495**	10	3.9	32	4.7	3	7.5						
10	4	**0.488**	10	3.9	32	4.7	4	8						
10	4	**0.508**	10	2.5	13	2.5	32	7.3	4	6.8				

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
10	5	**0.551**	10	7.5	5	5								
10	5	**0.562**	10	7.5	5	7.5								
10	7	**0.645**	10	2.5	13	2.7	7	5.9						
10	7	**0.665**	10	2.5	13	8.1	7	5.6						
10	8	**0.594**	10	2.5	13	2.3	7	2.4	26	5.1	8	3.1		
10	8	**0.612**	10	2.5	13	8.1	26	7.7	8	3.1				
10	12	**0.618**	10	3.7	14	3.65	12	0.85						
10	12	**0.615**	10	4.3	14	3.95	12	0.85						
10	13	**0.57**	10	3.3	13	2.2								
10	13	**0.58**	10	3.2	13	2.8								
10	14	**0.582**	10	4.3	14	2.1								
10	14	**0.606**	10	3.9	14	3								
10	15	**0.57**	10	3.8	902	2.5	15	1.2						
10	15	**0.552**	10	6.9	902	2.5	15	1.2						
10	16	**0.633**	10	1.8	16	3								
10	16	**0.552**	10	4.3	16	1.2								
10	19	**0.606**	10	2.5	13	2.7	7	1.8	19	4.5				
10	19	**0.626**	10	2.5	13	8.1	19	4.5						
10	20	**0.667**	10	2.8	902	4.7	5	3.7	20	8.8				
10	20	**0.539**	10	3.8	32	4.6	3	9.5	20	5.3				
10	23	**0.688**	10	5.3	16	4.4	13	3.4	19	3.4	26	1.7	23	13.2
10	23	**0.696**	10	2.5	13	2.7	7	1.8	26	10.5	23	13.2		
10	26	**0.623**	10	5.3	16	4.4	13	3.4	19	2.4	26	6.3		
10	26	**0.62**	10	2.5	13	2.7	7	1.8	26	13.7				
10	32	**0.655**	10	2.3	902	6.1	32	1.9						
10	32	**0.52**	10	2.5	13	2.7	32	8.5						
10	902	**0.649**	10	2.9	902	3.5								
10	902	**0.679**	10	3.2	902	6.3								
12														
12	3	**0.535**	12	1	14	2.7	32	5.7	3	7.6				
12	3	**0.544**	12	2	14	3.3	32	2.8	4	5.5	3	4.9		
12	4	**0.56**	12	2.2	14	3.7	32	2.8	4	6.7				
12	4	**0.527**	12	1	14	2.7	32	5.7	4	8.1				
12	5	**0.634**	12	1	14	2.7	10	4.5	902	3.3	5	5.1		
12	5	**0.547**	12	1	14	2.7	32	4.4	4	4.2	3	4.6	5	3.4
12	7	**0.606**	12	2.7	7	2.2								
12	7	**0.702**	12	1	14	5.2	7	5.9						
12	8	**0.64**	12	1	14	5.2	7	2.3	26	4.9	8	3		

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
12	8	**0.563**	12	2.7	7	3.1	8	7						
12	10	**0.6**	12	1	14	2.7	10	4						
12	10	**0.593**	12	1.6	14	2.5	10	4.4						
12	13	**0.684**	12	1	14	2.7	13	2.3						
12	13	**0.703**	12	1	14	4.6	13	0.8						
12	14	**0.676**	12	1	14	1.2								
12	14	**0.655**	12	1.5	14	0.9								
12	15	**0.559**	12	1	14	2.7	32	4.9	15	0.6				
12	15	**0.55**	12	1	14	2.7	10	10.6	15	0.6				
12	16	**0.584**	12	1	14	2.7	10	7.8	16	1.3				
12	16	**0.694**	12	1	14	4.1	13	3.3	16	3.3				
12	19	**0.662**	12	1	14	5.2	7	1.6	19	4.7				
12	19	**0.631**	12	2.4	7	2.9	19	4.6						
12	23	**0.711**	12	1	14	5.2	7	2.1	26	10.1	23	13		
12	23	**0.699**	12	2.6	7	4.7	19	9.8	23	13				
12	26	**0.658**	12	1	14	5.2	7	2.1	26	13.5				
12	26	**0.672**	12	2.6	7	4.7	19	8.6	26	6.8				
12	32	**0.613**	12	1.1	14	4.8	32	4.2						
12	32	**0.56**	12	1	14	2.8	32	6.5						
12	902	**0.659**	12	1	14	2.7	10	4.7	902	5.3				
12	902	**0.628**	12	1	14	2.7	10	6.3	902	3.6				
13														
13	3	**0.519**	13	2.4	32	4.7	3	7.5						
13	3	**0.561**	13	2.4	10	6.6	5	7.9	3	5				
13	4	**0.51**	13	2.4	32	4.7	4	8.1						
13	4	**0.511**	13	2.8	32	7.2	4	6.7						
13	5	**0.574**	13	2.4	10	6.6	5	5.5						
13	5	**0.655**	13	2.4	10	3.6	902	5.8	5	3.1				
13	7	**0.676**	13	1.6	7	5.8								
13	7	**0.68**	13	4.7	19	2.5	7	3.8						
13	8	**0.595**	13	1.6	7	1.8	26	5.1	8	3.1				
13	8	**0.616**	13	4.7	19	4.5	26	3.3	8	3.1				
13	10	**0.574**	13	2.4	10	3.2								
13	10	**0.573**	13	2.1	10	2.9								
13	12	**0.68**	13	3.4	14	2.7	12	1						
13	12	**0.676**	13	0.9	14	3.4	12	2.6						
13	14	**0.719**	13	0.7	14	3.3								
13	14	**0.689**	13	3.4	14	2.2								

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
13	15	**0.512**	13	2.5	32	3.2	10	1.2	15	1.7				
13	15	**0.435**	13	2.4	10	1.7	15	8.6						
13	16	**0.686**	13	3	16	3.5								
13	16	**0.561**	13	2.4	10	6.9	16	1.2						
13	19	**0.645**	13	4.7	19	4.5								
13	19	**0.617**	13	1.6	7	1.5	19	4.7						
13	23	**0.706**	13	1.6	7	1.9	26	9.9	23	13.2				
13	23	**0.719**	13	8.3	19	4.3	23	13.8						
13	26	**0.647**	13	8.2	19	2.1	26	6.6						
13	26	**0.616**	13	1.6	19	8.9	26	6.4						
13	32	**0.524**	13	2.8	32	8.5								
13	32	**0.528**	13	2.4	32	6.6								
13	902	**0.656**	13	2.4	10	3.9	902	5.2						
13	902	**0.62**	13	2.4	10	5.5	902	3.5						
14														
14	3	**0.523**	14	2.1	32	5.8	3	7.5						
14	3	**0.571**	14	2.1	10	7.3	5	7.8	3	2.9				
14	4	**0.515**	14	2.1	32	4.9	4	8.9						
14	4	**0.574**	14	5.6	32	2.7	4	6.8						
14	5	**0.58**	14	2.1	10	7.3	5	5.7						
14	5	**0.539**	14	2.1	32	5.7	3	7.6	5	3.4				
14	7	**0.671**	14	2	7	2.2								
14	7	**0.709**	14	4.6	7	5.9								
14	8	**0.634**	14	4.6	7	1.9	26	5.1	8	3.1				
14	8	**0.597**	14	2	7	4.1	8	6.9						
14	10	**0.585**	14	2.1	10	4								
14	10	**0.65**	14	4	10	2.3								
14	12	**0.692**	14	2.1	12	1								
14	12	**0.65**	14	0.8	12	1.6								
14	13	**0.689**	14	2.1	13	3.2								
14	13	**0.672**	14	0.8	13	4.1								
14	15	**0.519**	14	2.1	32	5.9	15	1.3						
14	15	**0.529**	14	2.1	10	9.9	15	1.3						
14	16	**0.572**	14	2.1	10	7.9	16	1.2						
14	16	**0.699**	14	2.4	13	2.9	16	3.8						
14	19	**0.673**	14	4.6	7	2	19	4.4						
14	19	**0.657**	14	2	7	2.9	26	2.6	19	2.1				
14	23	**0.713**	14	4.6	7	2	26	9.8	23	13.2				

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
14	23	**0.711**	14	4.6	7	2	19	9.7	23	13.2				
14	26	**0.654**	14	4.6	7	2	26	13.5						
14	26	**0.652**	14	4.6	7	2	19	6.5	26	6.9				
14	32	**0.622**	14	5.5	32	4.2								
14	32	**0.64**	14	7.4	32	4.2								
14	902	**0.691**	14	2.1	10	3.2	902	6.7						
14	902	**0.691**	14	2.1	10	3.2	902	6.7						
15														
15	3	**0.46**	15	1.7	3	4.6								
15	3	**0.481**	15	1.1	3	8.1								
15	4	**0.478**	15	0.9	10	1.9	4	8.7						
15	4	**0.474**	15	1.1	3	3.6	4	4.9						
15	5	**0.552**	15	1.7	5	5.3								
15	5	**0.681**	15	0.9	902	8	5	5.7						
15	7	**0.58**	15	1.1	10	8.9	13	2.1	7	5.9				
15	7	**0.587**	15	1.2	32	3.8	14	4.5	7	2.2				
15	10	**0.612**	15	1.2	902	3.2	10	1.8						
15	10	**0.487**	15	1.3	902	0.3	10	3.8						
15	12	**0.56**	15	0.9	32	4.1	14	2.7	12	1				
15	12	**0.549**	15	0.9	10	9.5	14	2.7	12	1				
15	13	**0.631**	15	0.9	902	4.9	10	4.1	13	2.9				
15	13	**0.528**	15	0.9	32	4.8	13	2.9						
15	14	**0.654**	15	0.8	902	2.4	10	1.8	14	3				
15	14	**0.625**	15	1.3	902	4.5	10	4.5	14	2.3				
15	16	**0.682**	15	1.3	902	6.8	10	1	16	1.3				
15	16	**0.623**	15	2.6	902	4.9	10	1	16	1.3				
15	19	**0.613**	15	1.3	902	4.6	10	6.5	7	1.9	19	4.4		
15	19	**0.62**	15	1.3	902	2.1	32	2	13	7	19	4.5		
15	20	**0.607**	15	1.8	5	5.1	20	5.2						
15	20	**0.538**	15	2.2	3	4.2	20	3.8						
15	32	**0.456**	15	0.9	32	3.9								
15	32	**0.509**	15	0.9	902	1.7	32	9.8						
15	902	**0.732**	15	0.9	902	10.3								
15	902	**0.733**	15	0.9	902	10.6								
16														
16	5	**0.673**	16	1	10	1.3	902	5.6	5	5.6				
16	5	**0.681**	16	6.5	902	2.5	5	5.7						
16	7	**0.688**	16	3.9	13	7.2	19	1.6	7	4.1				

