Assignment of Patients to Hospitals in a Case of a Large-Scale Earthquake

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ABSTRACT

The main topic of this thesis is the transportation of injured persons to the hospitals after a large-scale disaster. The main tool for solving the problem is machine scheduling. Machine scheduling in production planning activities of enterprises is a frequent activity in short-term planning and it is very important to use resources efficiently. The scheduling of identical parallel machines is adapted to the humanitarian logistics problem. List scheduling method is applied for makespan minimization. The results show comparisons of the shortest processing time (SPT) and longest processing time (LPT) rules to get the optimum sequence for the addressed problem by an algorithm. For the heuristic method; single vehicle, 2 vehicles and 3 vehicles cases are discussed.

First of all, both demographic and geographic information have provided about Istanbul. It is assumed that in a case of a large-scale earthquake in İstanbul, the city is divided into regions by Voronoi diagram. The strategy is to dispatch him/her to the closest hospital according to location of the victim. The objective function of the study is to maximize the number of seriously injured people in post-disaster period by a proper assignment of existing ambulances to patients and the expected value of service level at the same time. The service level increases as the expected travel distance of patients decreases having inverse relation.

Keywords: Humanitarian logistics, Earthquake, Disaster management, List scheduling, Heuristic method.

ÖZ

Bu tezin ana konusu, ağır yaralı kişilerin büyük çaplı bir felaketten sonra hastanelere ulaştırılmasıdır. Problemi çözmek için makine çizelgeleme yöntemi kullanılmıştır. İşletmelerde üretim planlama faaliyetleri için kullanılan makine çizelgeleme, kısa süreli planlamada sık uygulanmaktadır ve kaynakların verimli kullanımında büyük önem taşımaktadır. Özdeş makine çizelgeleme insani lojistik problemlerine uyarlanmıştır. Uygulanan Liste Çizelgeleme yöntemi yaralıların hastaneye taşınması için geçen toplam süreyi en aza indirmeyi amaçlamaktadır. Çalışmada, elde edilen sonuçlar, geliştirilen algoritma ile ele alınan problem için en uygun işlem sırasını elde etmede en kısa işlem süresi (SPT) ve en uzun işlem süresi (LPT) kurallarının karşılaştırmasını göstermektedir. Sezgisel yöntem için; tek araç, 2 araç ve 3 araç durumları incelenmiştir.

Öncelikle, İstanbul hakkında hem demografik hem de coğrafi bilgiler sağlanmıştır. İstanbul'da büyük çaplı bir deprem olması durumunda, kentin Voronoi diyagramı ile bölgelere ayrıldığı varsayılmaktadır. Strateji, depremzedenin bulunduğu yere göre onu en yakın hastaneye taşımaktır. Çalışmanın amaç fonksiyonu, afet sonrası dönemde mevcut ambulansların hastalara uygun şekilde atanması ile kurtarılan ağır yaralıların sayısını ve aynı zamanda beklenen hizmet seviyesini maksimize etmektir.

Anahtar kelimeler: İnsani lojistik, Deprem, Afet yönetimi, Liste çizelgeleme, Sezgisel yöntem

DEDICATION

To my family

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LIST OF ABBREVIATIONS

AKOM	Metropolitan Municipality Disaster Coordination Center
AYM	Governorship Disaster Management Center
DM	Disaster Management
EM	Emergency Management
GIS	Geographical information systems
HL	Humanitarian Logistics
IFRC	International Federation of Red Cross and Red Crescent
IGO	Inter-Governmental Organizations
IMM	İstanbul Metropolitan Municipality
JICA	Japan International Cooperation Agency
KOERI	Kandilli Observatory and Earthquake Research Institute
NGO	Non-Governmental Organizations
TAY	Turkish Emergency Management Directorate
UAV	Unmanned Aerial Vehicle
UTM	Universal Transversal Mercator
WGS84	World Geodetic Reference System 1984
WHO	World Health Organization
WIP	Work in Process

Chapter 1

INTRODUCTION

1.1 Background

Several natural disasters occur every year all around the world such as earthquake, hurricane, tornadoes, floods, landslides, famine, droughts or tsunami. The World Disasters Report (2009) indicated that more than 7,000 disasters took place from 1999-2008. The number of people who died because of these disasters was 1.2 million and total cost exceeded one trillion dollars (Overstreet et al., 2011). These numbers take attention to disaster management which can reduce significantly the number of casualties and suffered people with a proper management. One of the most important things is disaster management which includes both preparedness and response. In large scale disaster may cause huge casualties particularly in metropolitan cities. Therefore, in these kind of cases, humanitarian operations become successful with necessary personnel and efficient dispatching activity. Dispatching is important to supply sources to the right place as quick as possible.

There are some study areas according to the components of humanitarian logistics (HL). These are personnel equipment, information of carriage, technology, arrangement, strategies, warehousing. Depending on the type of disaster, it is necessary to share many top practices in HL. The matters of interest to make medicines, nourishment and other necessities of relief accessible to the individuals affected by the disaster. HL appeals for distinct action in comparison to commercial logistics operations carried out by the corporate branch of an economy. HL activities deal with issues related to the insufficiency of dominant operational scheme, particularly in the immediate post-disaster environment. Designing, developing and implementing acceptable techniques for HL is demanded by the necessity to comprehend in its entirety associated with the intricate responsibility of meeting post-disaster relief demand. Preparedness measures includes many things such as positioning beforehand of aid provisions in warehouses, identifying potential providers of relief goods, developing standardized specifications. Distribution of aid substances, developing transport logistics to gather aid substances from warehouses and deliver them to areas that have been struck by the disaster is important in HL (Sahay et al., 2016).

Every moment many earthquakes are being detected in the whole world. Our focus in this study is an earthquake case in Istanbul in the future. As we see in the past and also geographic examinations show that there were some destructive earthquakes in Istanbul and there is a danger of tsunami in a major earthquake case (Necmioğlu et al., 2018).

1.2 Research Objectives and Questions

The problem of this study is to transport the seriously injured persons to hospitals as soon as possible. On the other hand, a new model for saving people in the post-disaster period has been developed. For this reason Istanbul has been chosen as the study area. As a result, given below are the research questions that are to be explored in this study:

- What has been the primary focus of HL research?

- What models have been proposed/tested?

- What are the regions within that city selected for research in the future?

As a way to answer the above stated questions, the following, in the study, have been developed:

- Istanbul is divided into regions and hospitals in each region cover the patients in the related area,

- Patients are assigned to the closest hospital and the developed model saves as much lives as possible,

- Determines the requirements for Istanbul in a case of large-scale earthquake.

1.3 Application after Earthquake

One type of disaster which may occur in Turkey with high probability is earthquake. The locations of earthquakes are not completely random. Especially cities on the faults including metropolitan cities face potential serious earthquakes in the future. After earthquake, hundreds or thousands casualties may be expected.

Chapter 2

LITERATURE REVIEW

In this particular chapter, a presentation of the considered literature material is given. Literature on scheduling in HL is little when juxtaposed with other type of scheduling problems. Nevertheless, it has proliferated in recent times. Related literature was analyzed in two sections. In the first place, in section 2.1, the studies on the disaster management and HL concept have been mentioned. In the second place, studies in parallel machine scheduling have been described in section 2.2.

2.1 Disaster Management and Humanitarian Logistics Concept

International Federation of Red Cross and Red Crescent (IFRC) Societies define disaster as the arrangement and administration of amenities and tasks to address all humanitarian emergency facets, particularly preparedness, response and recovery to decrease the effects of the catastrophes. Hence, HL activities as a whole includes both the periods prior to and after the disaster. International Federations, in conjunction with communities, labor together for the purpose of decreasing risk disaster emergency, reduce the impacts of, make ready to respond, react to and return to a somewhat normal state from disasters (IFRC, 2019).

According to World Health Organization (WHO) a disaster is an incident that disrupts standard living situations and leads to a level of agony that surpasses the ability of a community to conform (WHO, 2002).

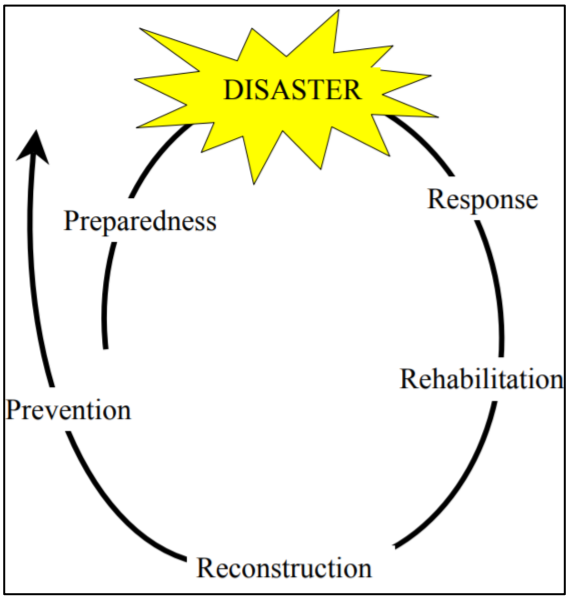

Figure 1: The disaster-development continuum (WHO, 2002)

In disaster management, preparedness and prevention works are included before the disaster to reduce the effects of damages. The response and rehabilitation periods are included in post-disaster period (Figure 1).

HL incorporates several undertakings like inventory tracking, customs clearance, local transport, storage, distribution, supply and transport. In fact, all logistical operations include design, transport, distribution, and additional operations. However, these undertakings are of high importance for HL since death is the result of any kind of disturbance (Bozkurt, 2011). Leiras et al, (2014) identified trends and challenges in HL.

Supply chain management is of high importance with regard to disaster relief operations since effectiveness and swiftness in giving aid to individuals who drive advantages are of high importance in the event of a catastrophe (Abidi et al., 2014) and also to take patients from their place to operating rooms (Shavarani and Vızvarı, 2018) to cure is so crucial.

The participation of local people and national and international organizations are very important in HL. (Sheppard et al., 2013) attempted to find out how locals, specifically those who are at the rural and municipal levels, can strengthen their capability to be ready and respond more effectually to the difficulties faced with regard to logistics in the post-disaster period. Study results indicate that the locals' ability to provide some kind of assistance to the processes of logistical preparation and response has for the most part been undervalued and underused. Consequently, they point out on the volunteering work of the local population has important contribution in HL.

Disaster Management (DM), in other words emergency management (EM) has studied on emergency plan for state of California and emergency plan was put forward (Schwarzenegger, 2009). Similarly, earthquake master plan has studied by a group of universities (Ansal et al., 2003).

Another important issue for HL is to communicate with people after the earthquake period. Özdamar and Ertem, (2015) discussed models, solutions and enabling technologies on the response and recovery planning phases of the catastrophe’s lifecycle. Remote sensing techniques are used to assess damage and needs or post-earthquake response. These techniques can be provided by small unmanned aerial vehicle (UAV) (Nedjati et al., 2016).

Geographical information systems (GIS) are used for the improvement of damage and loss scenarios in areas more susceptible to earthquakes. Fiedrich et al, (2000) developed an optimized resource allocation model for post-disaster period. (Chang et al., 2014), suggested an algorithm for managing the administration of accessible amenities and automatically producing an array of feasible emergency logistics plans for decision-makers.

Feng and Wang, (2003) carried out a study on highway emergency recovery (the works of road repairing in the rescue period, i.e., after the happening of the earthquake, which is 72 hours later). As an objective of this study, they have developed a planning scheme for highway emergency rehabilitation following the earthquake and they have defined firstly the emergency rehabilitation problem. Consequently, a multi objective-programming model is created with considerations to the time and resources constraints. The following aims are established: maximizing the performance of emergency rehabilitation; minimizing the risk of rescuers; and maximizing the saving of lives. Lastly, Chi-Chi earthquake which happened in central Taiwan a few years ago has been carried out in the case study.

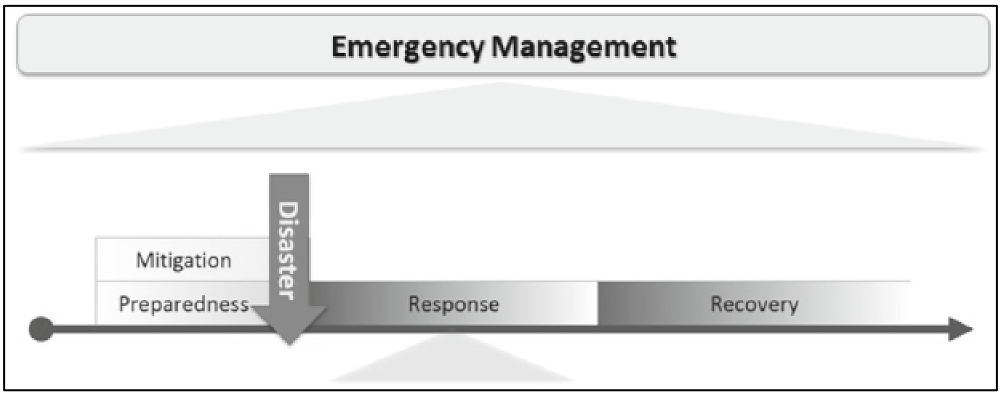

Figure 2: Emergency management scheme (Anaya-Arenas et al., 2014)

Emergency management scheme can be seen in the Figure 2. Mitigation and preparedness belong to the period before the disaster. Response and recovery can deductible after the disaster period.

