DETERMINATION OF IDENTICAL AFAD WAREHOUSES FOR FASTER RESPONSE IN DISASTER RELIEF

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DETERMINATION OF IDENTICAL AFAD WAREHOUSES FOR FASTER RESPONSE IN DISASTER RELIEF

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STATEMENT OF NON-PLAGIARISM PAGE

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ÖZ

AFETLERE DAHA HIZLI MÜDAHALE İÇİN ÖZDEŞ AFAD DEPOLARININ KULLANIMI

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Afetzedelere afet sonrasında yardım malzemelerinin önceden konumlandırılmış envanterden sevki sağlanır, bu nedenle depo konumları ve malzemelerin afet öncesi sevke hazır olması afet sonrası müdahalede büyük önem arz eder. Türkiye'nin iklimi, tektonik, sismik ve topoğrafik yapısı nedeni ile sık sık doğal afetler meydana gelmekte ve can kaybı, maddi ve manevi zararlarla sonuçlanmaktadır. Sel, çığ, heyelan ve yangınlar bu doğal afetlere örnek verilebilir, ancak en önemlileri depremdir. Türkiye en aktif sismik bölgelerden biri olan Kuzey Anadolu Fay (KAF) hattı üzerinde yer almaktadır. Depremler, sayılarına ve neden oldukları hasara bağlı olarak Türkiye'de meydana gelen en yıkıcı doğal afetlerdir. T.C. Başbakanlık Afet ve Acil Durum Yönetimi Başkanlığı (AFAD), Türkiye'deki hazırlık seviyesini artırmak,afetlere etkili bir şekilde cevap vermek ve afetzedelere hızlı bir şekilde yardım malzemesi gönderebilmek için 25 farklı ilde konteynır depoları kurmuştur. Depolarda, yatak, çadır, battaniye, kılıf ve mutfak kitleri bulunmaktadır. Mevcut durumda depolar özdeş olarak işletilmemekte ve kapasiteleri verimli olarak kullanılamamaktadır. Depolarda yardım malzemeleri farklı adetlerde stoklanmakta ve bazı depolarda tüm çeşitlerde yardım malzemeleri stoklanmamaktadır. Bu nedenle afet sırasında gereğinden fazla depo kullanımı gerekmekte, müdahale zamanı artmaktadır. Bu çalışmanın amacı, Türkiye'deki afete müdahale operasyonlarında özdeş AFAD depolarının(diğer bir deyişle, her envanter kaleminden yeterli stok seviyesine sahip) kullanımının olası yararlarını araştırmaktır. Geliştirilen konumlandırma ve tekrar atama tipi matematiksel modelle mevcut depo kapasitelerinin etkin ve verimli bir şekilde kullanımı hedeflenmiştir. Kurulan model 3500 farklı senaryo ile 175 adet gerçek geçmiş deprem verisi ile test edilmiş ve sonuçlar üç farklı performans kriteri ile değerlendirilmiştir: (1) talep ağırlıklı toplam mesafe, (2) depo kullanım sıklığı, (3) depoların özdeşe çevrim sıklığı. Bu tez özdeşe çevrilmesi için AFAD depolarının sayısını ve yerlerini önermektedir. Sonuçlar önerilen özdeş depo modelinin önemli kazanımlar sağladığını göstermektedir.

.

Anahtar Kelimeler:İnsani Yardım Lojistiği, Afetlere müdahale, özdeş depo, Konumlandırma-Tekrar Atama Modeli

ABSTRACT

DETERMINATION OF IDENTICAL AFAD WAREHOUSES FOR FASTER RESPONSE IN DISASTER RELIEF

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Beneficiaries are provided from pre-positioned inventory after a disaster strike, this is why making these materials ready for dispatch is of vital significance for an effective response. In the classical approach, using permanent warehousing with shelves is considered mainly on pre-positioning of relief materials. As an original idea implemented in Turkey, pre-positioning of relief supplies using freight containers for storage of relief supplies is considered. Turkey is faced with frequent natural disasters due to its climatic, tectonics, seismic and topographic structure; hence, experienced unacceptable life losses and damages. Floods, avalanches, landslides, fires can be give as an example for these natural disasters, but the most important one is earthquakes. Turkey is located on one of the most active seismic zones, North Anatolian Fault (NAF) line. Earthquakes are the most destroying natural disasters happened in Turkey related to the number of causalities and financial damage. Recently, Republic of Turkey Prime Ministry Disaster and Emergency Management Presidency (i.e. AFAD in Turkish) located 25 container warehouses to different cities in Turkey to respond disasters effectively and deliver relief supplies to beneficiaries quickly. The relief supplies stored in containers are tents, beds, blankets, cover sheets, and kitchen kits. Currently, warehouses are not operated identically and the capacity of warehouses are not used effectively. Some warehouses store one type of item and none from other types. Therefore, several warehouses have to be activated during a response operation to fully satisfy the needs of beneficiaries for each relief item type. The aim of this study is to investigate the benefits of operating identical (i.e. having a proper level of inventory from each relief item type) AFAD warehouses using current total capacity in disaster relief operations in Turkey. A location-(re)allocation type of mathematical model is developed to decide on how to use existing warehouses efficiently. The model is tested with 3500 different scenarios using 175 past earthquake data. Different scenarios are based on the available amounts at the supply points and whether identical warehouse option is allowed or not. The results are examined in terms of two performance measures: (1) demand weighted distance (2) usage frequency of warehouses, and (3) conversion frequency of warehouses to an identical one. The results indicate savings for the proposed identical warehouse model.

Keywords: Humanitarian Logistics, Disaster Relief, Identical Warehouses, Pre-Positioning, Location-(re)allocation

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1. INTRODUCTION

Natural and man-made disasters have caused both financial and moral losses. As an example, in 2015, 376 natural disasters were reported and these disasters caused 22,765 deaths, 110.3 million people were affected and also, US$ 70.3 billion damages worldwide (Guha-Sapir *et al.* ,2016) These disasters often affect normal supply chain activities and make it challenging for treatment centers such as hospitals and distribution centers to obtain relief materials. The resulting inability to supply the necessary care to beneficiaries could lead to increased fatality rates. As a consequence, the development of disaster preparedness and response activities within a robust decision making framework is of prime importance. According to CRED report (Guha-Sapir *et al.* ,2016) the number of reported natural disasters in 2015 is 376 and in 2014 is 330, which means that an increase of 13.9% in 2015's number compared to 2014's number. EM-DAT (2017) states that a disaster enters the database only if the following conditions hold: Ten (10) or more people are recorded killed, hundred (100) or more people are recorded affected, state of emergency is declared, international assistance is called. The substantial level in the number of recorded disasters have increased the fear factor and have made 'readiness' the principal priority. Increasing the readiness for disasters can be classified under the area of humanitarian logistics.

Since number of people who are affected by natural disasters increase, humanitarian logistics has attract considerable attention from scholars and practitioners recently. Humanitarian logistics is defined as "planning, implementing and controlling the efficient, cost-effective flow of and storage of goods and materials as well as related information, from point of origin to point of consumption for the purpose of alleviating the suffering of vulnerable" by

Thomas and Kopczak(2005). Humanitarian logistic is vital in case of a disaster. The effectiveness of the humanitarian logistic rely heavily on the speed and efficiency of the response activities. Efficiency of response activities mostly depends on the readiness (i.e. preparedness) level of the humanitarian actors. The main objective of humanitarian logistics studies is to decrease the loss of life and properties by orchestrating several humanitarian actors such as local government, non-governmental organizations (NGOs), international NGOs, as well as dedicated institutions such as FEMA (Federal Emergency Management Agency) in the US, ECHO (European Civil Protection and Humanitarian Aid Operations) in EU, AFAD (Prime Ministry Disaster and Emergency Management Authority) in Turkey. Balcik and Beamon (2008) categorized the key challenges in humanitarian logistic as inherent demand, place and timing uncertainties, complex communication and coordination environment, difficulty in making efficient and timely delivery using limited resources. Increasing the preparedness of humanitarian actors is one way to overcome these challenges. As a disaster relief preparation method, disaster relief material is pre-positioned near disaster-prone areas in order to meet the urgent needs of beneficiaries.

Beneficiaries are provided from pre-positioned inventory after a disaster strike, this is why making these materials ready for dispatch is of vital significance. In the classical approach, using permanent warehousing with using shelves is mainly considered on pre-positioning of relief materials. As an original idea implemented in Turkey, pre-positioning of relief supplies using freight containers for storage of relief supplies can be considered (Şahin *et al*., 2014).Turkey is faced with frequent natural disasters due to its climatic, tectonics, seismic and topographic structure; hence, experienced unacceptable life losses and damages. Floods, avalanches, landslides, fires can be given as examples for these natural disasters but the most important one is earthquakes. Turkey is located at one of the most active seismic zone which is called North Anatolian Fault (NAF) line. According to Emergency Management Database (EM-DAT) website, earthquakes are the most destructive natural disasters happened in Turkey related to the number of causalities and financial damage.

To increase the preparedness in Turkey, AFAD located 25 container warehouses as seen in Figure1 to different cities in Turkey to respond disasters effectively and deliver relief supplies to beneficiaries quickly.

The relief supplies stored in containers are tents, beds, blankets, cover sheets, and kitchen kits. Currently, warehouses are not operated identically and the capacity of warehouses are not used effectively. Some warehouses store one type of item and none from other types. Therefore, several warehouses have to be activated during a response operation. The purpose of this study is to investigate the benefits of operating identical (i.e. having a proper level of inventory from each relief item type) AFAD warehouses with current total capacity in disaster relief operations in Turkey. A location-(re)allocation type of mathematical model is developed to decide on how to use existing warehouses efficiently. The model is tested with past earthquake data.

Figure1. AFAD warehouse inside view

The remaining of this study is organized as follows. In section 2, a review of literature related with this study is provided. In Section 3, the characteristics of the problem is given and the data set is explained. Section 4 presents the proposed mathematical model. In section 5, experimental and computational results are provided to test the mathematical model. Finally, we conclude and discuss suggestions on the future work.

2. LITERATURE REVIEW

Humanitarian logistics is a branch of logistics which aims “to plan, implement and control the flow and the storage of the goods from point of origin to the point of consumption efficiently and effectively for the people affected by the disaster” (Thomas and Kopczak, 2005). Van Wassenhove(2006) classifies disasters as being natural or man-made and sudden-onset or slow-onset. By disaster the author means "a disruption that physically affects a system as a whole and threatens its priorities and goals" (Van Wassenhove, 2006). Natural disasters are classified as slow-onset such as famine and drought and sudden onset disasters such as the tsunami or earthquakes. Man-made disasters are also divided the same as natural disasters, which are sudden onset disasters such as a terrorist attack and slow onset disasters such as political or refugee crises(see Figure 2).

	Natural	Man-made
Sudden-onset	Earthquake Hurricane Tornadoes	Terrorist Attack Chemical leak
Slow-onset	Famine Drought Poverty	Political Crisis Refugee Crisis

Figure 2: Disaster Classification (Van Wassenhove, 2006)

In literature, Altay and Green (2006) classify disaster operations management into four phases which are mitigation, preparedness, response and recovery. This classification seems to be followed in the literature.

These phases are also referred in the literature as “the life cycle of a disaster” and can be seen on Figure 3(Altay and Green, 2006). Mitigation activities are preventive activities that decrease the effects of disaster and it can be classified as a pre-disaster phase. Improving resistance of the structures are given as an example of mitigation phase. Preparedness activities prepares the society to disaster. The aim of the response activities is to respond the demand in emergency cases for preserving life. Evacuation of vulnerable people, shelter location decisions are included in the response phase. The last phase of disaster operations management is recovery. Recovery phase are usually long-term, recovering the disaster effects after the initial disaster impact disappears. In general, mitigation and preparedness are treated as pre-disaster(i.e. pro-active) operations while response and recovery are treated as post-disaster(i.e. reactive) operations management.

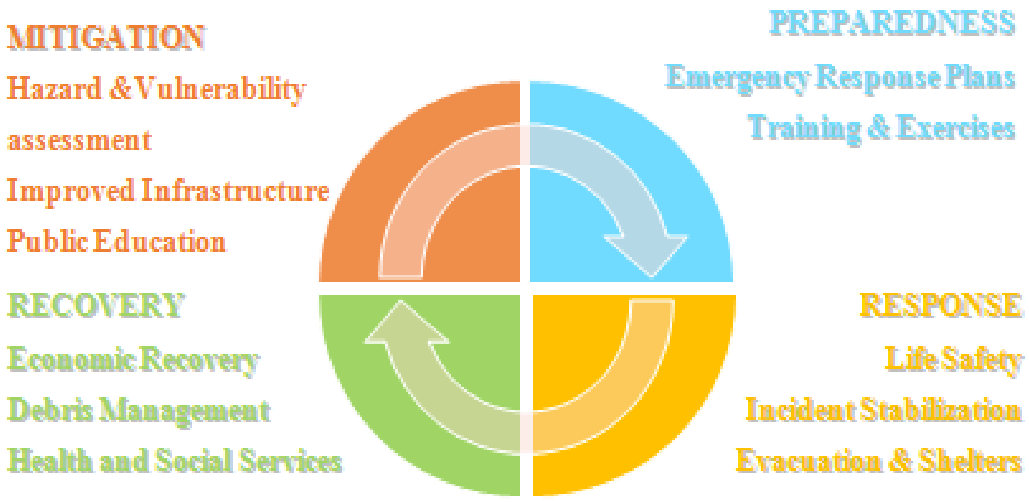

Figure 3: Disaster Relief Life Cycle

However, some cases can be evaluated as both preparedness and response operations. For example, Döyen *et al.* (2012)considered two stage stochastic integer programming model which can be used during preparedness and response cases. The objective is minimizing the facility location, inventory holding, transportation and shortage cost. Model formulated as mixed integer programming and solved by Lagrange heuristic. In addition, Mitigation decisions are considered in model.

In this thesis, in accordance with the thesis subject, main focus of the literature survey is the studies about preparedness and response phases, specifically locating identical warehouses. Despite varying constraints, the models constructed for the preparedness phase have similar objectives such as minimizing response time, demand weighted distance and unsatisfied demand. Response phase studies are shaped within the frame of minimizing evacuation time and unsatisfied demand(i.e. maximum coverage). Response phase also includes decisions about selection of a shelter area according to some predefined selection criteria. In general, facility opening costs are not included these models, since human life is beyond any cost measures. Most of the research papers in the last decade found in the literature is about the locating Disaster Relief Facilities(DRFs) owing to the fact that the disaster relief facilities provide a critical lifesaving service(Ko *et al.*,2016). Performance of the selected DRF's is measured in terms of the total transportation cost and response time. Therefore, for an effective planning of response activities, allocation of relief materials and location of DRF's becomes critical in case of an emergency (Khayal *et al.*,2015).

