Transport the Injured People to Hospitals on the Post-Disasters

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ABSTRACT

After a large-scale disaster in a metropolitan city, there are a lot of people who need urgent medical treatment in hospitals. The demand for emergency transportation of seriously injured people suddenly increases far above the available capacity. The reports on the locations and states of the injured persons arrive continuously. Firstly, a strategy of assignment and transportation of patients are analyzed. The transportation strategy of one hospital is modeled by the the problems $P||C_{max}$ and $P||\sum C_j$ of scheduling theory. It is also analyzed what the city should do to decrease the demand of transportation in both the pre-disaster and post-disaster periods. The research aims to describe a methodology on how the existing transportation capacity can be used in the best way. It consists of two parts. First, a Voronoi diagram of the existing hospitals is formed. Each hospital is responsible for its region in the diagram. The ambulance vehicles work for hospitals. Every patient has an estimated deadline until the person must reach the hospital, otherwise, he/she will die. Second, the objective of the schedule is to transport the maximal number of patients in time. In terms of scheduling theory, it is a problem having the objective function to minimize the sum of the unit penalties. More formally, it is $P||\sum U_j$ as the vehicles are supposed to be identical. Very few papers deal with this problem. Thus, the present research contains some new theoretical results on that problem as well. An algorithmic tool called partial oracle is also introduced and the meta-heuristic solution is based on that. The results of evaluate the capacity are demonstrated in the metropolitan city Istanbul and the result of the scheduling ambulances are demonstrated in three hospitals of the metropolitan city Tehran. Istanbul lies close to a geographic fault and Tehran has a high risk of earthquakes because the city is in the middle of the triangle of three geological faults.

Keywords: Humanitarian logistics, Post-disaster, Voronoi diagram, Partial oracle, Scheduling problems.

ÖZ

Büyükşehirde yaşanan büyük bir felaketten sonra hastanelerde acil tıbbi tedaviye ihtiyaç duyan çok sayıda insan var. Ağır yaralıların acil taşıma talebi, birdenbire mevcut kapasitenin çok üstüne çıkar. Yaralıların yerleri ve durumlarıyla ilgili raporlar sürekli gelir. İlk olarak, bir hasta atama ve nakil stratejisi analiz edilir. Bir hastanenin ulaşım stratejisi, zamanlama teorisinin $P||C_{max}$ and $P||\sum C_j$ problemleri ile modellenmiştir. Hem afet öncesi hem de afet sonrası dönemde kentin ulaşım talebini azaltmak için neler yapması gerektiği de analiz edilmektedir. Araştırma, mevcut ulaşım kapasitesinin en iyi şekilde nasıl kullanılabileceğine dair bir metodoloji tanımlamayı amaçlamaktadır. İki bölümden oluşur. İlk olarak, mevcut hastanelerin bir Voronoi diyagramı oluşturulur. Her hastane, diyagramdaki bölgesinden sorumludur. Ambulans araçları hastaneler için çalışıyor. Her hastanın hastaneye ulaşması için tahmini bir son tarihi vardır, aksi takdirde ölür. İkincisi, programın amacı maksimum hasta sayısını zamanında taşımaktır. Çizelgeleme teorisi açısından, birim cezaların toplamını en aza indirmek için amaç fonksiyonuna sahip bir problemdir. Daha resmi olarak, araçların aynı olması gerektiği için $P||\sum U_j$ şeklindedir. Bu sorunla ilgili çok az makale var. Bu nedenle, mevcut araştırma, bu problemle ilgili bazı yeni teorik sonuçlar da içermektedir. Kısmi oracle adı verilen algoritmik bir araç da tanıtıldı ve meta-sezgisel çözüm buna dayanıyor. Kapasite değerlendirmesinin sonuçları, İstanbul büyükşehir kentinde gösterildi ve ambulans planlamasının sonucu, büyükşehir Tahran'daki üç hastanede gösterildi. İstanbul coğrafi bir fayın yakınında yer alıyor ve Tahran, üç jeolojik fay üçgeninin ortasında olduğu için deprem riski yüksek.

Anahtar Kelimeler: İnsani yardım lojistiği, Afet sonrası, Voronoi diyagramı, Kısmi oracle, Çizelgeleme sorunları.

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To my Family

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ARP	Ambulance Routing Problem
BF	Best Fit
DM	Disaster Management
EDD	Earliest Due Date
EDDBF	Earliest Due Date Best Fit
EDDWF	Earliest Due Date Worst Fit
EMS	Emergency Medical Service
ERC	Emergency Reply Centers
GA	Genetic Algorithm
GIS	Geographical Information Systems
ILP	Integer Linear Programming
IMM	Istanbul Metropolitan Municipality
LPT	Longest Processing Time
LS	List Scheduling
NAF	North Anatolian Fault
PMS	Parallel Machine Scheduling
SA	Simulated Annealing
SPT	Shortest Processing Time
TS	Tabu Search
UAV	Unmanned Aerial Vehicle
USGS	United States of Geological Survey
UTM	Universal Transversal Mercator
WF	Worst Fit

WGS	World Geodetic System
WHO	World Health Organization
WIP	Work-In-Process

Chapter 1

INTRODUCTION

Many natural disasters cannot be predicted. Demand real-time, dynamic, immediate, effective and efficient solutions to protect the human being, animals, constructions, and property, restrain or contemplate hazards and immediately recover after a disaster. Earthquakes, flood, hurricanes, wildfire, terrorist attacks, bioterrorism, i.e. terrorism using biological weapons (Ózsvári, Kasza, & Lakner, 2017), volcano eruption, etc. usually involve a huge part of the city infrastructure which leads the rescue operations more difficult, such a problem is often computationally intractable. In fact, many different approaches and methods were used from operational research and system management to tackle these types of problems. For a survey see (Altay and Green III 2006). Every year lots of lives were taken around the world because of the disasters. United States of Geological Survey (USGS) stated that lots of earthquakes happen each year on earth also there have been more than 800,000 lost lives only for 15 years ending with 2015 due to earthquakes. 250 million people per year are affected by disasters, it was found that 125 catastrophe happened yearly around the world (United Nations 2007).

Earthquake is a natural disaster which has known place; however its time is unknown and its occurrence is sudden. It follows that both the pre-disaster and post-disaster periods are very important (World Health Organization 2002). It is possible to make measures in the pre-disaster period which decrease the effect of the disaster. The post-disaster period is a very operative time for the emergency and relief organizations. They can apply policies which are elaborated much earlier in the pre-disaster period and actions exercised also in the pre-disaster period.

If there are human lives to be saved and it is not possible to save everybody, then there is the serious problem which ethical principle should be applied. The underlying technical problem is that the capacity of the emergency services is smaller than the demand for savings. The ethical principle applied in this thesis is the maximization of the number of the saved lives. To save a life has two main phases which are transportation to the hospital and obtaining the medical treatment. This thesis is devoted to the transportation. Maximizing the number of the working operating rooms is the topic of another study (Shavarani, Golabi et al. 2019). One more ethical principle is applied in the thesis that no region is without service. Furthermore, it must be clear which unit is responsible for which patient. It is true both on the level of hospitals and ambulance vehicles.

(Altay and Green III 2006) stated that emergency response efforts be composed of four disaster operations management phases: mitigation, preparedness, response, and recovery. The definition of mitigation can be as a continuing action to preclude or reduce the risk to mankind and property from perils and their effects. Preparedness is the measures taken to prepare for and -while possible- prevent or reduce the effects of disasters. The response is using emergency procedures and resources as transcribed by emergency plans to save lives, the environment, property, etc. Recovery is the long-term actions taken to restore normalcy and stabilize the community after the immediate impact of the disaster has passed. Implementing plans, establishing command posts and shelters, and provisioning of all necessary emergency services are the activities of the disaster response phase. It is necessary to prepare for potential disaster situation in detail, however, once the actual disaster takes a place, complex responses must be developed by the managers on the scene in a compressed timeframe without higher-level managers' support.

Emergency Medical Service (EMS) is the most important service in saving lives and Ambulance Routing Problem (ARP) is one of its challenge which can increase the number of saved lives during a disaster (Tlili, Harzi et al. 2017). The operations research experts have been attracted to EMS decision making problems because of their sensitivity. They studied various problems and solutions in managing the EMS systems (e.g. (Kadri, Chaabane et al. 2014), (Bozorgi-Amiri, Tavakoli et al. 2017), and (Molenbruch, Braekers et al. 2017)).

In recent literature, EMS establishes emergency facilities, transfers injured patients to hospitals, provides medical assistance, rescues survivors, and orchestrates activities across multiple organizations. The response to a disaster classified into five categories: (1) Transportation planning: The suppliers' delivery program without assigning the ambulance. (2) Ambulance assignment: Allocating the ambulances to the appropriate emergency point. (3) Routing: Giving routes to the ambulances to save the patients. (4) Road repair: Repair damaged roadways and restore lifelines to affected areas. (5) Integrated problems: Set of individual problems have to be solved with one or more common objectives (Wren and Holliday 1972). The ARP addresses the routing issue followed by the strategy in which patients are transported between origin and destination points.

To supply first help to somewhat injured individuals and to bring truly injured individuals to working hospitals in the post-disaster period is the main mission of managing ambulances. It is massively complicated to manage the ambulances operations in the immediate post-disaster because the environment would be dynamics, i.e. the relevant information changes over time and leads to change the plan. The hospitals capacity, the ambulances availability, the information required to support the ambulances plans, and the location and number of people calling for help are the required information to support the ambulances' planning.

A lot of patients whose requires crucial medical care after any serious disaster in a metropolitan city, according to the injury and the severity of it. There is a deadline for every patient before he/she have to be in the operating room, otherwise, a live will be lost. This deadline can be obtained from expert system of triage using the information that has been given by the individual who will report the victim towards the emergency center. And of course, also the location will be known in the same way.

