ASSIGNMENT OF AFAD WAREHOUSES TO CONTAINER PORTS IN TURKEY

MEHMET CAN KILINÇ

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ASSIGNMENT OF AFAD WAREHOUSES TO CONTAINER PORTS IN TURKEY

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Submitted by **Mehmet Can KILINÇ**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University.

Prof. Dr. Halil Tanyer EYYUBOĞLU
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Ferda Can ÇETİNKAYA
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Mustafa Alp ERTEM
Supervisor

Examination Date: 08.02.2017
Examining Committee Members

Assoc. Prof. Dr. Serhan DURAN

Assist. Prof. Dr. Mustafa Alp ERTEM

Assist. Prof. Dr. Haluk AYGÜNEŞ

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Name, Last Name	:	Mehmet Can KILINÇ
Signature	:	
Date	:	08.02.2017

ABSTRACT

ASSIGNMENT OF AFAD WAREHOUSES TO CONTAINER PORTS IN TURKEY

KILINÇ, Mehmet Can
M.Sc., Department of Industrial Engineering
Supervisor: Assist. Prof. Dr. Mustafa Alp ERTEM

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The assignment of AFAD warehouses to container ports is a vital topic, but it has not been studied thoroughly in the literature. Turkey is a special case for using maritime transportation in humanitarian logistics, because of the geopolitical location and vulnerability of our country. The main objective of this thesis is to investigate the use of maritime transportation in humanitarian logistics to respond natural disasters effectively for Turkey via the assignment of AFAD warehouses to container ports. In this thesis, a mathematical model for assigning 25 Prime Ministry Disaster and Emergency Management Authority (AFAD in Turkish) logistics warehouses to suitable ports in Turkey is developed. The capabilities of ports to handle humanitarian logistics activities, ports' closeness to AFAD logistics warehouses, suitability of access using different transportation modes and capacities of AFAD logistics warehouses are some of the criteria that is considered in this model. Assignments are also analyzed by taking into consideration of container ports' railway connections availability. The developed approach provides an alternative solution to humanitarian operations in Turkey.

Keywords: Intermodal Transportation, Humanitarian Logistics, Assignment, Ports, Containers.

ÖZ

AFAD DEPOLARININ TÜRKİYE'DEKİ KONTEYNER LİMANLARINA ATANMASI

KILINÇ, Mehmet Can
Yüksek Lisans, Endüstri Mühendisliği Anabilim Dalı
Tez Yöneticisi: Yrd. Doç. Dr. Mustafa Alp ERTEM

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AFAD depolarının konteyner limanlarına atanması hayati bir konudur ancak literatürde yeterince çalışılmamıştır. Türkiye, jeopolitik konumundan dolayı insani yardım lojistiğinde deniz taşımacılığının kullanımı için özel bir durumdadır. Bu tezin temel amacı, Türkiye'deki doğal afetlere etkin cevap vermek için insani yardım lojistiğinde deniz taşımacılığının kullanımını AFAD depolarının konteyner limanlarına atanması ile araştırmaktır. Bu tezde, Türkiye'deki 25 AFAD deposunun uygun limanlara atanması için bir matematiksel model geliştirilmiştir. Bu araştırmanın matematiksel modelinde, limanların özellikleri, limanların AFAD depolarına yakınlığı, farklı taşıma yöntemleriyle erişilebilirliğin uygunluğu ve AFAD depo kapasiteleri gibi ölçütler dikkate alınmıştır. Konteyner limanlarının tren yolu uygunlukları da göz önüne alınarak atamalar karşılaştırılmış ve analizleri yapılmıştır. Türkiye için insani yardım operasyonları için alternatif bir çözüm sunulmuştur.

Anahtar Kelimeler: İntermodal Taşımacılık, İnsani Yardım Lojistiği, Atama, Limanlar, Konteynerler.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

IFRC	International Federation of Red Cross and Red Crescent Societies
EM-DAT	Emergency Events Database
TCDD	Turkish State Railways
AFAD	Prime Ministry Disaster and Emergency Management Authority
TEU	Twenty-Foot Equivalent Unit

CHAPTER 1
INTRODUCTION

International Federation of Red Cross and Red Crescent Societies (IFRC) describes a disaster as "A sudden, calamitous event that seriously disrupts the functioning of a community or a society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources" [1]. Disaster is a natural or man-made event that causes physical, economic, and social casualties. The categories of disasters are presented in Table 1 by Van Wassenhove [2]. There are natural and man-made as well as sudden-onset or slow-onset types of disasters.

Table 1 Classification of Disasters.

Classification of Disasters	Sudden-onset	Slow-onset
Natural	Earthquake Hurricane Tornadoes	Famine Drought Poverty
Man-made	Terrorist Attack Coup D'Etat Chemical Leak	Political Crisis Refugee Crisis

Disasters affect daily life negatively. The precautions taken before the disasters are very important because many people's lives depend on the effectiveness of these precautions. Thus, academic studies in the literature focus on which precautions to take. The focus of this study is to investigate the use of maritime transportation in humanitarian logistics for responding natural disasters effectively in Turkey. A mathematical model is developed by considering constraints for Turkey. Turkey has risky geographical and climatic properties related to disasters. These properties stimulate several disaster types which are earthquake, flood, storm, landslide, snow slide, drought and man-made harmful events. The most destructive disaster type is earthquake for Turkey. For instance, many people died at Kocaeli earthquake in 1999.

Table 2 Natural Disasters in Turkey Between 1990 and 2016.

Disaster type	Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Earthquake	Ground movement	77	89236	6924329	24685400
Epidemic	Bacterial disease	1	11	150	0
Epidemic	Parasitic disease	2	0	100000	0
Epidemic	Viral disease	5	602	104705	0
Extreme temperature	Cold wave	3	69	0	0
Extreme temperature	Heatwave	2	14	300	1000
Extreme temperature	Severe winter conditions	2	17	8150	0
Flood	--	15	946	372620	65000
Flood	Flash flood	10	243	1341382	1892000
Flood	Riverine flood	19	210	64521	238500
Landslide	Landslide	10	293	13481	26000
Mass movement (dry)	Avalanche	3	407	1075	0
Storm	Convective storm	6	51	13636	2200
Wildfire	Forest fire	5	15	1150	0

As it is seen in Table 2, the highest number of casualties stems from earthquakes. According to EM-DAT international disaster database web site, Turkey had many losses of lives between years 1900 and 2016 as it is illustrated in Table 3. Thus, especially the earthquakes are put on the agenda for precautions. Also, maritime transportation gains importance because earthquake may destruct road transportation. [3]

Table 3 Top 10 Disasters of Turkey Between 1900-2016.

Disaster No	Type	Date	Total deaths
1939-0010	Earthquake	26.12.1939	32962
1999-0268	Earthquake	17.08.1999	17127
1903-0007	Earthquake	29.04.1903	6000
1942-0025	Earthquake	26.11.1942	4000
1944-0003	Earthquake	01.02.1944	3959
1976-0075	Earthquake	24.11.1976	3840
1942-0011	Earthquake	20.12.1942	3000
1943-0014	Earthquake	26.11.1943	2824
1966-0062	Earthquake	19.08.1966	2394
1975-0053	Earthquake	06.09.1975	2385

The International Federation of Red Cross and Red Crescent Societies (IFRC) defines humanitarian logistics as "Humanitarian logistic comprises acquiring and delivering requested supplies and services, at the places and times they are needed, whilst ensuring best value for money." [4]. Disaster operations are managed in mitigation, preparedness, response, and recovery (reconstruction) phases as in Figure 1.