Khayal *et al.*(2015) studied a network flow model for dynamic selection of temporary distribution facilities and resource allocation for emergency response planning. Facility location, allocation, community flow, and supply assignment problems were included in the developed model. The objective of the model is minimizing the logistics and penalty costs for the delay in the relief distribution. A numerical analysis was conducted for a sample network including 15 cities in South Carolina, USA.

Görmez *et al.*(2011) consider locating disaster response and relief facilities (DRF) in İstanbul. In this article, a mixed integer mathematical programming model was developed to decide the location of the facilities by minimizing average weighted distance while opening a small number of facilities. Models was constructed by considering the facility capacity and demand satisfaction requirement constraints. In the first model, average distance is minimized with a specified number of facilities. In the second model, maximum distance is minimized. After solving the first two models the result was unacceptable. In third case, the model was modified. Objective of the third case was finding the minimum number of facilities limiting an average distance.

Renkli and Duran (2015) studied an Uncapacitated Location Problem with Chance constrains (UNCP-C). They propose a mixed integer programming model to decide the location of warehouses and the amount of relief material to be held in those warehouses. The objective of the proposed model is minimizing to response time by pre-positioning warehouses priori to a possible disaster. A numerical analysis is conducted with an application of Istanbul case for pre-positioning warehouses a priori to the possible expected large-scale earthquake.

Şahin *et al.*(2014) used earthquake risk data to assign DRF in Turkey. The objective of the mathematical model was minimizing the distance between the DRFs and demand points with considering the facility capacities and average earthquake destruction powers by an integer programming model. Şahin *et al*. (2014) also studied using containers as storage facilities in humanitarian logistic. Their mathematical model has been constructed to decide the location of warehouses and the quantity of containers as well as the type and amount of aid materials.

Konu (2014) studied prepositioning of relief items while considering the transportation vulnerability effect in İstanbul. Number of warehouses was determined by a mathematical model. The model contains 29 demands and 29 potential DRF locations. The objective minimizes the vulnerability and demand weighted distance.

Başkaya *et al.* (2016)compared direct shipment model (DT)with proposed lateral transshipment model (LTSP) and maritime lateral transshipment model (MLTSP)to investigate the inclusion of lateral transshipment opportunities into the humanitarian relief chain. The common objective of the proposed models is minimizing the average distance travelled per item. Vulnerability of the roads and heterogeneous capacitated facilities are utilized as parameters to decide the number and the location of the warehouses. Proposed models are compared using an earthquake scenario for İstanbul.

Although there are many humanitarian logistics studies on locating DRF's, studies which take into account locating and/or converting DRF's to identical facilities are not frequent. Some of the relevant studies are analyzed here. In Table 1 comparison of most related literature and our study is summarized.

Thanh *et al.* (2008) have studied Multi Period Facility Location problem (MFLP). A multi-echelon, multi-commodity production–distribution network has been considered in the model wherein facility capacities change overtime with deterministic demands. Organizing a production–distribution system a mixed integer linear program (MILP) has been used. Dynamic decisions are included in model which means that these decisions may change within the planning horizon. These decisions are supplier selection, opening, closing or enlargement of facilities and flows among the supply chain. The objective of the model is minimizing the total fixed and variable cost of supplier selection, opening, closing or enlargement of facilities. A numerical analysis is conducted with an application of planning the expansion of a company that has to face increasing demands.

Hernández *et al*. (2012) studied a multi-period facility location problem with stochastic demands. The model consists of locating a given number of new prisons, deciding where and when to expand the both new and existing prisons' capacity. The objective of the model is minimizing the expected cost of the prison system. A real-life problem of selecting prison facility sites is addressed in the paper and applied to the Chilean prison system.

Maximum prisoners' transfer distances, prison capacities' upper and lower limits, and scheduling of prison openings and expansion are the included in the model as constraints.

Bagherinejad *et al*. (2018) integrate modular capacitated maximal covering location problem and multi-period maximal covering location problem. The objective of the model is maximizing the overall covered demand. In the model facilities' capacity is changing periodically. Another assumption of the model is that potential locations are identical in all periods. In each potential location, only one facility can be located and if a facility were located in location *j* in period *t*, a facility would serve in this location until the end of the time horizon. It is assumed that opening and closing of facilities and relocation of them has no cost. Maximum number of vehicles and maximum and minimum number of new facilities in period *t* is taken as parameter in the model. A genetic algorithm is used to solve the model.

Ko *et al*. (2016) consider both capacity and capability design of emergency medical centers(EMCs) and location decision under the closest assignment rule and minimum required survival rate of the patients. EMC can enlarge its capacity with additional subsidies and also initiate a new medical treatment which is not included in the its original capacity. The capacity of each candidate facility is not necessarily identical. The mathematical model is formulated using Integer Programming and the objective is minimizing the total amount of subsidies paid by the government. In addition, a hybrid genetic algorithm was developed for generating near-optimal solution. A numerical example is given with randomly generated data.

In our problem, a single-period, single-echelon, multi-commodity flow is considered with deterministic demand and supply. Total capacity of warehouses cannot change, but re-allocation of available inventory among warehouses is permitted, which means that while some warehouses' capacity can be enlarged, some of them can be decreased different than the literature.

All of the last four related studies covered here include locating/opening a new facility or closing existing facility and enlargement of total capacity however, these are not considered in our case since, in this study, we try to find out the benefits of identical warehouses with current total stock level. Moreover, previous studies did not consider making identical warehouses, according to their constraints only upper and lower limits are defined for warehouses in the proposed models. Also, the objective functions of the relevant studies are different than our study.

Author	Type	Capacity Decisions	Location Decisions	Objectives	Constraints		Type
					Capacity	Requirements &Bounds	
Thanh et al. (2008)	Multi Period Multi Echelon Multi Commodity	Opening, Closing, Enlargement	Location- allocation	Total fixed and variable cost	Maximal installable Capacity		Article
Hernández et al. (2012)	Multi Period Single Echelon Single Commodity	Opening, Enlargement	Location- allocation	Total fixed and variable cost per prison	Upper and lower bound for facility capacity	Maximum inmate transfer distances	Article
Bagherinejad et al. (2018)	Multi Period Single Echelon Single Commodity	Opening	Location- allocation	Overall covered Demand	Total capacity of facilities Number of new facilities Number of vehicles	Desired coverage distance	Article
Ko et al. (2016)	Single Period Single Echelon Multi Commodity	Opening, Enlargement	Location- allocation	Amount of subsidies in USD	Capacity in man-hours of EMC	Minimum survival rate	Article
Our Study	Single Period Single Echelon Multi Commodity	Stay as current	Location- allocation-(re)allocation	Total demand weighted distance	Total capacity of facilities	identical facility capacity	Master Thesis

Table 1: Comparison of related literature

3. PROBLEM DEFINITION

3.1. Problem Environment

Prime Ministry Disaster and Emergency Management Authority (abbreviated as AFAD in Turkish) located 27 regional logistics warehouses in different cities in Turkey to respond disasters effectively and deliver relief supplies to beneficiaries quickly. There are three types of warehouses and a total of 27 warehouses are incorporated with AFAD:

- Two shelved type warehouses (shown in Figure 4 in blue color) located in Balıkesir and Hatay
- Type 1:*16 warehouses with48 container capacity*. Materials are kept in standard 40ft dry freight containers to save from handling time. With dimensions of W:20m x L:60m x H:15m making up a total area of 1200 m^2(shown in Figure 4 in black color) located in Kocaeli, Yalova, Bursa, Muğla, Antalya, Düzce, Kastamonu, Ankara, Kırıkkale, Aksaray, Sivas, Adıyaman, Elazığ , Erzincan, Diyarbakır and Van.
- Type 2: *9 warehouses with 96 container capacity*. Materials are kept in standard 40ft dry freight containers to save from handling time. With dimensions of W:40m x L:60m x H:15m, making up a total area of2400 m^2(shown in Figure 4 in orange color) located in Tekirdağ, Manisa, Denizli, Afyonkarahisar, Samsun, Adana, Kahramanmaraş, Erzurum and Muş.

Figure 4: Location of AFAD Warehouses

Figure 5: Type 1 warehouse (capacity of 48 containers)

Figure 6: Type 2 warehouse (capacity of 96 containers)

In our problem, we only consider 25 containerized type of warehouses; Type 1 (illustrated in Figure 5)and Type 2 (illustrated in Figure 6).Containers are located inside the warehouses as three containers on top of each other. Containers are arranged two parallel rows in both warehouses.

In Type 1 warehouse, 48 containers and an overhead crane exists. In Type 2 warehouse,96 containers and two overhead cranes exists with the same layout with Type 1 warehouse. Each container is filled with different types of relief materials such as beds, tents, blankets, and pillows (Figure 7).

Figure 7:Bed, bed sheet, pillow cover and blanket

For instance, in Figure 8 tent pallet layout is shown. 20 tents can be placed a standard pallet and a5 pallets can be placed a container; hence, a container can contain 100 tents as shown in Table 2. In our case, we consider three types of material; (1) tent, (2) bed and we combine (3) blanket, bed sheet and pillow cover and we assume as the third type of material. Also, a tent can serve 4 people and each person needs 2 blanket. A bed sheet and a pillow cover is needed per person. Capacities in APPENDIX C is calculated using these conversion ratios.

Figure 8: Tent pallet

Table 2: Dimension of materials in a container

Material	Dimensions of materials (cm)	Weight (kg)	Pallet dimensions (cm)	Total Units in one pallet	Total Units in one Container
16,5 m^2 Tent	210x47x47	105	205x205	20	100
Bed	90x190x12	6	205x205	34	187
Blanket	50X100X45	2	205x205	320	1760
Bed sheet, pillow cover	120x45x65	1	100x120	120	2640

Currently, these warehouses cannot be operated in full capacity, because some of the containers are empty. Also, the empty containers must be located on the top layer since the full containers damages the empty ones when it is on the top and it increases the loading time of the containers to the trucks. In addition to this problem, containers can contain different type of relief items in the current layout, such as while container in first layer contains bed, second layer contains tent and the third layer is empty. In the current case, if the crane operator wants to load a container to a truck which is at the bottom layer, he must ground the two containers located at the upper two layers. To complicate the matter, there is not a maneuvering area for two containers within the warehouse. Because of the security reasons, containers are kept in warehouses and this restricts the mobility of containers. The only solution in the current case is to load the empty containers on a truck, then bring in a new truck to load the loaded containers. Trucks are a scarce resource at the time of disasters. In case of an emergency, this situation can cause delays to deliver the aid materials to sufferers.

Moreover, warehouses are not identical to each other except for their capacities. For example, while some of the warehouses hold only tents and beds, some of them hold only beds and blankets. In a typical response operation, since different types of items are stored in different warehouses, several warehouses must be activated to fully satisfy the requirements of beneficiaries. Activating several warehouses even for a small operation increases the complexity of coordination and the response time. To quickly respond to a disaster, it is essential to meet the requirements from the nearest warehouse(s).

However, in the proposed layout(i.e. .identical warehouse), all types of relief items are located in each layer as seen in Figure 9. All layers in identical warehouse are the same, this layout helps to eliminate the unnecessary movement of containers. In all of the identical warehouses, there is same amount of each relief item. Hence, both the layout and the amount of relief materials are identical.

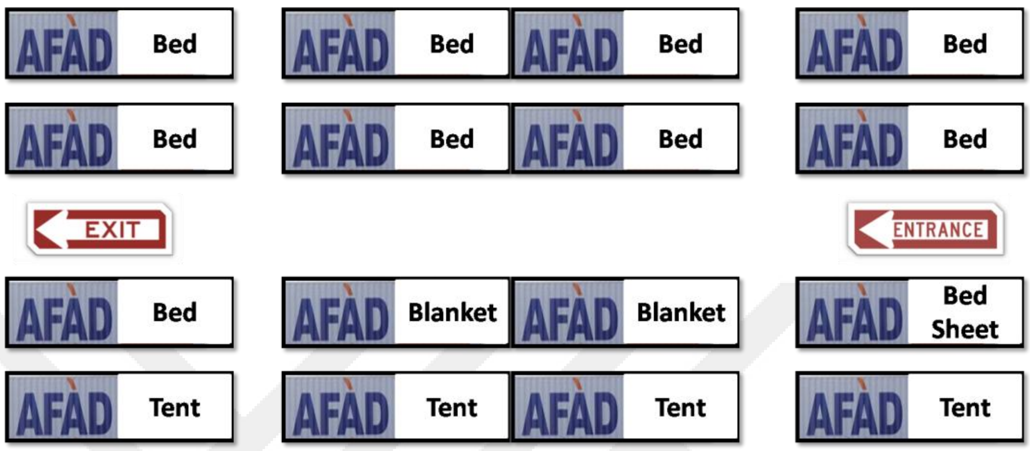

Figure 9: A Layer of Proposed layout for aid materials

4800 beneficiaries' requirements can be fully satisfied from a single 48 container warehouse if the item types are organized among warehouses according the proposed layout. We assume that all item types are required in case of an emergency, proposed layout is assumed as identical which means that the amount of each relief item is same. According to the greatest common divisor, all types of relief items to satisfy the needs of 1600 people can be stored in one layer.

As shown in Table 2 and Figure 9,a container can contain 100 tent, and four tent containers are in each layer, which means in a layer there are 400 tents and each tent can serve a family of four persons. As a result, 1600 beneficiaries requirement can be satisfied from one layer. For a bed container, there are nine containers in one layer, in a container 187 bed can be stored, so totally 1683 beds can be stored in one layer. For a blanket container, there are two containers in one layer, in a container 1760 beds can be stored and each person needs two blankets, so totally 1760 beneficiaries' requirement can be satisfied from one layer.

Lastly, there are one bed sheet and pillow cover container in one layer, in a container 2640 bed sheets and pillow covers can be stored, so totally 2640 bed sheet and pillow cover can be store in one layer. In brief, at least 1600 beneficiaries' requirement can be supplied from one layer and since there are three layers, totally at least 4800 beneficiaries' requirements can be fully satisfied from a single 48 container warehouse, and at least 9600 beneficiaries' requirements can be fully satisfied from a single 96 container warehouse.