When the capacity of the emergency transportation system is high, then finding a schedule to show that everyone can survive and arrive to the hospital in time isn't needed and won't be a problem for the operations management. Although, when the capacity of a transportation vehicle is low, this is the situation in reality. Then saving all the persons will not be possible (Thomson 1985). Some studies projected the incorporation of military properties into the emergency taskforce in the period of post-disaster (Kallehauge 2008). If not all lives can be saved, then apparently it is necessary what type of ethical principles are used in the procedure of transportation. Maximizing the saved lives number is the easiest one (Shavarani and Vizvari 2018). Persons in isolated places have a small chance of surviving is result of this approach.

Nevertheless, maximizing the saved patient number principle is practical in this study. This research is focusing in the two indicated ethical principles and no more detailed the investigation of the ethical matters.

This research consists of two parts: Capacity evaluation and scheduling the ambulances of saving the seriously injured people by transporting them to the hospitals which have districts. Several ambulances in each district hospital with capacity 1, i.e. one seriously injured person can be taken in a route were assumed.

The rest of the research is as follows; the following Chapter reviews the associated literature. Chapter 3 considers the capacity evaluation of the ambulances. Chapter 4 awareness into the scheduling the ambulances problem explanation and mathematical model has been provided in case of small vehicle capacity, and finally in Chapter 5 provides a conclusion and future studies directions.

Chapter 2

LITERATURE REVIEW

The related literature is analyzed in four sections. In section 2.1, the studies on the disaster management and humanitarian logistics concept have been mentioned. The studies on Emergency response systems of a post-disaster is showed in sections 2.2 Section 2.3 described the studies of Voronoi diagram and it is applications. The scheduling concept of the parallel machine is illustrated in section 2.4.

2.1 Humanitarian Logistics and Disaster Management

According to International Federation of Red Cross and Red Crescent (IFRC) Societies "Disaster Management can be defined as the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, in particular preparedness, response and recovery in order to lessen the impact of disasters." (IFRC 2019). If the event contains at least two of the following criteria, then it called a disaster: (1) sudden, rapid event, (2) human and/or great economics loss, and (3) surpasses the community's ability in adapting with it (Papp 2019). Hence, humanitarian logistic activities include both the periods prior to and after the disaster. 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 (World Health Organization 2002). The preparedness and the prevention works in the disaster management are included before the disaster to reduce damages effect. The response and the rehabilitation periods are included in post-disaster period, see Figure 2.1.

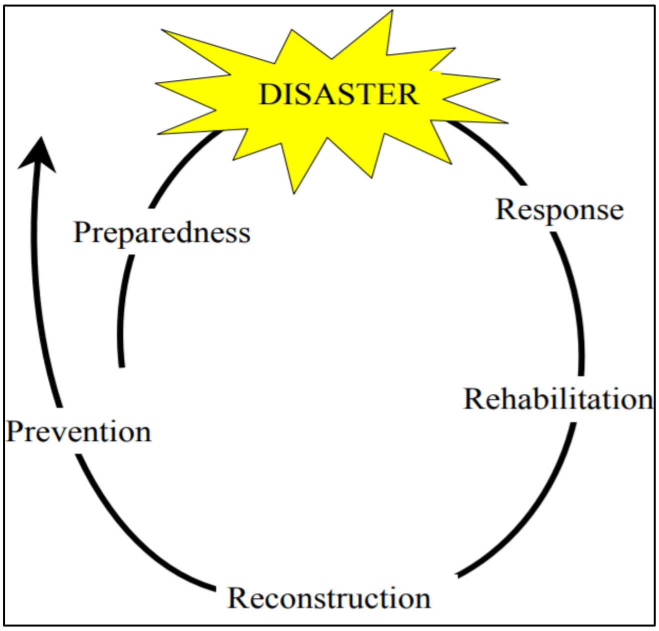

Figure 2.1: The disaster-development continuum. (World Health Organization 2002)

Disaster Management (DM) is the responsibility of the state first of all. Many countries and states published their DM plan including California which can be considered one of the best ones (CAL-EMA 2009). The group of universities have studied the master plan of earthquake (Ansal, Özaydın et al. 2003).

Local people and national and international organizations participations are extremely important in human logistics. (Sheppard, Tatham et al. 2013) identified how local people whom are at the domestic and hamlet levels, can consolidate their capacity to be ready and react more efficiently and effectively to the challenges in logistics that will appear in the post-disaster period. Their results showed that the ability of the local people has been altogether underestimated and underused. Subsequently, they found that an importance contribution is local population volunteering work in humanitarian logistic. Chong et al. (2018) studied on how the social media connects to infrastructure resilience with a community, the case was Chennai flood 2015, and they only used Twitter data as texts and geotags for identifying the locations of the affected areas, evaluating the seriousness of the damages, and identifying how to use the information to interpret the infrastructure resilience (Chong, Naganathan et al. 2018).

People communication is one of the important issues in humanitarian logistic during the disaster period. Özdamar and Ertem (2015) has studied some models, arrangements and empowering innovations on the reaction and recuperation arranging stages of the disaster period (Özdamar and Ertem 2015). Camera image processing or satellite are used as remote technologies to evaluate the damage and needs or assess the post-earthquake response, small Unmanned Aerial Vehicle (UAV) can be used in this sense (Nedjati, Vizvari et al. 2016).

Geographical Information Systems (GIS) based mapping frameworks are utilizing for the advancement of harm and misfortune scenarios in the disaster areas. Fiedrich et al (2000) created an optimized asset allotment model for post-disaster period (Fiedrich et al. 2000). Chang et al (2014) proposed an algorithm for controlling the dispersion of accessible assets and consequently producing a assortment of doable emergency logistics plans for decision-makers (Chang, Wu et al. 2014).

2.2 Emergency Response Systems of a Post-Disaster

Afterward a disaster, a huge number of victims should be evacuated to temporary resettlement sites. Many information from many different places and sources like police, reports of the civilian through satellite technologies were received by Emergency Reply Centers (ERC) (Delmonteil and Rancourt 2017). Because of the disaster a lot of connections might be lost that’s why this info contains data as well on the status of the transportation grid (Li and Tsukaguchi 2003). Instead, a significant rule is played by the period from the injury to medical involvement in the rescue procedures results (Wang, Cheng et al. 2009). To maximize the number of saved lives, ERCs use the information to plan the emergency vehicles ordering and which roads should be used. (Jotshi, Gong et al. 2009) divided the causalities to 4 types, the first one is slightly injured; the second type is temperately injured; the third type is severely injured; the forth type is mortally injured. An approximate deadline for patients can be determined with this categorization. Post-disaster decisions have to be fast so it can be operative, which dictates the solutions approaches to be fast and timely.

Obtaining the shortest routes among hospitals and casualties is the primary phases in calculating the roads for emergency vehicles, and among casualties themselves, in a situation as the capacity of the vehicle is one or more. However, by associating the 15 shortest path algorithms speed, Zhan and Noon (1998), and Vizvári, Shavarani (2020) confirmed that the applying the algorithms of shortest path can be time-consuming in large networks and a proper solution must be carefully chosen (Zhan and Noon 1998, Vizvári and Shavarani 2020), Chou, Romeijn et al. (1998) projected a hierarchical algorithm to reduce the needed period for the shortest route calculations, and to discover the distance among the nodes of a large grid (Chou, Romeijn et al. 1998). These are three extra approaches used in recent literature (Kula, Tozanli et al. 2012). Kovács et al (2019) stated that the shortest paths depend on the used weights. A shortest path is a basic feasible solution of a suitable basis of a linear programming problem (Kovács, Nagy, & Vizvári, 2019).

A model has been proposed by (Gong and Batta 2007) to find an alternative emergency vehicles location to clusters of causalities in the period of post-disaster. The minor geographic areas having some casualties close to each other are called clusters. The objective of their study is to minimize the makespan and the total flow time, by defining the amount of vehicles assigned to every cluster. The distances, life loss, waiting time and the hospitals capacity, are the most significant issues in dispatching emergency vehicles. Similarly, the statistics on infrastructure damages and networks are dynamic to road generation for emergency vehicles (Gong and Batta 2004). A dispatching model has been proposed by (Schaack and Larson 1989) that as an alternative of lessening the distance of the roads they functioned to minimize the waiting time of the target. When many patients are waiting and an emergency vehicle becomes free then the shortest path is used. In this situation, the nearest target is given the importance. In contrast, a model has been presented by (Kula, Tozanli et al. 2012) that reduces the vehicle traveling period and as an outcome maximize the amount of transported casualties. Each vehicle capacity is assumed one and no deadlines or time windows. In a different study, a multi-period robust optimization model has been proposed by (Yang, Guo et al. 2009) for the distribution of ambulances to hospitals. Their two stages solutions consisted of the knapsack problem and the shortest path. Only one center/depot has been considered for modeling the problem. (Gong and Batta 2004) made an interesting study where they considered the waiting periods of low priority patients and the allocation of ambulances for more urgency patiets.(Sacks, Larson et al. 1993), (Schaack and Larson 1986), (Sacks, Larson et al. 1993) discussed the Priority queuing in emergency response.

Feng and Wang, (2003) have considered on interstate emergency recovery (implies the works of street repairing within the saving period, i.e., post-disaster 72 hours) (Feng and Wang 2003). Development of a scheduling model for highway emergency rehabilitation right after earthquake was the aim of their study, defining the emergency response problem was the first work they have done. Then they have developed a multi objective-programming model to maximize the performance of emergency rehabilitation, minimize the risk of rescuers, and maximize the savings of life. Their results were examined by using Chi-Chi earthquake data that happened in Taiwan in 1999.