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
16	7	**0.605**	16	1	10	8.8	13	2.2	7	6				
16	8	**0.574**	16	1	10	8.8	13	2.2	7	1.9	26	5.2	8	3.1
16	8	**0.614**	16	3.9	13	3.5	19	6	8	5.8				
16	10	**0.537**	16	1	10	6.1								
16	10	**0.546**	16	1	10	4.4								
16	12	**0.573**	16	1	10	9.3	14	2.7	12	1.1				
16	12	**0.588**	16	1	10	6.7	14	2.7	12	1.1				
16	13	**0.56**	16	1	10	8.8	13	3						
16	13	**0.695**	16	5.9	13	2								
16	14	**0.564**	16	1	10	9.3	14	2.2						
16	14	**0.584**	16	1	10	6	14	2.2						
16	15	**0.62**	16	1	10	4.4	902	4.9	15	1.2				
16	15	**0.599**	16	1	10	4.4	902	4.5	15	1.9				
16	19	**0.664**	16	3.9	13	4	19	4.2						
16	19	**0.657**	16	2.1	13	4.4	19	4.4						
16	23	**0.726**	16	3.9	13	4.1	26	4.4	23	13.2				
16	23	**0.715**	16	1.5	13	10.1	26	4	23	13.2				
16	26	**0.659**	16	3.9	13	4.1	26	8.1						
16	26	**0.663**	16	3.9	13	4.7	26	5.6						
16	32	**0.51**	16	1	10	6.8	32	6.2						
16	32	**0.505**	16	1	10	8.9	32	8.9						
16	902	**0.717**	16	1	10	1.2	902	5.4						
16	902	**0.737**	16	4	902	4.3								
19														
19	5	**0.6**	19	4.2	7	2.1	13	1.9	10	6.6	5	5.6		
19	5	**0.674**	19	3.2	13	4.1	16	4.7	902	3.5	5	4.5		
19	7	**0.667**	19	1.9	26	2.8	7	2.3						
19	7	**0.677**	19	5	7	4								
19	8	**0.586**	19	2	26	3.2	8	3.1						
19	8	**0.581**	19	2.7	26	1.8	8	3.1						
19	10	**0.604**	19	3.9	7	2.1	13	1.9	10	3.2				
19	10	**0.618**	19	4.5	13	7	10	3.2						
19	12	**0.622**	19	4	7	1.9	14	5.7	12					
19	12	**0.621**	19	4.7	7	2.6	12	2.5						
19	13	**0.603**	19	3.9	7	2	13	0.9						
19	13	**0.644**	19	4.6	13	4.4								
19	14	**0.665**	19	4	7	1.9	14	4.1						
19	14	**0.656**	19	1.9	26	2.8	7	2.6	14	2.1				

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
19	15	**0.555**	19	4	7	1.9	13	2.1	32	4.5	15	1.5		
19	15	**0.687**	19	3.1	13	4.6	16	4.4	902	9.1	15	1.5		
19	16	**0.668**	19	3.1	13	4.6	16	4.1						
19	16	**0.549**	19	4	7	1.9	13	3.4	16	4.1				
19	23	**0.728**	19	3.1	26	4.1	23	12.9						
19	23	**0.707**	19	3.6	8	3.5	23	13.2						
19	26	**0.632**	19	3.2	26	4.3								
19	26	**0.631**	19	3.8	26	3.6								
19	32	**0.55**	19	4	7	1.9	13	2	32	9.4				
19	32	**0.573**	19	4.3	13	7.3	32	9.4						
19	902	**0.648**	19	4	7	1.9	13	2	10	3.9	902	5.3		
19	902	**0.692**	19	3.2	13	4.5	16	4.3	902	3.9				
20														
20	2	**0.647**	20	4.5	2	7.7								
20	2	**0.655**	20	14.9	2	15.3								
20	3	**0.595**	20	5	3	4.7								
20	3	**0.616**	20	4	3	2.4								
20	4	**0.58**	20	4.4	4	4.9								
20	4	**0.604**	20	8.8	4	6								
20	5	**0.675**	20	7.3	5	1.5								
20	5	**0.672**	20	6.6	5	1.7								
20	9	**0.456**	20	4.5	2	6.7	9	4.8						
20	9	**0.384**	20	4.5	2	4.2	9	15.1						
20	10	**0.634**	20	8.8	5	4.2	902	2.7	10	5.9				
20	10	**0.57**	20	9.2	3	5.9	32	4.2	10	4.3				
20	15	**0.673**	20	8.8	5	4.2	902	7.1	15	1.7				
20	15	**0.565**	20	7.2	3	5.4	15	2.5						
20	16	**0.68**	20	8.9	5	4.4	902	1.6	16	3.5				
20	16	**0.696**	20	9	5	4	902	5.5	16	2.1				
20	32	**0.53**	20	4.1	4	10.7	32	2.6						
20	32	**0.564**	20	8.7	4	10.4	32	2.6						
20	902	**0.695**	20	8.9	5	2.9	902	4.3						
20	902	**0.662**	20	8.9	5	2.9	902	4.3						
23														
23	7	**0.725**	23	13.7	19	8.6	7	4.2						
23	7	**0.702**	23	18.2	8	8	7	2.9						
23	8	**0.67**	23	12.8	8	8.9								
23	8	**0.726**	23	18.2	8	4.7								

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
23	10	**0.678**	23	12.8	19	10.9	7	1	13	1.9	10	3.2		
23	10	**0.681**	23	12.8	19	5.2	13	3.4	16	4.4	10	6.2		
23	12	**0.704**	23	12.8	19	10.7	7	1.2	14	5.7	12	1		
23	12	**0.664**	23	12.8	8	8.9	7	3.2	12	2				
23	13	**0.682**	23	12.8	8	5	26	4.9	7	2	13	1.2		
23	13	**0.714**	23	12.8	19	5.5	13	7.7						
23	14	**0.689**	23	12.8	8	5	26	4.9	7	2	14	4		
23	14	**0.673**	23	12.8	8	8.9	7	3.2	14	2.2				
23	16	**0.722**	23	12.8	19	5.2	13	3.4	16	4.1				
23	16	**0.698**	23	12.8	26	9.7	19	4.3	13	5.2	16	1.8		
23	19	**0.731**	23	12.8	19	6.3								
23	19	**0.731**	23	12.8	19	6.4								
23	26	**0.752**	23	12.8	26	3.3								
23	26	**0.294**	23	1	26	8.8								
23	902	**0.728**	23	12.8	19	5.2	13	3.4	16	4.4	902	3.8		
23	902	**0.734**	23	12.8	19	5.2	13	3.4	16	4.4	902	9.6		
26														
26	7	**0.657**	26	7.1	19	6.1	7	4.1						
26	7	**0.649**	26	14.5	7	2.3								
26	8	**0.596**	26	8.6	8	3.8								
26	8	**0.667**	26	3.7	23	7.6	8	4.8						
26	10	**0.617**	26	13.3	7	2.1	13	2	10	3.2				
26	10	**0.624**	26	4.6	19	9	7	1.8	13	2	10	3.2		
26	12	**0.657**	26	13.3	7	2.1	14	5.7	12	1				
26	12	**0.609**	26	8.6	8	3.7	7	3.4	12	3.4				
26	13	**0.635**	26	13.3	7	2.1	13	1.3						
26	13	**0.641**	26	3.3	19	6.6	13	5.1						
26	14	**0.652**	26	13.4	7	2	14	4.1						
26	14	**0.65**	26	6.4	19	6.7	7	4.5	14	2.1				
26	16	**0.658**	26	6.3	19	2.3	13	3.6	16	4.1				
26	16	**0.65**	26	6.4	19	6.3	13	2.9	16	3.6				
26	19	**0.631**	26	2.6	19	4.4								
26	19	**0.631**	26	3.7	19	5.3								
26	23	**0.713**	26	7.8	23	8.8								
26	23	**0.283**	26	8.8	23	1								
26	902	**0.68**	26	8.3	13	3.9	16	4.3	902	3.8				
26	902	**0.636**	26	13.4	7	2	13	2	10	4.5	902	4.6		
32														

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
32	2	**0.528**	32	2	4	14.8	2	8						
32	2	**0.658**	32	2.3	902	9.2	5	4.8	20	5.6	2	15		
32	3	**0.488**	32	2	4	5.4	3	4.9						
32	3	**0.525**	32	1.7	902	1.8	15	1.4	3	4.6				
32	4	**0.482**	32	2	4	6.7								
32	4	**0.483**	32	2	4	14.6								
32	5	**0.508**	32	2	4	10.6	3	4	5	3.4				
32	5	**0.644**	32	3.4	15	1	902	8.2	5	5				
32	7	**0.641**	32	2.8	14	6.1	7	2.3						
32	7	**0.588**	32	7.1	13	1.5	7	6						
32	8	**0.556**	32	7.1	13	1.5	7	2	26	5	8	3.2		
32	8	**0.562**	32	2.8	12	6.1	7	3.3	8	6.8				
32	10	**0.499**	32	3.4	10	6.8								
32	10	**0.567**	32	3.4	15	1	902	3.1	10	1.8				
32	12	**0.618**	32	2.8	14	3.6	12	1.8						
32	12	**0.573**	32	5.1	14	2.8	12	1						
32	13	**0.54**	32	5.8	13	2.9								
32	13	**0.671**	32	2.8	14	9.1	13	0.8						
32	14	**0.648**	32	2.8	14	5.7								
32	14	**0.57**	32	5.1	14	2.9								
32	15	**0.453**	32	3.7	15	1								
32	15	**0.564**	32	6.8	10	3.9	902	5.3	15	1.3				
32	16	**0.653**	32	3.4	15	1	902	6.9	16	2.2				
32	16	**0.513**	32	6.7	10	7.2	16	1.3						
32	19	**0.559**	32	6.7	13	1.9	7	1.7	19	4.6				
32	19	**0.592**	32	5.9	13	7.3	19	4.6						
32	20	**0.516**	32	2.1	4	12.2	20	2.8						
32	20	**0.512**	32	2.1	4	14.3	20	2.8						
32	902	**0.669**	32	3.4	15	1	902	9.9						
32	902	**0.579**	32	6.8	10	4.1	902	5.2						
902														
902	3	**0.586**	902	1.2	5	7.8	3	5						
902	3	**0.59**	902	1.2	5	6.8	3	4.1						
902	5	**0.649**	902	1.2	5	4								
902	5	**0.641**	902	1.2	5	5.4								
902	7	**0.716**	902	6	10	3.9	13	2.4	7	5.9				
902	7	**0.703**	902	3.6	16	4.5	13	7.5	19	1	7	4.2		
902	10	**0.637**	902	3.5	10	3.5								