As an illustration, assume that an earthquake strikes Konya. Since there is no AFAD warehouse in Konya, relief materials are delivered to Konya from nearest warehouses. If we operate in current situation, we have to activate the nearest three warehouses (i.e. Afyonkarahisar with bed and blanker, Ankara with tent and bed, Aksaray with tent and blanket) to meet the all types of beneficiary demand fully (Figure 10).

Figure 10: Current case solution

In the proposed situation in this thesis, we can meet all types of beneficiary demand fully by only activating Aksaray warehouse if it is converted to an identical warehouse (Figure 11).

Figure 11: Proposed identical case solution

This study proposes a better layout for warehouses and a better usage of their capacities. However, it is too expensive and sometimes operationally infeasible to make all AFAD warehouses identical(according to the proposed layout). Therefore, we aim to find a operationally feasible number of converted warehouses and to determine the warehouses that should be converted to identical. The objective of this thesis is to investigate the benefits of operating identical AFAD warehouses in disaster relief operations in Turkey.

A mathematical model is developed to determine the number of identical warehouses and to select identical warehouses among existing warehouses for faster response. Capacity of warehouses, estimates of population under risk, and the distances between cities are some of the criteria to be considered.

3.2. Data Gathering

Demand (potential number of affected people) is obtained by using the damaged building numbers from the Turkish earthquake database (TABB, 2012) between years 1894 and 2011(APPENDIX A). The potential number of affected people in each city is calculated by multiplying the affected number of buildings by ten(Khazai *et al.*, 2012). 175 different demand scenario is obtained by using these data and can be seen on APPENDIX A. The intercity distances are obtained from General Directorates for Highways (KGM, 2017) and given in APPENDIX B. The number, location and the capacity of warehouses are obtained from AFAD (AFAD, 2013). Full capacity of warehouses is obtained using Table 2 organized as shown in Figure 9 and calculations explained detailed in problem environment. According to the proposed layout, Type1 warehouses can serve 4800 beneficiaries and Type 2 warehouse can serve 9600 beneficiaries in full capacity. The containers are not fully loaded in the current situation. Therefore, to make a viable comparison, identical warehouse capacity is taken as %70 percentage of the proposed layout capacity (full capacity) and type 1 warehouse can serve up to 3600 beneficiaries while type 2 can serve up to 7200 beneficiaries. In APPENDIX C, identical capacity of warehouses are given. Current supply amount of warehouses are randomly generated by using uniform distribution. %70 of the total capacity is distributed randomly. 10 different sample data set was generated for simulating current warehouses stock, and to reduce dependency of the solution of the model from current supply amount(APPENDIX D). When total demand (number of beneficiaries) is greater than the total supply, total demand is assumed to be equal to the total supply. Total supply amount is assumed as 97.240 people (%70 of the total capacity), demand above this value cannot be satisfied.

4. MATHEMATICAL MODEL

The defined problem is formulated as a mixed integer programming (MILP) model that is a variant of location-(re)allocation problem. The objective of the model is to determine the number and location of the identical warehouses using a limited quantity of relief materials. The model re-allocates an available total inventory among existing warehouses while converting some warehouses to an identical type. The objective function minimizes the total demand weighted distance to respond quickly the immediate necessities of vulnerable people.

The assumptions of the formulated mathematical model are;

- For identical warehouses, all capacity must be used if it is converted.
- There are three types of products; tent, bed, and blanket.
- •Current capacity of warehouses cannot be increased.
- Supply can only be re-allocated from current warehouses to identical warehouses.
- Total supply amount cannot be exceeded.
- Transportation, purchasing, operational, and converting costs are left out of scope of this thesis since life-saving of affected people is prioritized in humanitarian settings.

The sets, parameters and decision variables are presented below.

<u>Sets</u>

K set of product types; $k \in K$

J set of warehouses $j \in J$

I set of demand nodes $i \in J$

Parameters

W: number of current warehouses

P: number of warehouses converted to be an identical warehouse

d_{ij}: distance between node i ϵ I and warehouse j ϵ J

h_{ik}: demand at node i ϵ I for product type k ϵ K

$de_{i,k}$: $\begin{Bmatrix} 1, \text{if demand at node i } \in \text{I for product type k exists} \\ 0, \text{OW} \end{Bmatrix}$

$c_{j,k}$: current capacity of warehouse j ϵ J for product type k ϵ K

$f_{j,k}$: identical current capacity of warehouse j ϵ J for product type k ϵ K

M: Big number

Decision variables

X_j: $\begin{Bmatrix} 1, \text{if warehouse is converted to an identical warehouse} \\ 0, \text{OW} \end{Bmatrix}$

Z_j: $\begin{Bmatrix} 1, \text{if warehouse is operated under current policy} \\ 0, \text{OW} \end{Bmatrix}$

$Y_{ij,k}$:fraction of demand from node i ϵ I that is served by a warehouse j ϵ J for product type k ϵ K

$U_{j,k}$: allocated capacity of warehouse j ϵ J for product type k ϵ K for current

$r_{j,k}$:product of $U_{j,k}$ and Z_j

The mathematical model is as follows:

$$(1)\ min \sum_{i \in I} \sum_{k \in K} \sum_{j \in J} h_{ik} d_{ij}\ Y_{ijk}$$

Subject to

$$(2) \sum_{j \in J} Y_{ijk} = de_{ik} \qquad \forall i \in I\ k \in K$$

$$(3)\ Y_{ijk} \leq X_j + Z_j \qquad \forall i \in I\ j \in J\ k \in K$$

$$(4) \sum_{i \in I} h_{ik} Y_{ijk} \leq f_{j,k} \times X_j + \boldsymbol{r_{j,k}} \qquad \forall j \in J\ k \in K$$

$$(5) \sum_{j \in J} r_{j,k} + \sum_{j \in J} f_{j,k} \times X_j = \sum_{j \in J} c_{j,k} \qquad \forall k \in K$$

$$(6)\ U_{j,k} \leq \boldsymbol{c_{j,k}} \times Z_j \qquad \forall i \in I\ j \in J\ k \in K$$

$$(7)\ X_j + Z_j \leq 1 \qquad \forall j \in J$$

$$(8) \sum_{j \in J} X_j \leq P$$

$$(9)\sum_{j\in J} X_j + Z_j = W$$

$$(10)\ X_j \le \sum_{i\in I}\sum_{k\in K} Y_{ijk} \times M \qquad \forall j \in J$$

$$(11)\ Z_j \le \sum_{i\in I}\sum_{k\in K} Y_{ijk} \times M \qquad \forall j \in J$$

$$(12)\ f_{j,k} + M \times (X_j - 1) \le \sum_{i\in I} Y_{ijk} \times h_{ik} \qquad \forall j \in J\ k \in K$$

$$(13)\sum_{j\in J} u_{j,k} \le M \times Z_j \qquad \forall k \in K$$

$$(14)\ r_{j,k} \le u_{j,k} \qquad \forall j \in J\ k \in K$$

$$(15)\ r_{j,k} \le u_{j,k} - M \times (1 - Z_j) \qquad \forall j \in J\ k \in K$$

$$(16)\ X_j, Z_j \in \{0,1\} \qquad \forall j \in J$$

$$(17)\ Y_{i,j,k} \ge 0,\ r_{j,k} \ge 0\ and\ u_{j,k} \ge 0 \qquad \forall i \in I\ j \in J\ k \in K$$

In the model above, objective (1) is minimizing the serving cost of node $i \in I$ which is the product of the demand at node $i \in I$ and the distance node $i \in I$ and the nearest warehouse $j \in J$. This constraint is similar with the objective function of *p*-median problem. Constraint (2) states that demand at node $i \in I$for product type $k \in K$ can only be assigned to warehouse $j \in J$ if a warehouse is operated at node $j \in J$. Constraint (3) requires that demand at node $i \in I$for product type $k \in K$ cannot be assigned to a warehouse at node $j \in J$ unless a warehouse is opened at node $j \in J$. Constraint (4) stands for capacity if warehouse at node $j \in J$ is operated under current policy, total demand that is served by a warehouse $j \in J$ cannot exceed the current capacity. If warehouse at node $j \in J$ is converted to an identical warehouse, total demand that is served by a warehouse $j \in J$ cannot exceed the identical capacity.Constraint (5) states that total capacity usage cannot exceeds total current capacity. Constraint (6) states that capacity usage for not converted warehouse cannot exceeds its current capacity. Constraints (7)state that warehouse $j \in J$ can only be operated either under current policy or converted to identical.

Constraints (8) state that number of converted warehouse cannot exceed P value. As a variant of the problem,

$$\sum_{j \in J} X_j \leq P \qquad or \qquad \sum_{j \in J} X_j = P$$

limits or fixes the number of converted warehouse to P value, and converts model to the *p*-median location model. Constraint (9) states that the total number of warehouses must be equal to existing number of warehouses. Constraints (10) and (11) stand for warehouse is operated under current or identical policy (if it is used). Constraint (12) provides, if warehouse is operated under identical policy, all capacity must be used. Constraints (13), (14) and (15) are for linearization. Constraints (16) and (17) are non-negativity and binary constraints.

5. EXPERIMENTAL RESULTS

In this section, the experimental results of the proposed mathematical model are presented. A total of 3500 (10x175x2) instances with varying parameters were solved by using GAMS 24.0 IDE with CPLEX 12.5 solver. Solutions are varied by changing supply(i.e.10 different randomly generated current warehouse capacities), demand (i.e. 175 historical earthquake data) and P (i.e. maximum number of warehouses (i.e. *p*-value) that can be converted to identical: 0 and 25) value. The average solution time for scenarios is 0,022 second, maximum is 0,06 second and minimum is 0,01 second.

The performance measures that are analyzed in each scenario are the total demand weighted distance, usage frequency of warehouses and conversion frequency of warehouses. These values are obtained from the objective function value(demand weighted distance), (warehouse usage frequency) total warehouse usage divided by 3500 shown in equation 18 and(conversion frequency) total warehouse converted number divided by 1750 which is equal to the number of scenarios for when P is equal to 25 shown in equation 19.

$$usage\ frequency\ for\ warehouse\ j\ = \frac{\#\ of\ usage\ \ in\ 3500\ run\ \ of\ ware\ house\ j}{3500} \quad (18)$$

$$conversion\ frequency\ of\ warehouse\ j = \frac{\#\ of\ converted\ \ runs\ \ for\ ware\ house\ j}{1750} \quad (19)$$

To give an example, for 10 different randomly generated current warehouses supply amounts average objective values are summarized for earthquake scenario 1 and shown in Figure 12. All scenarios are listed in APPENDIX A. Solutions are compared for *P* value is equal to 0 and 25. On average, an approximate 10% percent improvement is satisfied on the objective value and can be shown in Figure 12.

Table 3: Earthquake scenario 1

Scenario	Date	Province	Magnitude	Num of Building	Num Of beneficiaries
1	27.6.1998	Adana	5,9	10675	106750

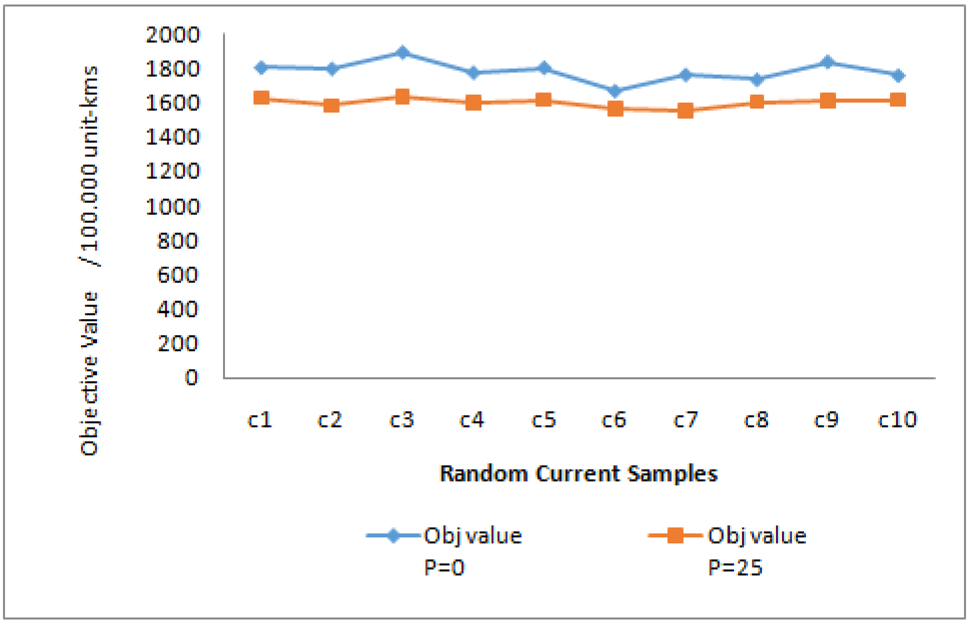

Figure 12: Objective value for earthquake scenario 1

As an example, for demand scenario1 and random current supply set 2, for p=0 and for p=25 values, used warehouses and allocation of aid materials are summarized in following tables. In Table 4, from-to re-allocation matrix for p=0 value is shown and in Figure 13 this case is graphically summarized in map. To satisfy the demand, all 25 warehouses were used and the objective value is calculated as 180,162,964unit-kms.

Table 4: From-To re-allocation matrix for *p*=0 for earthquake scenario 1

From	To	tent	bed	blanket
Adana	Adana	5600	561	8800
Adıyaman	Adana	2400	1122	1760
Afyonkarahisar	Adana	2800	5423	3520
Ankara	Adana	6400	3553	1173
Antalya	Adana	400	2057	1173
Bursa	Adana	6400	2057	4106
Denizli	Adana	11600	7106	5280
Diyarbakır	Adana	4800	3179	7626
Elazığ	Adana	6800	1496	2346
Erzincan	Adana	5600	5423	5866
Erzurum	Adana		5236	448
Kastamonu	Adana	800	3553	4693
Kocaeli	Adana	4800	374	586
Manisa	Adana	440	8789	4693
Kahramanmaraş	Adana	12400	6358	8800
Muğla	Adana		3553	
Muş	Adana	5600	7667	11733
Samsun	Adana	10000	8415	4693
Sivas	Adana	4800	935	586
Tekirdağ	Adana		2057	
Van	Adana		5797	5866
Aksaray	Adana	2800	1870	1760
Kırıkkale	Adana	800	2805	586
Yalova	Adana		3179	7040
Düzce	Adana	2000	4675	4106

Figure 13: Solution of case *p*=0 for earthquake scenario 1

In Table 5, from-to re-allocation matrix for p=25 value is shown. In this case to satisfy the demand, 20 warehouses were used and the objective vale is calculated as 158,418,746 unit-kms. 11 warehouses are converted to identical, and 9 warehouse is used as current. Solution is summarized graphically in Figure 14.