Figure 1 Disaster life cycle

Maritime transportation is growing in Turkey. The compound annual growth rate (CAGR) of total freight handling in Turkish ports increased by 8,2 % from 2003 to 2012 [5]. Maritime transportation is increasingly used to carry products. Therefore, it is also important for humanitarian logistics. Using maritime transportation for humanitarian logistics is a vital topic, but has not been studied thoroughly in the literature. Turkey is a special case for using maritime transportation in humanitarian logistics, because of the geopolitical location and vulnerability of the country.

Turkey is surrounded on three sides by the sea. Thus, Turkey has several advantages for maritime transportation. Firstly, maritime transportation is a reliable transportation mode in crisis times because of road transportations' dependence on vulnerable infrastructure. Furthermore, safety is another significant advantage of maritime transportation. Products can be carried on the seaway safer than other transportation modes. Maritime transportation has these advantages, but it cannot be used as a single-mode of transportation. It has to be coupled with other transportation modes, which makes the trip intermodal. The United Nations Convention on Multimodal Transport defines intermodal transport as "The carriage of goods by at least two different modes of transport on the basis of a multimodal transport contract from a place in one country at which the goods are taken over by the multimodal transport operator to a place designated for delivery situated in a different country" [2]. As it is seen in definition, at least two different types of transportation are combined in intermodal transportation to ship products. This type of transportation may be useful during disasters. It can be passed through other types of transportation depending on the availability of the roads, railways, or seaways after disasters.

Intermodal transportation may be efficient for Prime Ministry Disaster and Emergency Management Authority (AFAD)'s disaster relief operations. AFAD is the responsible government authority to prevent destructive effects of disasters. Moreover, AFAD aims to recover and coordinate all relief processes after disasters. AFAD's strategy is to take a risk management approach and take precautions in time (before a disaster happens). AFAD has prepositioned 27 warehouses to realize these aims in Turkey.

172 ports are located in different regions of Turkey. These ports are classified into three categories according to ownership status. [7] There are 21 public ports, 23 municipality ports and 128 private sector ports [8]. Only 16 ports in Turkey have a railway connection. These 16 railway ports are suitable for intermodal transportation of relief supplies via railway connections. On the other hand, all other ports are suitable for intermodal transportation of relief supplies via highway connections.

The motivation behind this thesis is a possible Istanbul earthquake. Istanbul is the biggest city in Turkey in terms of population. In an emergency case, demand from this city must be supplied at the maximum level. In Ozkapici et al 2016 [9], an *within-city* maritime intermodal relief item distribution model is developed for an earthquake in İstanbul. Thesis proposes an assignment model for *inter-city* transportation connecting the source nodes (i.e. AFAD warehouses) with container ports. After AFAD warehouses' assignment to container ports in Turkey, the assignment model in Ozkapici et al 2016 can be used for a possible İstanbul earthquake. Because all containers will be shipped from AFAD warehouses to container ports in all cities of Turkey, then relief item distribution model can be used for İstanbul in Ozkapici et al 2016.

The objective of this thesis is to investigate the practicality of the idea for using maritime transportation in sending relief supplies out of the newly constructed AFAD warehouses. A mathematical model and a heuristic approach are developed. Later, experimental study related to possible Istanbul earthquake is performed. The rest of the thesis is as follows: In Chapter 2, academic studies that are related with the thesis subject are given. Background information about the studied problem is given and the problem is defined in Chapter 3. In Chapter 4, the mathematical model is presented. In Chapter 5, the results of the case study are explained. Conclusion and future research directions are given in Chapter 6.

CHAPTER 2
LITERATURE REVIEW

Van Wassenhove (2006) broadly defines humanitarian logistics terms. Van Wassenhove (2006) indicates the importance of supply chain management and logistics as;

> ''Since disaster relief is about 80 % logistics it would follow then that the only way to achieve this is through slick, efficient and effective logistics operations and more precisely, supply chain management.'' [2].

Supply chain management is important for private sector as well as humanitarian sector. Van Wassenhove (2006) explains the similarities and differences between private sector and humanitarian logistic sector. Furthermore, some principles of humanitarian logisticians are given. These principles are humanity, neutrality and impartiality to operate humanitarians' job effectively.

There are five components of maritime transportation which are ships, ports, intermodal hubs, users, and waterways in Şahin-Arslan and Ertem (2015) [10]. Ships are irreplaceable in maritime transportation. Different types of ships are used on waterways by users. Besides, there are ports and intermodal hubs. Ports are storage, loading and unloading areas. Intermodal hubs are transfer points in maritime transportation. In our thesis, ports act like hubs. After our mathematical model solution, containers are carried by ships in waterways to the disaster area.

Alumur and Kara (2008) mentioned the importance of hub location. Hubs are special facilities in terms of many advantages such as easy distribution and transshipment between warehouses and destinations. Hubs are located in the position between warehouse and destinations. There are two kinds of hub location problems which are single allocation and multiple allocation. In multiple allocations, each destination center can receive and send flow through more than one hub. Alumur and Kara (2008) claim that the number of research about this topic is increasing especially after 2000s. [11] In our study, container ports are like hub locations. Because all containers received from AFAD warehouses are carried to disaster area via container ports. Container ports are like bridges between AFAD warehouses and disaster areas.

Aksoy and Özyörük (2015) mentioned the importance of using railway and freight villages in Turkey. There are 12 freight villages in their study where starting points and distribution points are located. The procedure starts from starting points and then it continues with distribution points. After all, it is completed with transportation from distribution points to freight villages. Real data is used for Turkey case. Furthermore, the capacities of starting points, distribution points and freight villages are taken into account. After the mathematical model solution, objective value (total transport performed in terms of ton-kilometers) decreased by 88 %. [13] This solution is important for AFAD because of railway connections. If AFAD warehouses have railway connections, intermodal transportation can be considerable via railway in terms of container transportation.

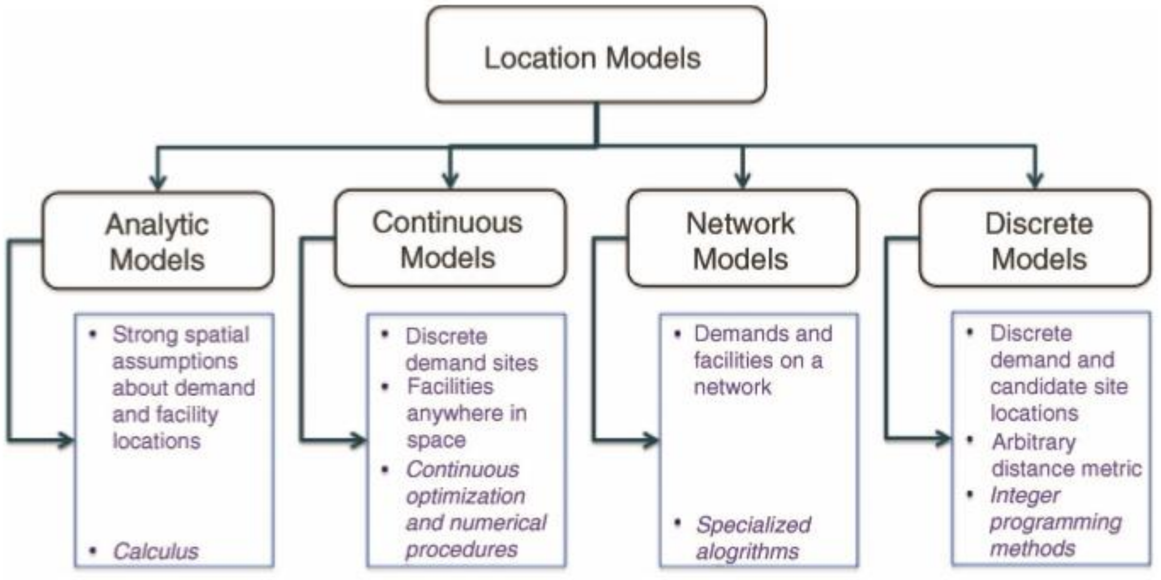

Figure 2 Taxonomy of location models [6]

In Figure 2, the location models are divided into four categories which are analytic models, continuous models, network models and discrete models by Daskin [6]. In this thesis, a discrete location model for Turkey is presented in the next chapters. Because discrete models cover discrete demand and candidate site locations, arbitrary distance metric and integer programming methods. The location model in this thesis has the characteristic of a discrete model.