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
902	10	**0.677**	902	5.7	10	3								
902	12	**0.652**	902	4.5	10	4.9	14	2.9	12	1				
902	12	**0.669**	902	6.9	10	4.9	14	2.9	12	1				
902	13	**0.645**	902	4.6	10	4.4	13	3						
902	13	**0.656**	902	5.8	10	4.4	13	3						
902	14	**0.655**	902	4.6	10	4.7	14	2.4						
902	14	**0.665**	902	5.8	10	4.7	14	2.4						
902	15	**0.701**	902	9.1	15	1.7								
902	15	**0.623**	902	5.2	15	2.8								
902	16	**0.673**	902	3.6	10	2.3	16	1.3						
902	16	**0.73**	902	3.6	16	5.4								
902	19	**0.688**	902	3.6	16	4.4	13	4.7	19	4				
902	19	**0.622**	902	3.6	10	5.3	13	2.3	7	1.9	19	4.4		
902	20	**0.681**	902	1.9	5	3.2	20	9						
902	20	**0.681**	902	1.9	5	3.2	20	9.7						
902	23	**0.733**	902	3.6	16	4.4	13	3.4	19	4.2	23	14.1		
902	23	**0.689**	902	4.6	10	4.2	13	2.4	7	2	26	10.2	23	12.9
902	26	**0.677**	902	3.6	16	4.4	13	3.4	19	4.2	26	4.5		
902	26	**0.648**	902	4.6	10	4.2	13	2.4	7	2	26	13.9		
902	32	**0.63**	902	7	32	6.3								
902	32	**0.558**	902	4.5	10	4.3	32	9.2						
903														
903	2		903	6.5	2	9.2								
903	2		903	6.5	9	5.3	2	5.2						
903	9		903	6.5	9	3.2								
903	9		903	6.5	9	4.6								
903	904		903	6.5	904	5								
903	904		903	6.5	904	11								
904														
904	9		904	5.6	9	3.2								
904	9		904	11	9	3.2								
904	903		904	5	903	6.5								
904	903		904	5	903	6.5								
6														
6	17	**0.615**	6	12.9	29	5.8	17	4.1						
6	17	**0.38**	6	4.5	29	8.6	17	4.7						
6	29	**0.571**	6	12.9	29	2.1								
6	29	**0.747**	6	16.4	29	5.4								

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
6	30	**0.722**	6	12.9	29	8.7	30	3.2						
6	30	**0.737**	6	16.4	30	7.4								
17														
17	6	**0.645**	17	4.7	29	6.4	6	12.9						
17	6	**0.368**	17	4.7	29	8.6	6	3.7						
17	18	**0.424**	17	4.8	29	5	18	8.1						
17	18	**0.565**	17	5.4	21	6.5	18	6.9						
17	21	**0.588**	17	5.4	21	6.8								
17	21	**0.615**	17	4.7	29	3.8	21	11.7						
17	29	**0.62**	17	3.8	29	6.1								
17	29	**0.619**	17	3.7	30	4	29	2.8						
17	30	**0.6**	17	3.6	30	3.8								
17	30	**0.606**	17	6	29	1.5	30	5.9						
18														
18	17	**0.574**	18	4.4	21	6.8	17	4.3						
18	17	**0.419**	18	8.1	29	5	17	4.8						
18	21	**0.594**	18	4.4	21	8.8								
18	21	**0.575**	18	7.9	21	7.2								
18	28	**0.685**	18	4.5	22	9.6	28	6						
18	28	**0.672**	18	4.8	22	6.3	28	10.4						
18	22	**0.595**	18	4.1	22	1.7								
18	22	**0.621**	18	4.3	22	2.9								
18	29	**0.495**	18	7.9	17	1.2	29	11.7						
18	29	**0.63**	18	4.4	21	6.8	17	5.6	29	5.7				
18	30	**0.587**	18	4.4	21	6.8	17	5.2	30	3.5				
18	30	**0.616**	18	8.1	29	11.9	17	2.6	30	6.4				
21														
21	17	**0.593**	21	7	17	4.4								
21	17	**0.539**	21	5.5	29	6.2	17	5.5						
21	18	**0.584**	21	9	18	7								
21	18	**0.589**	21	9.5	18	5.8								
21	22	**0.611**	21	9	18	6.2	22	2.5						
21	22	**0.616**	21	9.5	18	5.3	22	2.5						
21	29	**0.614**	21	7.1	17	5.5	29	5.8						
21	29	**0.488**	21	5.1	17	1	29	11						
21	30	**0.605**	21	6.8	17	5.2	30	3.8						
21	30	**0.502**	21	5.1	29	6.8	17	2.7	30	6.2				
22														

Table B.1 (continued)

From	To	Narrow Road Vuln. Rate	Dist. 1	Dist. 1 Lg.	Dist. 2	Dist. 2 Lg.	Dist. 3	Dist. 3 Lg	Dist. 4	Dist. 4 Lg	Dist. 5	Dist. 5 Lg	Dist. 6	Dist. 6 Lg
22	21	**0.613**	22	2.8	18	6.2	21	9						
22	21	**0.618**	22	2.8	18	5.3	21	10						
22	28	**0.728**	22	8.1	28	6.1								
22	28	**0.715**	22	6.6	28	10.1								
28														
28	18	**0.67**	28	6.8	22	8.1	18	5.9						
28	18	**0.645**	28	10.6	22	3.7	18	7.4						
28	22	**0.728**	28	6.8	22	9.4								
28	22	**0.715**	28	10.3	22	6.8								
29														
29	6	**0.649**	29	5.2	6	12.8								
29	6	**0.747**	29	5.4	6	16.1								
29	17	**0.613**	29	5.1	17	4								
29	17	**0.633**	29	3.5	30	4	17	2.5						
29	18	**0.459**	29	10.1	17	1.2	18	8.1						
29	18	**0.59**	29	5.2	17	5.4	21	7.1	18	6.6				
29	21	**0.613**	29	5.2	17	5.4	21	7.2						
29	21	**0.538**	29	12.6	17	1.2	21	4.1						
29	30	**0.665**	29	3	30	2.4								
29	30	**0.663**	29	3	30	5.6								
30														
30	6	**0.721**	30	3.1	29	9.2	6	13						
30	6	**0.703**	30	14.3	6	9.3								
30	17	**0.579**	30	3.2	17	6.1								
30	17	**0.62**	30	6.1	29	1.8	17	4						
30	18	**0.589**	30	6	17	5.3	21	6.9	18	6.7				
30	18	**0.474**	30	5.7	17	2.9	29	6.2	18	8.1				
30	21	**0.615**	30	6.2	17	4.7	21	7.4						
30	21	**0.393**	30	5.3	29	8.6	17	1.2	21	4.2				
30	29	**0.664**	30	3	29	2.8								
30	29	**0.662**	30	5.3	29	2.8								

APPENDIX C

THE CALCULATION AND RESULTS FOR BRIDGE VULNERABILITY RATE

Appendix C includes the calculation results of Bridge Vulnerability Rate of the routes. The number of bridges are calculated from JICA Report and given in the fourth column of the table in this appendix. Bridge Vulnerabilirt Rate ise calculated as follows:

total number of bridges of the route / the length of the route

The calculation inputs and results are given in the following table:

Table C. 1 Bridge Vulnerability Rates

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
West Side of Istanbul					
AVCILAR	**2**				
Bahçelievler	2	3	**29.3**	21	**0.717**
Bahçelievler	2	3	**24.1**	11	**0.456**
Bakırköy	2	4	**16.5**	7	**0.424**
Bakırköy	2	4	**22.9**	9	**0.393**
Bağcılar	2	5	**24.4**	20	**0.820**
Bağcılar	2	5	**23.1**	11	**0.476**
Büyükçekmece	2	9	**15.1**	5	**0.331**
Büyükçekmece	2	9	**18.5**	5	**0.270**
Küçükçekmece	2	20	**14.4**	5	**0.347**
Küçükçekmece	2	20	**29.4**	24	**0.816**
Zeytinburnu	2	32	**24.6**	13	**0.528**
Zeytinburnu	2	32	**27.4**	16	**0.544**
BAHCELIEVLER	**3**				
Avcılar	3	2	**17.3**	8	**0.462**
Avcılar	3	2	**29.1**	21	**0.722**
Bakırköy	3	4	**9.2**	6	**0.652**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Bakırköy	3	4	**8.8**	9	**1.023**
Bağcılar	3	5	**7.6**	5	**0.658**
Bağcılar	3	5	**7.1**	0	**0.000**
Beyoğlu	3	7	**21.3**	20	**0.939**
Beyoğlu	3	7	**20**	24	**1.200**
Bayrampaşa	3	10	**17.8**	25	**1.404**
Bayrampaşa	3	10	**15.5**	31	**2.000**
Eminönü	3	12	**17.5**	16	**0.914**
Eminönü	3	12	**23**	44	**1.913**
Fatih	3	14	**21.5**	40	**1.860**
Fatih	3	14	**14.3**	22	**1.538**
Güngören	3	15	**6.1**	0	**0.000**
Güngören	3	15	**10**	8	**0.800**
Gaziosmanpaşa	3	16	**17.2**	16	**0.930**
Gaziosmanpaşa	3	16	**20.6**	39	**1.893**
Küçükçekmece	3	20	**5.9**	1	**0.169**
Küçükçekmece	3	20	**8.6**	4	**0.465**
Zeytinburnu	3	32	**16.2**	10	**0.617**
Zeytinburnu	3	32	**11.4**	9	**0.789**
Esenler	3	902	**14.8**	15	**1.014**
Esenler	3	902	**11.5**	4	**0.348**
BAKIRKOY	**4**				
Avcılar	4	2	**16.2**	6	**0.370**
Avcılar	4	2	**15.4**	6	**0.390**
Bahçelievler	4	3	**8.1**	5	**0.617**
Bahçelievler	4	3	**10**	10	**1.000**
Bağcılar	4	5	**13.5**	9	**0.667**
Bağcılar	4	5	**15.3**	14	**0.915**
Beyoğlu	4	7	**18.5**	19	**1.027**
Beyoğlu	4	7	**21**	30	**1.429**
Bayrampaşa	4	10	**18.2**	27	**1.484**
Bayrampaşa	4	10	**16.5**	34	**2.061**
Eminönü	4	12	**11.8**	12	**1.017**
Eminönü	4	12	**16.5**	23	**1.394**
Fatih	4	14	**15.3**	15	**0.980**
Fatih	4	14	**15.2**	23	**1.513**
Güngören	4	15	**11.6**	8	**0.690**
Güngören	4	15	**9.9**	10	**1.010**
Küçükçekmece	4	20	**8.6**	5	**0.581**
Küçükçekmece	4	20	**9.8**	6	**0.612**
Zeytinburnu	4	32	**8.6**	8	**0.930**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Zeytinburnu	4	32	**9.7**	11	**1.134**
BAGCILAR	**5**				
Avcılar	5	2	**22**	14	**0.636**
Avcılar	5	2	**24.3**	20	**0.823**
Bahçelievler	5	3	**8.7**	5	**0.575**
Bahçelievler	5	3	**6.9**	0	**0.000**
Bakırköy	5	4	**13.8**	9	**0.652**
Bakırköy	5	4	**13.1**	8	**0.611**
Bayrampaşa	5	10	**15.7**	37	**2.357**
Bayrampaşa	5	10	**13.7**	14	**1.022**
Eminönü	5	12	**18**	40	**2.222**
Eminönü	5	12	**23.2**	29	**1.250**
Fatih	5	14	**16.7**	36	**2.156**
Fatih	5	14	**21.9**	25	**1.142**
Güngören	5	15	**6.6**	0	**0.000**
Güngören	5	15	**15.8**	23	**1.456**
Gaziosmanpaşa	5	16	**12.3**	13	**1.057**
Gaziosmanpaşa	5	16	**14.8**	15	**1.014**
Küçükçekmece	5	20	**8.8**	6	**0.682**
Küçükçekmece	5	20	**11.1**	2	**0.180**
Zeytinburnu	5	32	**20.7**	15	**0.725**
Zeytinburnu	5	32	**18.3**	27	**1.475**
Esenler	5	902	**10**	11	**1.100**
Esenler	5	902	**7.1**	4	**0.563**
BEYOGLU	**7**				
Bahçelievler	7	3	**19.8**	34	**1.717**
Bahçelievler	7	3	**22.4**	29	**1.295**
Bakırköy	7	4	**20.4**	31	**1.520**
Bakırköy	7	4	**18.8**	23	**1.223**
Bağcılar	7	5	**19.7**	40	**2.030**
Bağcılar	7	5	**24.2**	30	**1.240**
Beşiktaş	7	8	**10.9**	16	**1.468**
Beşiktaş	7	8	**9.4**	5	**0.532**
Bayrampaşa	7	10	**10.7**	28	**2.617**
Bayrampaşa	7	10	**11.5**	28	**2.435**
Eminönü	7	12	**6.4**	8	**1.250**
Eminönü	7	12	**12.2**	14	**1.148**
Eyüp	7	13	**6.8**	10	**1.471**
Eyüp	7	13	**6.7**	7	**1.045**
Fatih	7	14	**5.2**	7	**1.346**
Fatih	7	14	**9.7**	11	**1.134**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Güngören	7	15	**13.8**	23	**1.667**
Güngören	7	15	**13.2**	23	**1.742**
Gaziosmanpaşa	7	16	**16**	19	**1.188**
Gaziosmanpaşa	7	16	**13.1**	14	**1.069**
Kağıthane	7	19	**5.7**	5	**0.877**
Kağıthane	7	19	**7.9**	5	**0.633**
Sarıyer	7	23	**25.6**	21	**0.820**
Sarıyer	7	23	**25.9**	27	**1.042**
Şişli	7	26	**16**	17	**1.063**
Şişli	7	26	**16.3**	23	**1.411**
Zeytinburnu	7	32	**13.4**	18	**1.343**
Zeytinburnu	7	32	**17**	20	**1.176**
Esenler	7	902	**16.7**	35	**2.096**
Esenler	7	902	**19.9**	25	**1.256**
BESIKTAS	**8**				
Beyoğlu	8	7	**11.6**	16	**1.379**
Beyoğlu	8	7	**8.5**	4	**0.471**
Bayrampaşa	8	10	**15.6**	37	**2.372**
Bayrampaşa	8	10	**23.3**	32	**1.373**
Eminönü	8	12	**17.1**	28	**1.637**
Eminönü	8	12	**12.9**	12	**0.930**
Eyüp	8	13	**11.7**	21	**1.795**
Eyüp	8	13	**16.9**	20	**1.183**
Fatih	8	14	**14.6**	23	**1.575**
Fatih	8	14	**11.6**	10	**0.862**
Güngören	8	15	**18.7**	33	**1.765**
Güngören	8	15	**25.6**	37	**1.445**
Gaziosmanpaşa	8	16	**20.7**	45	**2.174**
Gaziosmanpaşa	8	16	**21.2**	30	**1.415**
Kağıthane	8	19	**7.9**	12	**1.519**
Kağıthane	8	19	**10.9**	14	**1.284**
Sarıyer	8	23	**13.6**	11	**0.809**
Sarıyer	8	23	**17.5**	4	**0.229**
Şişli	8	26	**9.3**	9	**0.968**
Şişli	8	26	**15.1**	14	**0.927**
Zeytinburnu	8	32	**21.9**	33	**1.507**
Zeytinburnu	8	32	**19.9**	16	**0.804**
BUYUKCEKMECE	**9**				
Avcılar	9	2	**15.1**	5	**0.331**
Avcılar	9	2	**18.4**	6	**0.326**
Küçükçekmece	9	20	**23.3**	10	**0.429**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Küçükçekmece	9	20	**35.4**	25	**0.706**
Çatalca	9	903	**19.5**	2	**0.103**
Çatalca	9	903	**34.3**	15	**0.437**
Silivri	9	904	**31.1**	8	**0.257**
Silivri	9	904	**44.3**	25	**0.564**
BAYRAMPASA	**10**				
Bahçelievler	10	3	**19.9**	23	**1.156**
Bahçelievler	10	3	**16.1**	34	**2.112**
Bakırköy	10	4	**16.6**	31	**1.867**
Bakırköy	10	4	**19.1**	15	**0.785**
Bağcılar	10	5	**12.5**	13	**1.040**
Bağcılar	10	5	**15**	17	**1.133**
Beyoğlu	10	7	**11.5**	13	**1.130**
Beyoğlu	10	7	**16.2**	10	**0.617**
Beşiktaş	10	8	**15.8**	21	**1.329**
Beşiktaş	10	8	**21.4**	21	**0.981**
Eminönü	10	12	**8.2**	22	**2.683**
Eminönü	10	12	**9.1**	7	**0.769**
Eyüp	10	13	**5.5**	1	**0.182**
Eyüp	10	13	**6**	3	**0.500**
Fatih	10	14	**6.4**	2	**0.313**
Fatih	10	14	**6.9**	16	**2.319**
Güngören	10	15	**7.5**	10	**1.333**
Güngören	10	15	**10.6**	14	**1.321**
Gaziosmanpaşa	10	16	**4.8**	1	**0.208**
Gaziosmanpaşa	10	16	**5.5**	1	**0.182**
Kağıthane	10	19	**11.9**	14	**1.176**
Kağıthane	10	19	**15.1**	6	**0.397**
Küçükçekmece	10	20	**20**	21	**1.050**
Küçükçekmece	10	20	**23.2**	32	**1.379**
Sarıyer	10	23	**31.4**	23	**0.732**
Sarıyer	10	23	**30.7**	32	**1.042**
Şişli	10	26	**21.8**	21	**0.963**
Şişli	10	26	**21.1**	30	**1.422**
Zeytinburnu	10	32	**10.3**	14	**1.359**
Zeytinburnu	10	32	**13.7**	8	**0.584**
Esenler	10	902	**6.4**	2	**0.313**
Esenler	10	902	**9.5**	11	**1.158**
EMINONU	**12**				
Bahçelievler	12	3	**17**	28	**1.647**
Bahçelievler	12	3	**18.5**	22	**1.189**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Bakırköy	12	4	**15.4**	16	**1.039**
Bakırköy	12	4	**17.5**	27	**1.543**
Bağcılar	12	5	**16.6**	34	**2.048**
Bağcılar	12	5	**20.3**	25	**1.232**
Beyoğlu	12	7	**5.4**	9	**1.667**
Beyoğlu	12	7	**12.5**	22	**1.760**
Beşiktaş	12	8	**16.8**	29	**1.726**
Beşiktaş	12	8	**13.3**	15	**1.128**
Bayrampaşa	12	10	**7.7**	24	**3.117**
Bayrampaşa	12	10	**8.5**	6	**0.706**
Eyüp	12	13	**6**	12	**2.000**
Eyüp	12	13	**6.4**	10	**1.563**
Fatih	12	14	**2.2**	5	**2.273**
Fatih	12	14	**2.4**	3	**1.250**
Güngören	12	15	**9.2**	13	**1.413**
Güngören	12	15	**14.9**	34	**2.282**
Gaziosmanpaşa	12	16	**12.8**	27	**2.109**
Gaziosmanpaşa	12	16	**11.7**	12	**1.026**
Kağıthane	12	19	**12.9**	22	**1.705**
Kağıthane	12	19	**10.3**	14	**1.359**
Sarıyer	12	23	**31.7**	43	**1.356**
Sarıyer	12	23	**30.6**	29	**0.948**
Şişli	12	26	**22.1**	41	**1.855**
Şişli	12	26	**22**	27	**1.227**
Zeytinburnu	12	32	**10.1**	13	**1.287**
Zeytinburnu	12	32	**10.3**	9	**0.874**
Esenler	12	902	**13.7**	32	**2.336**
Esenler	12	902	**13.6**	26	**1.912**
EYUP	**13**				
Bahçelievler	13	3	**14.6**	26	**1.781**
Bahçelievler	13	3	**21.9**	40	**1.826**
Bakırköy	13	4	**15.2**	24	**1.579**
Bakırköy	13	4	**16.7**	14	**0.838**
Bağcılar	13	5	**14.5**	30	**2.069**
Bağcılar	13	5	**14.9**	11	**0.738**
Beyoğlu	13	7	**7.9**	12	**1.519**
Beyoğlu	13	7	**11**	7	**0.636**
Beşiktaş	13	8	**12.1**	20	**1.653**
Beşiktaş	13	8	**15.6**	18	**1.154**
Bayrampaşa	13	10	**5.6**	20	**3.571**
Bayrampaşa	13	10	**5**	16	**3.200**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Eminönü	13	12	**7.1**	12	**1.690**
Eminönü	13	12	**6.9**	7	**1.014**
Fatih	13	14	**4**	5	**1.250**
Fatih	13	14	**5.6**	8	**1.429**
Güngören	13	15	**8.6**	14	**1.628**
Güngören	13	15	**12.7**	27	**2.126**
Gaziosmanpaşa	13	16	**6.5**	1	**0.154**
Gaziosmanpaşa	13	16	**10.6**	22	**2.075**
Kağıthane	13	19	**9.2**	14	**1.522**
Kağıthane	13	19	**8.3**	12	**1.446**
Sarıyer	13	23	**27**	29	**1.074**
Sarıyer	13	23	**26.4**	16	**0.606**
Şişli	13	26	**16.9**	14	**0.828**
Şişli	13	26	**17.4**	21	**1.207**
Zeytinburnu	13	32	**11.3**	8	**0.708**
Zeytinburnu	13	32	**9**	13	**1.444**
Esenler	13	902	**11.5**	27	**2.348**
Esenler	13	902	**11.4**	23	**2.018**
FATIH	**14**				
Bahçelievler	14	3	**15.4**	24	**1.558**
Bahçelievler	14	3	**20.1**	29	**1.443**
Bakırköy	14	4	**15.9**	23	**1.447**
Bakırköy	14	4	**15.1**	15	**0.993**
Bağcılar	14	5	**15.1**	30	**1.987**
Bağcılar	14	5	**18.8**	20	**1.064**
Beyoğlu	14	7	**4.6**	6	**1.304**
Beyoğlu	14	7	**10.9**	16	**1.468**
Beşiktaş	14	8	**15.1**	25	**1.656**
Beşiktaş	14	8	**13.4**	12	**0.896**
Bayrampaşa	14	10	**6.1**	18	**2.951**
Bayrampaşa	14	10	**6.3**	2	**0.317**
Eminönü	14	12	**3.1**	5	**1.613**
Eminönü	14	12	**2.4**	3	**1.250**
Eyüp	14	13	**5.3**	7	**1.321**
Eyüp	14	13	**4.9**	4	**0.816**
Güngören	14	15	**9.3**	13	**1.398**
Güngören	14	15	**13.3**	29	**2.180**
Gaziosmanpaşa	14	16	**11.2**	23	**2.054**
Gaziosmanpaşa	14	16	**9.1**	3	**0.330**
Kağıthane	14	19	**11.3**	13	**1.150**
Kağıthane	14	19	**10**	11	**1.100**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Sarıyer	14	23	**30**	35	**1.167**
Sarıyer	14	23	**29.9**	30	**1.003**
Şişli	14	26	**20.5**	33	**1.610**
Şişli	14	26	**20.4**	28	**1.373**
Zeytinburnu	14	32	**9.7**	9	**0.928**
Zeytinburnu	14	32	**11.6**	8	**0.690**
Esenler	14	902	**12**	27	**2.250**
Esenler	14	902	**12**	22	**1.833**
GUNGOREN	**15**				