Arenas et al (2014) illustrated the emergency management scheme which shows the four phases : Mitigation, Preparedned, Response and Recovry. See Figure 2.2 (Anaya-Arenas, Renaud et al. 2014).

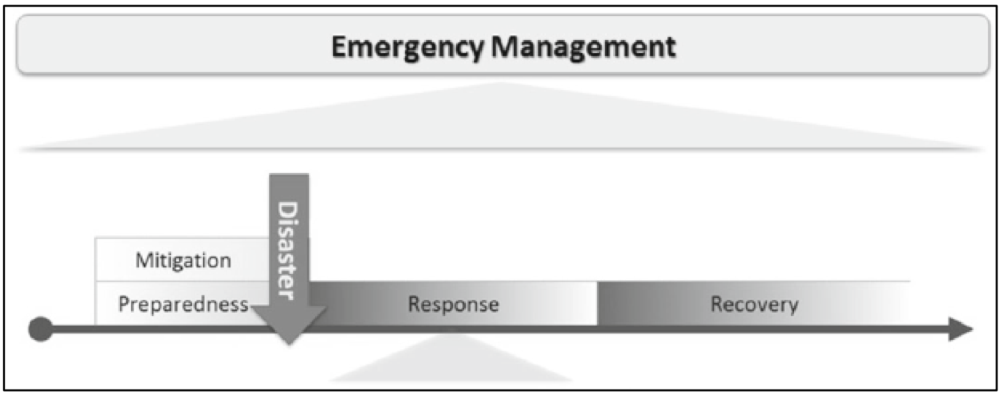

Figure 2.2: Scheme of the emergency management

The post-disaster period of an earthquake has many different problems to be solved. Immediate important tasks are distribution of relief items, saving people trapped under the ruins of collapsed buildings, reconnaissance of the damage in the city, communication to people, debris collection, etc. In the pre-disaster period resource allocation and stocking of relief items are important among others.

The problem of the transportation of seriously injured people to hospitals is one of the most important tasks. It is raised on in (Shavarani and Vizvari 2018) some models and mathematical properties are discussed in that paper. However, no general solution is provided.

2.3 Voronoi Diagrams

Georgy Voronoi defined Voronoi diagrams in 1908 (Aurenhammer, Klein et al. 2013), (Voronoi 1908). The dual of Voronoi structure was considered by Georgy Voronoi where any two sites are connected whose regions have a boundary in common (Voronoi 1908). A numerous, and different geometric problems can be solved by using the Voronoi diagram and its dual. Voronoi diagrams used in different fields of study such as a robot navigation (Thrun 1998), and material physics (Sze and Ng 2006). Representation or quantization problems in geometry usually used Voronoi diagrams, and in the field of robotics they are using Voronoi diagrams for creating a protocol for avoiding detected obstacles. They are useful for modeling natural occurrences, they are used in the studies of zoology, anthropology and archaeology, patterns of urban settlements, and forestry and ecology (Drysdale 1996). The geographic spread of the dialects of human languages is also described by Voronoi diagrams (Goebl 2010). In this paper, we considered the hospitals that have been district and the Voronoi diagram is used to know the nearest hospital for each injured person.

Azimi et al. (2012) proposed a multi-agent based modeling for optimal allocation of space to emergency centers using Voronoi diagram, in the result they minimized the ambulances travel time and path length (Azimi, Delavar et al. 2017).

Yushimito (2012) developed heuristic methods based on Voronoi diagram to allocate the distribution centers in the disaster, they minimized the social cost function for the chosen facility in the selected Voronoi region (Yushimito, Jaller et al. 2012).

Tai et al (2010) applied the weighted Voronoi diagram analysis to find the suitable plan for disaster prevention living area. They considered residents' evacuation demand including shelter choice preference, intention of evacuation, high-risk people of aged and children, and route of safety (Tai, Lee et al. 2010).

In this research, Voronoi diagram is used to divide the affected city in to regions to find the nearest hospital or medical center for each seriously injured person. When the responsible hospital is found using Voronoi diagram, then the scheduling process is needed for the Voronoi regions.

2.4 Scheduling of Parallel Machines

The main modeling and algorithmic tool in this research is the scheduling of identical parallel machines. Scheduling is mainly determining the time or order of operations. However, it is also used to assigning tasks to machines.

The scheduling of parallel machines has been intensively studied in the last ten years of the previous century and the beginning of this century. There are m machines and n jobs in the classical Parallel Machine Scheduling (PMS) problem. Each job j needs to be executed on one of the machines during fixed processing time p_j. Thus, finding the schedule that optimizes a certain performance measure is the objective (Mokotoff 2001). Two kinds of decisions are involved by the scheduling process, sequencing, and assignment of the jobs to the machines. Single machine problems ask just to find an optimal job sequencing, but in the multiple machines case, it is necessary to find an optimal job-machine assignment as well. When the number m of machines is increase; the problem becomes more complex and intractable. The combinatorial optimization problems are the class of this problem, many of which are known to be NP-hard (Cook 1971); (Karp 1972); (Garey and Johnson 1979); and (Papadimitriou 1994). Thus, it is not likely that there are polynomial exact algorithms to solve them. For cases where polynomial algorithms could not be found, heuristic methods were developed, and acceptable performance were shown for some of them.

The parallel machines can be identical, uniform or unrelated (Mokotoff 2001). This research considers parallel identical machines case. The intensive investigation of the identical parallel machine started by the famous paper of Graham, (Graham 1969) introduced the List Scheduling (LS) heuristics for minimizing the makespan problem $P||C_{max}$. (Coffman, Garey et al. 1978) introduced the multi-fit heuristics. (Glover and Hubscher 1994) presented a Tabu Search (TS) approach to the $P||C_{max}$ problem. They introduced an influential diversification, which improves the behavior and quality of the solutions obtained by general TS. Because $P||C_{max}$ is symmetric to the MinMax Bin Packing, they applied their approach to bin-packing, by improving the Simulated Annealing (SA) approach developed by (Kämpke 1988). (Frangioni, Necciari et al. 1999) also considered the $P||C_{max}$ problem by introducing new local search techniques whose neighborhood structure is based on multiple exchanges of jobs among machines. They showed that employing the proposed algorithms, near-optimal solutions could be obtained when the running time is not important, and satisfactory ones could be found rapidly. (Hashemian, Diallo et al. 2012) solved the problem of minimizing the makespan in large-scale problems and obtained effective numerical results. (Józefowska, Mika et al. 1998) combined linear programming and local search methods (Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithm (GA)). They showed that to find the largest number of optimal solutions and the smallest deviation for all sizes of the problem, they have to apply TS approach.

A Genetic Algorithm for the tardiness multiple machine problems were developed, and introducing random keys whose purpose is to maintain feasibility from parent to offspring (Bean 1994). When a set of independent jobs, with different due dates and ready times with sequence-dependent setups on a set of parallel machines needed to be scheduled to minimize the sum of the weighted earliness and tardiness, this will lead the problem to become more complex. (Sivrikaya-Şerifoğlu and Ulusoy 1999) provided two GAs that seem to be efficient for this complex problem.

In the case of parallel machines, only one machine processes each task. If the machines are identical, then the processing time of each job is the same on every machine. The most famous problem in the area of identical parallel machines is the minimization of the makespan. The makespan is the completion time of the last job. Another problem is also important for transporting injured people and it is the total waiting time which is called Work-In-Process (WIP) quantity in scheduling theory. These problems are denoted by $P||C_{max}$ and $P||\sum C_j$ on the usual notation of scheduling theory. The problem $P||C_{max}$ is NP-complete. This fact means in the practice that fast methods give only good approximate solutions instead of guaranteed optimal ones.

There are several different trends in recent research. These trends are not disjoint. There are studies which can solve large scale problems (Hashemian 2010), (Hashemian, Diallo et al. 2014), and (Kramer, Dell'Amico et al. 2019). Further constraints are added in other problems (Ozer and Sarac 2019), (Hashemian, Diallo et al. 2014), (Ji, Zhang et al. 2019) and (Kaabi and Harrath 2019). Different objective functions are also important (Lee 2018), (Li, Xiao et al. 2019), and (Nattaf, Dauzère-Pérès et al. 2019). The natural background and the basis of exact methods is integer programming. If the constraints are different, then the models are also different, see (Ozer and Sarac 2019) , and (Muñoz-Villamizar, Santos et al. 2019).

In this this research, the minimization of the sum of the unit penalties, which denoted by $P||\sum Uj$ in scheduling theory, is also applied with the help of its relations to the $P||Cmax$ problem (Pinedo 1995). Few papers discussed the minimization of tardy jobs in identical parallel machines. It started with the Bedworth and Baily book where they discussed a heuristic procedure that solves the problem (Bedworth and Bailey 1987). Ho and Chang (1995) presented two heuristics with several variations to achieve the same objective (Ho and Chang 1995). Süer et al. (1993) solved the problem by formulating an integer programming mathematical model and presented three simple heuristics, and later they evaluated their performance (Süer et al. 1993). Recently, Najat et al. (2019) discussed the same problem in case of several maintenance periods needed during the scheduling process, and they proposed a mathematical model and heuristic procedure to minimize the number of tardy jobs (Najat, Yuan et al. 2019). All of the previous research focuses on the manufacturing systems where finding the results can be done in reasonable time. To the best of our knowledge, no paper discussed the problem when an immediate answer required as in the situation of this research, where finding a schedule for saving the maximum number of serious injured people has to be fast, otherwise the person may die.

Chapter 5 considered the problem of saving seriously injured people by transporting them on time to the hospitals which have districts, where a large amount of data exists and an immediate answer is required to decide the routes. We assume that there are two ambulances with the same specifications in each district hospital with capacity 1, i.e., one seriously injured person can be taken in a route.