Table 5: From-To re-allocation matrix for *p*=25 for earthquake scenario 1

From	To	tent	bed	blanket	Converted
Adana	Adana	7200	7106	7040	X
Adıyaman	Adana	3600	3553	3520	X
Afyonkarahisar	Adana	7200	7106	7040	X
Ankara	Adana	6400	3553	1173	
Antalya	Adana	3600	3553	3520	X
Bursa	Adana	40	2057	3963	
Denizli	Adana	7200	7106	7040	X
Diyarbakır	Adana	4800	3179	7626	
Elazığ	Adana	3600	3553	3520	X
Erzincan	Adana	5600	5423	5866	
Kastamonu	Adana	3600	3553	3520	X
Kocaeli	Adana	3600	3553	3520	X
Manisa	Adana		6171		
Kahramanmaraş	Adana	12400	6358	8800	
Muş	Adana	5600	7667	11733	
Samsun	Adana	10000	8415	4693	
Sivas	Adana	3600	3553	3520	X
Aksaray	Adana	3600	3553	3520	X
Kırıkkale	Adana	3600	3553	3520	X
Düzce	Adana	2000	4675	4106	

Figure 14: Solution of case *p*=25 for earthquake scenario 1

Among 3500 instances, 1750 are solved for *P*=0 (i.e. identical warehouses are not allowed) and 1750 are solved for *P*=25 (i.e. maximum number of potential identical warehouses). Then, the results are compared with each other. When the average objective function values for 175 scenarios and10 random current warehouse stock level and varying *P* values (i.e. 0 and 25) are investigated, we can see that there is a 14% improvement (i.e. decrease) in the average objective function value for the identical warehouse case. Results are depicted in Figure 15.

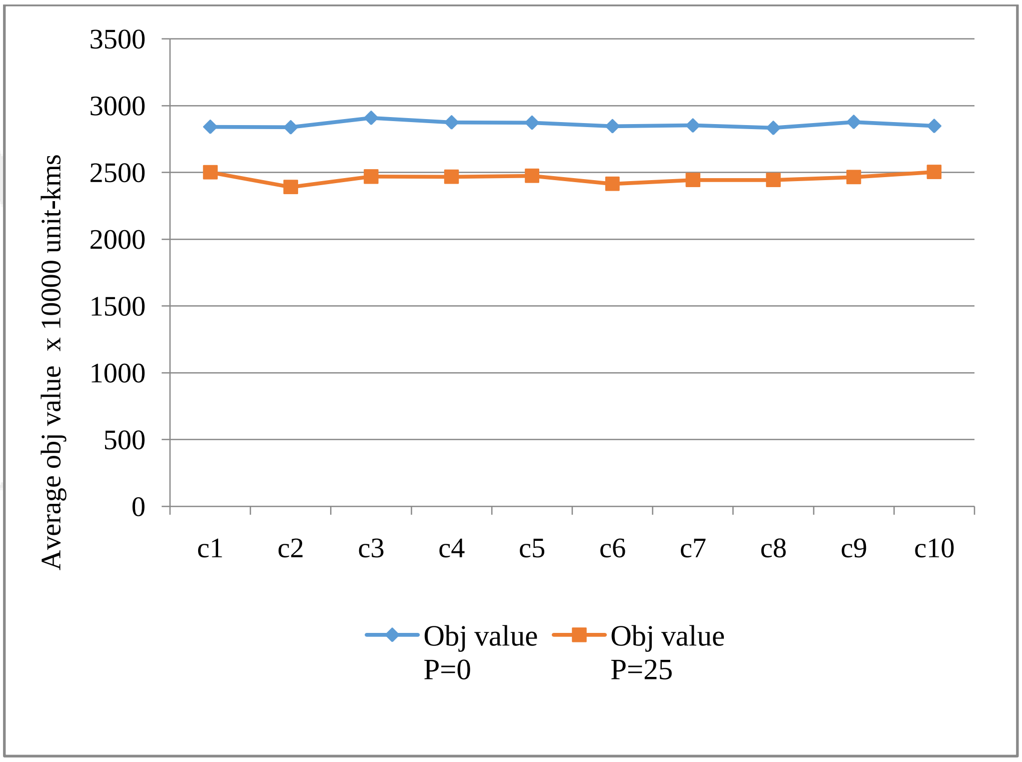

Figure 15: Average Objective Values for 175 earthquake scenarios

Table 6 shows the total usage of warehouses in 3500 instances as well as the total converted runs in 1750 (since only in *P*=25 value, warehouses can be converted).

Table 6: Total Usage in 3500 run and Total conversion in 1750 instances

WH	Total Usage in 3500 run	Total conversion in 1750 instances (when *P*=25)
Adana	680	149
Adıyaman	765	176
Afyonkarahisar	973	225
Aksaray	987	254
Ankara	962	221
Antalya	634	128
Bursa	805	112
Denizli	1073	111
Diyarbakır	774	145
Düzce	814	141
Elazığ	920	195
Erzincan	910	188
Erzurum	1044	149
Kahramanmaraş	768	159
Kastamonu	784	134
Kırıkkale	947	225
Kocaeli	825	207
Manisa	938	178
Muğla	909	152
Muş	1109	151
Samsun	760	139
Sivas	742	136
Tekirdağ	545	88
Van	712	132
Yalova	788	109

In Figure 16, scaled total usage of warehouses in 3500 run is shown in the Turkey fault lines map prepared by Prof. Dr. Ahmet Ercan. As seen in the Figure 16, the most used warehouses are the warehouses which are on and around the fault lines, since past earthquake data are used as input parameters in the solution of the mathematical model. Here, red circles are scaled with usage rate (i.e. larger circle means larger usage).

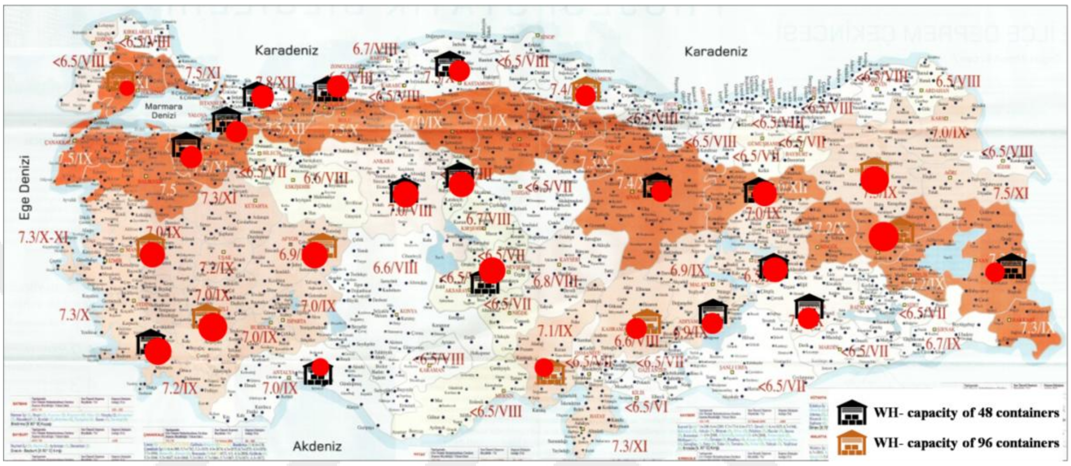

Figure 16: Scaled total usage of warehouses in 3500 run in earthquake risk map prepared by Prof. Dr. Ahmet Ercan (2010)

In Table 7 the converted frequency for each warehouse is shown. In the first column total converted number for each warehouse is divided to 1750 (total convertible run for *p*=25 case) is given and rows which are above the average are highlighted. In the second row, total usage value (both converted warehouses and current warehouses) for each warehouse is divided to 1750 and rows which are above the average are highlighted. Two rows are compared to each other and the common warehouses are selected as candidate warehouses which can be converted.

Table 7:The total warehouse conversion frequency

Warehouse	**X/1750**	**X+Z/1750**	**Warehouse Type**
Adana	0,085	0,201	2
Adıyaman	0,101	0,234	1
Afyonkarahisar	0,129	0,290	2
Ankara	0,126	0,294	1
Antalya	0,073	0,188	1
Bursa	0,064	0,226	2
Denizli	0,063	0,320	1
Diyarbakır	0,083	0,225	1
Elazığ	0,111	0,275	1
Erzincan	0,107	0,284	1
Erzurum	0,085	0,298	2
Kastamonu	0,077	0,227	2
Kocaeli	0,118	0,250	1
Manisa	0,102	0,277	1
Kahramanmaraş	0,091	0,231	2
Muğla	0,087	0,269	1
Muş	0,086	0,323	2
Samsun	0,079	0,225	2
Sivas	0,078	0,211	1
Tekirdağ	0,050	0,150	2
Van	0,075	0,201	1
Aksaray	0,145	0,305	1
Kırıkkale	0,129	0,277	1
Yalova	0,062	0,235	1
Düzce	0,081	0,239	1
X: Number of Converted Warehouses in 1750 run			
Z: Number of Warehouses used as-is in 1750 run			

In Figure 17 the scaled total usage and the scaled total warehouse conversion frequency is shown in Earthquake risk map prepared by Prof. Dr. Ahmet Ercan. Since, the objective function of the model is similar with *p*-median model, most of the converted warehouses are around the center region of the Turkey. In mathematical model, *P* value is not given in advance different than a *P*-median problem. The model is relaxing the *P* value. According to the required number of converted warehouses, *P* value can be decreased and increased to upper limit. Moreover, instead of locating new warehouses, model selects the warehouses to convert to an identical warehouse among exiting warehouses.

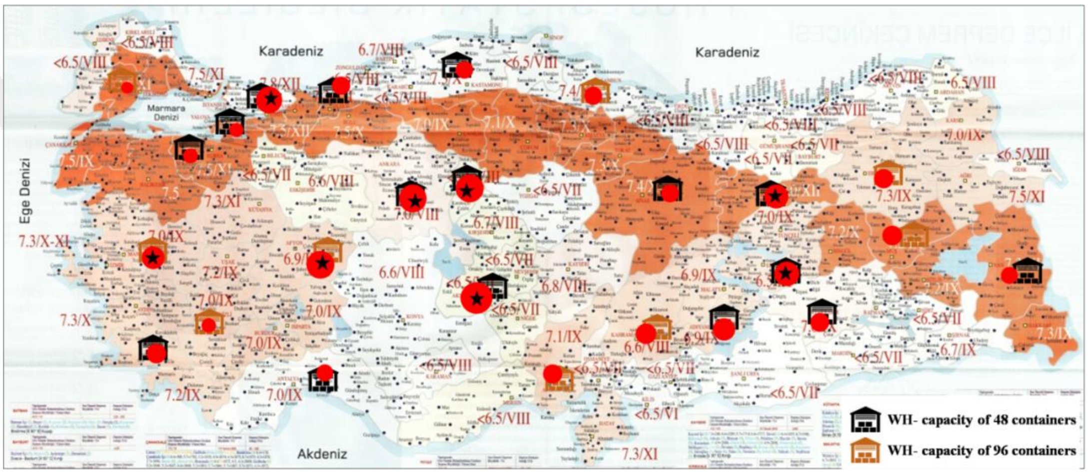

Figure 17: The scaled total conversion frequency in Earthquake risk map prepared by Prof. Dr. Ahmet Ercan (2010)

To determine an effective *p-value*, model was run for each *p*-value from 0 to 25 for current random supply set 2 shown in APPENDIX D for 175 different earthquake(demand) scenario shown in APPENDIX A. Total objective values are plotted with respect to *p-values* and illustrated in Figure 18. As seen on the Figure 18, the improvement (i.e. decrease) in the total objective value slows down after p=8. Therefore, our proposed number of warehouses (i.e. eight cities with stars in Figure 17) for conversion to be identical is effective.

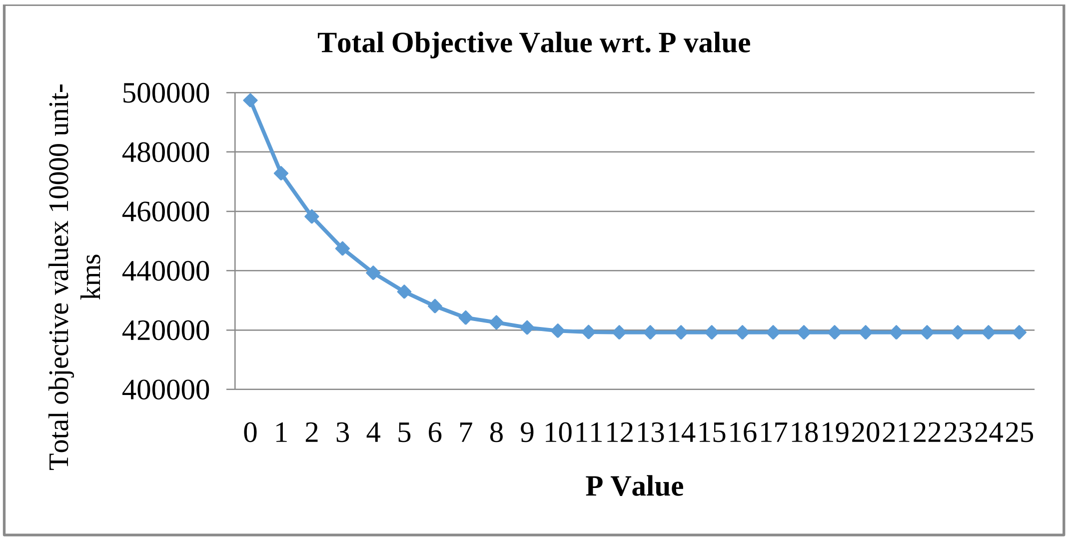

Figure 18:Total Objective Value with respect to P value

In addition to this solution, when the total usage frequency values and total conversion frequency (values above the average) are compared, the candidate warehouses are Aksaray, Afyonkarahisar, Kırıkkale, Ankara, Kocaeli, Elazığ, Erzincan, and Manisa, respectively. The *P* value is found as eight as a result of the experimental runs. In Figure 17, these warehouses are highlighted with stars. If we compared the most used warehouses and the most converted warehouses, they match up with each other. In total, conversion ratio is found as 32% (8/25).Figure 19 shows the average number of needed warehouses and average number of converted warehouses to meet the required amount of aid materials for given number of beneficiaries.