In areas occupied greatly by people, a huge amount of them can be affected or killed with natural disasters such as high magnitude earthquake. A paramount feature that aids the determination of the complete list of individuals who met their demise following an earthquake is the search-and-rescue performance in the first few days after the disaster.

Also operational areas are important for disaster response. These are in the following:

- Depots: Airports, barracks and other places where extra amenities might come as well as operational fields. The customs and procedures are also very important for international relief. Haiti earthquake gives a bad example. Preparedness may contain the elaboration of special emergency procedures.

- Hospitals: This incorporates, with regards to the hospitals in the places struck by the calamity, temporal hospitals that have been set up for the purpose of that particular crisis. The assignment of injured people to hospitals is the most important factor.

-Crossroads: Although crossroads do not have any particular function for emergency response measures, they have an important role in calculating the shortest paths from depot to operational area (Fiedrich et al., 2000).

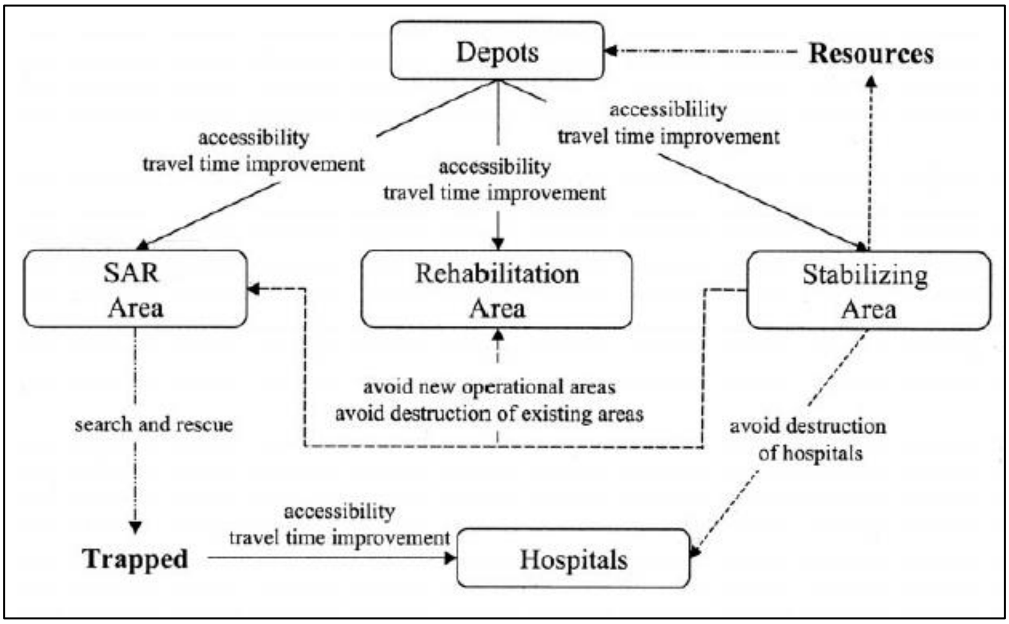

Figure 3: Resource allocation example for emergency response (Fiedrich et al., 2000)

There are three different operational areas (Figure 3). Resources which includes the machines and equipment can be used in any area. In this model, related resources are assumed to be ready for action.

As Institutional and Legal Considerations; mainly the actors in HL are governments, donors, international and regional organizations (Inter-Governmental Organizations (IGO)), non-governmental organizations (NGO), media, private sector, local populations (Sheppard et al., 2013).

2.2. Parallel Machine Scheduling

Scheduling theory includes parallel identical machine scheduling problems and it is one of the most studied topics in this area. Scheduling is a very common activity for industries and also for non-industry settings which is a study field that deals with optimality for allocation or assignment of limited resources to a set of activities in a period of a time (Parker, 1996). Tasks and resources can be handled as jobs and machines in production system; patients, emergency vehicles and hospital equipment in health care problem; ships and shipyards in a logistic system etc. In each system requires decision-making process. Scheduling plays an important role in the systems and decision makers try to optimize an objective function. Objective function can be determined such as minimization of makespan or minimization of total tardiness (Hashemian et al., 2014; Li et al., 2019). Objectives also might be maximizing the number of customers or patients served depending on type of problem. In the same way meetings, vacations, work periods, sport games are set by a decision making process. Other examples of scheduling are: bicycle assembly, classroom assignment, soft drink bottling, scheduling athletic events, etc (Parker, 1996).

Continuous availability of machines is assumed over the horizon of the schedule in the classical machine scheduling problems. This assumption might work in some cases but it is not justified in mostly practical situations. The operation of a machine can be obstructed for a defined period of time because of incidental obstruction, maintenance work, repairs being done periodically or other reasons (Hashemian, 2010).

Nattaf et al, (2019) aimed to minimize the flow time and the number of disqualifications of job families on parallel machines. They proposed an integer linear programming model and a constraint programming model to solve problem by developing a Re-cursive Heuristic and a Simulated Annealing algorithm. According to computational analysis, both model is efficient enough to obtain result.

Cheng and Gen, (1996) considered parallel machine scheduling problem with an objective of minimization the maximum weighted absolute lateness. Memetic algorithms are applied and job partition among machines and job sequence within each machine are considered to solve the problem. According to results they have concluded that this algorithm can solve the problem efficiently for parallel machine scheduling problems.

Peng and Liu, (2004) purposed a research to create a procedure for making a model on parallel machine scheduling problems with fuzzy processing times. They have shown three novel types of fuzzy scheduling models. A hybrid intelligent algorithm is also created for solving these models. As a result, some numerical examples are given to demonstrate the computational efficiency of the suggested algorithm.

Rabadi et al, (2006) considered the non-preemptive unrelated parallel machine scheduling problem with the objective of minimizing the makespan and machine-dependent and job sequence-dependent setup times are taken into account. The problem in the paper is a NP-hard problem and optimal solutions are established for small problems exclusively. A meta-heuristic (Meta-RaPS) method is introduced for larger problems. The results demonstrate that heuristic method found all optimal solutions for the small problems and outperformed the solutions obtained by the existing heuristic for larger problems.

Muñoz-Villamizar et al, (2019) examied the parallel machine scheduling problem. They have defined a mixed-integer linear programming formulation with four different objective functions assessed the effectiveness in scheduling independent jobs and considered of earliness/tardiness costs and variable setup times. The objective of this study is to help management make decisions regarding the measurement and improvement.

Vallada and Ruiz, (2011) considered a genetic algorithm for the unrelated parallel machine scheduling problem. In the problem, the machine and the job sequence depend upon the setup times. The developed genetic algorithm contains a fast local search and a local search enhanced crossover operator. These algorithms are compared by using the Design of Experiments (DOE) approach. After statistical analysis it has been concluded that the proposed methods provide the best results especially for large instances.

Hashemian et al, (2014) aimed to minimize makespan for parallel machines scheduling with several planned non availability periods. The problem is designed as a mixed integer linear programming model and is solved to optimality using CPLEX. Numerical results are gathered for several experiments and they demonstrate the validity and performance improvements presented by both the MILP model and the new enumeration algorithm.

Kramer et al, (2019) aimed to minimize the total weighted completion time of the problem of scheduling a set of jobs on a set of identical parallel machines. They have solved the problem by representing it on a capacitated network at first. Then, a mixed integer linear model applied with a pseudo-polynomial number of variables and constraints. Moreover, the arc-flow formulation has been developed to solve all samples with up to 400 jobs.

Kim et al, (2002) presented a scheduling problem for unrelated parallel machines with sequence-dependent setup times by using a meta-heuristic method (simulated annealing). In the paper, each machine has its own processing times and setup times are machine independent but job sequence dependent. This study determines a scheduling model in order to minimize total tardiness. From the experimental analysis it has been shown that the proposed simulated annealing method significantly outperforms a neighborhood search method in terms of total tardiness.

Weng et al, (2001) addressed the problem of scheduling a set of independent jobs on unrelated parallel machines with job sequence dependent setup times. The objective function is to minimize a weighted mean completion time. The study of the problem stemmed from a real service industry problem. This problem which is studied in the paper is NP-hard problem. Seven different heuristic algorithms have been developed and tested. The computational results indicate that the weighted mean completion time by a suggested algorithm linearly increases as the number of jobs grows up to 100.

Bajestani and Tavakkoli-Moghaddam, (2009) proposed a new branch-and-bound (B&B) algorithm for unrelated parallel machine scheduling problems with sequence-dependent setup time in order to minimize the total weighted tardiness. The lower bound is derived through assignment problem and upper bound is resulted from generalizing the composite dispatching rule. The developed algorithm gives the optimal solution for problems with up to 10 jobs and 4 machines in all combinations of tardiness factors and due date ranges.

Chapter 3

METHODOLOGY

3.1 Scheduling Background of Transportation of Patients

The concept of the scheduling of identical parallel machines will be used for the scheduling of patients to hospitals. The parallel machines are discussed first. The equivalence is established at the end of the section.

In general, the machine scheduling problems are classified into two classes as deterministic machine scheduling problem and probabilistic (stochastic) machine scheduling problem. The deterministic machine scheduling problem can be used when it is possible to ascertain with certainty the processing constraints and parameters. Probabilistic machine scheduling problem can be used when it is impossible to determine certain processing conditions or parameters previously.

The deterministic machine scheduling problems are categorized into four types as: single machine, parallel machines, flow shop, and job shop. The uncertain machine scheduling problems are grouped into two types as: fuzzy machine scheduling problem and stochastic machine scheduling problem.

There is only one machine in single machine scheduling models, and the routes on this machine consist of only one operation. On the other hand, there are N jobs and

M machines in parallel machine scheduling and each job can be processed on any of the available machines (Sabti, 2017).

There are three types of parallel machines (Sabti, 2017):

- **Identical machines:** If each processing time of a job is independent of the machine when performing a job.

- **Uniform machines:** The machines process at different rates.

- **Unrelated parallel machines:** The processing time of a job depends on the machine assignment.

In the basic model of parallel machine scheduling, jobs are provided with N and machines are provided with M. Each job j has a necessary condition for processing p_j units. Job j can only be operated on a single machine at any given time, and a job on one of the machines must be processed uninterruptedly. If the machines are uniformly related, then processing p units on any machine takes time p so that each machine i runs at a defined speed s_i, and processing p units takes time p/s_i on machine i. A solution to an instance of the problem is a schedule that specifies a time interval on one machine for each job j, while ensuring that no machine processes more than one job simultaneously. If C is the point in time at which job j has finished processing, then the makespan or length of the schedule is C_{max} = max_i C_j (Shmoys et al., 1995).

Some terms in machine scheduling are given bellow (Pinado, 2005; Sabti, 2017):

- **Makespan:** The total amount of time required to complete a group of jobs. In the literature makespan is denoted by C_{max}.

- **Processing time (P_{ij}):** The required time of job j to complete its processing on machine i.

- **Release date (r_j):** Time at which job j ∈ N becomes available for processing.

- **Deadline:** It is the time by which a job j ∈ N must be finished.

- **Due-date (d_j):** It is the time at which job j ∈ N is expected to be completed.

- **Completion time (C_j):** It is the time when job j is completed.

- **Lateness (L_i):** Lateness expresses the digression of the completion time of a job j from a due-date, it can be positive, negative or zero L_i= C_j-d_j.

Dispatching rules can be categorized in several manners. For instance, we can make a distinction between static and dynamic rules. Static rules are time independent. They are just a function of the job and/or machine data. Meanwhile, dynamic rules depend on time. Some dispatching rules are given below:

- **The Longest Processing Time first (LPT):** This rule orders the jobs in decreasing order of processing times. Keeping jobs with short processing times for later is advantageous since these jobs are useful in creating a balance of the workload at the end. After the allocation of jobs to respective machines has been established, the jobs on any particular machine can be re-sequenced without affecting the workload balance.

- **The Shortest Processing Time first (SPT):** Jobs are ordered in decreasing order of p_j.

- **The Earliest Due Date first (EDD):** This rule express to minimize the maximum lateness among the jobs waiting for processing. The job which has the earliest due date is selected next to be processed. In a single machine setting, with N jobs available at time zero, the EDD rule does minimize the maximum lateness.

Before formulating the problem, the following assumptions are considered:

1. The vehicles are identical (vehicles work independently of each other).

2. The jobs are non-identical (jobs have different transportation times on each vehicle).

3. Each vehicle can process only one job at a time.

4. Each vehicle is available at time zero, however some vehicles may not be available at that time.

5. Preemption of a job on another vehicle and vehicle breakdowns are not allowed.

6. No setup time is required. Or setup times are independent of job sequence and are included in the transportation times.

3.2 LPT List Scheduling

Transportation problem is equivalent with scheduling identical parallel machines. Emergency vehicles work like machines, transportations of patients to hospitals work as tasks. Vehicles work independently of each other. LPT List scheduling is used for assignment of patients to the vehicles like tasks to machines. But, order is made according to SPT rule. In a case of a large-earthquake in İstanbul, patients need to be taken to hospitals as soon as possible. If each hospital has its own dispatching region for the patients, this makes to accelerate the situation. Anatolian side is determined as 75 regions by Voronoi diagram. To show the case; 100 patients have been distributed into the region randomly by ArcGIS software processing times are calculated.