Chapter 3

CAPACITY EVALUATION

This chapter is developed to evaluate the ambulance capacity. It is assumed that an earthquake can hit the metropolitan city can occur at any time. A great number of people will need medical help in hospitals. A strategy of assignment and transportation of patients are analyzed. The approach is based on the assumption that each hospital has its region of responsibility. The transportation strategy of one hospital is modeled by the two well-known problems of scheduling theory. It is also analyzed what the city should do to decrease the demand of transportation in both the pre-disaster and post-disaster periods.

3.1 Methodology

The responsibility regions of the hospitals are determined by Voronoi diagram. The transportation within one region is scheduled by the methods of scheduling of identical parallel machines.

3.1.1 Voronoi Diagram

The concept of Voronoi diagrams dates back to the 17th century and is different from other aspects of computational geometry. It was first used in astronomy. In an illustration, the space was partitioned into convex regions; each consisting of matter revolving around one of the fixed stars.

The general notion of Voronoi diagram is as follows: Let M be a space, and $S \subset M$ a finite set of points. The space M is partitioned among the points of S such that the region of $p \in S$ consists of points of M closest to p among the points of S. Notice that the Voronoi diagram depends on the used distance. Thus, a set S may have several Voronoi diagrams. This concept has gotten to be valuable in different areas of science. For occurrence, medial axis change in biology and physiology, Wigner-Seitz zones in chemistry and material science, spaces of activity in crystallography, and Thiessen polygons in meteorology and topography. Voronoi as a mathematician has characterized this concept. As Voronoi specified, the double structure is where any two point of S are connected if their regions have a boundary in common (Aurenhammer and Klein 2000).

In this application, the collection of regions that divide up the plane is called a Voronoi diagram of "sites". Each site has its own region, and all the points in the interior of one region are closer to the corresponding site than to any other site. Where there is not one closest point, there is a boundary. In Figure 4.1, P1 and P2 are the points that are closer to site H1 than to any other site. Moreover, note that point P3, which is on the boundary between sites H3 and H5, is equidistant from both of those sites.

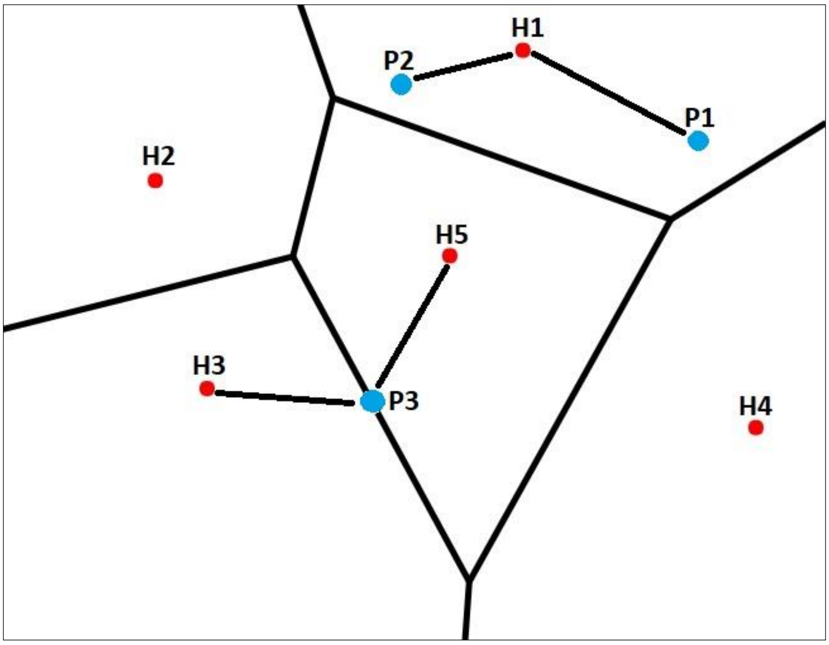

Figure 3.1: Voronoi diagram example in the plane

3.1.2 Scheduling

The concept of the scheduling of identical parallel machines will be used for the scheduling of patients to hospitals. In the basic model of parallel machine scheduling, there are n jobs and m machines. Each job is processed by only one machine. The machines are identical if and only if the processing times are independent of the machines and are dependent only on the job. A feasible solution of a problem instance assigns the jobs to machines and determines the time interval of the process of each job. These time intervals may not overlap on the same machine. If C_j is the point in time at which job j has finished processing, then the makespan or length of the schedule is $C_{max} = max\ C_j$ ((Pinedo 1995); (Sabti 2017); (Shmoys, Wein et al. 1995)). Some terms use in scheduling theory are as follow:

- **Processing time (p_j):** This is the time required by job j on each machine.
- **Due-date (d_j):** It is the time where job j should be completed.
- **Completion time (C_j):** It is the time when job j is finished.

- **Makespan:** The total amount of time required to complete all jobs. It is denoted by $C_{max} = max\ C_j$.

Dispatching rule is the method how the next job/operation is selected if another job/operation is completed. Three rules are used in this study as follows:

- **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.
- **The Shortest Processing Time first (SPT):** This rule orders the jobs in increasing order of processing times. Keeping jobs with long processing times for later.
- **The Earliest Due Date first (EDD):** This rule selects the job which has the earliest due date to be processed.

The following assumptions are considered before the problem formulation:

- Each machine can process only one job at a time.
- Each machine is available at time zero, however some jobs may not be available at that time.
- The machines are unrelated (the completion time of a job depends on the machine assignment).
- The jobs are non-identical (jobs have different processing times on each machine). All machines are identical and are able to perform all operations (all eligible).

- Preemption of a job on another mahcine and machine breakdowns are not allowed.
- No setup time is required. Or setup times are independent of job sequence and are included in the processing times.

3.1.2.1 List Scheduling

List scheduling is a way to assign jobs to machines. LPT list scheduling of identical parallel machines assigns the job to machines in the LPT order of the jobs. Each job is assigned to the currently least loaded machine. The method is shown by a small example. Assume that there are two machines, say M1 and M2, and five jobs with processing times 7, 6, 5, 3 and 1, respectively. The LPT list scheduling solution is as follows: the load of M1 is 7, 3, and 1; the load of M2 is 6, and 5. Notice that the job of processing time 5 is the third in the LPT order. When the algorithm assigned it, the loads of M1 and M2 were 7, and 6, respectively. As M2 had the smaller load, the job was assigned to M2. The performance ratio of LPT list scheduling is (Graham 1969)

$$\frac{C_{max}(LPT)}{C_{max}(OPT)} \leq \frac{4}{3} - \frac{1}{3m} \tag{3.1}$$

Here, m denotes the number of machines.

3.1.2.2 Work in Process Quantity

Work-In-Process (WIP) (Conway, Maxwell et al. 1988), stands for the total waiting time of the jobs. Each job waits until it is completed. Thus, the total waiting time is the sum of the completion times. Let p_j denote the processing time of the job in the jth position in the sequence of jobs on a single machine. The total completion time can be expressed on a single machine as

$$WIP = \sum C_j = np_{(1)} + (n-1)p_{(2)} + \cdots + 2p_{(n-1)} + p_{(n)} \tag{3.2}$$

This implies that there are n coefficients $n, n-1, \ldots, 1$ to be assigned to n different processing times. The highest coefficient which is assigned is n and assigned the first processing times, the second processing time, and so on. This implies that SPT gives the minimal WIP quantity on a single machine (Pinedo 1995).

3.2 Model and Solution Method

The aim is to analyze the performance of the emergency system. The available current and future capacities are assumed to be smaller than the potential demand. In the case of a real earthquake the situation is dynamic. The calls for asking transportation arrive to a center randomly. Therefore, there is no optimal solution, because the constraints are changing and what was optimal a short time ago is not optimal anymore. Thus, it doesn't make sense to develop a very large scale mathematical model as the model must be changed if the constraints are changed and the numerical solution of the model must be restarted. The result of this calculation policy would be wasting time. The decisions what must be made are as follows:

(1) Which hospital is responsible for an injured person?

(2) Which vehicle is responsible for a transportation?

(3) At what time will take place a transportation?

The capacity is analyzed in a static situation. It means that all the demands are known at time 0. As the decision maker has more information than in the dynamic case, better decisions can be made. Even the static version of the problem is too large for exact optimization. Therefore, a decomposition method must be applied and further methods are needed for solving the sub-problems. The scheduling theory is applied in a way such that what is machine in the language of scheduling theory, is vehicle in this research. The following assumptions are applied:

(1) The vehicles are identical.

(2) The vehicles work independently of each other even in the case if they belong to the same hospital.

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

(4) Each vehicle can process only one job at a time.

(5) Each vehicle is available at the time when the disaster occurs, *i.e.* at time 0 on the language of scheduling theory.

(6) Preemption of a job, i.e. temporary stopping of a transportation, and vehicle breakdowns are not allowed.

(7) Setup times are independent of job sequence and are included in the transportation times.

The first Problem is the decomposition. It is solved by Voronoi diagrams. Each hospital has a region of responsibility. This region consists of that part of the city which is closest to the hospital in question. Hospitals have emergency vehicles which are also called ambulances. Every mission starts and finishes at the hospital. If a hospital has more than one vehicle, then the second problem is that the demands must be assigned to vehicles. As the vehicles are assumed to be identical, this assignment problem is a special case of the assignment of jobs to identical parallel machines. Thus, the well-known method of scheduling theory can be used. It is LPT list scheduling which is provides a good approximate solution. Vehicles work independently of each other (Pınarbaşı et al 2020). The order of transportations on a vehicle is determined by the SPT rule. In a case of a large-earthquake, patients need to be taken to hospitals as soon as possible. This method is a bi-objective approach. Makespan has a low value because of LPT list scheduling. The WIP quantity, i.e. the total waiting time of patients, is minimized by the SPT rule on each vehicle separately. In the case of data structure, what can be expected in one region in Voronoi diagram in a metropolitan city is the LPT makepsan value should be very close to the optimal makespan value, and the mathematical explanation is in the Appendix A.