Table 4 Main Characteristics of the Studies Reviewed.

Study	Methodology	Performance measures (min. of)	Multi-modal	Maritime transportation	Sea-basing	A real life case study used
Tatham and Kovacs (2007)	Conceptual comparison	Cost	X	X	X	X
Wilberg and Olafsen (2012)	Simulation	Cost/response time	X	X	X	X
Bemley et al. (2013)	Stochastic programming	Unsatisfied demand		X		X
Sahin et al (2014)	Mixed integer programming	Distance				X
Aksoy and Özyörük (2015)	Mixed integer programming	Cost				X
Sahin Arslan and Ertem (2015)	Conceptual comparison	None	X	X		
Ozkapici et al (2016)	Integer programming	Response time	X	X	X	X
Our study	Integer programming	Min-Max distance		X		X

Table 4 summarizes main characteristics of the studies reviewed in this thesis. Tatham and Kovacs (2007) [14] specify that using of cost minimization and total response time minimization as well as multimodal and maritime transportation are used. Bemley et al. (2013) study maritime transportation by using stochastic programming [15]. A mixed integer programming model is used for a real life case study to minimize distance in Sahin et al (2014) [12]. Ozkapıcı et al (2016) presents an integer programming model to minimize response time for a real case. Besides, multimodal and maritime transportation is also observed.

In our study, maritime transportation and real life case study are studied. The objective function of our study is to minimize the maximum distance between AFAD warehouses and container ports in a big disaster. In Ozkapici et al 2016, an *within-city* maritime intermodal relief item distribution model is developed for an earthquake in İstanbul to minimize the response time. An intercity assignment model is developed here. In our thesis, AFAD warehouses are assigned to container ports in Turkey.

CHAPTER 3
PROBLEM DEFINITION

This study is at the intersection of the subjects about AFAD warehouses, container ports, intermodal transportation, and humanitarian logistics in Turkey as shown in Figure 3. Relief supplies in AFAD warehouses are carried to container ports via intermodal transportation in humanitarian logistics. When intermodal transportation is implemented in humanitarian logistics, response time from AFAD warehouses to container ports may decrease.

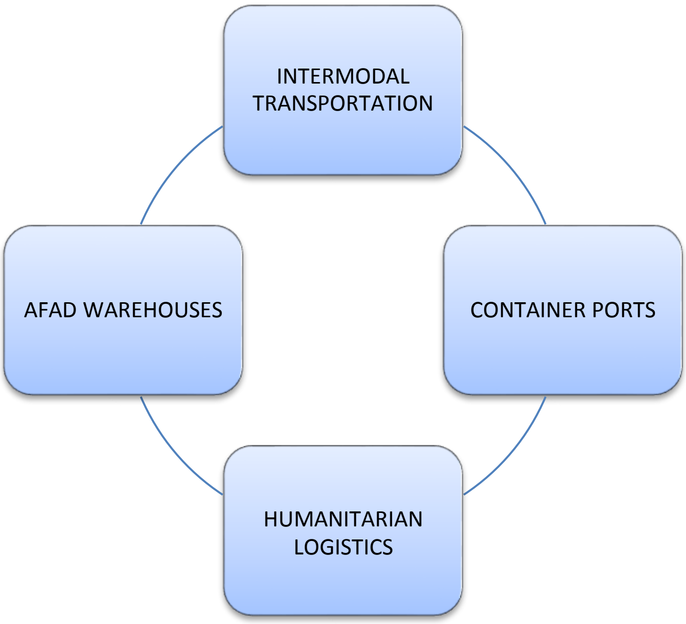

Figure 3 Problem framework

The main objective of this thesis is to investigate the use of maritime transportation in humanitarian logistics to respond natural disasters effectively for Turkey. In this study, a mathematical model to assign container ports in Turkey to AFAD logistics warehouses is developed. Only 19 ports transship via containers according to last three years' data from Ministry of Transport, Maritime Affairs and Communications Directorate General of Merchant Marine. Although AFAD stores disaster materials in 27 warehouses, the materials in two AFAD warehouses are unsuitable to transship with containers. These two warehouses store relief materials on shelves and are excluded from the study. 19 container ports and 25 AFAD warehouses are considered as demand and source points. Relief materials are carried from AFAD warehouses to container ports, from container ports to a disaster area. Since all stocks in warehouses are needed after a big natural disaster, it is assumed that all relief materials have to be shipped in full.

Some criteria that are going to be considered in the assignment model are the capabilities of ports to handle humanitarian logistics activities, ports' closeness to AFAD logistics warehouses, suitability of access using different transportation modes and capacities of AFAD logistic warehouses.

Intermodal transportation can be an alternative solution to solve freight transportation problem using ports. Railway infrastructure and highway transportation may not be enough in crisis times for freight shipment. Hence, other transportation modes are considered together.

Figure 4 Location of 27 AFAD warehouses in Turkey

AFAD has many responsibilities in every disaster case. 27 AFAD warehouses are prepositioned in Adana, Adıyaman, Afyon, Aksaray, Ankara, Antalya, Balıkesir, Bursa, Denizli, Diyarbakır, Düzce, Elazığ, Erzincan, Erzurum, Hatay, Manisa, Kahramanmaraş, Kastamonu, Kırıkkale, Kocaeli, Muğla, Muş, Samsun, Sivas, Tekirdağ, Van, and Yalova as can be seen in Figure 4. They have total 120,000 tents in total to satisfy the demand for 600,000 beneficiaries (each tent accommodates five people). AFAD warehouses have many advantages such as high transportation speed, closeness to disaster area, easy tracking of stock, and minimizing time to transport. If intermodal transportation is applied, humanitarian logistics processes might be completed in a shorter time.

The number of ports which are used effectively for freight shipment with the help of railway transportation is limited. However, the long-term investment plans of Turkish government for railway positively affects the future of railway transportation.