In the implementation of the method, LPT is used for distribution of processing times in 2 and 3 vehicles cases. After that, the order of processing times are changed. After application of this method, the time required to serve each patient was found.

3.2.1 Work in Process Quantity

Work in process (WIP) (Conway et al., 1988), stands for the total waiting time of the patients. The role of the amount of WIP is to demonstrate how many minutes the patients wait for the transportation.

For the WIP Quantity 2 theorems need to be discussed;

1. The performance ratio of LPT list scheduling is (Graham, 1969)

$$\frac{C_{max}(LPT)}{C_{max}(OPT)} \leq \frac{4}{3} - \frac{1}{3m}$$

Here, m denotes the number of machines.

2. Let $P_{(j)}$ denote the processing time of the job in the jth position in the sequence. The total completion time can be expressed on a single machine as

$$WIP = \sum C_j = np_{(1)} + (n-1)p_{(2)} + \cdots + 2p_{(n-1)} + p_{(n)}$$

This implies that there are n coefficients n, n-1,…,1 to be assigned to n different processing times. The highest coefficient is assigned (n) is assigned the first processing times, the second processing time, and so on. This implies that SPT is optimal (OPT) (Graham, 1969; Pinedo, 1995).

3.3 Voronoi Diagram

The concept of Voronoi diagrams dates back to the 17th century and is different from other aspects of computational geometry. It is a space breakdown into convex regions; each consisting of matter revolving around one of the fixed stars is shown in Figure 4.

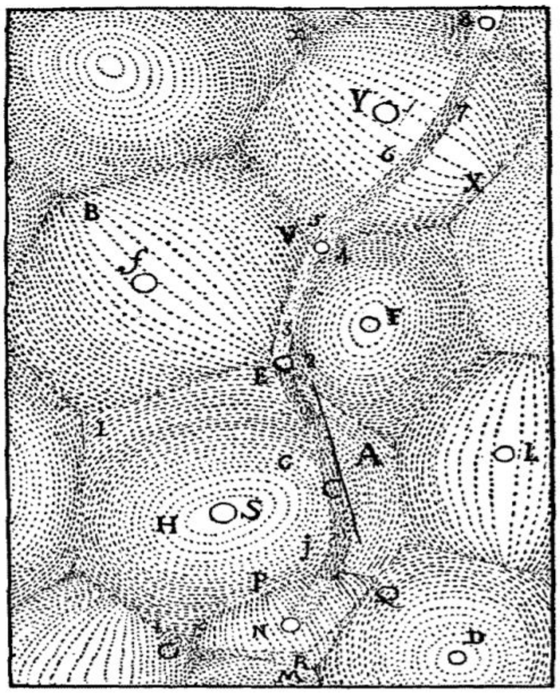

Figure 4: The disposition of matter in the solar system and its environs by Descartes (Okabe et al., 2009)

The basic idea of these regions is as follows:

Let a space M, and a set S of sites p in M be given, together with a notion of the impact a site p exerts on a point x of M. This concept has become useful in various fields of science. For instance, medial axis transform in biology and physiology, Wigner-Seitz zones in chemistry and physics, domains of action in crystallography, and Thiessen polygons in meteorology and geography. Voronoi as a mathematician has defined this concept and his working of structure has been named as the Voronoi diagram. As Voronoi mentioned the dual structure is where any two point sites are connected whose regions have a boundary in common (Aurenhammer and Klein, 2000).

The points of Voronoi diagram are a collection of regions that divide up the plane. Each region corresponds to one of the points, and all of the points in one region are closer to the matching point than to any other point. In the event that there is not a nearest point it means there is a boundary. As exhibited in Figure 5, the point p is closer to $p_1$than to any other enumerated points. Also p′ (on the boundary between $p_1$and p_3) is equidistant from both of those points (Dobrin, 2005).

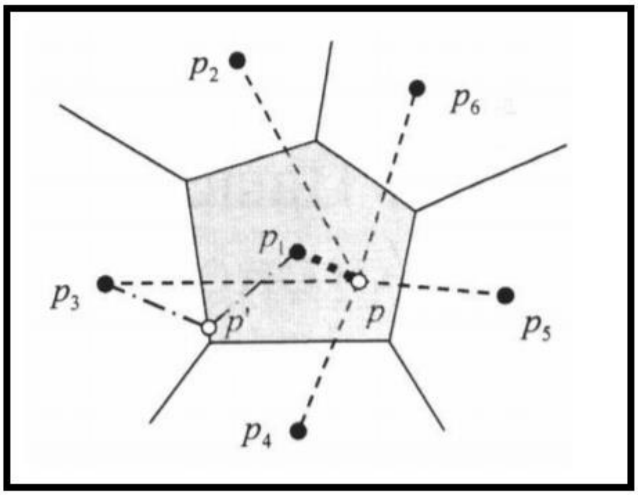

Figure 5: A basic Voronoi diagram (Dobrin, 2005)

Figure 6 shows a data set and its Voronoi diagram. This diagram is an exact structure used for the closest point problems. The Voronoi polygon of this point separates any point from the closest points to it. The edges of the polygon are composed of the edge middle planes of the correct parts which connect the dot and neighboring edges.

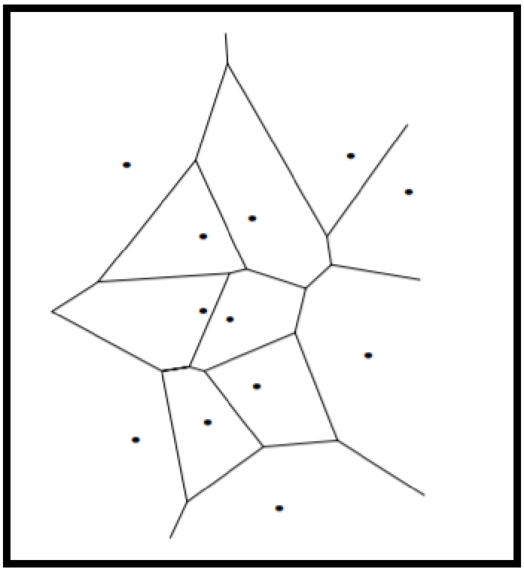

Figure 6: Voronoi diagram (Yanalak, 2001)

ArcGIS software has been used to divide Anatolian side into regions by Voronoi diagram. 75 regions were obtained on the map.

Chapter 4

SITUATION AND ASSUMPTIONS IN İSTANBUL

In the study İstanbul has chosen as studied area because of many reasons. First of all, İstanbul is the largest city with high population in Turkey. It is a metropolitan affecting the world and affected by the world with regard to economic, social and other aspects. Besides, İstanbul is one of the prominent cities in what is regarded as emergent Europe, a geographic space that runs between Eastern Europe and West Asia (Burdett, 2009). On the other hand, the city is on the fault zone that it increases the possibility of earthquake occurrence in the near future. It makes necessary researchers to search in many aspects of reducing damages in this case.

4.1 Population

İstanbul is the most populous city in Turkey with an estimated population of 15 million in 2018 (Nufusu, 2019). Istanbul is an intercontinental city on the Bosphorus waterway in northwestern Turkey. It is found between the Black Sea and the Marmara Sea. In spite of the fact that it has consistently had a high population in the recent past, Istanbul has greatly expanded over the past one hundred years.

The city of İstanbul has been a major population center with a prominent role in cultural commercial activities for at least two millennia. Even though İstanbul is a very old city of 2500-3000 years, it grew very rapidly especially after 1950s. It can be seen also from Table 1.

Table 1: Population of İstanbul (İnceoğlu and Yürekli, 2011)

Year	1860	1890	1901	1940	1960	1970
Population	715.000	874.000	942.900	793.949	1,466.535	2,132.407
Year	1980	1985	1990	2000	2010	2018
Population	2,772.708	5,475.982	6,629.431	8,803.468	13,120.596	15,067.724

While the existing settlements between 2000 and 2015 have grown and developed; at the same time, Istanbul's spatial spread rate increased with the establishment of new settlement areas. In the years between 2000 and 2015, the E-5 Highway of Istanbul was rapidly expanding to the north from the east-west line. Settlements have been trapped between factories and organized industrial sites over time (Gökburun, 2017). Figure 7 show that the residential areas of İstanbul in 2010.

Figure 7: Residential areas of İstanbul in 2010 (Gökburun, 2017)

The first industrial movements in Istanbul began around the Golden Horn (Feshane and the shipyard area), Beykoz (paper mill) and Bakırköy (iron and printing factories). According to 2011 data, approximately 52% of the industrial sector is in

Marmara Region. The biggest share within the region and within the country is in İstanbul (Doğan, 2013).

On the other hand, rapid population growth has some negative effects. Density and crowd cause environmental, noise, image and light pollutions. Additionally, some other problems can be observed such as squatters and unplanned urbanization, infrastructure, transportation, unemployment, health, education, sociocultural degeneration and expensive life are experienced (Sarıtaş, 2017).

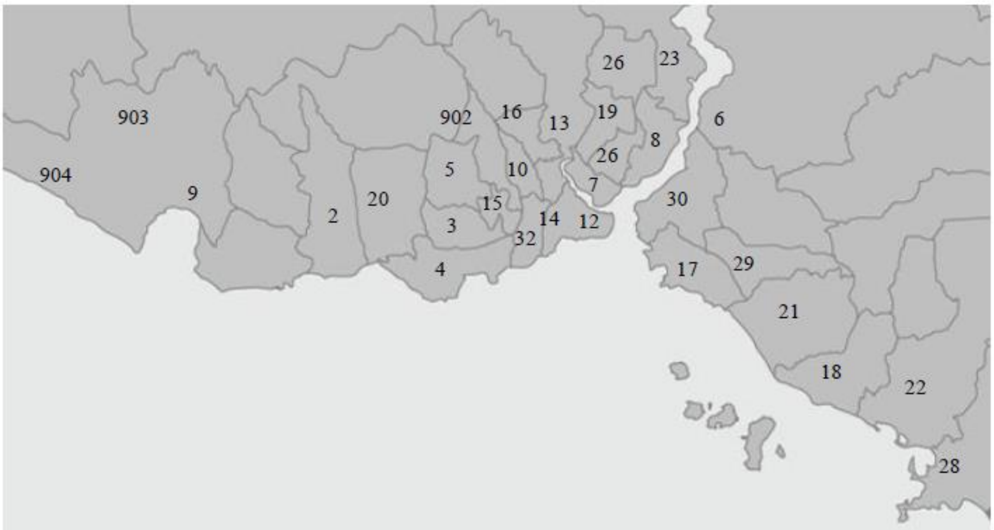

Figure 8: The location of districts on İstanbul map

In the Figure 8 the location of districts in İstanbul (studied in JICA report) are shown. However, "Adalar" district is not acknowledged in the models because of its very small population (Table 2).

Table 2: Data of districts in İstanbul (Konu, 2014)

No	District	Population	Side
1	Adalar	14,552	-
2	Avcılar	395,758	West
3	Bahçelievler	600,162	West

4	Bakırköy	221,336	West
5	Bağcılar	749,024	West
6	Beykoz	220,364	East
7	Beyoğlu	246,152	West
8	Beşiktaş	186,067	West
9	Büyükçekmece	201,077	West
10	Bayrampaşa	269,774	West
12	Eminönü	24,873	West
13	Eyüp	349,470	West
14	Fatih	403,385	West
15	Güngören	307,573	West
16	Gaziosmanpaşa	980,470	West
17	Kadıköy	916,763	East
18	Kartal	443,293	East
19	Kağıthane	421,356	West
20	Küçükçekmece	1,033,006	West
21	Maltepe	460,955	East
22	Pendik	622,200	East
23	Sarıyer	258,035	West
26	Şişli	318,217	West
28	Tuzla	197,657	East
29	Ümraniye	645,238	East
30	Üsküdar	535,916	East
32	Zeytinburnu	292,407	West
902	Esenler	458,694	West
903	Çatalca	36,863	West
904	Silivri	197,861	West

4.2 Geography

Located in the northwestern part of Turkey, Istanbul is situated in a very important point because of its geographical location. İstanbul Province, located between 41°33’ and 40° 28’ northern latitudes with 28°01’ and 29°55’ eastern longitudes. The city occupies an area of 1,539 km^2, while the metropolitan region covers an area of 6,220 km^2 (Ormeci et al., 2009).

İstanbul is surrounded; the Black Sea in the north, the Marmara Sea in the south, the water section line of the Ergene Basin in the west and the light elevations between İzmit and Sapanca in the east (Gökburun, 2017). The most densely populated areas are the southwest, west and northwest of the city center as well as the European side. Üsküdar is the most densely populated town in the Anatolian side (World Population Review, 2019). İstanbul map is shown in Figure 9.