3.3 Example

In this chapter, the city Istanbul has been chosen to illustrate the results of the method used. Istanbul is a huge metropolitan city. Its population is estimated to 15 million. The city is located both on Europe and Asia on the two sides of the Bosporus strait and on the shore of the Sea of Marmara. The city’s main airport was the Istanbul Atatürk Airport. However, this airport was closed on 6 April 2019. Its function was taken over by the new Istanbul Airport which can accomodate 200 million passengers a year. The new airport is far from the center of the city and is close to the Black Sea. It gives space to the development of new parts of the city. Thus, one can expect that the population of the city will increase by several millions soon.

The area of Turkey is tectonically active including the Marmara Sea region which is one of the most active regions in Eurasia with one third of the Turkish population. The long North Anatolian Fault (NAF) has a branch under the Marmara Sea. NAF is formed in the northern territory of Turkey over 1,000 km long from east to west, and historically there have been many heavy earthquakes along the line of the 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, Gülkan et al. 2008), (Picozzi, Strollo et al. 2009).

An earthquake in Istanbul can cause very serious damage. (JICA 2002) estimated the numbers of collapsed houses, seriously injured people and death toll in the case of several scenarios. The number of injured people is very high. Thus, both the transportation of the patients and the running of the hospitals including the operating rooms need good organization and management. The topic of this chapter is the analysis of the capacity of the emergency transportation system of the Asian side of Istanbul.

There are several large cities in a situation similar to Istanbul. San Francisco, Los Angeles, Tehran, and Tokyo are good examples. They all face the possibility of serious earthquake. Hence, if some principles and methods can be applied to Istanbul, then something similar can be applied to other such cities.

The most populous city in Turkey is Istanbul with 15 million people in 2018 (Nufusu 2018). Istanbul is an interconversion city on the Bosporus strait in northwestern Turkey. It is located between the Black Sea and the Marmara Sea.

Istanbul city has been the foremost crowded city with a conspicuous role in social and commercial activities for at least two millennia. Even though Istanbul may be an exceptionally ancient city of 2500-3000 years, it developed very quickly particularly after 1950s. (Inceoglu and Yurekli 2011) illustrated in a table which can be seen in Table 3.1.

Table 3.1: Population of Istanbul

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

Rapid population growth has some negative effects. Density and crowd cause environmental, noise, image and light pollutions. Moreover, squatters and unplanned urbanization, problems in infrastructure, transportation, health services, etc. can be observed as well (Saritas 2017).

District "Adalar" consists of small islands in the Marmara Sea. Thus, ambulance vehicles cannot connect it with other parts of the city. Even its population is small. Therefore, it was excluded from the analysis. Table 3.2 illustrates the populations of the all 14 districts in Asian side of Istanbul (Nufusu 2018).

Table 3.2: Data of districts in Istanbul

No.	**District**	**Population**	**No.**	**District**	**Population**
1	Ataşehir	416.318	8	Sancaktepe	414.143
2	Beykoz	246.700	9	Sultanbeyli	327.798
3	Çekmeköy	251.937	10	Üsküdar	529.145
4	Kadıköy	458.638	12	Şile	36.516
5	Kartal	461.155	13	Tuzla	255.468
6	Maltepe	497.034	14	Ümraniye	690.193
7	Pendik	693.599			

3.3.1 Hazards and Vulnerabilities

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.

Geologically, Turkey is located at the boundary area where the Arabian Plate and African Plate are moving north towards the Eurasian Plate. One of the foremost dynamic region in Eurasia is the Marmara Sea region with one third of the Turkish population. The largest city in this area is Istanbul. One of the factors controlling the earthquake hazard for Istanbul is the North Anatolian Fault which in the Marmara Sea region forms a complex fault system.

Tsunami also is one of the disasters that Istanbul is suffered from, as, more than 90 tsunami have occurred in Turkey in the last 3000 years with more than 8300 km of coastline. It was detected in all seas of the country, the Marmara Sea in special. More than 300 destructive earthquakes occurred in the Sea of Marmara. 40 of them caused tsunami during the last 4100 years (BDTIM 2017).

As of now, there are completely 219 active emergency vehicles in Istanbul. The mission time for an emergency vehicle is approximately 20 minutes, however, this time might be increased in the emergency case (YILMAZ, KARAKUŞ et al. 2014). The number of hospitals are 74 in total in the Anatolian side of Istanbul. Figure 3.2 shows the locations of the hospitals in the map of Istanbul used by ArcGIS software. The location of the hospitals are in Universal Transversal Mercator (UTM) projection, distances were registered in World Geodetic System (WGS84) spheroid and datum, UTM Zone 35 North.

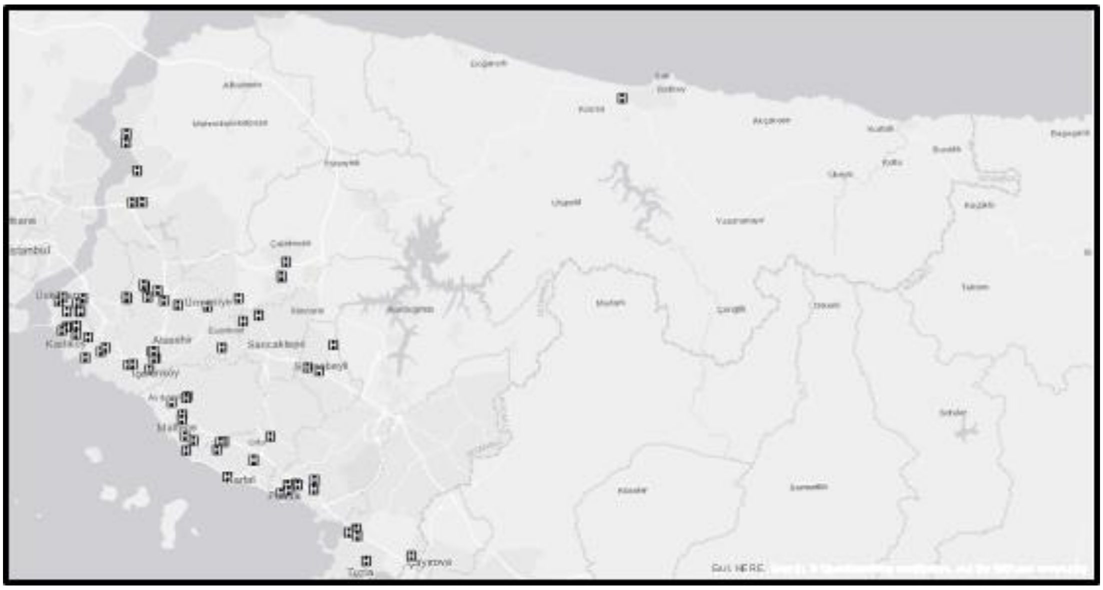

Figure 3.2: The location of the Anatolian side Hospitals of Istanbul

The estimation of the number of human death and injuries are 73,000 and 120,000, respectively in case of an earthquake of strength 7 on the Richter scale. The study was made by Japanese International Cooperation agency with Istanbul Metropolitan Municipality (IMM) in 2002. They indicated that 51,000 buildings were damaged and that was 7.1% of the total buildings in the area of study. The gotten results show that the southern region of Istanbul is more intensely harmed than the northern region since of the earthquake movement dispersion (JICA 2002).

3.4 Results and Discussion

Voronoi diagram divided the Anatolian side of Istanbul into 74 regions. This means, every hospital has its own region to serve the patients as shown in Figure 3.3.

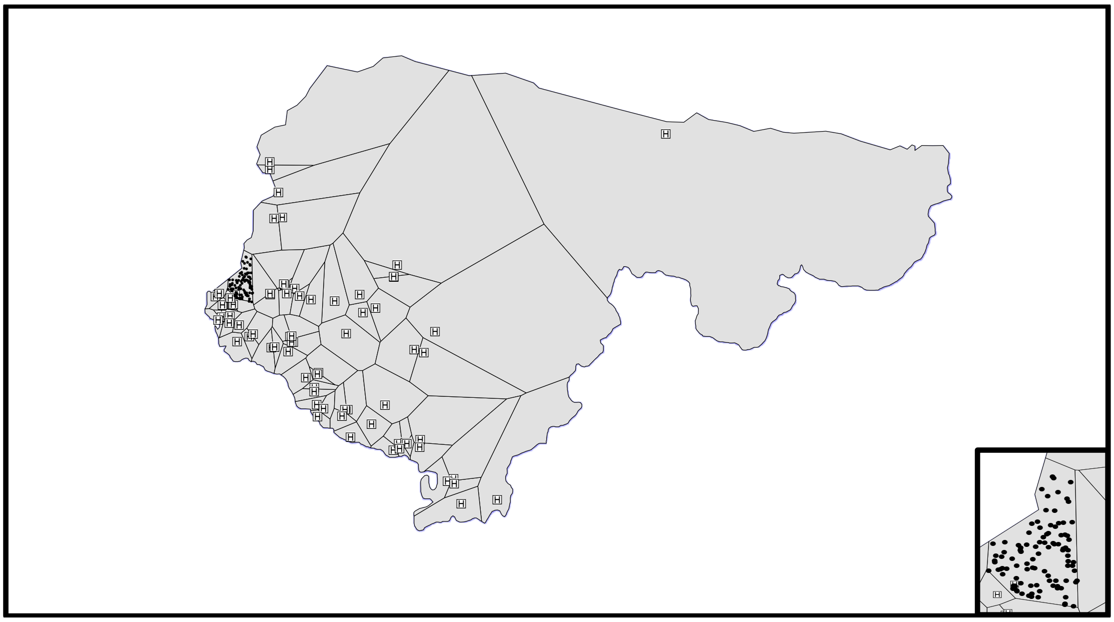

Figure 3.3: Istanbul Anatolian side divided by Voronoi diagram into 74 regions.