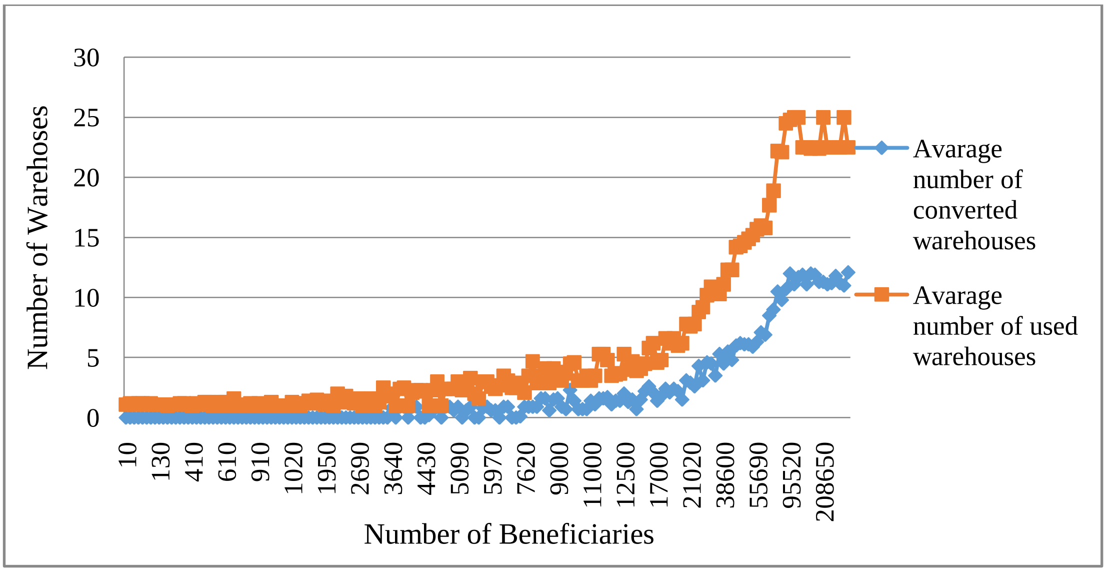

Figure 19: Average number of warehouses wrt. the number of beneficiaries

Among the selected warehouses, six of them are Type 1(i.e. warehouses with 48 container capacity) and two of them are Type 2 (i.e. warehouses with 96 container capacity). The total percentage of Type 2 warehouse is 36% whereas the percentage of converted Type 2 warehouse is 25%. Similarly, the total percentage of Type 1 warehouse is 64% whereas the percentage of converted Type 2 warehouses is 75%. Solution shows us that most of the converted warehouses are of Type 1 warehouse. Making Type 1 warehouse identical requires less budget because of the lower capacity. Therefore, if converting all eight warehouses is found infeasible by the decision makers (i.e. AFAD), converting only Type 1 warehouses can be valuable. Also, among the occurred earthquakes between years 1894 and 2011, there were lower than 20,000 beneficiaries in 75% of them. When 10 current random supply set is analyzed, the average number of used warehouses below 20,000 beneficiaries is calculated on average as 2,24 warehouses. It means that by using a maximum of two to three warehouses, needs of beneficiaries can be met or there is no need for converted warehouses in some cases where demand and supply points are the same. On the other hand, when the number of beneficiaries is above 20,000 people, for 43 past earthquakes out of 175, the average opened warehouse number is calculated as eight.

From this aspect, since the great majority of the occurred earthquakes caused less than 20,000 beneficiaries, considering only this case can be an alternative solution. This gives us a solution that on average only converting the first three warehouses(i.e. Aksaray, Afyonkarahisar, Kırıkkale) can be satisfactory. According to the dedicated budget, the number of converted warehouse can be increased or decreased.

To see the effectiveness of the proposed identical warehouses, another sample supply set (APPENDIX E) which is a good approximation of the actual stock level is used. Model was run for *p*=0 value for 175 scenario with the actual stock level. Then, our proposed eight warehouses (*p*=8)(i.e. Aksaray, Afyonkarahisar, Kırıkkale, Ankara, Kocaeli, Elazığ, Erzincan, and Manisa)are given their identical stock levels. Selected warehouses are assumed to have stocks at their corresponding identical capacity(APPENDIX G) and the model is run with these stock levels for 175 scenario. Comparison of objective values are plotted for p=0, p=3 and p=8 values for 175 scenarios, results are displayed in Figure 20 for demand less than 5000, between 5000 and 20 000 and above 20 000.

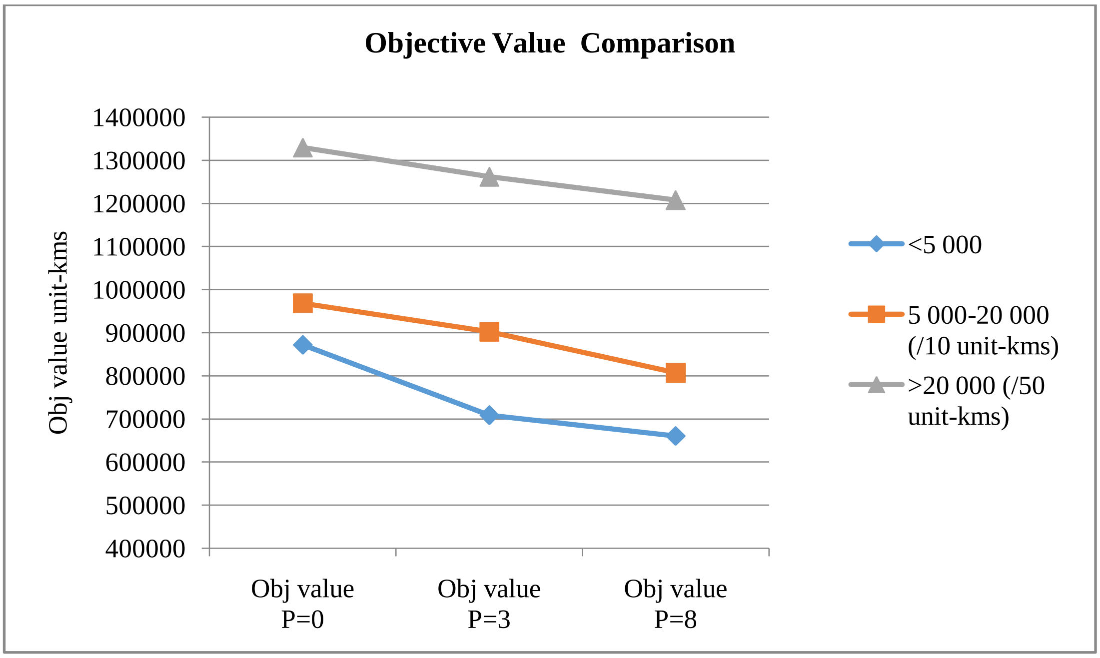

Figure 20: Comparison of Objective values for demand less than 5000 between 5000 and 20 000 and greater than 20 000

When we compare the total objective function values for the current case and the converted case, an approximate 11% improvement (i.e. decrease) is achieved in the total objective value and 9% improvement is achieved in the total number of activated warehouse (i.e. less number of warehouses are activated). Then, our alternatively proposed three warehouses(p=3) (i.e. Aksaray, Afyon and Kırıkkale) are given their identical stock levels(APPENDIX F).Then, we compared the current case (p=0) and converted case (p=3).Approximately 6% improvement (i.e. decrease) is achieved in the total objective value and 7% improvement is achieved in the total number of activated warehouses.

6. CONCLUSION

In this study, a real-life problem of selecting warehouses among candidate warehouses to be converted to an identical warehouse is addressed. The objective of this thesis is to investigate the benefits of operating identical AFAD warehouses in disaster relief operations in Turkey. A mixed integer linear programming model is proposed for location-(re)allocation problem to evaluate the benefits of operating identical warehouse as well as to use existing warehouses efficiently. The model can be easily adapted the other type of warehouse location-(re)allocation and selection problems.

The model re-allocates an available total inventory among existing warehouses while converting some warehouses to an identical type. Also, allocation of the relief item from supply points to demand points. The objective function minimizes the total demand weighted distance to respond quickly the immediate necessities of vulnerable people. A single-period, single-echelon, multi-commodity flow is considered with deterministic demands and supplies. Total capacity of warehouses cannot change, but allocation among warehouses is permitted, which means that while some warehouses' capacity can be increased, some of them is decreased. The defined problem is formulated as a mixed integer programming (MILP) model, which is a variant of location-(re)allocation problem. The developed mathematical model is run for Turkey, and the experimental results are given. There are 25 existing warehouses (supply points) in the model. There are three types of products; tent, bed, and blanket. Current real capacity of warehouses is unknown, hence, ten different random current supply set were generated.

Reducing the response time in disaster relief has severe importance in humanitarian logistics. Increasing the number of warehouses increases the fixed and variable warehouse operating costs whereas decreases the total transportation cost and response time. Contrary to this, decreasing the number of warehouses, requires additional warehouse capacity to meet the demand, decreases the fixed and variable operating costs due to the economies of scale, however this increases the total transportation cost as well as the response time. In this study, total capacity remains unchanged. Existing capacity is re-allocated from least used warehouses to the most used ones. These most used ones are determined as the warehouses to make identical. The idea of using identical warehouses can have several advantages including decrease in response time. Therefore, we found an operationally feasible number of converted warehouses and determined the warehouses that should be converted to identical.

As a result of extensive experimental runs, the operationally feasible number of converted warehouses is determined to vary between three and eight. The set of three warehouses are proposed as Aksaray, Afyonkarahisar, and Kırıkkale. The set of eight warehouses are proposed as Aksaray, Afyonkarahisar, Kırıkkale, Ankara, Kocaeli, Elazığ, Erzincan, and Manisa. Depending on the to-be-allocated budget for the conversion, decision makers can choose from these eight warehouses. If the budget is limited, we strongly recommend that at least Aksaray, Afyonkarahisar, and Kırıkkale warehouses should be converted to identical and always kept with full capacity.

As a future study, reallocation cost, fixed and variable operational cost functions can be included. However, by including cost functions, in the current model, *P* value can be limited with budget and opening/closing and enlargement of total capacity decisions can be added to the model. Moreover, vehicle capacities are kept out of the scope of this study, as a future work vehicle selection and routing decisions can be considered. Additionally, vulnerability rates can be included in the future models.

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8. APPENDICES

APPENDIX A: Demand

Scenario	Date	Province	Magnitude	Num of Building	Num Of beneficiaries
1	27.6.1998	Adana	5,9	10675	106750
2	7.4.1967	Adana	5,3	91	910
3	22.10.1952	Adana	5,6	511	5110
4	20.3.1945	Adana	6	650	6500
5	15.12.2000	Afyonkarahisar	5,6	178	1780
6	1.10.1995	Afyonkarahisar	5,9	4909	49090
7	7.8.1925	Afyonkarahisar	5,9	2043	20430
8	3.2.2002	Afyonkarahisar	6,1	4951	49510
9	2.4.1976	Ağrı	4,8	236	2360
10	2.7.2004	Ağrı	5,1	531	5310
11	19.12.1900	Ağrı	4,8	55	550
12	21.1.2007	Ağrı	4,9	152	1520
13	14.8.1996	Amasya	5,4	707	7070
14	26.12.2007	Ankara	5,5	1170	11700
15	31.7.2005	Ankara	4,9	2	20
16	20.12.2007	Ankara	5,3	1170	11700
17	18.3.1926	Antalya	6,9	364	3640
18	28.5.1903	Ardahan	5,8	8000	80000
19	30.4.1976	Ardahan	5	300	3000
20	10.4.1960	Aydın	4,8	100	1000
21	16.7.1955	Aydın	6,8	470	4700
22	15.11.1942	Balıkesir	6,1	1262	12620
23	18.12.1901	Balıkesir	5,9	102	1020
24	6.10.1944	Balıkesir	7	1158	11580
25	4.1.1935	Balıkesir	6,7	1200	12000
26	3.3.1969	Balıkesir	5,7	20	200
27	6.10.1964	Balıkesir	7	5398	53980

APPENDIX A Continued

Scenario	Date	Province	Magnitude	Num of Building	Num Of beneficiaries
28	3.9.1968	Bartın	6,5	2073	20730
29	2.4.1959	Bilecik	4,6	1	10
30	7.7.1957	Bingöl	5,1	300	3000
31	4.2.1950	Bingöl	4,6	100	1000
32	17.8.1949	Bingöl	7	3000	30000
33	15.12.1934	Bingöl	4,9	200	2000
34	8.3.2010	Bingöl	5,8	269	2690
35	31.8.1965	Bingöl	5,6	1500	15000
36	22.5.1971	Bingöl	6,7	5617	56170
37	5.3.1909	Bingöl	5	62	620
38	1.5.2003	Bingöl	6,1	6385	63850
39	13.4.1998	Bingöl	5	69	690
40	26.2.1960	Bitlis	4	80	800
41	1.2.1944	Bolu	7,2	20865	208650
42	5.4.1944	Bolu	5,6	900	9000
43	26.5.1957	Bolu	7,1	4201	42010
44	3.10.1914	Burdur	7	20563	205630
45	12.5.1971	Burdur	6,2	1389	13890
46	5.2.1949	Bursa	5,2	150	1500
47	27.3.1975	Çanakkale	6,4	980	9800
48	5.7.1983	Çanakkale	4,9	85	850
49	26.4.1972	Çanakkale	5	400	4000
50	18.3.1953	Çanakkale	7,2	9670	96700
51	13.8.1951	Çankırı	6,9	3354	33540
52	9.3.1902	Çankırı	5,5	6000	60000
53	6.6.2000	Çankırı	5,9	2102	21020
54	7.9.1953	Çankırı	6,4	230	2300
55	2.12.1942	Çorum	5,4	300	3000
56	11.12.1942	Çorum	5,9	816	8160
57	21.11.1942	Çorum	5,5	448	4480
58	1.3.1926	Denizli	6	380	3800
59	22.11.1963	Denizli	4,7	298	2980
60	13.6.1965	Denizli	5,6	488	4880
61	11.3.1963	Denizli	5,5	54	540
62	21.12.1945	Denizli	6,8	400	4000
63	19.7.1933	Denizli	5,7	200	2000
64	19.8.1976	Denizli	4,9	887	8870