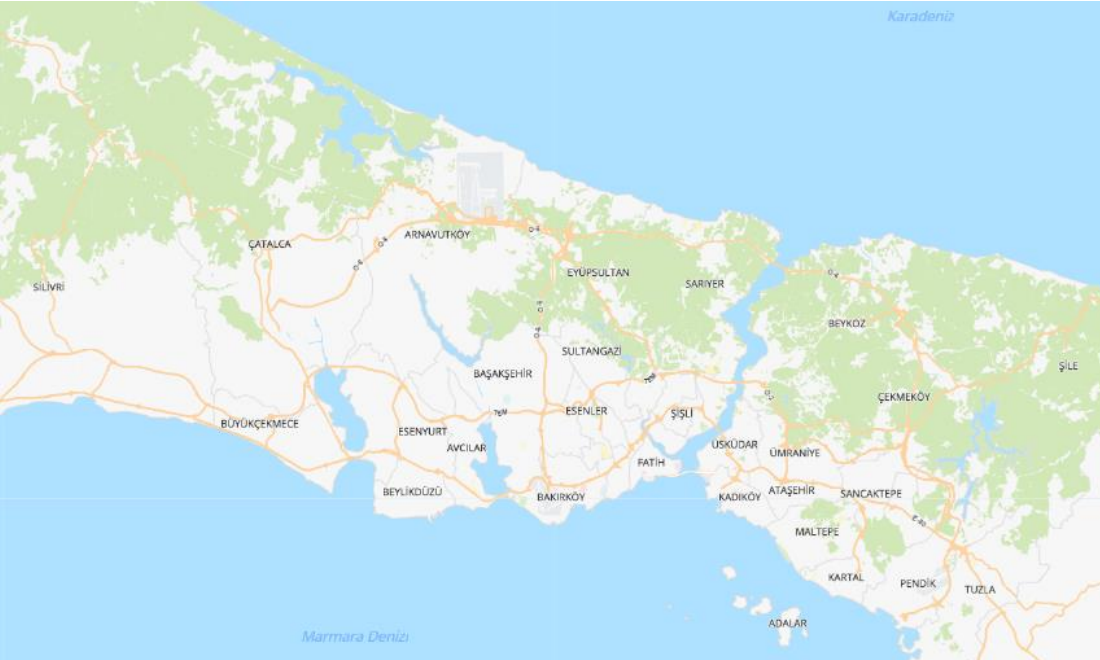

Figure 9: Map of the districts of İstanbul

4.3 Hazards and Vulnerabilities

The population in İstanbul is now at 15 million and continues to grow rapidly. Coupled with increased population in urban areas, this situation has resulted in the city spreading towards peripheries, causing the settled and built area to become larger. As a result, some problems have arisen such as stress on natural protection areas and forests, long travel time in traffic, air and environment pollution. Over-migration gives rise to transportation, infrastructure, housing, risk management problems. The problem of migration should be solved by strengthening local government, implementing national strategies and limiting migration to Istanbul.

Throughout history, Marmara region has been the site of numerous destructive earthquakes in Northwestern Turkey. The occurrence of the 1999 Kocaeli and Düzce earthquakes at the eastern end of the Marmara region underscored the need for a state-of-the-art earthquake hazard assessment. The presence of a single major tectonic entity crossing the Marmara Sea has been clearly delineated by recent extensive geophysical studies.

4.3.1 Earthquake Risk and Tectonic Setting of the Marmara Region

Geologically, Turkey is located at the boundary area where the Arabian Plate and African Plate are moving north towards the Eurasian Plate.

Marmara Sea region is one of the most tectonically active regions in Eurasia with one third of the Turkish population. İstanbul is the largest city in this area. There are factors controlling the earthquake hazard for İstanbul. Undoubtedly one of them is a large-scale fault line called North Anatolian Fault (NAF), which in the Marmara Sea region forms a complex fault system. NAF is formed in the northern territory of Turkey over 1,000 km long from east to west, and historically there have been many robust earthquakes along this line of fault. With two destructive earthquakes in 1999, seismic activity on the western extension of the NAF system has increased over the past decade. These Kocaeli and Düzce earthquakes resulted in major stress-drops on the NAF's western segment where it spreads under the Marmara Sea (Kalkan et al, 2008, Picozzi et al., 2009).

Istanbul and its surroundings are the settlements, which were damaged by many earthquakes along the history. In Figure 10, the fault map of Turkey is seen.

Figure 10: The fault map of Turkey (Kartal vd., 2015)

The Ministry of Public Works and Settlement published an official Earthquake Hazard Zoning Map of Turkey. It is based on expected a maximum acceleration value which has calculated with probabilistic method. The whole country is divided into the 5 different hazard zones (Figure 11).

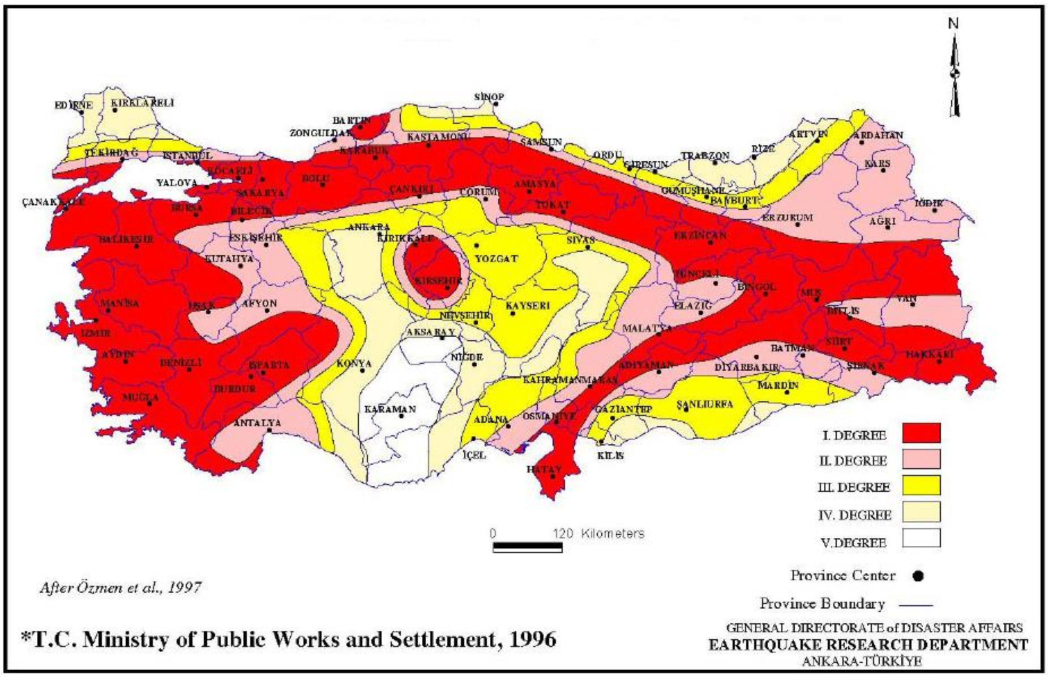

Figure 11: The official earthquake hazard map of Turkey (Özmen, 2013)

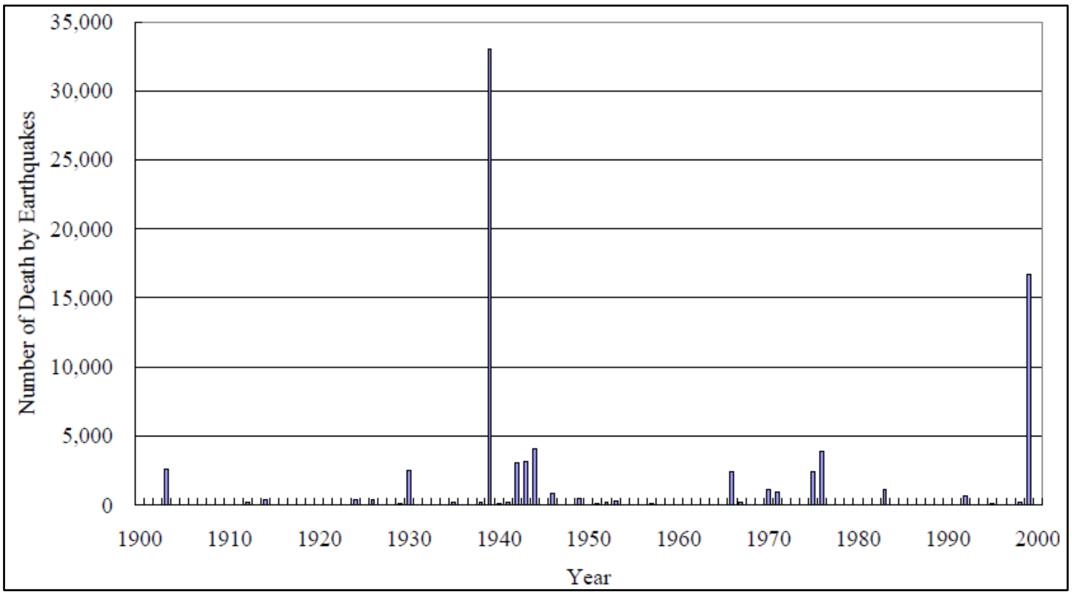

Figure 12: Number of deaths by earthquakes in Turkey (JICA, 2002)

Since 1900 till 2000 many earthquakes recorded and if we look at the close past results show in the period of 1940 more than 30, 000 people have died in Erzincan earthquake (Figure 12).

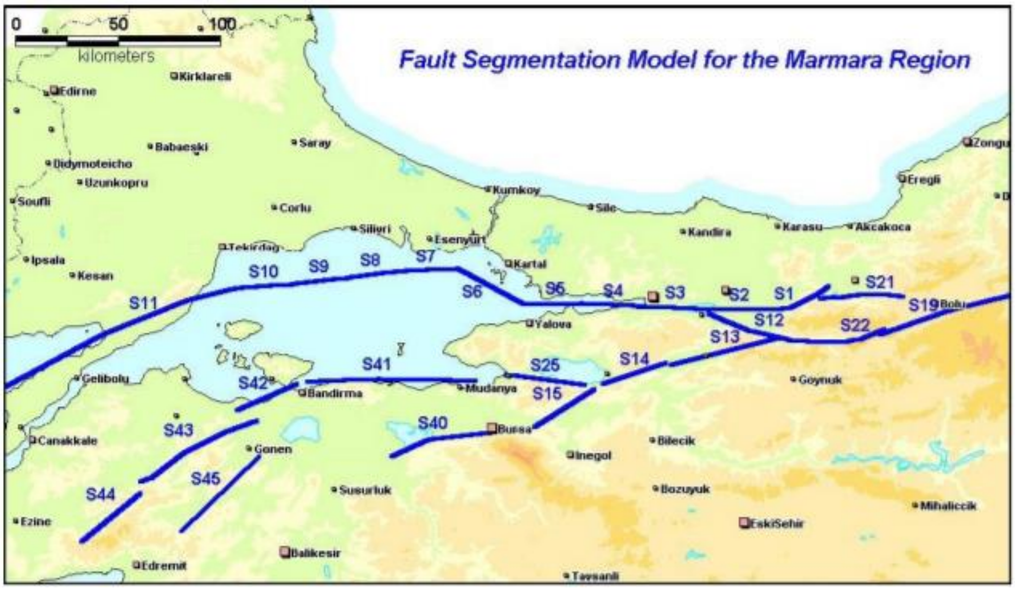

Figure 13: Resource zoning for the Marmara region (IMM, 2009)

Earthquakes with a destructive effect in Istanbul are expected to result from the active fault system in the Marmara Sea. In the light of the present sismo-tectonic information, two different source regions for the Marmara region are presented in Figure 13.

Table 3: Earthquakes all over the world (Sahay et al., 2016)

Year	Disaster	Type	Affect
Jan 12, 2012	Haiti Earthquake	Earthquake (7.0 on Richter Scale)	0.2 Million death, 2 million homeless and 3 million in need of emergency aid.
Oct 8, 2005	Pakistan Earthquake	Earthquake (7.6 on Richter Scale)	75,000 death and 106,000 injured
Dec 26, 2004	Indian Ocean Earthquake & Tsunami	Earthquake (9.1-9.3 on Richter Scale)	0.23-0.31 million
July 28, 1876	China Tangshan Earthquake	Earthquake (7.8 on Richter Scale)	240,000 deaths and 164,000 injuries
Mar 11, 2011	Tohoku, Japan Earthquake and Tsunami	Earthquake (9.0 on Richter Scale)	15 million dead or injured and 2814 missing, 18 prefectures and 250,000 buildings damaged/destroyed
Oct 11, 1138	Aleppo, Syria Earthquake	Earthquake	230,000 deaths
Dec 16, 1920	Haiyuan, China Earthquake	Earthquake	240,000 deaths
526	Antioch, Syria Earthquake	Earthquake	250,000 to 300,000 deaths
Feb 22, 2011	Christchurch, New Zealand Earthquake	Earthquake (6.3 on Richter Scale)	185 Deaths, 238 Missing and 164 Injured
Jan 26, 2001	Gujarat Earthquake	Earthquake (7.7 on Richter Scale)	20,000 deaths, 167000 injured, 400,000 homes destroyed, 600,000 homeless

Since time immemorial, the world has witnessed various types of disasters. Table 3 lists several disasters worldwide. These are the most representative of the worst disasters that have occurred in recent years.