The studied area can be seen as zoomed from the right bottom corner in Figure 3.3 which is the region for Başkent University Hospital. The reason of chosen is because the Başkent University Hospital is located in Üsküdar which has a highest population in this side of Istanbul. Moreover, it is larger than the most of the other populated regions.

After division of the city by Voronoi diagram, 100 patients have been assigned randomly to the studied region as shown in Figure 3.3. Each patient has a certain processing time which is obtained using the coordinate of the patient to calculate the distance and the speed of the vehicle. The Manhattan-like city is estimated to calculate the distances.

To get WIP quantity, some rules have applied as following:

- LPT List Scheduling is used to assign the patients to the vehicles.
- SPT order is applied on each vehicle.

The Başkent University Hospital can be considered typical. Table 3.3 shows results for the region of responsibility of every hospital. 100 patients have been distributed into every region randomly by ArcGIS software processing times are calculated. Three cases were considered in this research.

3.4.1 The Case of a Single Vehicle

In this case, single vehicle was put into service for 100 patients. SPT and LPT orders of transportation are compared as shown in Figure 3.4a. The WIP quantities were obtained by SPT and LPT order 36,448.1 and 52,995.1 minutes, respectively. SPT is the best strategy on a single vehicle while LPT is the worst. For instance, according to SPT rule; 68 people would be saved in 481.6 minutes. On the other hand, 697.1 minutes are required to save 68 people for LPT rule.

3.4.2 The Case of Two Vehicles

In this case, 2 vehicles transport 100 patients to the hospital. LPT rule has been applied for assignment of patients to vehicles as shown in Figure 3.4b. WIP quantities are found 9,210.8 and 9,236.3 minutes for the first and second vehicles, respectively using formula (3.2). The required time to transport all the patients to hospitals decreased. For example, 90 patients can be saved by 2 vehicles in 369.8 minutes. It is worth to compare this results with the transportation time of the first 45 patients with one vehicle which needs 285.1 and 518.4 minutes for SPT and LPT orders, respectively.

3.4.3 The Case of Three Vehicles

LPT rule has been applied on the processing times. The WIP quantities of the three vehicles are 4,396.8, 4,399.0 and 4,240.8, respectively as shown in Figure 3.4c. 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, 661.5 minutes are required for SPT order in the case 1 of a single vehicle.

The loads of the vehicles are 293.9, 293.9, and 297.9 minutes. The loads are also close one another in the case of two vehicles. The loads are determined by the LPT list scheduling. Based on the performance ratio of this method, one can expect much higher differences in the loads.

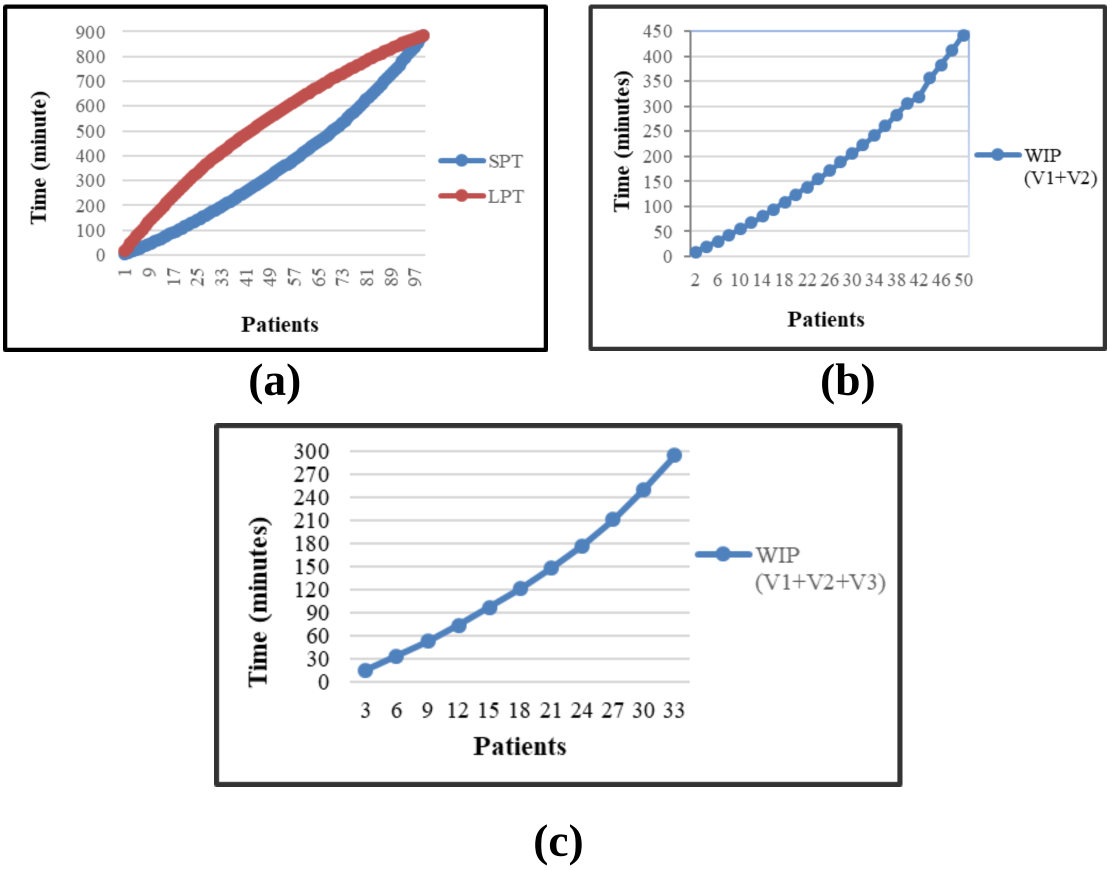

Figure 3.4: The C_j value for 100 patients according to LPT in the case of (a) single vehicle, (b) two vehicles, and (c) three vehicles.

3.4.4 Distribution of the vehicles among hospitals

Table 3.3 shows the number of patients transported to the hospitals according to the number of ambulances assigned to the hospitals (i.e. 1, 2, and 3 ambulances, respectively) in three hours.

As can be seen from Table 3.3, 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.

The number of emergency vehicles is low in Istanbul (YILMAZ, KARAKUŞ et al. 2014), as it was mentioned in section 3.4. It is important to use such a limited capacity in an effective way. In what follows a new model is presented for the distribution of the emergency vehicles among hospitals. The second ethical principle is applied in the model. Every hospital gets at least one vehicle. There is no region without service in this way. The basis of the model is Table 3.3. Similar results of the simulation of the post-disaster situation can be generated if more data are available.

Table 3.3: The number of patients transported to the hospitals within 3 hours

Hospitals	The number of vehicles			Hospitals	The number of vehicles		
	1	2	3		1	2	3
1	22	36	47	39	34	62	86
2	33	60	82	40	31	56	77
3	34	62	84	41	15	24	34
4	39	74	202	42	22	40	54
5	30	74	120	54	34	60	81
6	39	74	196	44	37	66	92
7	36	68	94	45	36	68	96
8	13	20	28	46	34	60	83
9	39	74	193	47	38	70	96
10	29	52	67	48	34	62	84
11	37	70	182	49	34	60	79
12	27	50	69	50	31	54	77
13	36	64	87	51	29	50	69
14	36	68	96	52	40	76	196
15	34	62	84	53	31	54	75
16	32	56	77	54	39	72	100
17	38	72	192	55	29	50	68
18	33	60	77	56	34	62	85
19	39	74	189	57	26	44	61
20	31	52	68	58	33	60	84
21	37	68	93	59	32	58	79
22	33	60	81	60	35	64	87
23	35	64	90	61	29	52	69
24	35	64	90	62	31	54	72
25	32	56	78	63	34	85	62
26	33	58	81	64	24	55	42
27	37	68	96	65	19	30	39
28	39	74	186	66	29	52	70
29	27	46	66	67	37	68	96
30	28	46	60	68	35	62	87
31	15	22	30	69	38	70	96
32	31	56	78	70	30	54	73
33	29	52	72	71	35	64	90
34	30	54	74	72	34	64	88
35	15	24	33	73	39	72	199
36	27	44	59	74	31	54	75
37	22	36	50				
38	30	52	69				

The model is based on the assumptions as follows:

- Every vehicle is assigned to a hospital.
- A hospital may have at least 1, and at most 3 vehicles.
- The objective is to maximize the number of persons who are transported to hospital within the first three hours.

The notations of the coefficients and variables are as follows:

t_{ij}: The number of injured persons transported to hospitals within the first three hours if hospital i has j vehicles (like the elements of table 3)

V : The total number of vehicles

x_{ij}: Binary variable; it is 1 if and only if hospital i has j vehicles

The objective is to maximize the number of transported persons:

$$\max \sum_i (t_{i1}x_{i1} + t_{i2}x_{i2} + t_{i3}x_{i3}) \tag{3.3}$$

All vehicles are used:

$$\sum_i (x_{i1} + 2x_{i2} + 3x_{i3}) = V \tag{3.4}$$

The number of vehicles of each hospital is between 1 and 3:

$$\forall i: x_{i1} + x_{i2} + x_{i3} = 1 \tag{3.5}$$

For the sake of completeness the binary property is mentioned once more:

$$\forall i \forall j: x_{ij} = 0 \text{ or } 1 \tag{3.6}$$

The model should be solved in the pre-disaster period. The application of the optimal solution is part of preparedness. Obviously, the values t_{ij} are taken from Table 3.3 or equivalent. The time limit, i.e. the 3 hours parameter of Table 3.3, can be changed to find the best policy for a city. Similarly, the value V can be changed and determine the best realistic value of the number of vehicles.