APPENDIX A Continued

Scenario	Date	Province	Magnitude	Num of Building	Num Of beneficiaries
65	28.2.2007	Diyarbakır	5,2	195	1950
66	6.9.1975	Diyarbakır	6,9	8149	41411
67	25.3.1977	Diyarbakır	4,8	210	2100
68	12.11.1999	Düzce	7,2	30389	97240
69	2.10.1944	Düzce	5,4	900	9000
70	3.11.2010	Edirne	5,3	1	10
71	18.6.1953	Edirne	5,1	323	3230
72	18.8.1910	Elazığ	5	1600	16000
73	21.2.2007	Elazığ	5,4	1080	10800
74	11.8.2004	Elazığ	5,3	483	4830
75	26.3.1977	Elazığ	5,2	842	8420
76	8.3.2010	Elazığ	5,8	3563	35630
77	22.9.2011	Erzincan	5,4	49	490
78	12.11.1941	Erzincan	5,9	500	5000
79	26.12.1939	Erzincan	7,9	116720	97240
80	21.11.1939	Erzincan	5,9	500	5000
81	10.12.1930	Erzincan	5,6	53	530
82	17.9.2008	Erzincan	4,9	2	20
83	13.3.1992	Erzincan	6,8	6702	41411
84	30.10.1983	Erzurum	6,8	3241	32410
85	18.9.1984	Erzurum	5,9	187	1870
86	13.5.1924	Erzurum	5,3	700	7000
87	8.11.1901	Erzurum	6,1	2000	20000
88	25.3.2004	Erzurum	5,1	1984	19840
89	25.10.1959	Erzurum	5	300	3000
90	3.1.1952	Erzurum	5,8	701	7010
91	13.9.1924	Erzurum	6,8	97	970
92	16.5.1900	Eskişehir	4,7	1	10
93	30.3.1912	Hakkari	5,1	6	60
94	25.1.2005	Hakkari	5,4	530	5300
95	30.6.1981	Hatay	4,4	2	20
96	8.4.1951	Hatay	5,7	13	130
97	10.7.1984	İstanbul	6,5	1087	10870
98	6.4.1969	İzmir	5,8	443	4430
99	2.1.1974	İzmir	5,2	47	470
100	9.12.1977	İzmir	4,8	11	110
101	16.12.1977	İzmir	5,3	40	400

APPENDIX A Continued

Scenario	Date	Province	Magnitude	Num of Building	Num Of beneficiaries
102	14.6.1979	İzmir	5,9	22	220
103	19.1.1909	İzmir	5,8	1700	17000
104	31.3.1928	İzmir	6,5	1200	12000
105	22.9.1939	İzmir	7,1	1235	12350
106	23.7.1949	İzmir	7	824	8240
107	2.5.1953	İzmir	5,1	73	730
108	10.4.2003	İzmir	5,6	229	2290
109	23.3.1936	Kars	4,5	100	1000
110	22.3.1972	Kars	4,6	100	1000
111	1.5.1935	Kars	6,2	1300	13000
112	25.3.1976	Kars	5,1	762	7620
113	12.7.1988	Kars	6,9	546	5460
114	12.7.1900	Kars	5,9	1100	11000
115	22.10.1926	Kars	6	1100	11000
116	14.12.1998	Kayseri	4,7	37	370
117	20.2.1940	Kayseri	6,7	530	5300
118	12.11.2008	Kayseri	4,8	29	290
119	19.4.1938	Kırşehir	6,6	3860	38600
120	16.12.1938	Kırşehir	4,8	300	3000
121	17.8.1999	Kocaeli	7,4	66441	97240
122	29.10.1909	Kocaeli	5,8	13	130
123	26.9.1921	Konya	5,9	665	6650
124	21.2.1946	Konya	5,6	509	5090
125	2.5.1928	Kütahya	6,2	800	8000
126	28.3.1970	Kütahya	7,2	9452	41411
127	19.4.1970	Kütahya	5,9	41	410
128	5.5.1986	Malatya	5,8	824	8240
129	4.12.1905	Malatya	6,8	15	150
130	6.6.1986	Malatya	5,6	1174	11740
131	13.7.2003	Malatya	5,7	392	3920
132	26.11.2005	Malatya	5,2	597	5970
133	14.6.1964	Malatya	6	678	6780
134	25.3.1969	Manisa	6	1826	18260
135	28.3.1969	Manisa	6,6	4372	41411
136	23.4.1970	Manisa	5,7	150	1500
137	23.3.1969	Manisa	6,1	1100	11000
138	18.11.1919	Manisa	6,9	16000	97240

APPENDIX A Continued

Scenario	Date	Province	Magnitude	Num of Building	Num Of beneficiaries
139	2.3.1965	Manisa	5,8	150	1500
140	14.1.1969	Muğla	6,2	42	420
141	23.5.1941	Muğla	6	500	5000
142	8.2.1926	Muğla	5	597	5970
143	13.12.1941	Muğla	5,7	400	4000
144	25.4.1957	Muğla	7,1	3100	31000
145	25.4.1959	Muğla	5,7	59	590
146	23.5.1961	Muğla	6,5	61	610
147	28.4.1903	Muş	6,3	12000	97240
148	19.8.1966	Muş	6,9	20007	97240
149	10.2.1962	Muş	4	97	970
150	27.3.1982	Muş	5,2	424	4240
151	31.5.1946	Muş	5,7	1986	19860
152	7.3.1966	Muş	5,6	1100	11000
153	12.7.1966	Muş	4,5	90	900
154	10.1.1940	Niğde	5	586	5860
155	22.7.1967	Sakarya	7,2	5569	41411
156	20.6.1943	Sakarya	6,6	2240	22400
157	26.11.1943	Samsun	7,2	25000	97240
158	24.3.1964	Siirt	4	100	1000
159	9.2.1909	Sivas	6,4	5000	41411
160	2.7.1970	Sivas	4,8	150	1500
161	18.5.1929	Sivas	6,1	1692	16920
162	9.8.1912	Tekirdağ	7,3	45169	97240
163	20.12.1942	Tokat	7	32000	97240
164	24.1.1916	Tokat	7,1	5000	41411
165	26.7.1967	Tunceli	6,2	1282	12820
166	27.1.2003	Tunceli	6,4	67	670
167	25.6.1944	Uşak	6,2	3476	34760
168	23.10.2011	Van	7	17005	97240
169	24.11.1976	Van	7,2	9552	41411
170	20.11.1945	Van	5,8	1000	10000
171	29.7.1945	Van	5,8	2000	20000
172	10.9.1941	Van	5,9	600	6000
173	16.7.1972	Van	5,2	400	4000
174	18.9.1963	Yalova	6,3	230	2300
175	13.4.1940	Yozgat	5,6	1250	12500

APPENDIX B: From-To Distance Matrix

	Adana	Adiyaman	Afyonkarahisar	Aksaray	Bursa	Denizli	Diyarbakir	Duzce	Elazig	Erzincan	Erzurum
Adana	0	330	570	260	851	794	525	714	496	739	929
Adiyaman	330	0	896	587	1177	1121	210	984	247	501	556
Afyonkarahisar	570	896	0	353	277	220	1090	373	953	946	1137
Agri	961	645	1318	965	1457	1542	441	1201	501	369	185
Amasya	643	588	597	463	720	818	714	465	570	369	560
Ankara	482	808	260	226	386	480	902	236	758	684	874
Antalya	643	969	289	457	547	223	1163	643	1052	1046	1238
Artvin	1122	753	1329	976	1341	1554	524	1086	516	380	198
Aydin	913	1240	339	698	427	125	1433	682	1296	1289	1480
Balikesir	959	1285	384	757	152	286	1457	407	1313	1231	1422
Bilecik	778	1105	206	525	131	407	1226	180	1082	1004	1195
Bingol	625	377	1082	729	1284	1306	147	1120	139	269	180
Bitlis	727	411	1291	945	1500	1515	206	1336	354	468	336
Bolu	666	936	416	413	304	617	1086	49	942	781	971
Burdur	740	1066	166	526	423	169	1260	519	1122	1116	1306
Bursa	851	1177	277	596	0	434	1297	260	1155	1084	1275
Canakkale	1128	1454	556	875	270	495	1576	525	1431	1349	1540
Cankiri	557	782	400	319	511	618	932	256	788	636	827
Corum	551	718	506	371	636	727	781	479	637	473	664
Denizli	794	1121	220	580	434	0	1314	574	1177	1170	1361
Diyarbakir	525	210	1090	744	1297	1314	0	1135	154	408	326

APPENDIX B Continued

	Adana	Adiyaman	Afyonkarahisar	Aksaray	Bursa	Denizli	Diyarbakir	Duzce	Elazig	Erzincan	Erzurum
Edirne	1167	1436	683	911	392	721	1587	456	1443	1281	1472
Elazig	496	247	953	600	1155	1177	154	991	0	264	318
Erzincan	739	501	946	593	1084	1170	408	829	264	0	188
Erzurum	929	556	1137	784	1275	1361	326	1020	318	188	0
Eskisehir	697	1023	167	441	155	378	1145	251	1000	926	1117
Gaziantep	223	186	788	478	1066	1012	312	932	352	664	661
Giresun	789	666	869	643	973	1090	718	719	575	308	360
Gumushane	849	635	1057	704	1131	1281	541	877	397	131	201
Hakkari	916	742	1482	1172	1763	1706	538	1654	637	822	637
Hatay	191	317	757	447	1038	982	511	902	482	760	792
Isparta	615	942	167	400	425	169	1136	520	998	991	1182
Mersin	76	402	577	267	856	801	597	721	567	746	937
Istanbul	937	1263	453	681	167	596	1358	227	1214	1050	1242
Izmir	903	1229	330	690	332	244	1425	589	1285	1278	1470
Kars	1134	761	1341	988	1479	1565	532	1224	523	392	207
Kastamonu	670	894	559	556	555	780	1004	300	860	654	845
Kayseri	301	435	509	156	711	733	585	549	441	445	637
Kirklareli	1141	1411	657	885	366	756	1561	431	1417	1255	1446
Kirsehir	344	569	449	108	580	670	719	415	575	569	759
Kocaeli	826	1152	342	570	144	543	1246	115	1102	939	1130
Konya	340	666	227	152	507	451	861	496	747	740	932

APPENDIX B Continued

	Adana	Adiyaman	Afyonkarahisar	Aksaray	Bursa	Denizli	Diyarbakir	Duzce	Elazig	Erzincan	Erzurum
Kutahya	670	997	96	456	181	298	1190	277	1053	1005	1196
Malatya	390	141	847	494	1049	1071	250	885	106	360	415
Manisa	881	1208	308	668	290	209	1402	547	1264	1257	1448
Kahramanmaras	195	162	761	451	984	985	385	820	328	584	637
Mardin	548	295	1114	804	1395	1338	92	1258	244	498	417
Mugla	939	1266	365	724	525	145	1459	718	1322	1315	1506
Mus	738	495	1195	842	1397	1419	290	1232	251	382	250
Nevsehir	252	517	427	74	666	651	668	508	524	517	708
Nigde	176	503	468	123	715	692	697	577	575	568	759
Ordu	778	693	825	631	929	1045	733	674	590	323	405
Rize	1022	815	1077	985	1182	1298	579	927	577	389	257
Sakarya	789	1115	304	533	189	506	1210	79	1066	902	1094
Samsun	718	715	673	538	777	893	842	522	697	441	633
Siirt	711	395	1276	929	1485	1500	191	1320	339	593	426
Sinop	851	848	742	671	737	962	974	482	830	624	815
Sivas	495	372	703	350	837	927	499	673	354	247	437
Tekirdag	1082	1352	603	831	307	693	1502	376	1358	1196	1387
Tokat	561	477	645	415	833	865	603	577	459	304	494
Trabzon	950	737	1001	807	1105	1221	642	850	500	233	297
Tunceli	625	376	1076	723	1214	1300	283	959	139	127	239
Sanliurfa	365	113	931	621	1212	1155	179	1075	317	572	500

APPENDIX B Continued

	Adana	Adiyaman	Afyonkarahisar	Aksaray	Bursa	Denizli	Diyarbakir	Duzce	Elazig	Erzincan	Erzurum
Usak	686	1012	112	472	321	154	1206	416	1068	1062	1252
Van	888	572	1453	1057	1707	1677	368	1452	466	620	435
Yozgat	467	634	480	219	610	700	720	446	576	470	661
Zonguldak	754	1024	502	498	373	722	1174	113	1030	852	1043
Aksaray	260	587	353	0	596	580	744	460	600	593	784
Bayburt	949	632	1155	802	1294	1380	446	1038	394	206	125
Karaman	312	638	341	256	613	565	832	604	751	744	935
Kirikkale	455	679	343	217	474	564	830	309	686	608	799
Batman	620	303	1184	874	1395	1408	98	1231	250	504	378
Sirnak	726	473	1292	982	1573	1516	295	1437	443	697	530
Bartin	771	1041	518	515	482	737	1191	226	1047	820	1010
Ardahan	1151	782	1358	1005	1496	1582	553	1241	544	409	227
Igdir	1058	741	1460	1107	1599	1685	538	1343	636	511	327
Yalova	904	1173	344	649	68	498	1324	194	1180	1018	1209
Karabuk	700	970	446	443	442	667	1120	187	976	735	925
Kilis	289	253	854	544	1137	1079	362	999	418	731	727
Osmaniye	96	239	661	351	943	885	432	806	404	684	714
Duzce	714	984	373	460	260	574	1135	0	991	829	1020