4.3.2 Tsunami Risk

Tsunamis are unpredictable events and caused by any large-scale sea floor disturbance, such as fault, landslide or volcanic eruption. A tsunami can spread in any direction and thus pose a risk to any vulnerable coastline depending on the location of the source, the path of propagation and near shore morphology. The morphology of the near shore seabed determines both the shore wave path as well as the characteristics of the wave run-up. Although the historical records of near-field tsunamis are often incomplete due largely to inadequate data and data of questionable quality, particularly for older events, it has known that in the last 1600 years at least 21 historic tsunamis have been felt in the region of İstanbul, almost half of which have affected its coasts. (Alpar et al., 2003).

Historical studies show that more than 90 tsunami have occurred in our country in the last 3000 years with more than 8300 km of coastline. These are observed in all seas surrounding our country, especially in the Marmara Sea. During the last 4100 years, more than 300 destructive earthquakes occurred in the Sea of Marmara. 40 of them were created tsunami (KOERI, 2017).

Table 4: Earthquake-induced tsunamis have occurred in Turkey

Earthquake year	Earthquake Venue	Magnitude Earthquake
10 September 1509	Marmara Sea	IX
1598	Amasya, Çorum	VIII
10 July 1894	İstanbul	X
9 August 1912	Şarköy-Mürefte	IX
27 December 1939	Erzincan	X-XI
18 September 1963	Çınarcık	VIII
3 September 1968	Bartın	VIII
17 August 1999	Kocaeli	X
21 July 2017	Bodrum	VII

As it is seen from the Table 4, many earthquakes triggered tsunamis in Turkey. In this table; the tsunamis that occurred in the 1598 and 1939 earthquakes were caused by landslides triggered by earthquakes.

4.4 Responsible Organizations for Disaster Management

A frequently expressed opinion on Turkish disaster management system's most basic problem is the existence of a number of different organizations, which are given-often overlapping-responsibilities, related to disaster preparedness and coordination activities by the current legal system. The following is a comprehensive but not exhaustive list of organizations with different responsibilities in preparation, response and recovery phases:

• Natural Disasters Coordination Board

• Turkish Emergency Management Directorate (TAY)

• Directorate of Technical Research and Development in the Ministry of Public Works and Settlements

• National Earthquake Council

• Emergency Response Teams

• Municipalities

• Turkish Red Crescent

Some of the institutions responsibilities are not clarified very well. This situation creates confusions. Local governments are not responsible for the disaster management. These administrations are the responsibility of the central government. On the other hand, regional plan preparations are optional, creating areas without macro-level plans and according to master plan for Istanbul. Construction safety is very important to reduce harmful effects of earthquake consequences. However, it has not yet been introduced into the legal framework since the earthquake in 1999. As recommendations they indicate to be reorganized of the duties and responsibilities of some of the institutions in their study (Ansal et al., 2003).

As a new administrative arrangement in İstanbul, Following the 1999 Marmara Earthquake, two new organizations were established in Istanbul to overcome the legal challenges that hinder the smooth functioning of disaster-related activities:

• Governorship Disaster Management Center (AYM)

• Metropolitan Municipality Disaster Coordination Center (AKOM).

4.5 Current Situation

Currently, there are totally 219 active emergency vehicles in İstanbul. Approximately mission time for an emergency vehicle is 20 minutes (Yılmaz-Karakuş, 2019). But in the emergency case this time is expected to increase. And the number of hospitals is totally 75 in Anatolian side of Istanbul.

In Anatolian side totally 75 hospitals were discussed. In Figure 14, it can be seen the locations of hospitals on İstanbul map. And hospitals are in UTM (Universal Transversal Mercator) projection, distances were registered WGS84 (World Geodetic System) spheroid and datum, UTM Zone 35 North. ArcGIS software has used for the coordination.

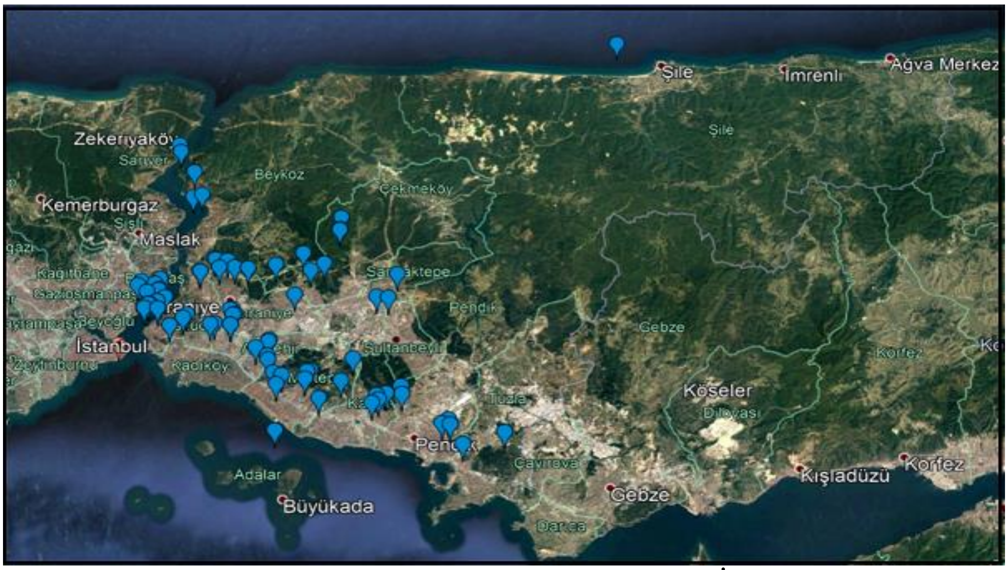

Figure 14: Hospitals in Anatolian side of İstanbul

4.6 Assumptions

In this thesis, models are developed specifically for Istanbul. Thus, the characteristics of Istanbul shaped the assumptions used for modeling. For instance, İstanbul is divided into two sides (Anatolian and European side) by Bosporus and these two sides are connected to each other by two bridges. Below are assumptions reflecting the situations that must be considered in order to achieve effective emergency management in İstanbul:

• All incidents are local.

• Emergencies may occur at any time with little or no warning and may exceed capabilities of local and the private sector in the affected areas.

• Emergencies may result in casualties, fatalities and can take people out of their homes.

• Emergency situations may lead to loss of property, interruption of essential public services, damage to basic infrastructure and significant environmental damage.

• The political subdivisions of the country will mobilize to deliver emergency and essential services under all threats and emergencies.

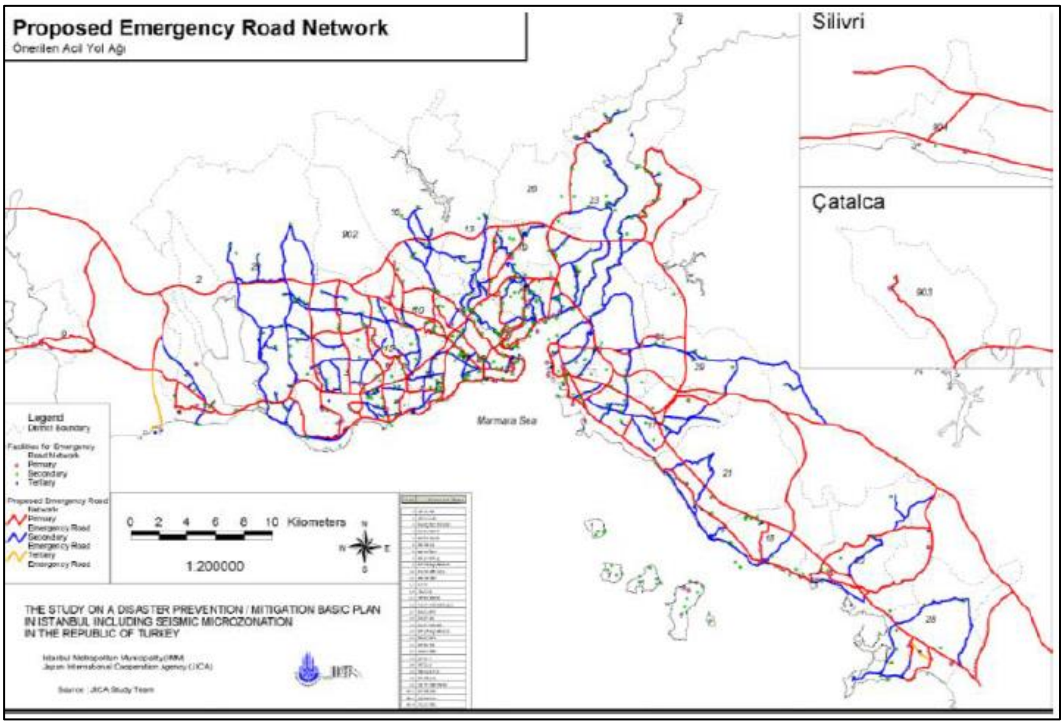

Figure 15: Proposed emergency road network (JICA, 2002)

(JICA, 2002) proposed a road network for the case of an earthquake in İstanbul (Figure 15). In the report, potential routes determined as a potential warehouse location and the demand point for each district. Between every district, from a potential warehouse to a demand point, they have considered two possible routes. It is the Proposed Emergency Road Network, which suggests primary, secondary and tertiary roads to be used after an earthquake strikes Istanbul (JICA, 2002; Konu, 2014).

Chapter 5

DISCUSSION OF RESULTS

In this chapter, the results obtained for the List Scheduling heuristic method to assign patients to the hospital described in the previous chapter are presented and discussed. For the algorithm, geographical data has been collected by Google Maps, Google Earth and ArcGIS. Similarly, Voronoi diagram has been generated by using ArcGIS.

5.1 Discussion on the City

According to Japanese International Cooperation Agency study (JICA Report, 2002) in coordination with İstanbul Metropolitan Municipality (IMM) the human casualties and injuries (MODEL A) 73,000 deaths and 120,000 severely injured, respectively. The same study indicates that the total number of heavily damaged buildings is estimated as 51,000 and this contain 7.1% of total buildings in the Study Area. The number of moderately and heavily damaged buildings that need repair in order to occupy, is 114,000. The obtained results show that the southern area of Istanbul is more heavily damaged than the northern area because of the earthquake motion distribution (JICA, 2002).

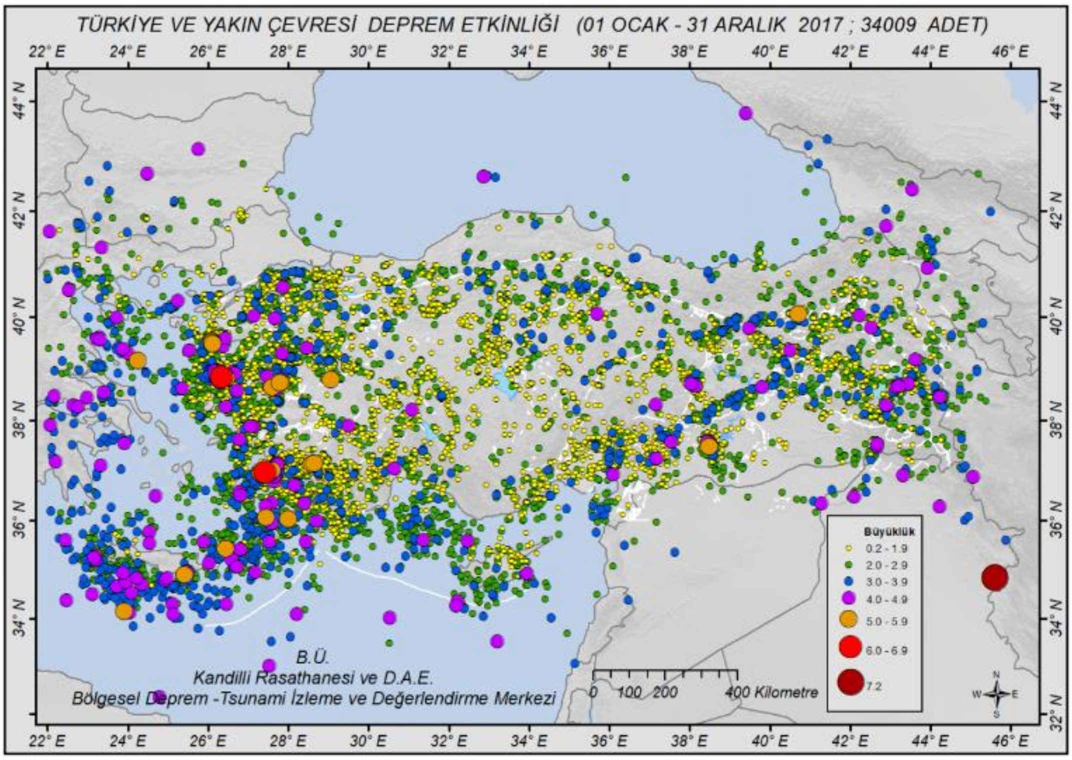

Figure 16: Earthquake activity in/around Turkey in 01 June-31 December 2017 period (KOERI, 2019)

Every moment some earthquakes strike in Turkey and Kandilli Observatory and Earthquake Research Institute, Boğaziçi University (KOERI) records these movements. Figure 16 shows recorded earthquakes in and around Turkey in 2017 (01 June-31 December).