Calculations were carried out based on Table 3.3. The locations of the injured persons were determined randomly. If the number of ambulances is 100, then 4060 can be transported to hospitals in the first three hours. If the number of vehicles are increased to 150, then 5427 persons are saved, see Figure 3.5.

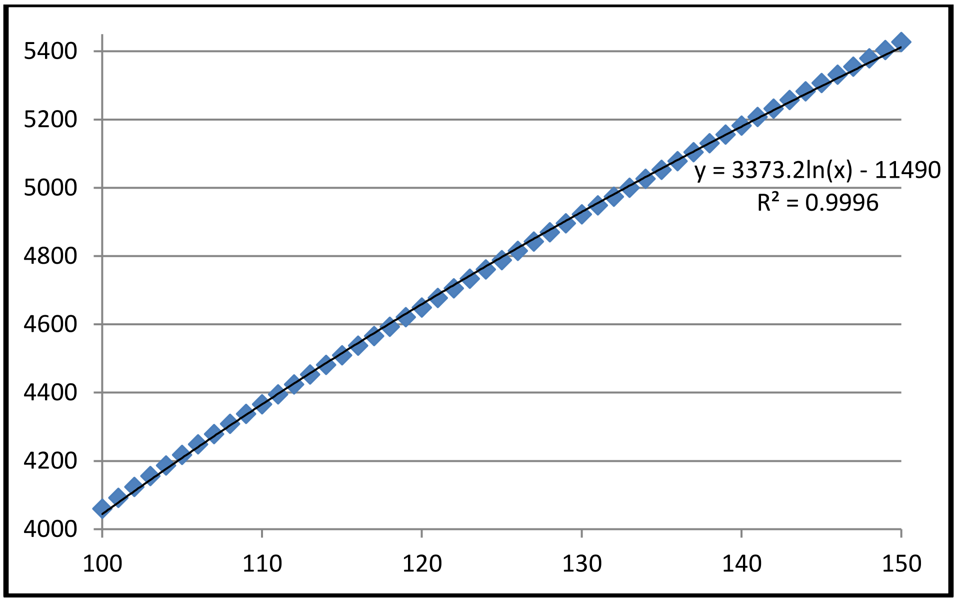

Figure 3.5: The number of saved persons depending on the vehicle number

Chapter 4

SCHEDULING AMBULANCES

In this chapter, the transportation of the seriously injured persons was considered to maximize the number of saved persons. It is massively complicated to manage the operations of ambulances in the immediate post-disaster because the relevant information changes over time and leads to changing the plan.

According to the type and severity of the injury, for every patient there is a deadline before which he/she must arrive at the operating room, otherwise the patient will die. This deadline can be obtained from the expert system of triage using the information that has been given by the person who will report the victim toward the emergency center. It is obvious that the location is also acquired in the same way. This chapter suggests a method for using the available ambulances in an effective way. The suggested method can be used in an automated system.

4.1 Methodology

Post-disaster transportation is a very hard problem. A large number of vehicles must be controlled. Each ambulance vehicle must execute several missions. A way of simplification is if the disaster area is divided among the hospitals. Several hospitals which can operate to save the injured people after the disaster happened were considered. A Voronoi diagram as in section 3.1.1 was applied in a metropolitan city to know which hospital is near the injured patient in a normal case.

4.1.1 Voronoi Diagram in a Dynamic Environment

The response part of the post-disaster period is a dynamic environment. Reports arrive to the headquarter ERC from different sources and with different content. The following four types of reports are important from the point of view of the problem in question: (a) report on an injured person, (b) report on the state of a road, (c) report on a mission of an ambulance, and (d) report on the capacity of a hospital.

If a hospital reports that it is temporarily full and cannot receive patients, then it is not possible to transport people to that hospital. The meaning of such an event, in the language of the Voronoi diagram, is that one site is deleted with its region. It implies the change of other regions as well. It raises the question of whether it is necessary to recalculate the Voronoi diagram from the beginning.

The sites of the diagram are the hospitals. The Voronoi diagram is only an informative object in the pre-disaster period. It is not possible to know before the disaster which hospitals will not be damaged and keep their ability for functioning. Thus, the disaster can change the set of sites of the diagram.

The way of thinking can be changed. The notion of the Voronoi diagram may give the impression that the regions of the sites/hospitals are the most important information. It is not true in the application in question. What the system must know is the converse information that is a location where an injured person can be found belongs to which hospital. It can be determined by the simple calculation of the distances of the location to the working hospitals. The potential patients of each hospital are stored in a list. If a hospital is reported to be full, then its list is deleted and its patients are distributed to the working hospitals. The list is created again if the hospital reports that further patients can be received. The calculation of the distances takes negligible time in an automated system.

4.1.2 Mathematical Model in Case of Small Vehicle Capacity

Assume that the capacity of each ambulance vehicle is 1, i.e., a vehicle can transport only one seriously injured person. The vehicles behave in that case like machines in a workshop. A job is the transportation of a person to the hospital. When it is completed, the vehicle immediately can go to the next person, i.e., it can start the process of the next job, in the language of scheduling theory. The vehicles are supposed to be identical. Each person is transported to the hospital only once, i.e., each job is processed by only one machine. This situation is called the case of identical parallel machines in scheduling theory.

It is also supposed that each person has his/her due date. It means that if the person reaches the hospital not later than the due date, then the person is saved. If the person arrives later, then he/she dies. The declared ethical principle is to save as many lives as possible. It is equivalent to minimizing the number of persons arriving at the hospital after the person's due date. In the language of scheduling theory, it means that every job has a due date. If a job is completed after its due date, then the job is tardy. This objective is to minimize the number of tardy jobs or, equivalently, to minimize the sum of unit penalties in scheduling theory where the unit penalty is 1 if the job is tardy and is 0 if the job is completed on time.

Thus, minimizing the sum of unit penalties on identical parallel machines is a proper mathematical model of the problem. It is denoted by $P||\Sigma U_j$ in scheduling theory. P stands for identical parallel machines. U_j is the unit penalty of job j.

More precisely, $P||\Sigma U_j$ is the model of the problem for the static case. The static case means that all necessary information is available at the beginning including all jobs, i.e. all injured persons with their location, transportation times and due dates. We present the Integer Linear Programming (ILP) model with the notations described below.

y_j: 1 if the patient j is saved, 0 otherwise

x_{ijk}: 1 if the patient j is the k^{th} patient of vehicle i, 0 otherwise

p_j: the time needed to take patient j to the hospital

d_j: the deadline of a patient j

M: a big positive number

n: the number of patients

v: the number of vehicles

k: the position number, where the maximum $k = n + 1 - v$

i: index for vehicles, $i = 1,2, \dots, v$

j: index for patient, $j = 1,2, \dots, n$

The objective is to maximize the saved persons in the model, as shown in Eq. (4.1).

$$max \sum_j y_j \tag{4.1}$$

The constraint of Eq. (4.2) ensures that each patient must be assigned to exactly one position.

$$\sum_i \sum_k x_{ijk} = 1, \qquad \forall j \tag{4.2}$$

Eq. (4.3) guarantees that no more than one patient can be transported in each vehicle trip.

$$\sum_{j} x_{ijk} \leq 1, \forall i, k \tag{4.3}$$

Finally, the transportation time required for reaching the hospital cannot exceed the deadline of the selected patients, which is ensured by Eq. (4.4) where M is a big number. Specifically, when $x_{ijk} = 0$, the dominant M ensures that the right term is greater than the left. When $x_{ijk} = y_j = 1$, we ensure that patient j arrived at the hospital by vehicle i on time.

$$\sum_{u=1}^{k-1} \sum_{w \neq j} p_w x_{iwu} + p_j x_{ijk} \leq d_j + M(1 - x_{ijk}) + M(1 - y_j), \forall i, j, k \tag{4.4}$$

The $P||\Sigma U_j$ problem in general is NP-complete. In the more or less chaotic post-disaster period, as it has been mentioned in Section 4.1.2, the reports on the injured persons arrive at different times. Every new report changes the problem. This feature is discussed in Section 4.2.5

4.2 Mathematical Analysis of the Problem $P||\Sigma U_j$

The problem $P||\Sigma Uj$ is NP-complete, see Appendix B. The practical meaning of this statement is as follows. If a problem is NP-complete, then the existence of a fast algorithm which can solve all instances of the problem class is unlikely. However, this existence is undecided in mathematics for the time being.

The problem $1||\Sigma U_j$ is closely related to $P||\Sigma U_j$. There is only one machine in $1||\Sigma U_j$. The solution method of $1||\Sigma U_j$ is called either Moore's algorithm, Hodgson's algorithm, or the Moore–Hodgson algorithm (Moore 1968). There is no original publication of Hodgson. However, Moore's paper contains the contribution of Hodgson as well (Hodgson 2018).

A short description of the problem $1||\Sigma U_j$ is as follows: The number of jobs is n. Every job j has a processing time (p_j) and due date (d_j). All jobs are available for processing at time 0. The machine can process one job at a time. There is no set-up or other technical breaks between two consecutive processes. The objective is to minimize the number of tardy jobs.

4.2.1 Moore–Hodgson Algorithm

The algorithm decides on the schedule of jobs one-by-one in the earliest due date (EDD) order. The due dates are monotone increasing in this order. If it is not possible to finish a job on time, then a job, either the same or an earlier scheduled one, becomes tardy. The non-tardy jobs are scheduled after each other in the EDD order. The tardy jobs are scheduled after the non-tardy jobs.

Notations. t_k is the total processing time of the jobs on time at the end of the kth iteration ($t_0 = 0$). The sets of scheduled and tardy jobs are denoted by S and T, respectively. At the beginning, $S = T = \emptyset$.