Bahçelievler	15	3	**6.3**	0	**0.000**
Bahçelievler	15	3	**9.2**	13	**1.413**
Bakırköy	15	4	**11.5**	10	**0.870**
Bakırköy	15	4	**9.6**	12	**1.250**
Bağcılar	15	5	**7**	0	**0.000**
Bağcılar	15	5	**14.6**	22	**1.507**
Beyoğlu	15	7	**18.4**	40	**2.174**
Beyoğlu	15	7	**12.2**	19	**1.557**
Bayrampaşa	15	10	**6.2**	11	**1.774**
Bayrampaşa	15	10	**5.4**	4	**0.741**
Eminönü	15	12	**8.7**	14	**1.609**
Eminönü	15	12	**14.1**	31	**2.199**
Eyüp	15	13	**12.8**	31	**2.422**
Eyüp	15	13	**8.6**	12	**1.395**
Fatih	15	14	**8**	11	**1.375**
Fatih	15	14	**12.6**	26	**2.063**
Gaziosmanpaşa	15	16	**10.4**	12	**1.154**
Gaziosmanpaşa	15	16	**9.8**	7	**0.714**
Kağıthane	15	19	**18.7**	31	**1.658**
Kağıthane	15	19	**16.9**	14	**0.828**
Küçükçekmece	15	20	**12.1**	4	**0.331**
Küçükçekmece	15	20	**10.2**	1	**0.098**
Zeytinburnu	15	32	**4.8**	5	**1.042**
Zeytinburnu	15	32	**12.4**	13	**1.048**
Esenler	15	902	**11.2**	13	**1.161**
Esenler	15	902	**11.5**	19	**1.652**
GAZIOSMANPASA	**16**				
Bağcılar	16	5	**13.5**	13	**0.963**
Bağcılar	16	5	**14.7**	11	**0.748**
Beyoğlu	16	7	**16.8**	19	**1.131**
Beyoğlu	16	7	**18.3**	32	**1.749**
Beşiktaş	16	8	**22.5**	43	**1.911**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Beşiktaş	16	8	**19.2**	23	**1.198**
Bayrampaşa	16	10	**7.1**	5	**0.704**
Bayrampaşa	16	10	**5.4**	1	**0.185**
Eminönü	16	12	**14.1**	28	**1.986**
Eminönü	16	12	**11.5**	17	**1.478**
Eyüp	16	13	**12.8**	24	**1.875**
Eyüp	16	13	**7.9**	0	**0.000**
Fatih	16	14	**12.5**	21	**1.680**
Fatih	16	14	**9.2**	3	**0.326**
Güngören	16	15	**11.5**	12	**1.043**
Güngören	16	15	**11.8**	9	**0.763**
Kağıthane	16	19	**12.1**	8	**0.661**
Kağıthane	16	19	**10.9**	3	**0.275**
Sarıyer	16	23	**25.6**	15	**0.586**
Sarıyer	16	23	**28.8**	16	**0.556**
Şişli	16	26	**16.1**	13	**0.807**
Şişli	16	26	**14.2**	5	**0.352**
Zeytinburnu	16	32	**14**	13	**0.929**
Zeytinburnu	16	32	**18.8**	26	**1.383**
Esenler	16	902	**7.6**	2	**0.263**
Esenler	16	902	**8.3**	5	**0.602**
KAGITHANE	**19**				
Bağcılar	19	5	**20.4**	43	**2.108**
Bağcılar	19	5	**20**	17	**0.850**
Beyoğlu	19	7	**7**	7	**1.000**
Beyoğlu	19	7	**9**	8	**0.889**
Beşiktaş	19	8	**8.3**	11	**1.325**
Beşiktaş	19	8	**7.6**	9	**1.184**
Bayrampaşa	19	10	**11.4**	30	**2.632**
Bayrampaşa	19	10	**14.7**	25	**1.701**
Eminönü	19	12	**13**	25	**1.923**
Eminönü	19	12	**10.3**	16	**1.553**
Eyüp	19	13	**7.5**	14	**1.867**
Eyüp	19	13	**9**	6	**0.667**
Fatih	19	14	**10.4**	15	**1.442**
Fatih	19	14	**9.8**	13	**1.327**
Güngören	19	15	**14.4**	25	**1.736**
Güngören	19	15	**22.7**	26	**1.145**
Gaziosmanpaşa	19	16	**11.8**	8	**0.678**
Gaziosmanpaşa	19	16	**16.5**	34	**2.061**
Sarıyer	19	23	**20.1**	5	**0.249**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Sarıyer	19	23	**20.3**	8	**0.394**
Şişli	19	26	**7.5**	4	**0.533**
Şişli	19	26	**7.4**	3	**0.405**
Zeytinburnu	19	32	**17.7**	23	**1.299**
Zeytinburnu	19	32	**21**	15	**0.714**
Esenler	19	902	**17.4**	36	**2.069**
Esenler	19	902	**15.9**	14	**0.881**
KUCUKCEKMECE	**20**				
Avcılar	20	2	**12.2**	5	**0.410**
Avcılar	20	2	**30.2**	23	**0.762**
Bahçelievler	20	3	**9.7**	5	**0.515**
Bahçelievler	20	3	**6.4**	1	**0.156**
Bakırköy	20	4	**9.3**	2	**0.215**
Bakırköy	20	4	**14.8**	9	**0.608**
Bağcılar	20	5	**8.8**	6	**0.682**
Bağcılar	20	5	**8.3**	4	**0.482**
Büyükçekmece	20	9	**21.6**	10	**0.463**
Büyükçekmece	20	9	**36**	27	**0.750**
Bayrampaşa	20	10	**21.6**	43	**1.991**
Bayrampaşa	20	10	**23.6**	40	**1.695**
Güngören	20	15	**21.8**	30	**1.376**
Güngören	20	15	**15.1**	5	**0.331**
Gaziosmanpaşa	20	16	**18.4**	16	**0.870**
Gaziosmanpaşa	20	16	**20.6**	23	**1.117**
Zeytinburnu	20	32	**17.4**	8	**0.460**
Zeytinburnu	20	32	**21.7**	14	**0.645**
Esenler	20	902	**16.1**	14	**0.870**
Esenler	20	902	**16.9**	12	**0.710**
SARIYER	**23**				
Beyoğlu	23	7	**26.5**	21	**0.792**
Beyoğlu	23	7	**29.1**	6	**0.206**
Beşiktaş	23	8	**21.7**	13	**0.599**
Beşiktaş	23	8	**22.9**	2	**0.087**
Bayrampaşa	23	10	**30.2**	46	**1.523**
Bayrampaşa	23	10	**32**	25	**0.781**
Eminönü	23	12	**31.8**	38	**1.195**
Eminönü	23	12	**27.3**	22	**0.806**
Eyüp	23	13	**26.3**	29	**1.103**
Eyüp	23	13	**26**	17	**0.654**
Fatih	23	14	**29.1**	34	**1.168**
Fatih	23	14	**27.5**	22	**0.800**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Gaziosmanpaşa	23	16	**25.5**	15	**0.588**
Gaziosmanpaşa	23	16	**33.8**	29	**0.858**
Kağıthane	23	19	**19.1**	10	**0.524**
Kağıthane	23	19	**19.2**	9	**0.469**
Şişli	23	26	**16.1**	2	**0.124**
Şişli	23	26	**21.7**	2	**0.092**
Esenler	23	902	**29.6**	21	**0.709**
Esenler	23	902	**35.4**	30	**0.847**
SISLI	**26**				
Beyoğlu	26	7	**17.3**	18	**1.040**
Beyoğlu	26	7	**16.8**	20	**1.190**
Beşiktaş	26	8	**12.4**	12	**0.968**
Beşiktaş	26	8	**16.1**	2	**0.124**
Bayrampaşa	26	10	**21**	45	**2.143**
Bayrampaşa	26	10	**20.6**	38	**1.845**
Eminönü	26	12	**22.5**	38	**1.689**
Eminönü	26	12	**19.6**	20	**1.020**
Eyüp	26	13	**17.1**	26	**1.520**
Eyüp	26	13	**15**	6	**0.400**
Fatih	26	14	**19.9**	26	**1.307**
Fatih	26	14	**20.2**	24	**1.188**
Gaziosmanpaşa	26	16	**16.3**	13	**0.798**
Gaziosmanpaşa	26	16	**19.2**	16	**0.833**
Kağıthane	26	19	**7**	3	**0.429**
Kağıthane	26	19	**9**	5	**0.556**
Sarıyer	26	23	**16.6**	2	**0.120**
Sarıyer	26	23	**22.5**	2	**0.089**
Esenler	26	902	**20.3**	19	**0.936**
Esenler	26	902	**26.9**	49	**1.822**
ZEYTINBURNU	**32**				
Avcılar	32	2	**24.8**	12	**0.484**
Avcılar	32	2	**36.9**	36	**0.976**
Bahçelievler	32	3	**12.3**	12	**0.976**
Bahçelievler	32	3	**9.5**	5	**0.526**
Bakırköy	32	4	**8.7**	7	**0.805**
Bakırköy	32	4	**16.6**	14	**0.843**
Bağcılar	32	5	**20**	14	**0.700**
Bağcılar	32	5	**17.6**	20	**1.136**
Beyoğlu	32	7	**11.7**	14	**1.197**
Beyoğlu	32	7	**15**	15	**1.000**
Beşiktaş	32	8	**19.2**	25	**1.302**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Beşiktaş	32	8	**19.5**	19	**0.974**
Bayrampaşa	32	10	**10.2**	19	**1.863**
Bayrampaşa	32	10	**9.3**	13	**1.398**
Eminönü	32	12	**8.2**	10	**1.220**
Eminönü	32	12	**8.9**	6	**0.674**
Eyüp	32	13	**8.7**	4	**0.460**
Eyüp	32	13	**12.7**	12	**0.945**
Fatih	32	14	**8.5**	9	**1.059**
Fatih	32	14	**8**	3	**0.375**
Güngören	32	15	**4.7**	6	**1.277**
Güngören	32	15	**17.3**	28	**1.618**
Gaziosmanpaşa	32	16	**13.5**	17	**1.259**
Gaziosmanpaşa	32	16	**15.2**	22	**1.447**
Kağıthane	32	19	**15.4**	15	**0.974**
Kağıthane	32	19	**17.8**	7	**0.393**
Küçükçekmece	32	20	**17.1**	13	**0.760**
Küçükçekmece	32	20	**19.2**	20	**1.042**
Esenler	32	902	**14.3**	16	**1.119**
Esenler	32	902	**16.1**	26	**1.615**
ESENLER	**902**				
Bahçelievler	902	3	**14**	15	**1.071**
Bahçelievler	902	3	**12.1**	2	**0.165**
Bağcılar	902	5	**5.2**	5.2	**1.000**
Bağcılar	902	5	**6.6**	4	**0.606**
Beyoğlu	902	7	**17.5**	31	**1.771**
Beyoğlu	902	7	**20.8**	26	**1.250**
Bayrampaşa	902	10	**7**	4	**0.571**
Bayrampaşa	902	10	**8.7**	9	**1.034**
Eminönü	902	12	**13.3**	28	**2.105**
Eminönü	902	12	**15.7**	31	**1.975**
Eyüp	902	13	**12**	24	**2.000**
Eyüp	902	13	**13.2**	30	**2.273**
Fatih	902	14	**11.7**	27	**2.308**
Fatih	902	14	**12.9**	34	**2.636**
Güngören	902	15	**10.8**	13	**1.204**
Güngören	902	15	**8**	4	**0.500**
Gaziosmanpaşa	902	16	**7.2**	3	**0.417**
Gaziosmanpaşa	902	16	**9**	7	**0.778**
Kağıthane	902	19	**16.7**	14	**0.838**
Kağıthane	902	19	**17.9**	33	**1.844**
Küçükçekmece	902	20	**14.1**	14	**0.993**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Küçükçekmece	902	20	**14.8**	13	**0.878**
Sarıyer	902	23	**29.7**	21	**0.707**
Sarıyer	902	23	**36.7**	57	**1.553**
Şişli	902	26	**20.1**	19	**0.945**
Şişli	902	26	**27.1**	55	**2.030**
Zeytinburnu	902	32	**13.3**	15	**1.128**
Zeytinburnu	902	32	**18**	27	**1.500**
CATALCA	**903**				
Avcılar	903	2	**35.6**	18	**0.506**
Avcılar	903	2	**33.7**	8	**0.237**
Büyükçekmece	903	9	**21.2**	4	**0.189**
Büyükçekmece	903	9	**32.9**	15	**0.456**
Silivri	903	904	**34.3**	10	**0.292**
Silivri	903	904	**40.6**	21	**0.517**
SILIVRI	**904**				
Büyükçekmece	904	9	**31.8**	7	**0.220**
Büyükçekmece	904	9	**45.7**	22	**0.481**
Çatalca	904	903	**33.6**	10	**0.298**
Çatalca	904	903	**40.5**	21	**0.519**
East Side of Istanbul					
BEYKOZ	**6**				
Kadıköy	6	17	**26.1**	14	**0.536**
Kadıköy	6	17	**31**	13	**0.419**
Ümraniye	6	29	**19.9**	9	**0.452**
Ümraniye	6	29	**21.8**	2	**0.092**
Üsküdar	6	30	**24.8**	16	**0.645**
Üsküdar	6	30	**23.8**	1	**0.042**
KADIKOY	**17**				
Beykoz	17	6	**26**	14	**0.538**
Beykoz	17	6	**30.3**	13	**0.429**
Kartal	17	18	**24.1**	13	**0.539**
Kartal	17	18	**18.8**	10	**0.532**
Maltepe	17	21	**12.2**	5	**0.410**
Maltepe	17	21	**20.2**	12	**0.594**
Ümraniye	17	29	**9.9**	14	**1.414**
Ümraniye	17	29	**10.5**	12	**1.143**
Üsküdar	17	30	**7.4**	5	**0.676**
Üsküdar	17	30	**13.4**	17	**1.269**
KARTAL	**18**				
Kadıköy	18	17	**15.5**	9	**0.581**
Kadıköy	18	17	**24.4**	13	**0.533**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Maltepe	18	21	**13.2**	4	**0.303**
Maltepe	18	21	**15.1**	2	**0.132**
Tuzla	18	28	**20.1**	4	**0.199**
Tuzla	18	28	**21.5**	9	**0.419**
Pendik	18	22	**5.8**	1	**0.172**
Pendik	18	22	**7.2**	4	**0.556**
Ümraniye	18	29	**25.6**	19	**0.742**
Ümraniye	18	29	**22.5**	18	**0.800**
Üsküdar	18	30	**19.9**	11	**0.553**
Üsküdar	18	30	**29**	20	**0.690**
MALTEPE	**21**				
Kadıköy	21	17	**11.4**	5	**0.439**
Kadıköy	21	17	**19.6**	12	**0.612**
Kartal	21	18	**16**	7	**0.438**
Kartal	21	18	**15.3**	1	**0.065**
Pendik	21	22	**17.7**	9	**0.508**
Pendik	21	22	**17.3**	4	**0.231**
Ümraniye	21	29	**18.4**	15	**0.815**
Ümraniye	21	29	**22.8**	19	**0.833**
Üsküdar	21	30	**15.8**	7	**0.443**
Üsküdar	21	30	**26.5**	21	**0.792**
PENDIK	**22**				
Maltepe	22	21	**18**	10	**0.556**
Maltepe	22	21	**18.1**	5	**0.276**
Tuzla	22	28	**14.2**	3	**0.211**
Tuzla	22	28	**16.7**	4	**0.240**
TUZLA	**28**				
Kartal	28	18	**20.8**	6	**0.288**
Kartal	28	18	**21.7**	8	**0.369**
Pendik	28	22	**16.2**	5	**0.309**
Pendik	28	22	**17.1**	8	**0.468**
UMRANIYE	**29**				
Beykoz	29	6	**20.6**	9	**0.437**
Beykoz	29	6	**21.5**	2	**0.093**
Kadıköy	29	17	**9.1**	11	**1.209**
Kadıköy	29	17	**10**	13	**1.300**
Kartal	29	18	**25.5**	17	**0.667**
Kartal	29	18	**24.3**	18	**0.741**
Maltepe	29	21	**17.8**	13	**0.730**
Maltepe	29	21	**21.7**	16	**0.737**
Üsküdar	29	30	**5.4**	6	**1.111**