5.2 Discussion on Voronoi Diagram

İstanbul Anatolian side is divided into 76 regions by Voronoi diagram. In another word, each hospital has its own region to serve the patients (Figure 17).

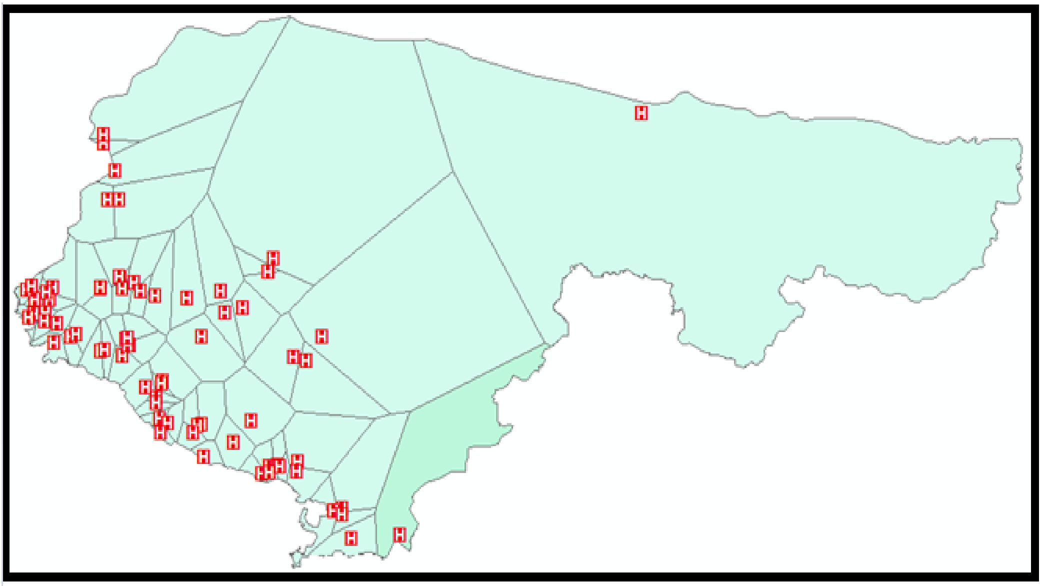

Figure 17: Voronoi diagram of hospitals in Anatolian side of İstanbul

As can be seen in Figure 18, Başkent University Hospital is chosen as the studied area. The reason of this, Başkent University Hospital is located in Üsküdar which has a high population. Moreover, this studied region is larger than the most of the other regions.

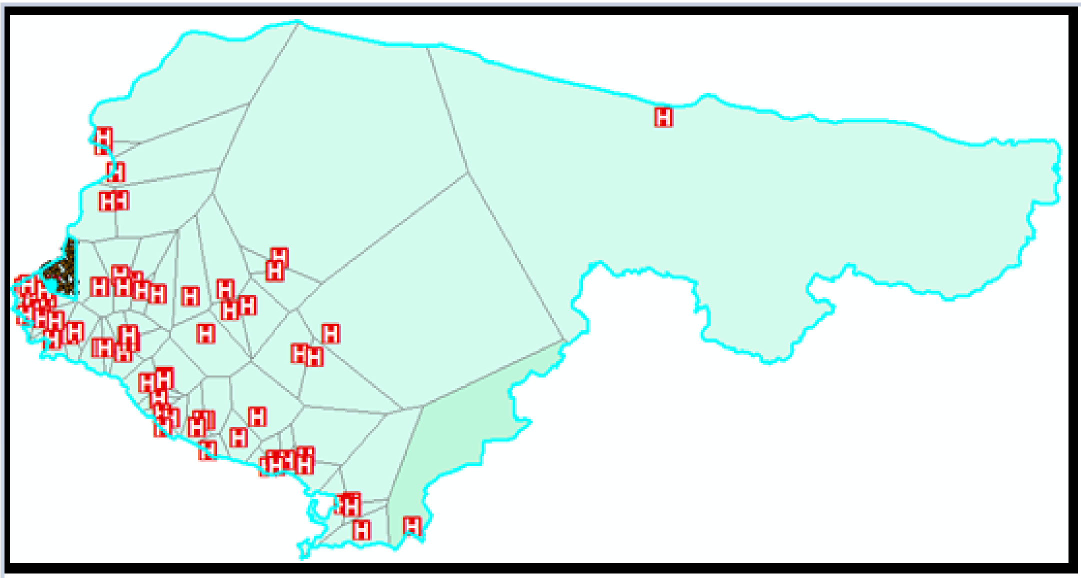

Figure 18: The studied area of the İstanbul map

Anatolian side of Istanbul divided into 75 regions with Voronoi diagram. After division, 100 patients have been assigned randomly to the region (Figure 19). Each patient has a certain distance to the hospital. So, these distances have been calculated. Distances obtained with the coordinates provided by the ArcGIS. These distances help to find WIP quantity. WIP quantity gives us, the number of saved people in a certain period of a time.

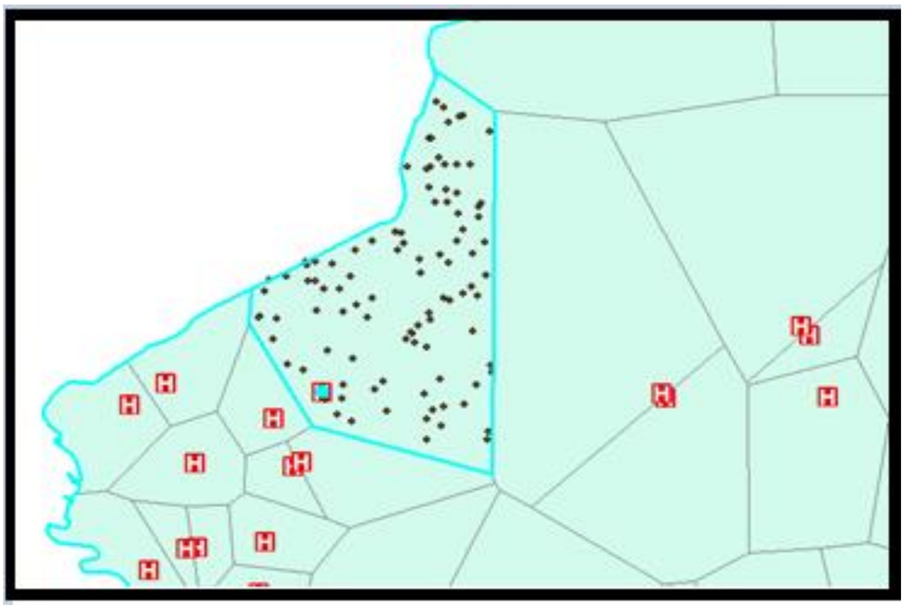

Figure 19: 100 patients in Voronoi region of Başkent University Hospital

After calculation of distances, processing times are obtained for each patient. To get WIP quantity, some rules have applied as following:

-Assign the patients to vehicles as it is done in LPT List Scheduling,

-Apply SPT order on each vehicle.

5.3 Discussion on the Model Cases

These 2 steps are followed for 3 cases which explain in more detail below.

5.3.1 Case 1

In this case, single vehicle was put into service for 100 patients. SPT and LPT rules were applied. After application of rules, WIP quantities were obtained by SPT and LPT order 36,448.13 and 52,995.05 minutes, respectively. As we can see in Figure 20, WIP quantity for LPT is higher than WIP quantity for SPT. Processing times for 100 patients in 1 vehicle case is given in Appendix B.

For instance, according to SPT rule; 68 people would be saved in 481.558 minutes. On the other hand, 697.118 minutes are required to save 68 people for LPT rule. Thus, it can be said that SPT gives a better solution than LPT for single vehicle.

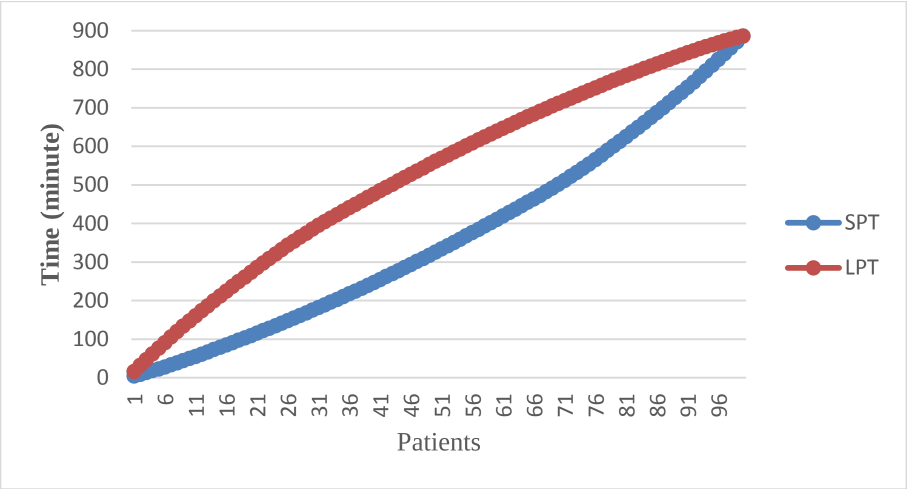

Figure 20: The comparison of WIP quantities according to LPT-SPT for 100 patients in the case of single vehicle

5.3.2 Case 2

In this case, 2 vehicles transport 100 patients to the hospital. LPT rule has been applied on the processing times. WIP quantities are found 9,210.792 and 9,236.264 minutes for the first and second vehicle, respectively. Using WIP quantities for two vehicles decrease the required time to transport all the patients (Figure 21).

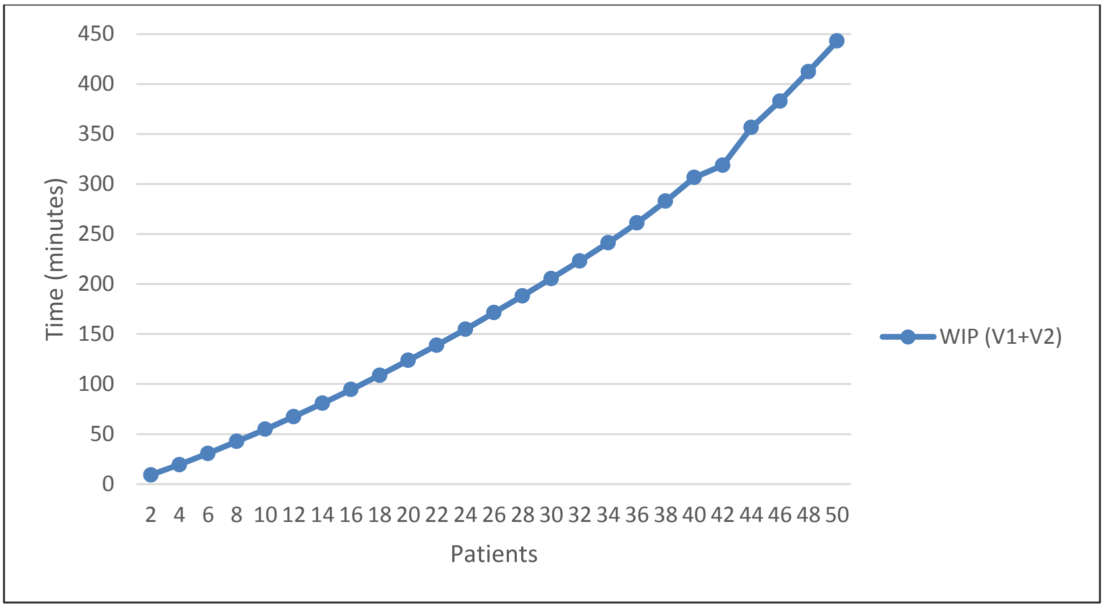

Figure 21: WIP quantities according to LPT in the case of 2 vehicles

For example, 90 patients can be saved by 2 vehicles in 369.798 minutes. 285.064 and 518.38 minutes are required for SPT and LPT in case 1, respectively.

Processing times of 100 patients are given in Table 5. As it can be seen, first vehicle (V1) transports 49 patients; second vehicle (V2) transports 49 patients in the region of Başkent University hospital. WIP quantities are also shown for the first vehicle (WIP/V1) and for the second vehicle (WIP/V2) in Table 5. Processing times of patients and WIP quantities for the vehicles should be considered as minutes.