APPENDIX B Continued

	Maras	Kastamonu	Kirikkale	Manisa	Mugla	Mus	Samsun	Sivas	Tekirdag	Yalova	Van	Ankara	Antalya	Kocaeli
Adana	195	670	455	881	939	738	718	495	1082	904	888	482	643	826
Adiyaman	162	894	679	1208	1266	495	715	372	1352	1173	572	808	969	1152
Afyon	761	559	343	308	365	1195	673	703	603	344	1453	260	289	342
Agri	821	1026	980	1630	1687	292	814	619	1569	1390	253	1057	1418	1311
Amasya	517	290	256	905	963	754	128	221	832	654	992	332	824	575
Ankara	587	243	78	567	625	1001	406	441	604	425	1307	0	547	348
Antalya	833	849	564	432	317	1295	899	802	869	615	1527	547	0	612
Artvin	968	879	895	1641	1698	436	562	630	1454	1275	565	971	1429	1196
Aydin	1104	899	683	135	97	1538	1012	1046	627	490	1796	599	342	566
Balikesir	1142	702	632	140	376	1555	924	996	413	215	1854	548	508	291
Bilecik	911	475	401	431	551	1324	697	764	410	149	1627	317	476	149
Bingol	457	927	815	1394	1451	113	714	484	1488	1309	328	888	1182	1232
Bitlis	586	1125	1031	1603	1660	91	913	700	1703	1525	168	1104	1365	1447
Bolu	771	252	261	592	762	1184	474	625	421	238	1403	188	687	159
Burdur	930	725	509	371	281	1364	839	873	750	491	1622	425	125	488
Bursa	984	555	474	290	525	1397	777	837	307	68	1707	386	547	144
Canakkale	1261	821	750	325	528	1673	1043	1114	198	334	1972	667	718	409
Cankiri	617	112	107	706	763	1030	329	471	628	445	1259	131	687	366
Corum	553	304	167	815	872	879	166	288	850	668	1096	240	732	589
Denizli	985	780	564	209	145	1419	893	927	693	498	1677	480	223	543
Diyarbakir	385	1004	830	1402	1459	290	842	499	1502	1324	368	902	1163	1246

APPENDIX B Continued

	Maras	Kastamonu	Kirikkale	Manisa	Mugla	Mus	Samsun	Sivas	Tekirdag	Yalova	Van	Ankara	Antalya	Kocaeli
Edirne	1272	752	762	551	754	1685	974	1125	143	326	1904	688	954	341
Elazig	328	860	686	1264	1322	251	697	354	1358	1180	466	758	1052	1102
Erzincan	584	654	608	1257	1315	382	441	247	1196	1018	620	684	1046	939
Erzurum	637	845	799	1448	1506	250	633	437	1387	1209	435	874	1238	1130
Eskisehir	829	534	319	453	523	1243	646	683	477	223	1549	232	448	220
Gaziantep	83	809	594	1099	1157	597	724	420	1300	1121	675	699	861	1044
Giresun	634	511	528	1177	1235	606	195	297	1086	908	792	604	1096	828
Gumushane	695	670	720	1369	1426	448	352	357	1244	1066	633	795	1156	986
Hakkari	776	1479	1313	1794	1851	390	1267	1072	2021	1843	202	1386	1555	1764
Hatay	178	857	642	1069	1126	725	905	516	1270	1091	874	669	829	1012
Isparta	806	727	511	373	315	1240	841	749	752	493	1498	428	126	490
Mersin	266	677	462	888	786	809	727	502	1089	911	959	488	471	832
Istanbul	1043	521	533	452	687	1456	743	897	154	101	1673	459	724	111
Izmir	1093	884	675	40	217	1527	1005	1035	532	398	1787	588	461	473
Kars	842	1049	1003	1652	1710	335	837	642	1591	1413	360	1080	1441	1334
Kastamonu	730	0	220	842	924	1039	315	511	671	489	1277	243	849	410
Kayseri	270	459	244	821	878	683	450	202	917	738	898	316	611	661
Kirklareli	1246	725	737	586	789	1659	948	1100	117	300	1878	663	928	315
Kirsehir	404	326	111	759	816	817	388	326	789	606	1032	184	561	527
Kocaeli	931	410	421	429	664	1344	632	785	256	78	1562	348	612	0
Konya	530	504	254	538	596	989	589	497	864	575	1224	262	307	606

APPENDIX B Continued

	Maras	Kastamonu	Kirikkale	Manisa	Mugla	Mus	Samsun	Sivas	Tekirdag	Yalova	Van	Ankara	Antalya	Kocaeli
Kutahya	861	572	402	316	442	1295	728	762	507	249	1553	315	366	246
Malatya	222	754	580	1158	1216	348	592	249	1253	1074	563	653	947	997
Manisa	1072	842	653	0	234	1506	981	1014	523	353	1764	567	432	429
Kahramanma	0	730	515	1072	1130	570	645	341	1187	1009	748	587	833	931
Mardin	409	1094	921	1425	1483	365	932	589	1626	1448	442	1026	1186	1369
Mugla	1130	924	710	234	0	1564	1038	1072	726	588	1822	625	317	664
Mus	570	1039	928	1506	1564	0	827	597	1600	1422	219	1001	1295	1344
Nevsehir	353	418	203	739	796	766	463	274	881	698	981	276	528	620
Nigde	367	500	285	780	837	817	548	325	951	768	1059	346	540	689
Ordu	622	467	483	1132	1190	650	150	327	1041	863	837	559	1051	783
Rize	976	719	736	1385	1443	503	403	530	1294	1116	689	812	1329	1037
Sakarya	895	373	385	473	650	1308	597	749	301	122	1525	311	575	42
Samsun	645	315	331	981	1038	827	0	349	890	711	1064	406	899	632
Siirt	571	1190	1016	1587	1645	181	1027	684	1688	1509	259	1088	1350	1432
Sinop	777	183	388	1022	1107	1010	157	481	850	672	1247	412	954	592
Sivas	341	511	365	1014	1072	597	349	0	1041	862	869	441	802	785
Tekirdag	1187	671	683	523	726	1600	890	1041	0	241	1819	604	869	256
Tokat	406	403	303	952	1010	701	240	110	945	767	926	379	868	687
Trabzon	798	643	659	1308	1366	545	326	460	1217	1039	729	735	1257	960
Tunceli	457	784	738	1387	1445	257	572	377	1326	1148	472	815	1176	1069
Sanliurfa	226	953	738	1242	1300	465	866	501	1443	1265	542	843	1003	1186

APPENDIX B Continued

	Maras	Kastamonu	Kirikkale	Manisa	Mugla	Mus	Samsun	Sivas	Tekirdag	Yalova	Van	Ankara	Antalya	Kocaeli
Usak	876	672	457	196	299	1310	785	819	643	388	1568	371	293	385
Van	748	1277	1143	1764	1822	219	1064	869	1819	1641	0	1307	1527	1562
Yozgat	469	413	138	788	845	818	276	227	814	635	1093	214	672	558
Zonguldak	859	215	350	657	867	1272	546	710	485	306	1475	276	790	228
Aksaray	451	556	217	668	724	842	538	350	831	649	1057	226	457	570
Bayburt	794	864	818	1467	1524	371	431	456	1406	1228	557	894	1255	1149
Karaman	502	701	362	645	701	993	697	501	977	681	1194	372	402	715
Kirikkale	515	220	0	653	710	928	331	365	683	500	1143	78	564	421
Batman	479	1100	926	1495	1553	219	938	595	1598	1420	296	999	1258	1343
Sirnak	587	1314	1099	1604	1661	285	1131	788	1804	1626	363	1204	1364	1547
Bartin	876	182	366	769	881	1289	513	677	598	415	1442	293	806	336
Ardahan	996	1066	1020	1670	1727	423	853	659	1609	1430	446	1096	1458	1351
Igdir	918	1169	1123	1772	1829	389	956	761	1711	1533	224	1199	1561	1454
Yalova	1009	489	500	353	588	1422	711	862	241	0	1641	425	615	78
Karabuk	805	113	295	729	811	1120	428	592	558	376	1357	222	736	297
Kilis	149	876	661	1166	1223	647	791	487	1366	1188	725	768	928	1111
Osmaniye	103	761	546	973	1030	646	810	441	1173	995	795	574	734	917
Duzce	820	300	309	547	718	1232	522	673	376	194	1452	236	643	115

APPENDIX C: Identical Capacity of Warehouses

Warehouse	tent (person)	bed (person)	blanket (person)	tent (container)	bed (container)	blanket (container)	empty (container)	Total Container
Adana	7200	7106	7040	18	38	12	28	96
Adıyaman	3600	3553	3520	9	19	6	14	48
Afyonkarahisar	7200	7106	7040	18	38	12	28	96
Aksaray	3600	3553	3520	9	19	6	14	48
Bursa	3600	3553	3520	9	19	6	14	48
Denizli	7200	7106	7040	18	38	12	28	96
Diyarbakır	3600	3553	3520	9	19	6	14	48
Düzce	3600	3553	3520	9	19	6	14	48
Elazığ	3600	3553	3520	9	19	6	14	48
Erzincan	3600	3553	3520	9	19	6	14	48
Erzurum	7200	7106	7040	18	38	12	28	96
Kahramanmaraş	7200	7106	7040	18	38	12	28	96
Kastamonu	3600	3553	3520	9	19	6	14	48
Kırıkkale	3600	3553	3520	9	19	6	14	48
Manisa	7200	7106	7040	18	38	12	28	96
Muğla	3600	3553	3520	9	19	6	14	48
Muş	7200	7106	7040	18	38	12	28	96
Samsun	7200	7106	7040	18	38	12	28	96
Sivas	3600	3553	3520	9	19	6	14	48
Tekirdağ	7200	7106	7040	18	38	12	28	96
Yalova	3600	3553	3520	9	19	6	14	48
Van	3600	3553	3520	9	19	6	14	48
Ankara	3600	3553	3520	9	19	6	14	48
Antalya	3600	3553	3520	9	19	6	14	48
Kocaeli	3600	3553	3520	9	19	6	14	48

APPENDIX D:Randomly Generated Current Warehouse Supply Amount

	c1			c2			c3			c4			c5		
	tent	bed	blanket	tent	bed	blanket	tent	bed	blanket	tent	bed	blanket	tent	bed	blanket
Adana	2400	4488	9386	5600	561	8800	4000	7854	4106	10800	7480	4693	6400	8976	586
Adiyaman	5200	1496	1760	2400	1122	1760	2000	4675	0	5600	4862	2933	6000	935	2346
Afyon	10800	5984	4693	2800	5423	3520	2000	6919	6453	2800	2431	2346	10800	5984	9973
Aksaray	2400	3740	586	2800	1870	1760	1200	935	2933	2000	4488	1760	2000	748	7040
Bursa	2400	2244	4693	6400	2057	4106	2800	3179	4693	400	3179	0	4400	4301	1760
Denizli	10800	6919	8213	11600	7106	5280	12000	6732	9973	6000	9537	4106	10800	5610	3520
Diyarbakir	3200	1870	4106	4800	3179	7626	5200	4675	586	0	935	7040	1200	2805	586
Duzce	0	2805	4693	2000	4675	4106	6000	2992	2933	4800	3927	4693	2800	187	2933
Elazig	2400	3927	2346	6800	1496	2346	4800	1496	2933	4000	1309	4106	1200	3927	3520
Erzincan	4400	2057	4106	5600	5423	5866	1600	187	1760	2000	1683	1173	2800	748	5866
Erzurum	3200	3553	9386	6400	5236	5866	10000	3553	7626	7200	1496	13493	8400	1309	12320
Maras	5200	5984	4106	12400	6358	8800	5200	5984	5866	10400	2805	2933	12800	5610	0
Kastamonu	5600	935	3520	800	3553	4693	3200	5610	4106	5600	3366	4693	6000	3740	2346
Kirikkale	5200	2618	0	800	2805	586	3200	2805	1760	2800	2244	6453	3200	2805	0
Manisa	9600	6358	0	6000	8789	4693	7600	6171	8800	4400	8976	12906	5600	1309	4693
Mugla	3600	3366	2346	400	3553	586	4000	5423	4106	6000	2618	3520	2000	2057	586
Mus	4800	6732	5866	5600	7667	11733	10000	5423	9386	8800	6545	1173	2000	9350	2933
Samsun	8800	10098	7040	10000	8415	4693	2400	1870	1760	6800	5610	13493	800	0	18773
Sivas	2800	4301	4693	4800	935	586	5200	748	586	2800	0	586	4800	4675	5280
Tekirdag	9200	1496	7626	4400	2057	2933	11600	7106	2346	7600	6732	1173	7200	13464	3520
Yalova	2800	2992	3520	2400	3179	7040	1600	5797	5280	3200	5236	1760	5200	4488	5866
Van	4400	1122	4106	6000	5797	5866	5200	935	5866	5600	1683	1173	4400	2431	0
Ankara	4800	4488	5280	6400	3553	1173	0	2244	5280	6400	2992	3520	4000	1683	4693
Antalya	4800	4301	0	400	2057	1173	6000	3740	4106	5600	1309	4106	4000	4488	5866
Kocaeli	3600	3366	4106	4800	374	586	5600	187	2933	800	5797	2346	3600	5610	1173
Total	122400	97240	106177	122400	97240	106177	122400	97240	106177	122400	97240	106178	122400	97240	106179

APPENDIX D Continued

	c6			c7			c8			c9			c10		
	tent	bed	blanket	tent	bed	blanket	tent	bed	blanket	tent	bed	blanket	tent	bed	blanket
Adana	6400	8228	9973	7200	1870	1173	3200	12155	7626	2800	8041	1760	1600	561	17600
Adiyaman	4800	3553	2346	800	3366	4106	2400	1870	4693	800	5610	2346	400	2057	2346
Afyon	800	12529	5280	6000	2244	8213	13600	2057	586	11200	1122	12320	5200	6545	7626
Aksaray	800	1683	2346	6000	3740	5866	1600	5049	2346	2400	187	1173	3200	3179	5866
Bursa	5600	3740	3520	4000	3927	4693	4800	187	1760	3600	4301	3520	4800	1122	4693
Denizli	800	374	4693	3600	6732	4106	1600	7293	4693	7600	8976	12320	8400	10472	4106
Diyarbakir	8400	1122	4106	400	2244	2933	1600	4488	2933	4400	2057	2346	7200	4488	3520
Duzce	8400	2431	1760	5600	3740	2346	3200	3179	2346	3600	3366	1173	5200	2992	586
Elazig	9600	935	5280	3200	3553	586	3200	5049	5866	2000	1496	5280	6400	4488	4106
Erzincan	0	1870	2346	2800	2244	0	3600	1870	2346	2400	561	8213	5600	748	5866
Erzurum	6800	4114	5280	6800	7293	5866	10000	7667	10560	6000	8228	11146	10400	11220	0
Kahramanmaras	8400	2992	12320	8800	9911	10560	9600	2244	4106	21200	5236	586	800	7293	10560
Kastamonu	3600	4488	4106	1600	5797	586	6400	1870	4106	6800	3553	0	0	2431	2346
Kirikkale	8000	2618	3520	7200	2805	4693	2400	3927	4693	0	187	5280	4400	5610	0
Manisa	12000	8228	2346	7200	2244	8800	2400	3553	9973	8000	7667	2933	5600	4488	1760
Mugla	1200	1309	4106	4000	1122	1173	800	2244	0	6800	2057	4693	5200	3553	2346
Mus	14000	4488	11733	11200	2057	4693	1200	7293	2346	1600	4114	5866	10000	2057	9973
Samsun	12800	2057	3520	6800	10472	4693	9600	5236	8800	6400	5049	1760	12000	3927	2346
Sivas	2800	4862	5866	2000	4862	5280	2800	3740	2933	4000	3553	3520	800	3740	4106
Tekirdag	2800	8602	1173	7200	8789	8213	13600	4114	7626	0	3179	7626	10800	5049	2346
Yalova	1200	4114	2933	3600	561	1760	2800	3740	1760	3600	4114	5280	4000	374	4693
Van	0	3366	4106	800	4862	2346	5200	1122	1173	6000	5423	1173	400	2431	5280
Ankara	1200	3740	0	6000	935	1173	8000	2244	4693	4000	2057	1173	5600	0	0
Antalya	2000	2805	2346	3200	374	7626	5200	1870	5866	4800	4301	0	3200	5797	586
Kocaeli	0	2992	1173	6400	1496	4693	3600	3179	2346	2400	2805	4693	1200	2618	3520
Total	122400	97240	106178	122400	97240	106177	122400	97240	106176	122400	97240	106180	122400	97240	106177