Table C.1 (continued)

District	From	To	Distance	Bridge #	Bridge Vuln. Rate
Üsküdar	29	30	**8.6**	10	**1.163**
USKUDAR	**30**				
Beykoz	30	6	**25.3**	17	**0.672**
Beykoz	30	6	**23.6**	1	**0.042**
Kadıköy	30	17	**9.3**	8	**0.860**
Kadıköy	30	17	**11.9**	14	**1.176**
Kartal	30	18	**24.9**	15	**0.602**
Kartal	30	18	**29**	20	**0.690**
Maltepe	30	21	**18.3**	10	**0.546**
Maltepe	30	21	**25.2**	19	**0.754**
Ümraniye	30	29	**5.8**	6	**1.034**
Ümraniye	30	29	**8.1**	9	**1.111**

APPENDIX D

THE CALCULATION AND RESULTS FOR SCALED VULNERABILITY RATES

The vulnerability rates given in Appendix B and Appendix C are not the rates used in the model. Using these rates the scaled vulnerability rates for bridges and narrow roads are calculated. In order to that, East and West Sides of Istanbul are evaluated separately and the max. and min. vulnerability values for bridge and narrow roads and the owner routes of these values are found. These are shown in the following table:

Table D. 1 Minimum and Maximum Vulnerability Rates

Rates	Routes	Values
	East Side of Istanbul	
Min. Bridge Vuln. Rate	from Üsküdar to Beykoz , from Beykoz to Üsküdar	**0.042**
Min. Narrow Road Vuln. Rate	from Kadıköy to Beykoz	**0.368**
Max. Bridge Vuln. Rate	from Kadıköy to Ümraniye	**1.414**
Max. Narrow Road Vuln. Rate	from Ümraniye to Beykoz, from Beykoz to Ümraniye	**0.747**
	West Side of Istanbul	
Min. Bridge Vuln. Rate	from Bahcelievler to Bağcılar, from Bahçelievler to Güngören, from Bağcılar to Bahçelievler, from Bağcılar to Güngören, from Güngören to Bahçelievler, from Güngören to Bağcılar, from Gaziosmanpaşa to Eyüp	**0.000**
Min. Narrow Road Vuln. Rate	from Şişli to Sarıyer	**0.283**
Max. Bridge Vuln. Rate	from Eyüp to Bayrampaşa	**3.571**
Max. Narrow Road Vuln. Rate	from Sarıyer to Şişli	**0.752**

Using these values in the following formulas the scaled bridge vulnerability rate and scaled narrow road vulnerability rates are calculated:

scaled bridge vuln. rate = [(bridge vuln. rate of the route – min.bridge vuln.rate of related side) / (max.bridge vuln.rate of related side - min.bridge vuln.rate of related side)] + 1

Scaled Narrow Road Vuln. Rate = [(Narrow Road Vuln. Rate of the Route – Min. Narrow Road Vuln.Rate of Related Side) / (Max. Narrow Road Vuln.Rate of Related Side - Min. Narrow Road Vuln.Rate of Related Side)] + 1