Table 5: The results of LPT in the case of 2 vehicles

Patients	**V1 (min)**	**WIP/V1 (min)**	**V2 (min)**	**WIP /V2 (min)**	**WIP/(V1+V2) (min)**
1	4.032	4.032	4.468	4.468	8.500
2	4.784	8.816	4.630	9.098	17.914
3	4.784	13.600	4.954	14.052	27.652
4	5.280	18.880	5.246	19.298	38.178
5	5.574	24.454	5.576	24.874	49.328
6	5.694	30.148	5.690	30.564	60.712
7	5.936	36.084	5.906	36.470	72.554
8	5.990	42.074	6.032	42.502	84.576

9	6.044	48.118	6.086	48.588	96.706
10	6.126	54.244	6.156	54.744	108.988
11	6.284	60.528	6.332	61.076	121.604
12	6.586	67.114	6.388	67.464	134.578
13	6.610	73.724	6.594	74.058	147.782
14	6.656	80.380	6.612	80.670	161.050
15	6.780	87.160	6.776	87.446	174.606
16	6.828	93.988	7.024	94.470	188.458
17	7.112	101.100	7.044	101.514	202.614
18	7.150	108.250	7.146	108.660	216.910
19	7.338	115.588	7.404	116.064	231.652
20	7.404	122.992	7.468	123.532	246.524
21	7.686	130.678	7.558	131.090	261.768
22	7.754	138.432	7.718	138.808	277.240
23	7.824	146.256	7.940	146.748	293.004
24	7.942	154.198	7.988	154.736	308.934
25	8.042	162.240	8.156	162.892	325.132
26	8.338	170.578	8.354	171.246	341.824
27	8.438	179.016	8.460	179.706	358.722
28	8.474	187.490	8.474	188.180	375.670
29	8.578	196.068	8.602	196.782	392.850
30	8.628	204.696	8.694	205.476	410.172
31	8.710	213.406	8.740	214.216	427.622
32	8.798	222.204	8.842	223.058	445.262
33	8.942	231.146	8.986	232.044	463.190
34	9.152	240.298	9.234	241.278	481.576
35	9.876	250.174	9.314	250.592	500.766
36	10.346	260.520	10.394	260.986	521.506
37	10.408	270.928	10.662	271.648	542.576
38	11.452	282.380	11.144	282.792	565.172
39	11.650	294.030	11.838	294.630	588.660
40	12.058	306.088	11.864	306.494	612.582
41	12.186	318.274	12.168	318.662	636.936
42	12.202	330.476	12.374	331.036	661.512
43	12.552	343.028	12.606	343.642	686.670
44	13.100	356.128	12.866	356.508	712.636
45	13.162	369.290	13.290	369.798	739.088
46	13.562	382.852	13.370	383.168	766.020
47	14.394	397.246	14.576	397.744	794.990
48	14.688	411.934	14.608	412.352	824.286
49	14.942	426.876	14.982	427.334	854.210

5.3.3 Case 3

In this case, 3 vehicles transport 100 patients to the hospital. LPT rule has been applied on the processing times. WIP quantities are found as 4,396.836, 4,399.02 and 4,240.804 minutes for first vehicle, second vehicle and third vehicle, respectively.

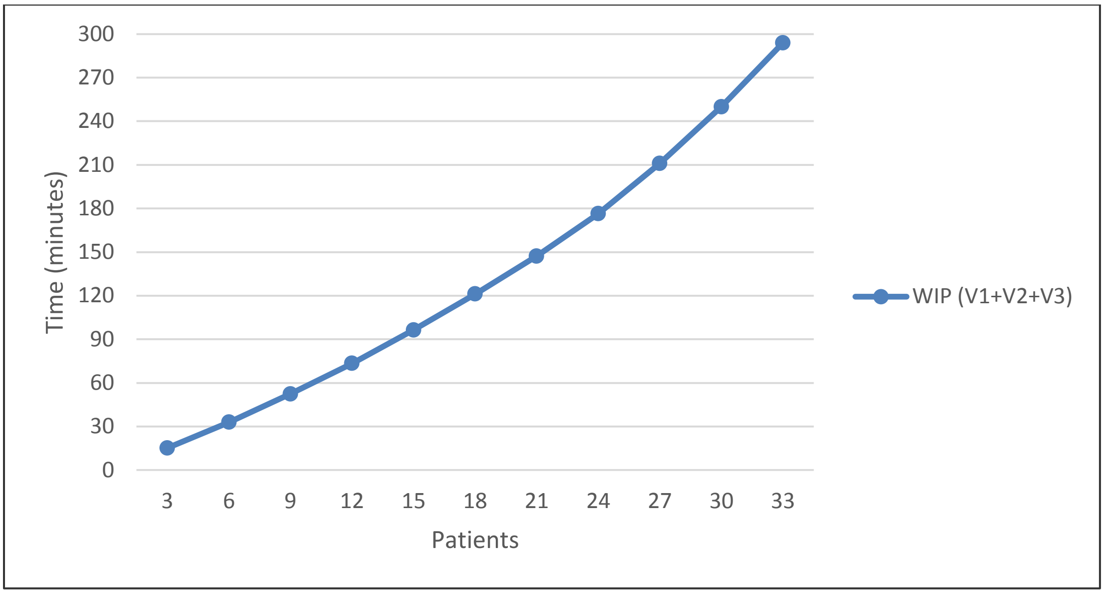

Figure 22: WIP quantities according to LPT in the case of 3 vehicles

For instance, 84 patients can be saved by 3 vehicles in 223.460 minutes although 331.036 minutes are required for 2 vehicles. On the other hand, 661.494 and 801 minutes are required for SPT and LPT in case 1, respectively.

Processing times of 100 patients are given in Table 6. As it can be seen, first vehicle (V1) transports 33 patients; second vehicle (V2) transports 33 patients and third vehicle (V3) transport 34 patients in the region of Başkent University hospital. WIP quantities are also shown for the first vehicle (WIP/V1), for the second vehicle

(WIP/2) and for the third vehicle (WIP/V1) in Table 6. Processing times of patients and WIP quantities for the vehicles should be considered as minutes.

Table 6: The results of LPT in case of 3 vehicles

Patients	V1 (min)	WIP/V1 (mi)	V2 (min)	WIP/V2 (min)	V3 (min)	WIP/V3 (min)
1	4.468	4.468	4.630	4.630	4.032	4.032
2	5.246	9.714	4.954	9.584	4.784	8.816
3	5.280	14.994	5.576	15.160	4.784	13.600
4	5.906	20.900	5.694	20.854	5.574	19.174
5	5.936	26.836	5.990	26.844	5.690	24.864
6	6.044	32.880	6.126	32.970	6.032	30.896
7	6.284	39.164	6.156	39.126	6.086	36.982
8	6.594	45.758	6.586	45.712	6.332	43.314
9	6.612	52.370	6.656	52.368	6.388	49.702
10	6.780	59.150	6.828	59.196	6.610	56.312
11	7.112	66.262	7.044	66.24	6.776	63.088
12	7.150	73.412	7.146	73.386	7.024	70.112
13	7.468	80.880	7.404	80.790	7.338	77.450
14	7.558	88.438	7.686	88.476	7.404	84.854
15	7.940	96.378	7.824	96.300	7.718	92.572
16	8.042	104.420	7.988	104.288	7.754	100.326
17	8.156	112.576	8.354	112.642	7.942	108.268
18	8.460	121.036	8.474	121.116	8.338	116.606
19	8.578	129.614	8.474	129.590	8.438	125.044
20	8.694	138.308	8.710	138.300	8.602	133.646
21	8.842	147.150	8.798	147.098	8.628	142.274
22	8.986	156.136	8.942	156.040	8.740	151.014
23	9.234	165.370	9.876	165.916	9.152	160.166
24	10.346	175.716	10.408	176.324	9.314	169.480
25	11.452	187.168	10.662	186.986	10.394	179.874
26	11.650	198.818	11.864	198.850	11.144	191.018
27	12.186	211.004	12.058	210.908	11.838	202.856
28	12.374	223.378	12.552	223.460	12.168	215.024
29	12.606	235.984	13.100	236.560	12.202	227.226
30	13.162	249.146	13.370	249.930	12.866	240.092
31	14.394	263.540	13.562	263.492	13.290	253.382
32	14.608	278.148	14.688	278.180	14.576	267.958
33	15.712	293.860	15.672	293.852	14.942	282.900
34	-	293.860	-	293.852	14.982	297.882

5.4 Generalization of all the Cases

Table 7 shows the number of patients transported to the hospitals according to the respective cases (i.e. case 1, case 2 and case 3). There are 75 regions, each with one hospital.

Table 7: The number of patients transported to the hospitals within 3 hours

Hospitals	The number of vehicles in the region		
	1	2	3
1	22	36	47
2	33	60	82
3	34	62	84
4	39	74	100
5	30	74	100
6	39	74	100
7	36	68	94
8	13	20	28
9	39	74	100
10	29	52	67
11	37	70	100
12	27	50	69
13	36	64	87
14	36	68	96
15	34	62	84
16	32	56	77
17	38	72	100
18	33	60	77
19	39	74	100
20	31	52	68
21	37	68	93
22	33	60	81
23	35	64	90
24	35	64	90
25	32	56	78
26	33	58	81
27	37	68	96
28	39	74	100
29	27	46	66
30	28	46	60
31	15	22	30
32	31	56	78
33	29	52	72
34	30	54	74

35	15	24	33
36	27	44	59
37	22	36	50
38	30	52	69
39	34	62	86
40	31	56	77
41	15	24	34
42	22	40	54
54	34	60	81
44	37	66	92
45	36	68	96
46	34	60	83
47	38	70	96
48	34	62	84
49	34	60	79
50	31	54	77
51	29	50	69
52	40	76	100
53	31	54	75
54	39	72	100
55	29	50	68
56	34	62	85
57	26	44	61
58	33	60	84
59	32	58	79
60	35	64	87
61	29	52	69
62	31	54	72
63	34	85	62
64	24	55	42
65	19	30	39
66	29	52	70
67	37	68	96
68	35	62	87
69	38	70	96
70	30	54	73
71	35	64	90
72	34	64	88
73	39	72	100
74	31	54	75
75	36	66	90

As can be seen from the table above, the larger the size of the region, the fewer the number of patients that can be transported in 3 hours. In addition, the fewer the vehicles used, the fewer the number of patients that can be transported.

Chapter 6

CONCLUSION

In the literature, most scheduling problems have been solved for manufacturing activities by using as much capacity as possible. In this study we have considered the problem of parallel machine scheduling in the field of HL. We have considered vehicles like machines. Time and number of emergency vehicles have been determined as capacity of the problem. Our mission can be described; transportation of slightly injured victims to the nearest hospital in a case of large-scale earthquake and objective function is the maximization of saved people in post-earthquake period.

Required geographic and population information were collected about İstanbul since it was chosen as the study area. In this study only Anatolian side have been considered and hospital list determined in the districts. Hospitals are divided by the Voronoi diagram to identify the regions they would serve. Finally, patients have been distributed randomly in the region of Başkent University Hospital.

6.1 General Summary and Conclusion

Disaster response is very important issue and means early post-disaster activities. It includes the transportation of injured people to hospitals. This activity includes the control of the fleet of the emergency vehicles and the decisions such as order of transportations or which person must be transported to which hospital. The topic of this application is to obtain strategies how the emergency vehicles should work after an earthquake. For instance, Istanbul has more than 150 hospitals and more than 210 emergency vehicles. Thus, there are very high numbers of decisions alternatives. Optimal or just very good alternatives can be selected by only computers.

In general, some work packages are followed as below:

- Modeling of the problem,
- Geographical data collection,
- Examination of List Scheduling method,
- Simulation of post-disaster situation and implementation of method,
- Final calculations in the model.

The numerical results show us, SPT dispatching rule has provided the most efficient solution for the problem in single vehicle case (Graham, 1969). On the other hand, it can be obtained that the more vehicles can save more people in a case of emergency. Since; WIP is 52,995.05 minutes for single vehicle; WIP is 18,447.056 for 2 vehicles; WIP is 13,036.65 for 3 vehicles for LTP rule. WIP is 36,448.13 for single vehicle for SPT.

The maximal differences of the loads cannot be greater than the minimal processing time in the case of LPT list scheduling. This maximal difference can be obtained if before the last job all loads are equal. In any other case the maximal difference is smaller.

While total completion time is approximately 2 weeks with single vehicle, it is observed that this period can be lowered with 3 vehicles.

6.2 Suggested Areas of Future Research

In this project, it is aimed to develop strategies on how emergency vehicles should work after a possible earthquake in Istanbul. The general principles of research are applicable in other cities and regions. If mobile health personnel teach people how to treat during emergency, more people can be saved.

When we consider the population of İstanbul, much number of vehicles would transport more people in the emergency case. As a result, preparedness has an important role in the disaster management. Aside from population, the area of regions may also need to be analyzed with regard to the assignment of ambulances.