Figure 5 Railway connections of ports in Turkey [8]

In Figure 5, 16 ports with railway connections are depicted in different regions of Turkey. Limak Port İskenderun and Mersin Port are located by the Mediterranean Sea. There is also one port which belongs to İşdemir at this area. Besides, İzmir Port and Nemport are located by the Aegean Sea. Moreover, Samsun Port and TTK Zonguldak Port are ports by the Black Sea. Most of the ports with connections of railway in Turkey are located by the Marmara Sea. These ports are Derince Port, Evyap Port, Haydarpaşa Port, Port of Bandırma, Tekirdağ Port and Yılport Yarımca. Furthermore, the ports located within the premises of Tüpraş, Gübretaş and Petrol Ofisi have connections of railways. [8]

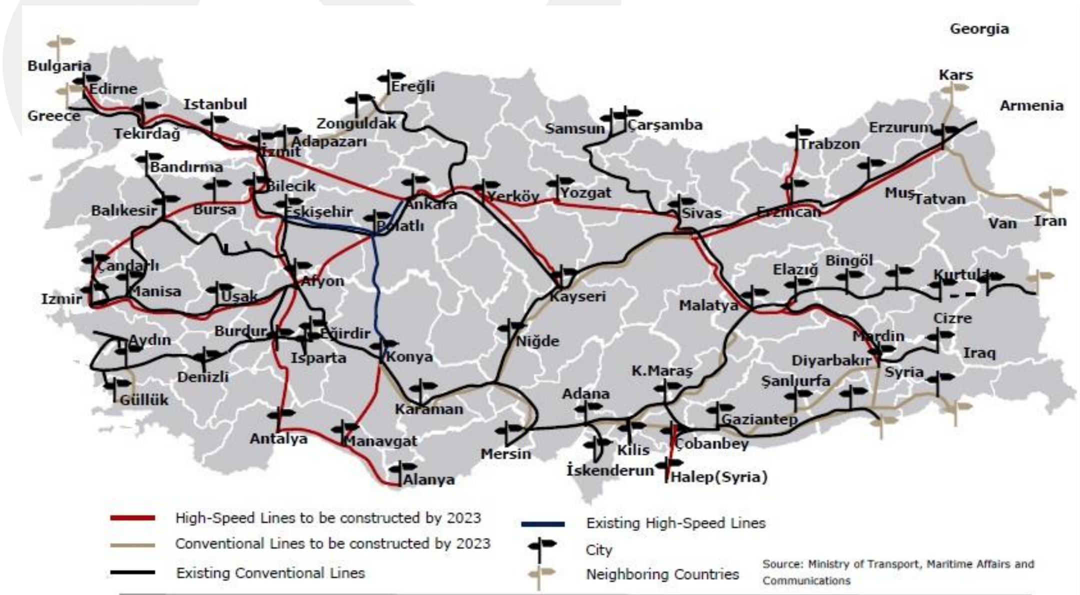

Figure 6 Current and future rail lines of Turkey [5]

The current rail lines and future rail lines projects of Turkey are as shown in Figure 6. The investment for rail lines affects the importance of railway transportation in future. Figure 6 shows that the future investment will increase the utilization of railways. It will also affect the intermodal transportation for humanitarian logistics in a positive way.

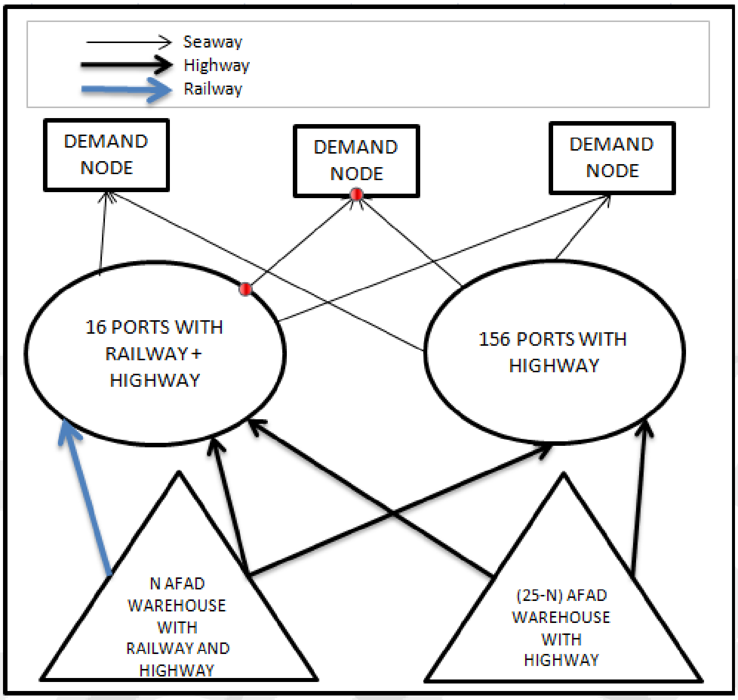

Figure 7 Illustration of container transportation network

The intermodal transportation network between AFAD warehouses, hubs (Turkish ports) and demand nodes (disaster areas) is shown in Figure 7. Some of AFAD warehouses have both railway connections and highway connections with ports. Only 16 of 172 ports in Turkey have both railway connections and highway connections. After the transportation from AFAD warehouses to ports, containers are shipped by utilizing seaway to disaster areas. All these shipment processes are considered according to closeness between AFAD warehouses and ports as well as container capacities of warehouses and ports.

Seven ports with connections of railway in Turkey are considered as intermodal container ports. These seven ports are located in İskenderun, Mersin, İzmir, Samsun, Zonguldak, Bandırma, and Tekirdağ. AFAD warehouses with connections of railway may send containers to these container ports via railway in emergency case using the mathematical model solution.

Table 5 The Capacities of AFAD Warehouses.

NO	CITY	STORAGE TYPE	NUMBER OF CONTAINERS	NUMBER OF TEU
1	ADANA	CONTAINER	96	192
2	ADIYAMAN	CONTAINER	48	96
3	AFYONKARAHİSAR	CONTAINER	96	192
4	AKSARAY	CONTAINER	48	96
5	BURSA	CONTAINER	48	96
6	DENİZLİ	CONTAINER	96	192
7	DİYARBAKIR	CONTAINER	48	96
8	DÜZCE	CONTAINER	48	96
9	ELAZIĞ	CONTAINER	48	96
10	ERZİNCAN	CONTAINER	48	96
11	ERZURUM	CONTAINER	96	192
12	KAHRAMANMARAŞ	CONTAINER	96	192
13	KASTAMONU	CONTAINER	48	96
14	KIRIKKALE	CONTAINER	48	96
15	MANİSA	CONTAINER	96	192
16	MUĞLA	CONTAINER	48	96
17	MUŞ	CONTAINER	96	192
18	SAMSUN	CONTAINER	96	192
19	SİVAS	CONTAINER	48	96
20	TEKİRDAĞ	CONTAINER	96	192
21	YALOVA	CONTAINER	48	96
22	VAN	CONTAINER	48	96
23	ANKARA	CONTAINER	48	96
24	ANTALYA	CONTAINER	48	96
25	KOCAELİ	CONTAINER	48	96

There are 27 warehouses of AFAD but the storage type of two of them is not container in Table 5. They are shelf type warehouse which are located in Balıkesir and Hatay. So, these warehouses are left out of the scope of this thesis. The capacity of nine of 25 container type warehouses is 96 containers. Remaining sixteen warehouses have capacity of 48 containers. One AFAD container equals 2 TEUs. TEU means twenty foot equivalent unit. The term TEU is often used to calculate the capacity of container. Thus, the value of warehouses' capacities in terms of TEU is calculated by multiplying container amount by two.