After calculating these, the combined transportation mean vulnerability rate can be obtained taking the average of these values:

(scaled narrow road vuln. rate + scaled bridge vuln. rate) / 2

Table D. 2 Vulnerability Rates

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
3	2	1.13	1.67	1.40
3	2	1.20	1.73	1.47
4	2	1.10	1.58	1.34
4	2	1.11	1.57	1.34
5	2	1.18	1.59	1.38
5	2	1.23	1.76	1.49
9	2	1.09	1.22	1.15
9	2	1.09	1.14	1.12
20	2	1.11	1.78	1.45
20	2	1.21	1.79	1.50
32	2	1.14	1.52	1.33
32	2	1.27	1.80	1.54
903	2	1.14	1.00	1.00
903	2	1.07	1.00	1.00
2	3	1.20	1.72	1.46
2	3	1.13	1.53	1.33
4	3	1.17	1.43	1.30
4	3	1.28	1.43	1.36
5	3	1.16	1.57	1.36

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
5	3	1.00	1.58	1.29
7	3	1.48	1.62	1.55
7	3	1.36	1.62	1.49
10	3	1.32	1.56	1.44
10	3	1.59	1.45	1.52
12	3	1.46	1.54	1.50
12	3	1.33	1.56	1.45
13	3	1.50	1.50	1.50
13	3	1.51	1.59	1.55
14	3	1.44	1.51	1.47
14	3	1.40	1.61	1.51
15	3	1.00	1.38	1.19
15	3	1.40	1.42	1.41
20	3	1.14	1.67	1.41
20	3	1.04	1.71	1.38
32	3	1.27	1.44	1.36
32	3	1.15	1.52	1.33
902	3	1.30	1.65	1.47
902	3	1.05	1.65	1.35
2	4	1.12	1.57	1.35
2	4	1.11	1.53	1.32
3	4	1.18	1.44	1.31
3	4	1.29	1.44	1.36
5	4	1.18	1.51	1.35
5	4	1.17	1.50	1.34
7	4	1.43	1.60	1.51
7	4	1.34	1.68	1.51
10	4	1.52	1.44	1.48
10	4	1.22	1.48	1.35
12	4	1.29	1.59	1.44
12	4	1.43	1.52	1.48
13	4	1.44	1.48	1.46
13	4	1.23	1.49	1.36
14	4	1.41	1.49	1.45

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
14	4	1.28	1.62	1.45
15	4	1.24	1.41	1.33
15	4	1.35	1.41	1.38
20	4	1.06	1.63	1.35
20	4	1.17	1.69	1.43
32	4	1.23	1.42	1.32
32	4	1.24	1.43	1.33
2	5	1.23	1.77	1.50
2	5	1.13	1.75	1.44
3	5	1.18	1.57	1.38
3	5	1.00	1.58	1.29
4	5	1.19	1.51	1.35
4	5	1.26	1.50	1.38
7	5	1.57	1.77	1.67
7	5	1.35	1.85	1.60
10	5	1.29	1.57	1.43
10	5	1.32	1.59	1.46
12	5	1.57	1.75	1.66
12	5	1.34	1.56	1.45
13	5	1.58	1.62	1.60
13	5	1.21	1.79	1.50
14	5	1.56	1.63	1.59
14	5	1.30	1.55	1.42
15	5	1.00	1.57	1.29
15	5	1.42	1.85	1.64
16	5	1.27	1.83	1.55
16	5	1.21	1.85	1.53
19	5	1.59	1.68	1.63
19	5	1.24	1.83	1.54
20	5	1.19	1.84	1.51
20	5	1.13	1.83	1.48
32	5	1.20	1.48	1.34
32	5	1.32	1.77	1.54
902	5	1.28	1.78	1.53

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
902	5	1.17	1.76	1.47
17	6	1.36	1.73	1.55
17	6	1.28	1.00	1.14
29	6	1.29	1.74	1.51
29	6	1.04	2.00	1.52
30	6	1.46	1.93	1.70
30	6	1.00	1.88	1.44
3	7	1.26	1.62	1.44
3	7	1.34	1.63	1.49
4	7	1.29	1.53	1.41
4	7	1.40	1.60	1.50
8	7	1.39	1.73	1.56
8	7	1.13	1.64	1.39
10	7	1.32	1.77	1.54
10	7	1.17	1.81	1.49
12	7	1.47	1.69	1.58
12	7	1.49	1.89	1.69
13	7	1.43	1.84	1.63
13	7	1.18	1.85	1.51
14	7	1.37	1.83	1.60
14	7	1.41	1.91	1.66
15	7	1.61	1.63	1.62
15	7	1.44	1.65	1.54
16	7	1.32	1.86	1.59
16	7	1.49	1.69	1.59
19	7	1.28	1.82	1.55
19	7	1.25	1.84	1.54
23	7	1.22	1.94	1.58
23	7	1.06	1.89	1.48
26	7	1.29	1.80	1.54
26	7	1.33	1.78	1.56
32	7	1.34	1.76	1.55
32	7	1.28	1.65	1.47
902	7	1.50	1.92	1.71

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
902	7	1.35	1.90	1.62
7	8	1.41	1.69	1.55
7	8	1.15	1.66	1.40
10	8	1.37	1.66	1.52
10	8	1.27	1.70	1.49
12	8	1.48	1.76	1.62
12	8	1.32	1.60	1.46
13	8	1.46	1.67	1.56
13	8	1.32	1.71	1.52
14	8	1.46	1.75	1.61
14	8	1.25	1.67	1.46
16	8	1.54	1.62	1.58
16	8	1.34	1.71	1.52
19	8	1.37	1.65	1.51
19	8	1.33	1.63	1.48
23	8	1.17	1.82	1.50
23	8	1.02	1.94	1.48
26	8	1.27	1.67	1.47
26	8	1.03	1.82	1.43
32	8	1.36	1.58	1.47
32	8	1.27	1.59	1.43
2	9	1.09	1.20	1.15
2	9	1.08	1.02	1.05
20	9	1.13	1.37	1.25
20	9	1.21	1.22	1.21
903	9	1.05	1.00	1.00
903	9	1.13	1.00	1.00
904	9	1.06	1.00	1.00
904	9	1.13	1.00	1.00
3	10	1.39	1.72	1.56
3	10	1.56	1.51	1.53
4	10	1.42	1.43	1.42
4	10	1.58	1.43	1.51
5	10	1.66	1.58	1.62

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
5	10	1.29	1.60	1.44
7	10	1.73	1.78	1.76
7	10	1.68	1.50	1.59
8	10	1.66	1.62	1.64
8	10	1.38	1.68	1.53
12	10	1.87	1.68	1.77
12	10	1.20	1.66	1.43
13	10	2.00	1.62	1.81
13	10	1.90	1.62	1.76
14	10	1.83	1.64	1.74
14	10	1.09	1.78	1.44
15	10	1.50	1.70	1.60
15	10	1.21	1.43	1.32
16	10	1.20	1.54	1.37
16	10	1.05	1.56	1.31
19	10	1.74	1.68	1.71
19	10	1.48	1.71	1.60
20	10	1.56	1.75	1.65
20	10	1.47	1.61	1.54
23	10	1.43	1.84	1.63
23	10	1.22	1.85	1.53
26	10	1.60	1.71	1.66
26	10	1.52	1.73	1.62
32	10	1.52	1.46	1.49
32	10	1.39	1.61	1.50
902	10	1.16	1.75	1.46
902	10	1.29	1.84	1.56
3	12	1.26	1.58	1.42
3	12	1.54	1.65	1.59
4	12	1.28	1.52	1.40
4	12	1.39	1.52	1.46
5	12	1.62	1.67	1.64
5	12	1.35	1.57	1.46
7	12	1.35	1.71	1.53

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
7	12	1.32	1.86	1.59
8	12	1.46	1.72	1.59
8	12	1.26	1.64	1.45
10	12	1.75	1.72	1.73
10	12	1.22	1.71	1.46
13	12	1.47	1.85	1.66
13	12	1.28	1.84	1.56
14	12	1.45	1.87	1.66
14	12	1.35	1.78	1.57
15	12	1.45	1.59	1.52
15	12	1.62	1.57	1.59
16	12	1.56	1.62	1.59
16	12	1.41	1.65	1.53
19	12	1.54	1.72	1.63
19	12	1.43	1.72	1.58
23	12	1.33	1.90	1.62
23	12	1.23	1.81	1.52
26	12	1.47	1.80	1.63
26	12	1.29	1.69	1.49
32	12	1.34	1.72	1.53
32	12	1.19	1.62	1.40
902	12	1.59	1.79	1.69
902	12	1.55	1.82	1.69
7	13	1.41	1.93	1.67
7	13	1.29	1.83	1.56
8	13	1.50	1.65	1.58
8	13	1.33	1.71	1.52
10	13	1.05	1.61	1.33
10	13	1.14	1.63	1.39
12	13	1.56	1.86	1.71
12	13	1.44	1.90	1.67
14	13	1.37	1.87	1.62
14	13	1.23	1.83	1.53
15	13	1.68	1.74	1.71

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
15	13	1.39	1.52	1.46
16	13	1.53	1.59	1.56
16	13	1.00	1.88	1.44
19	13	1.52	1.68	1.60
19	13	1.19	1.77	1.48
23	13	1.31	1.85	1.58
23	13	1.18	1.92	1.55
26	13	1.43	1.75	1.59
26	13	1.11	1.76	1.44
32	13	1.13	1.55	1.34
32	13	1.26	1.83	1.55
902	13	1.56	1.77	1.67
902	13	1.64	1.80	1.72
3	14	1.52	1.64	1.58
3	14	1.43	1.54	1.49
4	14	1.27	1.62	1.45
4	14	1.42	1.49	1.46
5	14	1.60	1.66	1.63
5	14	1.32	1.56	1.44
7	14	1.38	1.81	1.60
7	14	1.32	1.85	1.59
8	14	1.44	1.69	1.57
8	14	1.24	1.69	1.46
10	14	1.09	1.64	1.36
10	14	1.65	1.69	1.67
12	14	1.64	1.84	1.74
12	14	1.35	1.79	1.57
13	14	1.35	1.93	1.64
13	14	1.40	1.86	1.63
15	14	1.39	1.79	1.59
15	14	1.58	1.73	1.65
16	14	1.47	1.60	1.53
16	14	1.09	1.64	1.37
19	14	1.40	1.81	1.61