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APPENDICES

Appendix A: Information of Hospitals on Anatolian side of İstanbul

Table 1. Information of Hospitals in Anatolian side of İstanbul

Order	Name of Hospitals	Location
1	Beykoz Devlet Hastanesi	Beykoz
2	Erenköy Fizik Tedavi Ve Rehabilitasyon Hastanesi	Kadıköy
3	Medeniyet Üniversitesi Göztepe Eğitim Ve Araştırma Hastanesi	Kadıköy
4	Haydarpaşa Numune Eğitim Ve Araştırma Hastanesi	Üsküdar
5	Kartal Dr. Lütfi Kırdar Eğitim Ve Araştırma Hastanesi	Kartal
6	Dr. Siyami Ersek Göğüs Kalp Ve Damar Cerrahisi Eğitim Ve Araştırma Hastanesi	Üsküdar
7	Acil Servis Maltepe Devlet Hastanesi	Maltepe
8	Şile Devlet Hastanesi Yeni Bina	Şile
9	Üsküdar Devlet Hastanesi	Üsküdar
10	Yakacik Doğum ve Çocuk Hastalıkları Hastanesi	Kartal
11	Zeynep Kamil Kadın Ve Çocuk Hastalıkları Eğitim Ve Araştırma Hastanesi	Üsküdar
12	S.B.Ü Süreyyapaşa Göğüs Hastalıkları ve Göğüs Cerrahisi Eğitim Ve Araştırma Hastanesi C Blok	Maltepe
13	Pendik Devlet Hastanesi	Pendik
14	İstanbul Meslek Hastalıkları Hastanesi	Maltepe
15	Fatih Sultan Mehmet Eğitim Ve Araştırma Hastanesi	Ataşehir
16	Kartal Kosuyolu Hastanesi	Kartal
17	Ümraniye Eğitim Ve Araştırma Hastanesi	Ümraniye
18	Yavuz Selim Devlet Hastanesi	Kartal
19	Koşuyolu Medipol Hastanesi	Kadıköy
20	Npistanbul Beyin Hastanesi	Ümraniye
21	Dr. Nazif Bağrıaçık Kadıköy Hastanesi	Kadıköy
22	Özel Göztepe Hastanesi	Kadıköy
23	Kartal Yavuz Selim Devlet Hastanesi	Kartal
24	Avicenna Umut Hastanesi	Kartal
25	Özel Pendik Şifa Hastanesi	Pendik
26	Özel Pendik Hospital	Pendik
27	Özel Pendik Bölge Hastanesi	Pendik
28	Özel Remedy Hospital	Pendik
29	Çekmeköy Devlet Hastanesi	Çekmeköy
30	Çekmeköy Tıp Merkezi	Çekmeköy
31	Özel Alemdağ Şifa Tıp Merkezi	Çekmeköy

32	Sancaktepe Şehit Profesör İlhan Varank Eğitim Ve Araştırma Hastanesi	Sancaktepe
33	Özel Sancaktepe Bölge Hastahanesi	Sancaktepe
34	Saygı Hastanesi	Sultanbeyli
35	Sultanbeyli Devlet Hastanesi-Yeni Hastane (Tacirler Eğitim Vakfı)	Sultanbeyli
36	Sultanbeyli Ersoy Hastanesi	Sultanbeyli
37	İstanbul Okan Üniversitesi Hastanesi	Tuzla
38	Özel Gisbir Hastanesi	Tuzla
39	İstanbul Tuzla Devlet Hastanesi	Tuzla
40	Özel Tuzla Hastanesi	Tuzla
41	Şifa Poliklinik	Tuzla
42	Marmara Üniversitesi Pendik Eğitim ve Araştırma Hastanesi	Pendik
43	Özel Yüzyıl Hastanesi - Pendik	Pendik
44	Maltepe Ersoy Hastanesi	Maltepe
45	Özel Maltepe Bölge Hastanesi	Maltepe
46	Toprak Hastanesi	Maltepe
47	Bezmialem Vakıf Üniversitesi Dragos Hastanesi	Maltepe
48	Delta Hospital	Maltepe
49	Memorial Ataşehir Hastanesi	Ataşehir
50	Eren Hastanesi	Ataşehir
51	Özel Ataşehir Hastanesi	Ataşehir
52	Avicenna Hastanesi Ataşehir	Ataşehir
53	Ataşehir Florence Nightingale Hastanesi	Ataşehir
54	Ümraniye Eğitim Ve Araştırma Hastanesi	Ümraniye
55	T.C. Sağlık Bakanlığı Sbü Ümraniye Eğitim ve Araştırma Kadın Doğum Ve Çocuk Hastalıkları Hastanesi	Ümraniye
56	Atlas Hastanesi	Ümraniye
57	Özel Hekimler Cerrahi Tıp Merkezi	Ümraniye
58	İstanbul Erenköy Ruh Ve Sinir Hastalıkları Eğitim Ve Araştırma Hastanesi	Ümraniye
59	Özel Afiyet Hastanesi	Ümraniye
60	Çakmak Erdem Hastanesi	Ümraniye
61	Medicana Çamlıca	Ümraniye
62	Tepe Tıp Merkezi	Ümraniye
63	Özel Beykoz Tıp Merkezi	Beykoz
64	Medistate Kavacık Hastanesi	Beykoz
65	North Clinics	Beykoz
66	Özel Fsm Tıp Merkezi Kavacık	Beykoz
67	Özel Yunus Emre Hastanesi	Üsküdar
68	Üsküdar Devlet Hastanesi	Üsküdar
69	Üsküdar Hospitaltürk	Üsküdar
70	Başkent Üniversitesi İstanbul Sağlık Uygulama Ve Araştirma Merkezi Hastanesi	Üsküdar

71	İstanbul Sultan Abdülhamid Han Eğitim Ve Araştırma Hastanesi	Üsküdar
72	Kadıköy Florence Nightingale Tıp Merkezi	Kadıköy
73	Özel Academic Hospital	Üsküdar
74	Muhittin & Fatma Tatar Alemdağ Devlet Hastanesi	Çekmeköy
75	Özel Çağıner Hastanesi	Kadıköy
76	Beykoz Devlet Hastanesi	Beykoz

Table 2. Coordinates of Patients in the Voronoi region of Başkent University Hospital

Patients	X Coordinates	Y Coordinates	Processing Times (min)
1	672459	4543189	6.332
2	673326	4547092	14.576
3	673046	4546177	12.186
4	672573	4543474	5.990
5	673264	4542503	9.314
6	673270	4547057	14.394
7	671464	4543752	4.784
8	671782	4545260	7.824
9	673149	4544282	8.602
10	671095	4544133	6.284
11	672926	4542585	8.474
12	673259	4546174	12.606
13	673187	4543381	7.404
14	672984	4546065	11.838
15	673235	4547239	14.688
16	672945	4547676	14.982
17	671907	4543846	5.246
18	672491	4546571	11.864
19	672056	4543861	5.574
20	672867	4547567	14.608
21	672717	4543827	6.828
22	672736	4546827	12.866
23	673165	4543667	7.404
24	673027	4545928	11.650
25	672323	4545424	9.234
26	673081	4547520	14.942
27	673104	4543006	7.988
28	671789	4545578	8.474
29	672475	4545593	9.876
30	671394	4543524	4.468
31	672835	4546021	11.452
32	672181	4544522	7.146

33	673326	4545135	10.662
34	673170	4542847	8.438
35	671082	4544534	7.112
36	671609	4543897	4.784
37	672454	4543382	5.936
38	671010	4544203	6.594
39	672306	4545054	8.460
40	672896	4545806	11.144
41	673210	4543437	7.338
42	673279	4547707	15.712
43	672609	4543427	6.156
44	672623	4547192	13.370
45	672102	4543153	5.690
46	672852	4546923	13.290
47	672512	4544787	8.338
48	671246	4544164	6.044
49	672641	4545686	10.394
50	671924	4545049	7.686
51	672738	4544739	8.694
52	672648	4544881	8.798
53	671306	4543517	4.630
54	673196	4547770	15.672
55	672215	4543264	5.694
56	672757	4546457	12.168
57	672519	4544925	8.628
58	672814	4543704	6.776
59	672209	4545291	8.740
60	673172	4544442	8.968
61	673316	4543593	7.558
62	672474	4544046	6.780
63	672591	4546640	12.202
64	672393	4542984	6.610
65	672786	4544765	8.842
66	672652	4545054	9.152
67	672815	4543383	6.656
68	672414	4542798	7.024
69	671277	4543961	5.576
70	672369	4544839	8.156
71	673372	4543779	8.042
72	671951	4543819	5.280
73	671913	4543694	4.954
74	672580	4543856	6.612
75	672265	4544059	6.388
76	672725	4547186	13.562
77	672880	4546526	12.552
78	671528	4544467	6.086
79	672417	4542791	7.044

80	672189	4544800	7.718
81	672558	4547153	13.162
82	672064	4544019	5.906
83	673111	4545192	10.346
84	671564	4545431	7.942
85	672587	4544118	7.150
86	672357	4545062	8.578
87	672713	4542639	7.94
88	672013	4544133	6.032
89	672737	4546580	12.374
90	671617	4543497	4.032
91	672667	4543756	6.586
92	673226	4542767	8.710
93	672504	4543689	6.126
94	672400	4545201	8.942
95	673025	4546134	12.058
96	672477	4544530	7.754
97	672480	4547200	13.100
98	671488	4545118	7.468
99	672989	4542708	8.354
100	672899	4545435	10.408

Appendix B: Information of the Model

Table 1. The results of SPT-LPT in case of single vehicle

Patients	SPT Processing Time	SPT/WIP Quantity	LPT Processing Time	LPT/WIP Quantity
1	4.032	4.032	15.712	15.712
2	4.468	8.500	15.672	31.384
3	4.630	13.130	14.982	46.366
4	4.784	17.914	14.942	61.308
5	4.784	22.698	14.688	75.996
6	4.954	27.652	14.608	90.604
7	5.246	32.898	14.576	105.180
8	5.280	38.178	14.394	119.574
9	5.574	43.752	13.562	133.136
10	5.576	49.328	13.370	146.506
11	5.690	55.018	13.290	159.796
12	5.694	60.712	13.162	172.958
13	5.906	66.618	13.100	186.058
14	5.936	72.554	12.866	198.924
15	5.990	78.544	12.606	211.530
16	6.032	84.576	12.552	224.082
17	6.044	90.620	12.374	236.456
18	6.086	96.706	12.202	248.658
19	6.126	102.832	12.186	260.844
20	6.156	108.988	12.168	273.012
21	6.284	115.272	12.058	285.070
22	6.332	121.604	11.864	296.934
23	6.388	127.992	11.838	308.772
24	6.586	134.578	11.650	320.422
25	6.594	141.172	11.452	331.874
26	6.610	147.782	11.144	343.018
27	6.612	154.394	10.662	353.680
28	6.656	161.050	10.408	364.088
29	6.776	167.826	10.394	374.482
30	6.780	174.606	10.346	384.828
31	6.828	181.434	9.876	394.704
32	7.024	188.458	9.314	404.018
33	7.044	195.502	9.234	413.252
34	7.112	202.614	9.152	422.404
35	7.146	209.760	8.968	431.372
36	7.150	216.910	8.942	440.314
37	7.338	224.248	8.842	449.156
38	7.404	231.652	8.798	457.954
39	7.404	239.056	8.740	466.694
40	7.468	246.524	8.710	475.404
41	7.558	254.082	8.694	484.098

42	7.686	261.768	8.628	492.726
43	7.718	269.486	8.602	501.328
44	7.754	277.24	8.578	509.906
45	7.824	285.064	8.474	518.38
46	7.940	293.004	8.474	526.854
47	7.942	300.946	8.46	535.314
48	7.988	308.934	8.438	543.752
49	8.042	316.976	8.354	552.106
50	8.156	325.132	8.338	560.444
51	8.338	333.470	8.156	568.600
52	8.354	341.824	8.042	576.642
53	8.438	350.262	7.988	584.630
54	8.460	358.722	7.942	592.572
55	8.474	367.196	7.940	600.512
56	8.474	375.670	7.824	608.336
57	8.578	384.248	7.754	616.090
58	8.602	392.85	7.718	623.808
59	8.628	401.478	7.686	631.494
60	8.694	410.172	7.558	639.052
61	8.710	418.882	7.468	646.520
62	8.740	427.622	7.404	653.924
63	8.798	436.42	7.404	661.328
64	8.842	445.262	7.338	668.666
65	8.942	454.204	7.150	675.816
66	8.968	463.172	7.146	682.962
67	9.152	472.324	7.112	690.074
68	9.234	481.558	7.044	697.118
69	9.314	490.872	7.024	704.142
70	9.876	500.748	6.828	710.970
71	10.346	511.094	6.780	717.750
72	10.394	521.488	6.776	724.526
73	10.408	531.896	6.656	731.182
74	10.662	542.558	6.612	737.794
75	11.144	553.702	6.610	744.404
76	11.452	565.154	6.594	750.998
77	11.650	576.804	6.586	757.584
78	11.838	588.642	6.388	763.972
79	11.864	600.506	6.332	770.304
80	12.058	612.564	6.284	776.588
81	12.168	624.732	6.156	782.744
82	12.186	636.918	6.126	788.870
83	12.202	649.120	6.086	794.956
84	12.374	661.494	6.044	801.000
85	12.552	674.046	6.032	807.032
86	12.606	686.652	5.990	813.022
87	12.866	699.518	5.936	818.958
88	13.100	712.618	5.906	824.864

89	13.162	725.78	5.694	830.558
90	13.290	739.070	5.690	836.248
91	13.370	752.440	5.576	841.824
92	13.562	766.002	5.574	847.398
93	14.394	780.396	5.280	852.678
94	14.576	794.972	5.246	857.924
95	14.608	809.580	4.954	862.878
96	14.688	824.268	4.784	867.662
97	14.942	839.210	4.784	872.446
98	14.982	854.192	4.630	877.076
99	15.672	869.864	4.468	881.544
100	15.712	885.576	4.032	885.576