Table 6 Total Material Handling Value of Container Ports. [23]

PORTS	2013			2014			2015		
	TOTAL MATERIAL HANDLING			TOTAL MATERIAL HANDLING			TOTAL MATERIAL HANDLING		
	UNIT	TEU	TON	UNIT	TEU	TON	UNIT	TEU	TON
ALİAĞA	324.796	466.009	4.739.484	368.295	536.518	5.318.037	385.270	580.250	5.654.396
AMBARLI	2.117.199	3.318.128	34.065.513	2.199.239	3.444.925	36.038.622	1.972.899	3.061.501	32.598.089
ANTALYA	203.416	216.221	3.014.163	177.069	188.932	2.646.270	162.366	178.389	2.425.112
BANDIRMA	22.760	23.404	300.696	24.295	24.700	326.784	18.293	18.330	241.642
BARTIN	2	3	9	4	7	39	9	18	155
ÇEŞME	0	0	0	0	0	0	97	207	1.633
GEMLİK	450.836	669.305	6.418.224	477.801	708.365	6.795.474	457.756	685.605	6.717.054
İSKENDERUN	107.019	148.016	1.731.679	117.657	185.359	1.924.320	138.763	228.297	2.481.053
İSTANBUL	91.092	142.079	1.281.755	81.925	131.461	1.090.477	74.654	123.019	947.105
İZMİR	494.940	683.607	7.432.599	486.489	678.756	7.032.586	462.448	649.567	6.685.138
KARABİGA	679	898	8.724	428	456	5.145	400	492	5.837
KOCAELİ	513.053	807.757	8.831.953	570.799	899.104	9.337.438	639.277	988.906	10.485.817
MARMARA A.	441	441	5.418	528	528	7.012	609	609	8.439
MERSİN	882.352	1.367.134	15.365.193	944.149	1.483.945	16.745.488	918.124	1.428.301	16.340.858
SAMSUN	29.855	33.362	1.170.396	43.503	48.443	612.992	46.572	54.986	682.867
TEKİRDAĞ	768	1.602	7.169	356	784	4.357	88.852	129.259	1.505.987
TRABZON	18.278	21.258	274.164	15.448	18.039	242.364	16.214	18.655	238.578
YALOVA	0	0	0	0	0	0	5	5	10
ZONGULDAK	0	0	0	0	0	0	2	3	6.087
TOTAL	**5.257.486**	**7.899.224**	**84.647.139**	**5.507.985**	**8.350.322**	**88.127.405**	**5.382.610**	**8.146.399**	**87.025.857**

Total material handling value of container ports in 2013, 2014, 2015 is presented in Table 6. The data is retrieved from Ministry of Transport, Maritime Affairs and Communications Directorate General of Merchant Marine. The amount of total material handling is given in terms of unit, TEU and ton per year. Among the values in Table 6, the data in TEU are taken into account. The number of containers in AFAD warehouses is calculated in terms of TEU. [16]

Table 7 The Capacities of Container Ports.

PORTS	1 YEAR MAX TEU	1 DAY MAX TEU	3 DAY MAX TEU
ALİAĞA	580.250	1589,726	4769,1781
AMBARLI	3.444.925	9438,151	28314,452
ANTALYA	216.221	592,3863	1777,1589
BANDIRMA	24.700	67,67123	203,0137
BARTIN	18	0,049315	0,1479452
ÇEŞME	207	0,567123	1,7013699
GEMLİK	708.365	1940,726	5822,1781
İSKENDERUN	228.297	625,4712	1876,4137
İSTANBUL	142.079	389,2575	1167,7726
İZMİR	683.607	1872,896	5618,6877
KARABİGA	898	2,460274	7,3808219
KOCAELİ	988.906	2709,332	8127,9945
MARMARA A.	609	1,668493	5,0054795
MERSİN	1.483.945	4065,603	12196,808
SAMSUN	54.986	150,6466	451,93973
TEKİRDAĞ	129.259	354,1342	1062,4027
TRABZON	21.258	58,2411	174,72329
YALOVA	5	0,013699	0,0410959
ZONGULDAK	3	0,008219	0,0246575
TOTAL	**8.708.538**	**23.859**	**71.577**

In Table 7, the amount of container ports handling in terms of TEU in years 2013, 2014, 2015 is given. Maximum of three years is taken. Daily value is calculated by dividing yearly value to 365. Then, three days' value is calculated as three times the daily value. Three days time horizon was taken to ship all of the supplies in the first 72 hrs of emergency period. In the mathematical model, the capacities of AFAD warehouses are compared with the maximum three days` value of container ports.

If size of natural disasters is not large, such extreme conditions for ports will not occur. Container ports will have to transship at maximum capacity if the magnitude of the disaster is big. The most important thing is that the AFAD warehouses capacities connot exceed the three days maximum material handling amount of container ports. All AFAD containers must be shipped to all suitable container ports.

Figure 8 Location of AFAD warehouses and container ports in Turkey

In Figure 8, the location of AFAD warehouses and container ports are presented together in Turkey map. The distances between them are in Appendices A.

CHAPTER 4
MATHEMATICAL MODEL

There are some assumptions before mathematical model explanation. Firstly, there is no flow among ports. Containers in one ports cannot be shipped to another port. Moreover, the only source of supplies is AFAD warehouses. Containers in only AFAD warehouses can be shipped to container ports. Furthermore, AFAD have two warehouses which are shelf types. These two warehouses are left out of scope. Lastly, container ports capacities assume for 3 days because the transshipment should be completed in three days after a big disaster.

First assignment is critical after a big disaster. Distances travelled from AFAD warehouses to container ports should be minimized to satisfy all demand from disaster area quickly. The problem defined in the previous chapter is formulated as an integer programming model (i.e., a modified *p*-center formulation) to minimize the maximum distance between AFAD warehouses and container ports in Turkey.

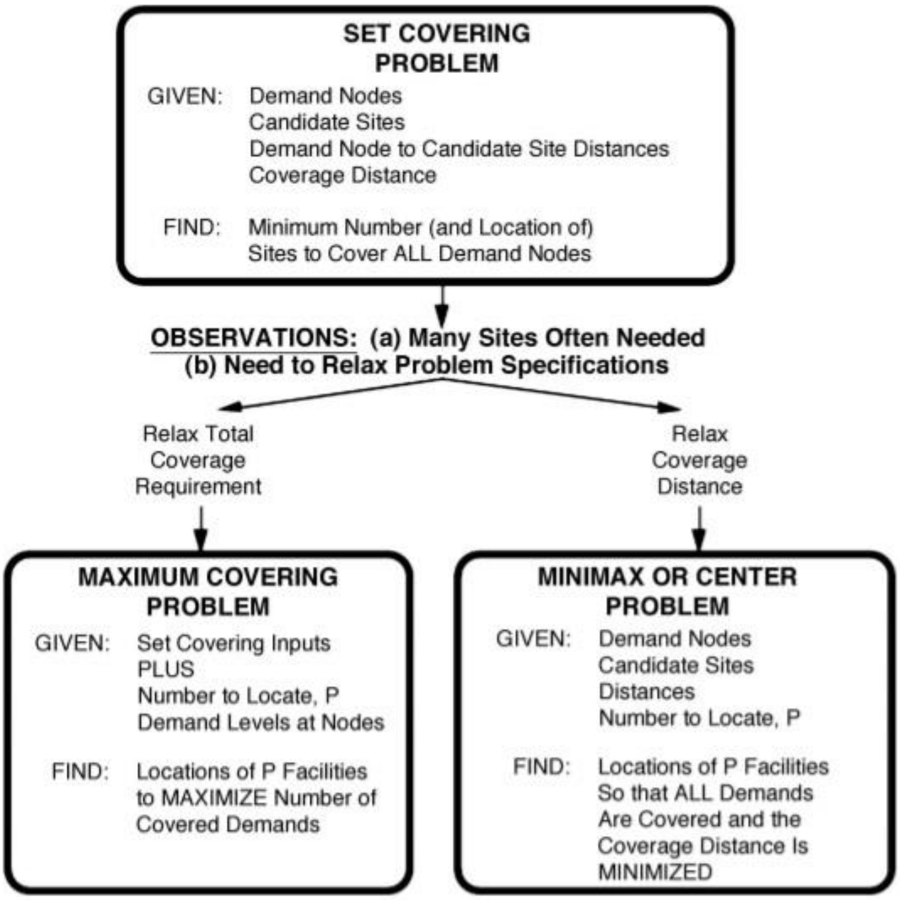

Figure 9 Relationships between problems [6]