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
19	14	1.37	1.80	1.58
23	14	1.33	1.87	1.60
23	14	1.22	1.83	1.53
26	14	1.37	1.79	1.58
26	14	1.33	1.78	1.56
32	14	1.30	1.78	1.54
32	14	1.11	1.61	1.36
902	14	1.65	1.79	1.72
902	14	1.74	1.82	1.78
3	15	1.00	1.38	1.19
3	15	1.22	1.36	1.29
4	15	1.19	1.40	1.30
4	15	1.28	1.40	1.34
5	15	1.00	1.43	1.22
5	15	1.41	1.54	1.48
7	15	1.47	1.64	1.55
7	15	1.49	1.66	1.57
8	15	1.49	1.56	1.52
8	15	1.40	1.65	1.53
10	15	1.37	1.61	1.49
10	15	1.37	1.57	1.47
12	15	1.40	1.59	1.49
12	15	1.64	1.57	1.60
13	15	1.46	1.49	1.47
13	15	1.60	1.33	1.46
14	15	1.39	1.50	1.45
14	15	1.61	1.53	1.57
16	15	1.29	1.72	1.50
16	15	1.21	1.67	1.44
19	15	1.49	1.58	1.53
19	15	1.32	1.86	1.59
20	15	1.39	1.83	1.61
20	15	1.09	1.60	1.35
32	15	1.36	1.36	1.36

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
32	15	1.45	1.60	1.53
902	15	1.34	1.89	1.61
902	15	1.14	1.72	1.43
3	16	1.26	1.73	1.50
3	16	1.53	1.60	1.57
5	16	1.30	1.81	1.55
5	16	1.28	1.82	1.55
7	16	1.33	1.83	1.58
7	16	1.30	1.85	1.57
8	16	1.61	1.61	1.61
8	16	1.40	1.69	1.54
10	16	1.06	1.75	1.40
10	16	1.05	1.57	1.31
12	16	1.59	1.64	1.62
12	16	1.29	1.88	1.58
13	16	1.04	1.86	1.45
13	16	1.58	1.59	1.59
14	16	1.58	1.62	1.60
14	16	1.09	1.89	1.49
15	16	1.32	1.85	1.59
15	16	1.20	1.73	1.46
19	16	1.19	1.82	1.51
19	16	1.58	1.57	1.57
20	16	1.24	1.85	1.55
20	16	1.31	1.88	1.60
23	16	1.16	1.94	1.55
23	16	1.24	1.88	1.56
26	16	1.22	1.80	1.51
26	16	1.23	1.78	1.51
32	16	1.35	1.79	1.57
32	16	1.41	1.49	1.45
902	16	1.12	1.83	1.47
902	16	1.22	1.95	1.59
6	17	1.36	1.65	1.51

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
6	17	1.28	1.03	1.15
18	17	1.39	1.54	1.47
18	17	1.36	1.13	1.25
21	17	1.29	1.59	1.44
21	17	1.42	1.45	1.43
29	17	1.85	1.65	1.75
29	17	1.92	1.70	1.81
30	17	1.60	1.56	1.58
30	17	1.83	1.66	1.75
17	18	1.36	1.15	1.25
17	18	1.36	1.52	1.44
21	18	1.29	1.57	1.43
21	18	1.02	1.58	1.30
28	18	1.18	1.80	1.49
28	18	1.24	1.73	1.48
29	18	1.46	1.24	1.35
29	18	1.51	1.58	1.55
30	18	1.41	1.58	1.50
30	18	1.47	1.28	1.38
7	19	1.25	1.82	1.53
7	19	1.18	1.78	1.48
8	19	1.43	1.64	1.53
8	19	1.36	1.61	1.48
10	19	1.33	1.69	1.51
10	19	1.11	1.73	1.42
12	19	1.48	1.81	1.64
12	19	1.38	1.74	1.56
13	19	1.43	1.77	1.60
13	19	1.40	1.71	1.56
14	19	1.32	1.83	1.58
14	19	1.31	1.80	1.55
15	19	1.46	1.70	1.58
15	19	1.23	1.72	1.48
16	19	1.19	1.81	1.50

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
16	19	1.08	1.80	1.44
23	19	1.15	1.96	1.55
23	19	1.13	1.95	1.54
26	19	1.12	1.74	1.43
26	19	1.16	1.74	1.45
32	19	1.27	1.59	1.43
32	19	1.11	1.66	1.38
902	19	1.23	1.86	1.55
902	19	1.52	1.72	1.62
2	20	1.10	1.70	1.40
2	20	1.23	1.79	1.51
3	20	1.05	1.72	1.38
3	20	1.13	1.62	1.38
4	20	1.16	1.56	1.36
4	20	1.17	1.70	1.43
5	20	1.19	1.84	1.51
5	20	1.05	1.84	1.45
9	20	1.12	1.43	1.28
9	20	1.20	1.36	1.28
10	20	1.29	1.82	1.56
10	20	1.39	1.55	1.47
15	20	1.09	1.69	1.39
15	20	1.03	1.54	1.29
32	20	1.21	1.50	1.35
32	20	1.29	1.49	1.39
902	20	1.28	1.85	1.56
902	20	1.25	1.85	1.55
17	21	1.27	1.58	1.42
17	21	1.40	1.65	1.53
18	21	1.19	1.60	1.39
18	21	1.07	1.55	1.31
22	21	1.37	1.65	1.51
22	21	1.17	1.66	1.42
29	21	1.50	1.65	1.57

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
29	21	1.51	1.45	1.48
30	21	1.37	1.65	1.51
30	21	1.52	1.07	1.29
18	22	1.10	1.60	1.35
18	22	1.37	1.67	1.52
21	22	1.34	1.64	1.49
21	22	1.14	1.65	1.40
28	22	1.19	1.95	1.57
28	22	1.31	1.92	1.61
7	23	1.23	1.93	1.58
7	23	1.29	1.93	1.61
8	23	1.23	1.85	1.54
8	23	1.06	1.96	1.51
10	23	1.21	1.86	1.53
10	23	1.29	1.88	1.59
12	23	1.38	1.91	1.65
12	23	1.27	1.89	1.58
13	23	1.30	1.90	1.60
13	23	1.17	1.93	1.55
14	23	1.33	1.92	1.62
14	23	1.28	1.91	1.60
16	23	1.16	1.94	1.55
16	23	1.16	1.92	1.54
19	23	1.07	1.95	1.51
19	23	1.11	1.91	1.51
26	23	1.03	1.92	1.48
26	23	1.02	1.00	1.01
902	23	1.20	1.96	1.58
902	23	1.43	1.87	1.65
7	26	1.30	1.76	1.53
7	26	1.40	1.76	1.58
8	26	1.27	1.57	1.42
8	26	1.26	1.61	1.44
10	26	1.27	1.72	1.50

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
10	26	1.40	1.72	1.56
12	26	1.52	1.80	1.66
12	26	1.34	1.83	1.59
13	26	1.23	1.78	1.50
13	26	1.34	1.71	1.52
14	26	1.45	1.79	1.62
14	26	1.38	1.79	1.59
16	26	1.23	1.80	1.51
16	26	1.10	1.81	1.45
19	26	1.15	1.74	1.45
19	26	1.11	1.74	1.43
23	26	1.03	2.00	1.52
23	26	1.03	1.02	1.02
902	26	1.26	1.84	1.55
902	26	1.57	1.78	1.67
18	28	1.11	1.84	1.48
18	28	1.27	1.80	1.54
22	28	1.12	1.95	1.54
22	28	1.14	1.92	1.53
6	29	1.30	1.54	1.42
6	29	1.04	2.00	1.52
17	29	2.00	1.66	1.83
17	29	1.80	1.66	1.73
18	29	1.51	1.33	1.42
18	29	1.55	1.69	1.62
21	29	1.56	1.65	1.61
21	29	1.58	1.32	1.45
30	29	1.72	1.78	1.75
30	29	1.78	1.78	1.78
6	30	1.44	1.93	1.69
6	30	1.00	1.97	1.49
17	30	1.46	1.61	1.54
17	30	1.89	1.63	1.76
18	30	1.37	1.58	1.48

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
18	30	1.47	1.65	1.56
21	30	1.29	1.63	1.46
21	30	1.55	1.35	1.45
29	30	1.78	1.78	1.78
29	30	1.82	1.78	1.80
2	32	1.15	1.52	1.34
2	32	1.15	1.56	1.36
3	32	1.17	1.43	1.30
3	32	1.22	1.44	1.33
4	32	1.26	1.42	1.34
4	32	1.32	1.43	1.37
5	32	1.20	1.48	1.34
5	32	1.41	1.56	1.49
7	32	1.38	1.74	1.56
7	32	1.33	1.63	1.48
8	32	1.42	1.61	1.51
8	32	1.23	1.69	1.46
10	32	1.38	1.79	1.59
10	32	1.16	1.51	1.33
12	32	1.36	1.70	1.53
12	32	1.24	1.59	1.42
13	32	1.20	1.51	1.36
13	32	1.40	1.52	1.46
14	32	1.26	1.72	1.49
14	32	1.19	1.76	1.48
15	32	1.29	1.37	1.33
15	32	1.29	1.48	1.39
16	32	1.26	1.48	1.37
16	32	1.39	1.47	1.43
19	32	1.36	1.57	1.47
19	32	1.20	1.62	1.41
20	32	1.13	1.53	1.33
20	32	1.18	1.60	1.39
902	32	1.32	1.74	1.53

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
902	32	1.42	1.59	1.50
3	902	1.28	1.72	1.50
3	902	1.10	1.66	1.38
5	902	1.31	1.79	1.55
5	902	1.16	1.85	1.50
7	902	1.59	1.87	1.73
7	902	1.35	1.90	1.63
10	902	1.09	1.78	1.43
10	902	1.32	1.84	1.58
12	902	1.65	1.80	1.73
12	902	1.54	1.74	1.64
13	902	1.66	1.80	1.73
13	902	1.56	1.72	1.64
14	902	1.63	1.87	1.75
14	902	1.51	1.87	1.69
15	902	1.33	1.96	1.64
15	902	1.46	1.96	1.71
16	902	1.07	1.93	1.50
16	902	1.17	1.97	1.57
19	902	1.58	1.78	1.68
19	902	1.25	1.87	1.56
20	902	1.24	1.88	1.56
20	902	1.20	1.81	1.50
23	902	1.20	1.95	1.57
23	902	1.24	1.96	1.60
26	902	1.26	1.85	1.55
26	902	1.51	1.75	1.63
32	902	1.31	1.82	1.57
32	902	1.45	1.63	1.54
9	903	1.03	1.00	1.00
9	903	1.12	1.00	1.00
904	903	1.08	1.00	1.00
904	903	1.15	1.00	1.00
9	904	1.07	1.00	1.00

Table D.2 (continued)

From	To	Scaled Bridge Vuln. Rate	Scaled Narrow Road Vuln. Rate	Combined Trans.Mean Vuln. Rate
9	904	1.16	1.00	1.00
903	904	1.08	1.00	1.00
903	904	1.14	1.00	1.00