APPENDIX E: Approximate Real Stock Level for *P=0*

WAREHOUSE	tent	bed	blanket
Adana	6854	296	10520
Adiyaman	560	1655	0
Afyonkarahisar	6636	3556	0
Aksaray	1827	1522	0
Bursa	1700	1812	45
Denizli	7373	3742	30
Diyarbakir	1464	0	5280
Duzce	3456	2062	0
Elazig	2618	10	10499
Erzincan	2569	605	0
Erzurum	6515	989	0
Kahramanmaras	7249	2412	13210
Kastamonu	2467	2062	0
Kirikkale	2663	362	2644
Manisa	3671	3745	145
Mugla	1780	2748	0
Mus	3650	3305	0
Samsun	6005	3642	0
Sivas	1061	1166	7204
Tekirdag	5002	3745	5284
Yalova	3020	1975	195
Van	0	0	0
Ankara	0	0	0
Antalya	0	0	0
Kocaeli	0	0	0
TOTAL	78140	41411	55056

APPENDIX F: Approximate Real Stock Level for *P=3*

WAREHOUSE	tent	bed	blanket
Adana	6854	296	7500
Adiyaman	560	1400	0
Afyonkarahisar	7200	7106	7040
Aksaray	3600	3553	3520
Bursa	1700	1300	45
Denizli	7373	2500	30
Diyarbakir	1464	0	5280
Duzce	3456	1062	0
Elazig	2618	10	9381
Erzincan	2569	605	0
Erzurum	6515	989	0
Kahramanmaras	6442	2300	9200
Kastamonu	0	2062	0
Kirikkale	3600	3553	3520
Manisa	3671	2200	145
Mugla	1780	2642	0
Mus	3650	2305	0
Samsun	6005	1642	0
Sivas	1061	1166	5000
Tekirdag	5002	2745	4200
Yalova	3020	1975	195
Van	0	0	0
Ankara	0	0	0
Antalya	0	0	0
Kocaeli	0	0	0
TOTAL	78140	41411	55056

APPENDIX G: Approximate Real Stock Level for *P=8*

WAREHOUSE	tent	bed	blanket
Adana	4000	296	2608
Adiyaman	560	500	0
Afyonkarahisar	7200	7106	7040
Aksaray	3600	3553	3520
Bursa	1700	500	45
Denizli	5000	500	30
Diyarbakir	1300	0	5280
Duzce	3000	500	0
Elazig	3600	3553	3520
Erzincan	3600	3553	3520
Erzurum	5580	250	0
Kahramanmaras	5000	500	3210
Kastamonu	2000	400	0
Kirikkale	3600	3553	3520
Manisa	7200	7106	7040
Mugla	1500	500	0
Mus	2000	500	0
Samsun	3500	385	0
Sivas	1000	500	5204
Tekirdag	4000	200	3284
Yalova	2000	350	195
Van	0	0	0
Ankara	3600	3553	3520
Antalya	0	0	0
Kocaeli	3600	3553	3520
TOTAL	78140	41411	55056

APPENDIX H: Comparison of Objective Values for Approximate Real Stock Level

Scenario	Province	Num Of beneficiaries	Obj value P=0	Obj value P=3	Obj value P=8
1	Adana	106750	57971750	56351134	62794682
2	Adana	910	119730	119730	127140
3	Adana	5110	1156460	1102140	2009375
4	Adana	6500	1702155	1488110	3228255
5	Afyonkarahisar	1780	598805	0	0
6	Afyonkarahisar	49090	61812441	51473288	43098501
7	Afyonkarahisar	20430	20089268	13473768	11384493
8	Afyonkarahisar	49510	61812441	51473288	43098501
9	Ağrı	2360	2060657	2060657	2093780
10	Ağrı	5310	4950359	5283469	5078434
11	Ağrı	550	446050	446050	438550
12	Ağrı	1520	1289537	1289537	1318460
13	Amasya	7070	3934149	4222105	4881072
14	Ankara	11700	9746140	6677146	4005252
15	Ankara	20	4680	4680	0
16	Ankara	11700	9746140	6677146	4005252
17	Antalya	3640	3702109	2748660	2880660
18	Ardahan	80000	112097734	113139682	115817351
19	Ardahan	3000	3379686	3379686	3089500
20	Aydın	1000	698885	497000	342700
21	Aydın	4700	3873001	2608484	1790200
22	Balıkesir	12620	13464379	11164388	7496582
23	Balıkesir	1020	715305	507660	350040
24	Balıkesir	11580	11330157	8835411	6187336
25	Balıkesir	12000	11912697	9317151	6528796
26	Balıkesir	200	72800	70600	65500
27	Balıkesir	53980	86589823	78424430	67217059
28	Bartın	20730	30721432	28554935	24047564
29	Bilecik	10	3930	3930	3930
30	Bingöl	3000	1095000	1141155	1186000
31	Bingöl	1000	365000	365000	378000
32	Bingöl	30000	41878946	42039074	45250574
33	Bingöl	2000	730000	730000	769000
34	Bingöl	2690	981850	1007235	1056730
35	Bingöl	15000	16837904	18074054	19574678
36	Bingöl	56170	72507241	73867290	81634703
37	Bingöl	620	226300	226300	229420
38	Bingöl	63850	72507241	73867290	81634703
39	Bingöl	690	251850	251850	256790
40	Bitlis	800	310400	310400	384800

APPENDIX H Continued

Scenario	Province	Num Of beneficiaries	Obj value P=0	Obj value P=3	Obj value P=8
41	Bolu	208650	66664725	61681586	52816435
42	Bolu	9000	7050671	6769795	4508690
43	Bolu	42010	66664725	61681586	52816435
44	Burdur	205630	77856889	68050125	59522023
45	Burdur	13890	15291147	9946745	9786580
46	Bursa	1500	397615	375880	312100
47	Çanakkale	9800	9862038	9361221	8622303
48	Çanakkale	850	504900	504900	559950
49	Çanakkale	4000	2024333	1447595	1300648
50	Çanakkale	96700	95560576	90018551	77503959
51	Çankırı	33540	45858090	41173063	36157646
52	Çankırı	60000	62860936	57622617	51889873
53	Çankırı	21020	23750154	20174215	16591264
54	Çankırı	2300	747990	738300	738300
55	Çorum	3000	1540076	1498358	1499615
56	Çorum	8160	5358841	5029502	4897157
57	Çorum	4480	2516110	2354518	2350241
58	Denizli	3800	2160084	1016305	1445630
59	Denizli	2980	1593605	717005	1102870
60	Denizli	4880	3065124	1410505	1897070
61	Denizli	540	217445	110605	112390
62	Denizli	4000	2327684	1089305	1529230
63	Denizli	2000	1040885	431805	693230
64	Denizli	8870	6831356	3889920	4305924
65	Diyarbakır	1950	506584	526984	400400
66	Diyarbakır	81490	73060852	74220293	83501118
67	Diyarbakır	2100	573184	593584	446600
68	Düzce	303890	67320025	61987120	52628909
69	Düzce	9000	6522985	6517685	4322429
70	Edirne	10	4290	4290	4290
71	Edirne	3230	1385670	1474425	1980360
72	Elazığ	16000	11272196	12004949	12126978
73	Elazığ	10800	5268870	5910521	5506508
74	Elazığ	4830	1614164	1657219	713288
75	Elazığ	8420	3635048	3753789	3136044
76	Elazığ	35630	48113846	48321205	53143827
77	Erzincan	490	121030	121030	0
78	Erzincan	5000	3020462	3020462	983268
79	Erzincan	1167200	70118644	70611156	71064714
80	Erzincan	5000	3020462	3020462	983268

APPENDIX H Continued

Scenario	Province	Num Of beneficiaries	Obj value P=0	Obj value P=3	Obj value P=8
81	Erzincan	530	130910	130910	0
82	Erzincan	20	4940	4940	0
83	Erzincan	67020	70118644	70611156	71064714
84	Erzurum	32410	54043510	54927523	56472747
85	Erzurum	1870	777400	777400	656120
86	Erzurum	7000	4284192	4630617	3685970
87	Erzurum	20000	23102257	23823788	23691444
88	Erzurum	19840	22767857	23461119	23348404
89	Erzurum	3000	1419240	1419240	1081000
90	Erzurum	7010	4294812	4642007	3694210
91	Erzurum	970	308460	308460	317720
92	Eskişehir	10	4650	4650	4650
93	Hakkari	60	79080	79080	79080
94	Hakkari	5300	7847339	8219603	8980963
95	Hatay	20	10680	10680	10680
96	Hatay	130	69420	69420	69420
97	İstanbul	10870	8343796	8000622	7346925
98	İzmir	4430	2851638	2300723	531600
99	İzmir	470	172530	148070	56400
100	İzmir	110	13200	13200	13200
101	İzmir	400	131700	119370	48000
102	İzmir	220	45660	45570	26400
103	İzmir	17000	20219155	16554902	10489314
104	İzmir	12000	12376399	9835655	5134280
105	İzmir	12350	12893349	10272805	5450680
106	İzmir	8240	7017933	5627760	1747660
107	İzmir	730	331650	254670	87600
108	İzmir	2290	1286370	910200	274800
109	Kars	1000	938408	938408	916250
110	Kars	1000	938408	938408	916250
111	Kars	13000	18520475	19445310	18789322
112	Kars	7620	9182645	9695665	8716917
113	Kars	5460	5893830	6246645	5741817
114	Kars	11000	14955489	15586464	14652102
115	Kars	11000	14955489	15586464	14652102
116	Kayseri	370	190180	173160	173160
117	Kayseri	5300	3327254	2772082	2802616
118	Kayseri	290	149060	135720	135720
119	Kırşehir	38600	49815014	45020664	43780261
120	Kırşehir	3000	1305433	972000	972000

APPENDIX H Continued

Scenario	Province	Num Of beneficiaries	Obj value P=0	Obj value P=3	Obj value P=8
121	Kocaeli	664410	70921540	65170213	53169642
122	Kocaeli	130	30420	30420	0
123	Konya	6650	5049499	3728175	3728175
124	Konya	5090	3563225	2665815	2665815
125	Kütahya	8000	5906487	2686380	2614675
126	Kütahya	94520	66587103	57291598	47590600
127	Kütahya	410	188600	118080	118080
128	Malatya	8240	4456841	4554016	4651988
129	Malatya	150	52600	52600	47700
130	Malatya	11740	7278547	7697310	7961590
131	Malatya	3920	1671737	1698062	1317005
132	Malatya	5970	2922321	2989218	2786138
133	Malatya	6780	3469881	3536778	3438728
134	Manisa	18260	21015960	17097982	10362045
135	Manisa	43720	81315260	73549309	59544727
136	Manisa	1500	655610	413560	0
137	Manisa	11000	10097757	7886263	3113952
138	Manisa	160000	81315260	73549309	59544727
139	Manisa	1500	655610	413560	0
140	Muğla	420	180115	127705	95610
141	Muğla	5000	4256411	2608215	2683330
142	Muğla	5970	5241931	3317257	3277940
143	Muğla	4000	3240411	1953215	2070330
144	Muğla	31000	57035608	50078510	42026212
145	Muğla	590	300815	189755	148440
146	Muğla	610	315015	197055	156020
147	Muş	120000	84839722	86429159	95036670
148	Muş	200070	84839722	86429159	95036670
149	Muş	970	243470	243470	361190
150	Muş	4240	0	0	0
151	Muş	19860	24430412	25400890	27025389
152	Muş	11000	8673133	9661484	9998778
153	Muş	900	225900	225900	326050
154	Niğde	5860	3620251	2747610	2747610
155	Sakarya	55690	68909071	62796081	52166626
156	Sakarya	22400	26172465	21897991	17426890
157	Samsun	250000	72813381	71911307	69439398
158	Siirt	1000	553000	553000	632000
159	Sivas	50000	57378235	56327809	57099245
160	Sivas	1500	190931	190931	370500

APPENDIX H Continued

Scenario	Province	Num Of beneficiaries	Obj value P=0	Obj value P=3	Obj value P=8
161	Sivas	16920	15000166	15179967	14397150
162	Tekirdağ	451690	91571905	87451453	76924820
163	Tokat	320000	60273275	59575063	58592217
164	Tokat	50000	60273275	59575063	58592217
165	Tunceli	12820	9510723	10383420	9076237
166	Tunceli	670	269590	269590	255270
167	Uşak	34760	50986645	42401345	33606571
168	Van	170050	110141344	111596997	122442680
169	Van	95520	110141344	111596997	122442680
170	Van	10000	12780534	13700097	13994972
171	Van	20000	36218587	37057847	39520665
172	Van	6000	6132822	6634510	7271548
173	Van	4000	3426270	3737932	4425650
174	Yalova	2300	521620	521620	331240
175	Yozgat	12500	10507980	8374076	7588975