In Figure 9, Daskin (2013) [6] indicates the differences of location allocation problem types. The reason for not using maximum covering is that the objective function must not be maximizing the number of covered demand. Because all containers in AFAD warehouses must be carried fully to suitable container ports in emergencies. The supplies from AFAD warehouses are not taken as partial. Moreover, demands do not differ considerably from each other. The value of demand is 96 or 192 in terms of TEU. Demand nodes, candidate sites, distances and number to locate (p) which are mentioned in Figure 9, are assumed to be given in this thesis. All these values are known. Thus, the mathematical model finds the location of *p* facilities (container ports). Then, all supplies (AFAD warehouses' capacities) are covered and the coverage distance is minimized.

The indices, parameters and variables of the integer model are presented below:

Indices:

i: the index for AFAD warehouse, $i = 1, \dots, 25$

j: the index for container port, $j = 1, \dots, 19$

Parameters:

D_{ij}: distance between *i* and *j*

H_i: capacities of AFAD warehouses

Q_j: capacities of container ports

M: sufficiently big number

Decision Variables:

$$X_j = \begin{cases} 1, & \text{if a container port is used at site } j \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{ij} = \begin{cases} 1, & \text{if supply at AFAD warehouse } i \text{ is assigned to container port } j \\ 0, & \text{otherwise} \end{cases}$$

W= maximum distance between a container port and an AFAD warehouse

Objective Function: Min W (1)

Constraints:

$$\sum_{j=1}^{19} Y_{ij} = 1 \qquad \forall i = 1, \dots, 25 \tag{2}$$

$$\sum_{j=1}^{19} X_j = p \tag{3}$$

$$Y_{ij} \leq X_j \qquad \forall i = 1, \dots ., 25\ ,\ \forall j = 1, \dots ., 19 \tag{4}$$

$$W \geq \sum_{j=1}^{19} D_{ij} . Y_{ij} \qquad \forall i = 1, \dots .., 25 \tag{5}$$

$$\sum_{i=1}^{25} H_i \,. Y_{ij} \leq\ Q_j \qquad \forall j = 1, \dots \dots ., 19 \tag{6}$$

$X_j \in \{0,1\}$, $Y_{ij} \in \{0,1\}$

Index *i* represents the location of AFAD warehouse and index *j* represents the location of container port. The objective (1) is minimizing the maximum distance between an AFAD warehouse and a container port. Constraint (2) specifies that all AFAD warehouses should be assigned to a port. Constraint (3) indicates that the maximum number of utilized container ports. Constraint (4) guarantees that if a candidate container port *j* is not used, no warehouse is assigned to it. However, the number of candidate container ports is same as the number of used container ports. Constraint (5) forces objective function (*W*) to be the minimum of the distances between any AFAD warehouse and container port. Constraint (6) presents that the assigned amount to a port cannot exceed its capacity.

CHAPTER 5
RESULTS

The problem on hand was solved first by a heuristic approach then by an exact approach. In the heuristic approach, the capacities of AFAD warehouses and container ports are not taken into consideration. All steps of flowchart in Figure 10 are implemented.

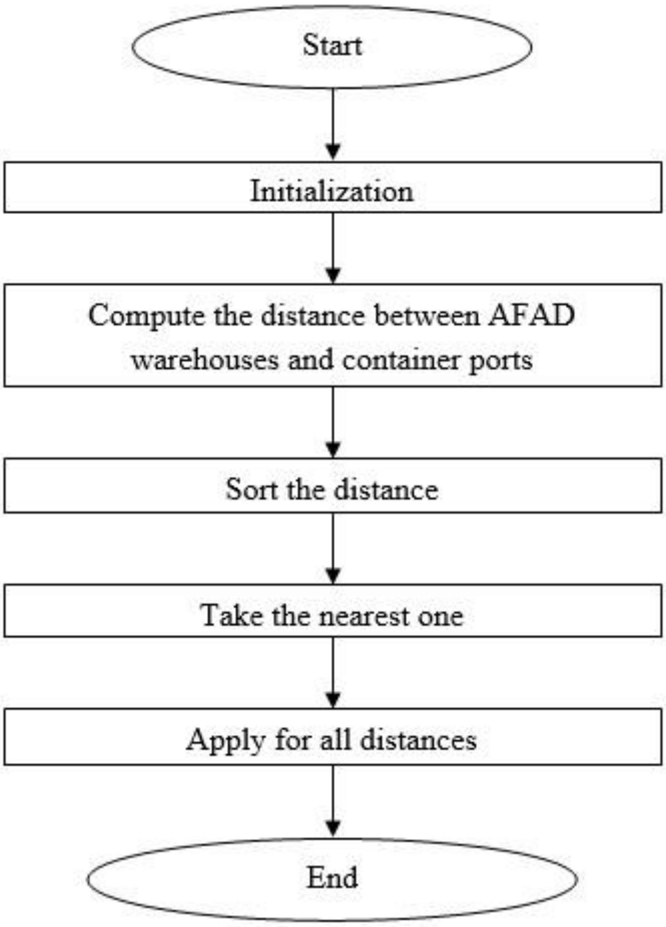

Figure 10 Flowchart of the heuristic approach

In flowchart, first step is computing the distance between AFAD warehouses and container ports. Then, sorting the distance and taking the nearest one are next steps. Lastly, all these rules are applied for all distances. However, the capacities of some ports assigned using heuristic solution are not enough in an emergency case. While four arcs stem from four nodes (AFAD warehouses) to a single container port, there are some container ports without any assignment. The objective function value is 729. It means that the maximum distance between all assignments is 729 which is the distance between Van and Trabzon.

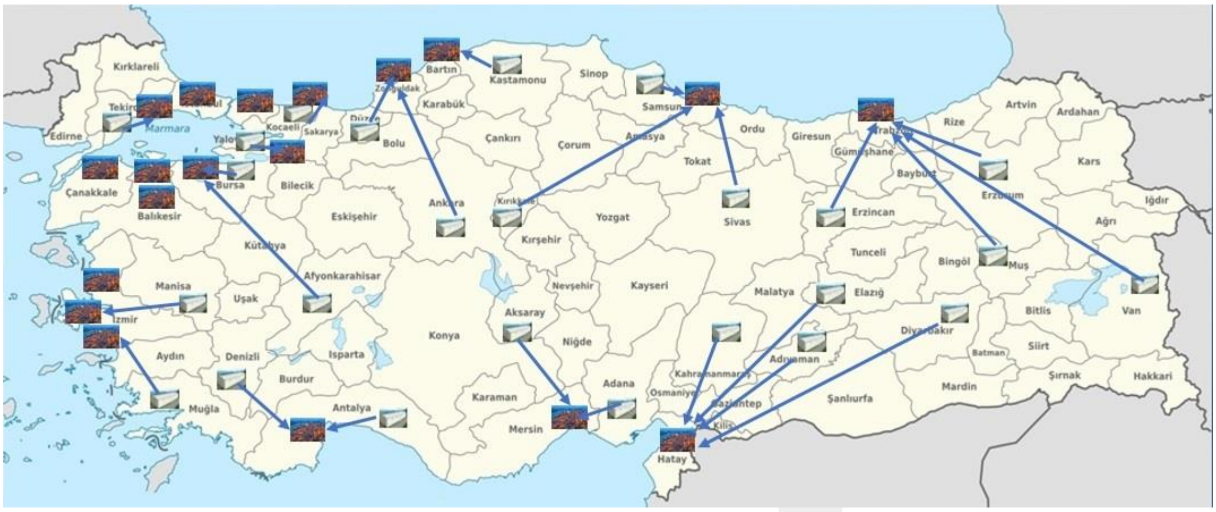

Figure 11 Results of heuristic approach

Then the mathematical model is solved using Gams for the uncapacitated problem (i.e. constraint (6) is dropped). The optimal solution yields the same result as the heuristic approach. Because the mathematical model is solved firstly without AFAD warehouses' capacities and container ports capacities. The map of uncapacitated mathematical model Gams solution is like in Figure 12.

Figure 12 The Results of uncapacitated mathematical model solution

H_i, capacities of AFAD warehouses are considered as supply sources. Y_{ij} is a considered as a binary variable because of the coordination challenges in humanitarian logistics. In the original formulation of the P-center model, fraction values are allowed. Here, there is no fraction value for Y_{ij}. It must be zero or one. All containers in AFAD warehouses should be assigned fully to a container port.

In the example case study, the problem is to assign 25 AFAD warehouses to 19 container ports, p is equal to 19 in this p-center problem. Mathematical model finds the optimum solution according to the distances and capacities. The solution of the mathematical model can be seen in Figure 13. All 25 AFAD warehouses are assigned to some of the 19 container ports. Optimal objective function value of 746 minimizes the maximum distance between any container port and any AFAD warehouse. All other assignment distances are less than 746 km. The aim of the p-center mathematical model is to minimize the maximum distance between all assigned distances to respond natural disasters effectively for Turkey. The Gams solution shows that there is no assignment to container ports Bartın, Zonguldak, Yalova, Çanakkale, Ambarlı, Marmara, Bandırma, İstanbul, Aliağa and Çeşme. The reason of no assignment for these container ports is high distance value or low capacities. These ports affect negatively the objective function if objective function value grows up when compared to the uncapacitated case.

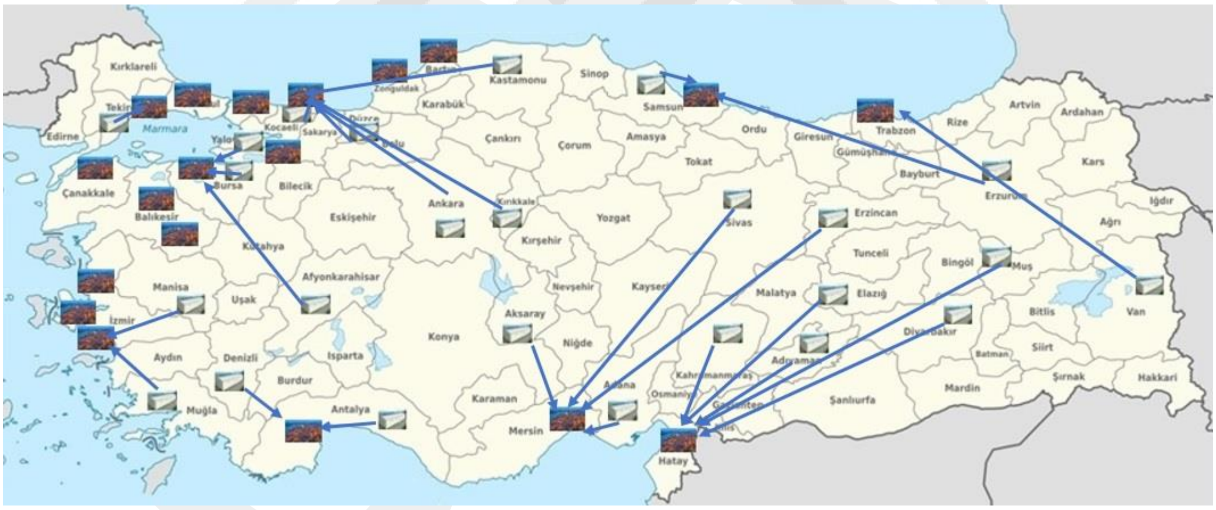

Figure 13 Map of the exact assignment solution

Best possible max distance in accordance with result of mathematical model solving is 729 which is same as heuristic solution (without capacities). However, the value of objective function for optimum solution is 746 by taking into consideration of AFAD warehouses' capacities and container port capacities. All 25 container types of AFAD warehouses are assigned to 8 container ports.

Table 8 Inactive Container Ports for Model Solution.

PORTS	1 YEAR MAX TEU	1 DAY MAX TEU	3 DAY MAX TEU
BARTIN	18	0,049315	0,1479452
ÇEŞME	207	0,567123	1,7013699
KARABİGA	898	2,460274	7,3808219
MARMARA A.	609	1,668493	5,0054795
YALOVA	5	0,013699	0,0410959
ZONGULDAK	3	0,008219	0,0246575

Inactive container ports extracted from the model solution are given in Table 8. These are Bartın, Çeşme, Karabiga, Marmara, Yalova, and Zonguldak because of low daily transshipment capacity for container transshipment. Three days maximum TEU capacities of these container ports are not enough to satisfy the minimum demand level (96 TEU) of AFAD warehouses. Hence, there is no assignment to these container ports in the GAMS solution. Especially, these container ports might need to tranship efficiently in emergencies. However, the real values of daily transshipment show that it is not possible.

A big disaster affects negatively 3.424.000 people which lives in İstanbul according to Ozkapici et al 2016 study. One tent's capacity is 5 people. Thus, 684.800 tents are needed after a big disaster in İstanbul. However, there are 120.000 tents in total at AFAD warehouses. This is not enough to satisfy all demand. All tents correspond only to 17% of demand. Because of this reason, all containers must be shipped to İstanbul after a big disaster. The relief items might be distributed according to Ozkapici et al 2016 after relief items arrive using maritime transportation to Istanbul.

After mathematical model results, Hatay, İzmir, Mersin, Samsun, Tekirdağ are the container ports that can carry containers via highway or railway. If, carrying materials via railway for that container port is more suitable than highway, AFAD might try to use railway to tranship containers according to GAMS results. This is the advantage of intermodal transportation.

The mathematical model is also solved by container ports with only railway connections. Bandırma (Balıkesir), İskenderun (Hatay), İzmir, Mersin, Samsun, Tekirdağ, and Zonguldak have both railway connections and container storage. According to these ports, the model is solved with i=25 and j=7. All AFAD warehouses have railway connections is an assumption on this case. Thus, i is equal to 25. The objective function is 874. This maximum distance is between Van and İskenderun Port (Hatay). In Figure 14, the assignment for container ports with railway connections is shown.

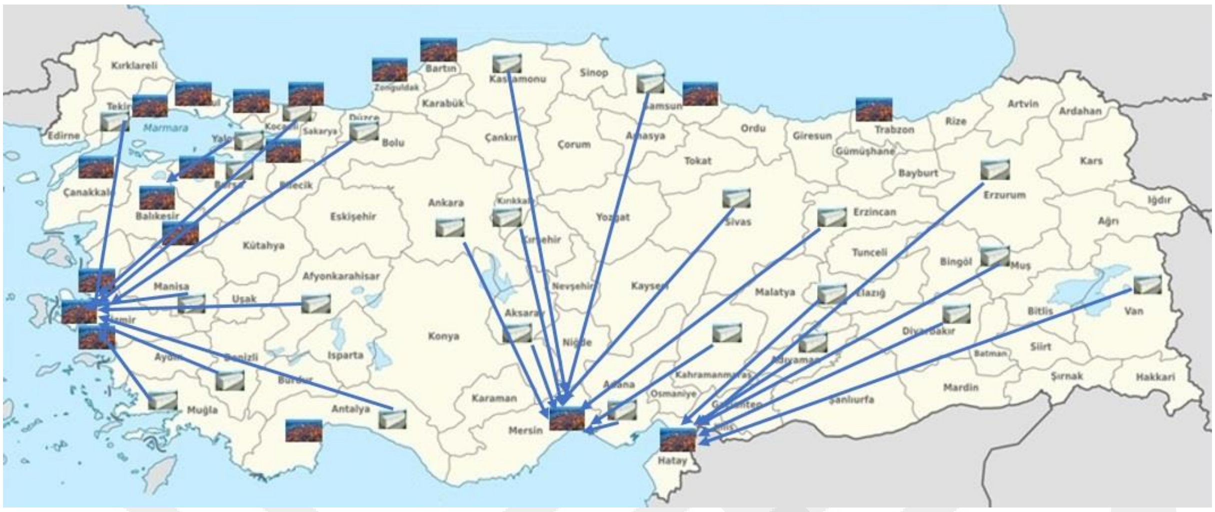

Figure 14 The assignment result map of container ports with railway

Figure 14 shows that the capacities of four assigned container ports are enough for all supplies. Although the objective function value increases to 874 from 746, this is an opportunity for using intermodal transportation for AFAD. If there are railway connections to AFAD warehouses, a block train can carry 80 TEU at one shipment. Thus, it provides more capacity to transport at once [17].

CHAPTER 6
CONCLUSION

The main objective of this thesis is to analyze the use of maritime transportation in humanitarian logistics to respond natural disasters effectively for Turkey. A mathematical model for assigning 25 AFAD warehouses to container ports in Turkey is developed by taking into consideration of the ports' closeness to AFAD logistics warehouses, suitability of access using different transportation modes and capacities of AFAD logistics warehouses. The motivating idea behind this thesis is to take advantage of Turkey's geographical position and infrastructure for intermodal transportation.

The mathematical model assigns 19 container ports to 25 AFAD warehouses according to constraints. Different scenarios are tested in the model with different parameters. Then the results are analyzed and compared with each other. The advantages of maritime transportation and intermodal transportation are explained. Alternative solutions are obtained to use in emergencies for Turkey. There is no study about this thesis topic in AFAD before. Thus, these alternative solutions are useful for AFAD to respond immediately for natural disasters. The increase in container ports number and opening of new container ports near AFAD warehouses will be effective in responding more quickly after a disaster.

Moreover, the railway connections of AFAD warehouses should be improved to meet demand for emergencies in short time. If AFAD invests for railway connections, the intermodal transportation will be more important in humanitarian logistics. Also, Turkish government will invest to develop new railway connections. Furthermore, airway transportation is an additional and improvable transportation way in intermodal transportation.

This thesis focused on an assignment problem. To get the benefits of intermodal transportation, this assignment problem should be combined with a transportation problem in the future. We believe that intermodal transportation will garner greater research interest in the future in Turkey because of the recent investments of AFAD and TCDD. This thesis is a humble start to consider maritime transportation mode for responding to natural disasters in Turkey.

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APPENDICES

Appendices A. Actual Distance between Container Ports and AFAD Warehouses.

PORTS(j)\AFAD WAREHOUSES(i)	ADANA	ADIYAMAN	AFYON	AKSARAY	ANKARA	ANTALYA	BURSA	DENİZLİ	DİYARBAKIR	DÜZCE	ELAZIĞ	ERZİNCAN	ERZURUM	MANİSA	MARAŞ	KASTAMONU	KIRIKKALE	KOCAELİ	MUĞLA	MUŞ	SAMSUN	SİVAS	TEKİRDAĞ	VAN	YALOVA
ALİAĞA (İZMİR)	903	1229	330	690	588	461	332	244	1425	589	1285	1278	1470	40	1093	884	675	473	217	1527	1005	1035	532	1787	398
AMBARLI (İSTANBUL)	937	1263	453	681	459	724	167	596	1358	227	1214	1050	1242	452	1043	521	533	111	687	1456	743	897	154	1673	101
ANTALYA	643	969	289	457	547	0	547	223	1163	643	1052	1046	1238	432	833	849	564	612	317	1295	899	802	869	1527	615
BANDIRMA (BALIKESİR)	959	1285	384	757	548	508	152	286	1457	407	1313	1231	1422	140	1142	702	632	291	376	1555	924	996	413	1854	215
BARTIN	771	1041	518	515	293	806	482	737	1191	226	1047	820	1010	769	876	182	366	336	881	1289	513	677	598	1442	415
ÇEŞME (İZMİR)	903	1229	330	690	588	461	332	244	1425	589	1285	1278	1470	40	1093	884	675	473	217	1527	1005	1035	532	1787	398
GEMLİK (BURSA)	851	1177	277	596	386	547	0	434	1297	260	1155	1084	1275	290	984	555	474	144	525	1397	777	837	307	1707	68
İSKENDERUN (HATAY)	191	317	757	447	669	829	1038	982	511	902	482	760	792	1069	178	857	642	1012	1126	725	905	516	1270	874	1091
İSTANBUL	937	1263	453	681	459	724	167	596	1358	227	1214	1050	1242	452	1043	521	533	111	687	1456	743	897	154	1673	101
İZMİR	903	1229	330	690	588	461	332	244	1425	589	1285	1278	1470	40	1093	884	675	473	217	1527	1005	1035	532	1787	398
KARABİGA (ÇANAKKALE)	1128	1454	556	875	667	718	270	495	1576	525	1431	1349	1540	325	1261	821	750	409	528	1673	1043	1114	198	1972	334
KOCAELİ	826	1152	342	570	348	612	144	543	1246	115	1102	939	1130	429	931	410	421	0	664	1344	632	785	256	1562	78
MARMARA A. (BALIKESİR)	959	1285	384	757	548	508	152	286	1457	407	1313	1231	1422	140	1142	702	632	291	376	1555	924	996	413	1854	215
MERSİN	76	402	577	267	488	471	856	801	597	721	567	746	937	888	266	677	462	832	786	809	727	502	1089	959	911
SAMSUN	718	715	673	538	406	899	777	893	842	522	697	441	633	981	645	315	331	632	1038	827	0	349	890	1064	711
TEKİRDAĞ	1082	1352	603	831	604	869	307	693	1502	376	1358	1196	1387	523	1187	671	683	256	726	1600	890	1041	0	1819	241
TRABZON	950	737	1001	807	735	1257	1105	1221	642	850	500	233	297	1308	798	643	659	960	1366	545	326	460	1217	729	1039
YALOVA	904	1173	344	649	425	615	68	498	1324	194	1180	1018	1209	353	1009	489	500	78	588	1422	711	862	241	1641	0
ZONGULDAK	754	1024	502	498	276	790	373	722	1174	113	1030	852	1043	657	859	215	350	228	867	1272	546	710	485	1475	306