STEP 1. Determine the EDD order of the jobs. (It is assumed without loss of generality that this order is the index order of the jobs.)
$t_0 := 0$
STEP 2. For $k := 1$ **to** n **do**
begin
if $t_{k-1} + p_k \leq d_k$
then
begin
$S := S \cup \{k\}$
$t_k := t_{k-1} + p_k$
end
else
begin
$i := argmax\{p_j : j \epsilon S \cup \{k\}\}$
$S := (S \cup \{k\}) \setminus \{i\}$
$t_k := t_{k-1} + p_k - p_i$
$T := T \cup \{i\}$
end
end

The key observation is that if the inequality $t_{k-1} + p_k > d_k$ is satisfied, then it is exact evidence that there must be a tardy job in the set $S \cup \{k\}$. It is possible to generalize the structure of the algorithm for the problem $P||\Sigma U_j$.

In the theory of algorithms, the word oracle means a procedure that gives the correct answer for a decision (YES/NO) problem. The complexity of an oracle-using algorithm is measured many times in the number of used oracles. This time, it helps to explore the structure of the optimal solution. Let X be a subset of jobs. The oracle answers the question as follows:

Is it possible to complete all the jobs of X on time? (4.5)

If the answer is YES, then such a schedule exists. If the answer is NO, then there is at least one tardy job in any schedule of the jobs of X. The notation $oracle(X)$ is used for the answer in the description of the algorithm. Thus, $oracle(X)$ is a Boolean-valued function, i.e. its value is either YES or NO. Notice that the underlying problem in question (4.5) is a sub-problem of the complete problem. Thus, it belongs to the same problem class.

The running time of the oracle can be long as it solves an instance of the NP-complete problem. The concept of this oracle is still algorithmically useful, as discussed in Section 4.2.4

The algorithm has the same basic steps as the Moore–Hodgson algorithm. It selects the jobs to be scheduled on time in the EDD order. If a tardy job must exist, then it selects the job having the longest processing time among the candidates being on time and changes its state from on time to tardy.

4.2.2 Structural Algorithm of $P||\Sigma Uj$

STEP 1. Determine the EDD order of the jobs. (It is assumed without loss of generality that this order is the index order of the jobs.) Set $S = T = \emptyset$.

STEP 2. For $k := 1$ **to** n **do**
begin
if $oracle(S \cup \{k\})$
then $S := S \cup \{k\}$
else
begin
$i := argmax\{p_j : j \epsilon S \cup \{k\}\}$
$S := (S \cup \{k\}) \setminus \{i\}$
$T := T \cup \{i\}$
end
end

Theorem 1 shows that the Structural Algorithm provides an optimal solution.

Theorem 1. The set S provided by the Structural Algorithm is a set of on-time schedulable jobs of maximal cardinality.

Proof. Induction is used to prove that the set S has the following two properties in every iteration k.

(1) S is a maximal cardinality subset of the first k jobs such that all jobs of S can be scheduled on time.

(2) Among the subsets of the first k jobs satisfying property (i), S has minimal total processing time.

The statement is true for $k = 1$. If the first job can be completed without tardiness, then the only maximal cardinality subset is $S = \{1\}$; otherwise, S remains empty set. In a general iteration k, there are three cases. If job k can be added to set S without the deletion of any other job, then the number of on-time jobs is increased by 1. Assume that a set of jobs denoted by U satisfies properties (1) and (2) in iteration k. U must contain job k, otherwise it contains a smaller number of jobs than S. Hence, it follows from the inductive assumption that S also satisfies property (2). If job k cannot be added to set S without the deletion of another job and itself has the maximal processing time, i.e. set S is unchanged in iteration k, then (1) and (2) are satisfied.

The last case is when job j changed for job k with $j < k$ and $p_j > p_k$. Property (1) is satisfied if it is shown that it is not possible to add both job k and another job $l \in T$ to S. If $j < l < k$, then $p_l > p_j$ as a job j was present in S at the deletion of job l. Thus, the repositioning of job l back to S increases loads of the machines. If $l < j$, then the repositioning of job l back to S creates infeasibility among the jobs contained in S at the end of the iteration when job l was moved to T. Thus, another job must be deleted, that is, the cardinality of S is not increased. It follows from the selection of job j that S has the minimal possible total processing time among the sets of jobs that satisfy property (2).

4.2.3 Relationship of the Problems $P||\Sigma Uj$ and $P||Cmax$

In the problem $P||C_{max}$, the makespan, i.e. the greatest completion time, is to be minimized. If it is greater than the maximal due date in the problem $P||\Sigma U_j$, i.e. $d_n = max\{d_j: 1 \leq j \leq n\}$, then it is obvious that at least one tardy job must exist in $P||\Sigma U_j$. Let Q be an optimization problem. The optimal value of Q is denoted by $\nu(Q)$. In a more formal way, the statement is

$$\nu(P||C_{max}) > d_n \ \ implies \ \ \nu(P||\Sigma U_j) \geq 1 \tag{4.6}$$

It is not inevitable to solve the problem $P||C_{max}$ with a complicated and long algorithm to obtain a conclusion of type (4.6). The theory of the problem $P||C_{max}$ is rich, and there are easy tools to get such a conclusion. The first thing to be mentioned is that there is a well-known lower bound of $\nu(P||C_{max})$, which is

$$LB = max\left\{\frac{\sum_{j=1}^{n} p_j}{m}, max\{p_j: 1 \leq j \leq n\}\right\} \tag{4.7}$$

The first term is the average load of the machines, and the second term is the longest processing time. Both are individual lower bounds. There is an upper bound of $\nu(P||C_{max})$, which is

$$UB = max\left\{\frac{2 * (\sum_{j=1}^{n} p_j)}{m}, max\{p_j: 1 \leq j \leq n\}\right\} \tag{4.8}$$

The first term is the double of the average load of the machines.

A large part of the literature of $P||C_{max}$ started with the celebrated paper (Graham 1969). Graham analyzes a heuristic method of $P||C_{max}$. It is called the longest processing time (LPT) list scheduling. The method assigns the jobs to machines in the decreasing order of processing times. Each job is assigned to a temporarily least loaded machine. Graham proves an implicit lemma in the proof of the main theorem.

Lemma 1. If the LPT list scheduling assigns on each machine two jobs at most, then the provided solution is optimal (Graham 1969).

Lemma 1 means that the solution of the problem can be possible if the number of jobs is low relative to the number of machines.

The LPT list scheduling and any other heuristic methods can be used in the opposite direction as well. If all jobs are on time in the solution provided by a heuristic method, then the answer of $oracle(S)$ is YES. The LPT list scheduling method has some improvements (Dósa and Vizvári 2004). The optimal positions of the next k jobs are determined in each iteration of this method. However, only the first of the next k is assigned to its optimal position. If k is fixed, then the complexity of the iterations is $O(1)$.

The performance of a heuristic method of a positive minimization problem can be characterized by the so-called performance ratio. It is the largest possible value of the ratio of the value of a solution provided by the heuristic method and the optimal value of the same problem instance. For example, let $C(LPT)$ be the makespan by the LPT list scheduling. Then

$$sup_{P:} \frac{C(LPT)}{v(P||C_{max})} \tag{4.9}$$

is the performance ratio of LPT list scheduling.

4.2.4 Fast Heuristics Using a Partial Oracle

As the oracle must solve a problem which is NP-complete, it is not reasonable to assume that a perfect oracle can be applied in real practice. Therefore, a weaker notion is introduced which can be a procedure of a computer program. A partial-$oracle(X)$ is a partially defined Boolean-valued function, i.e., its value is either YES or NO or UNDEFINED.

The partial oracle contains procedures for proving and disproving feasibility. A feasible solution is tried to be constructed by implementing heuristic methods. If a method is successful, then the feasibility is proven. On the other hand, if a lower bound on the makespan is greater than the last due date, then it is obvious that a tardy job must exist, i.e., the problem is infeasible. It is possible, of course, that none of these methods decides. In that case, the answer of partial-$oracle(X)$ is UNDEFINED, which means “I don’t know”.

The important question is which algorithmic elements are worth including in the partial oracle. The constructive heuristics should be able to find a feasible solution likely if it exists. In general, each heuristic method has a “philosophy” on how is it possible to obtain a good solution. Each “philosophy” works for certain types of problem instances. Thus, it is worth having different heuristic methods in the partial oracle. For example, LPT list scheduling and multi-fit heuristics of $P||C_{max}$ have different approaches. A third heuristic method is the better of these two methods. It is difficult to find problem instances such that the performance ratio of the third one is high (Demir and Vizvári 1992).

4.2.4.1 Algorithmic Tools of Proving the Feasibility

The applied heuristic methods have three parts. First, to form an ordered list of patients, it requires an ordering rule. The patients are assigned to vehicles in this order. Second, to select an appropriate vehicle for the patient, applying the vehicle selection rule is required. Third, if the selected patient is not saved, then a patient rejection rule is implemented to reject a patient from the scheduled and selected patients no matter which vehicle it is assigned to and places into the set of removed patients. That patient is always with the longest travel time.

The first and second heuristic approaches are called EDDBF and EDDWF, respectively, BF for the best fit and WF for worst fit. The EDD dispatching rule is employed in both EDDBF and EDDWF. EDDBF assigns the current patient to the least loaded vehicle. EDDWF assigns the patient to the vehicle which still can deliver the patient on time and has the maximal load among such vehicles. The third heuristic method is the LPT list scheduling, which is LPT.

If none of the constructive heuristics give a feasible solution and even the disproving tools are not working, then an attempt can be made to improve the solution. It means the exchange of jobs between two machines. It is shown by an example.

	Job				
	1	2	3	4	5
$\boldsymbol{p_j}$	3	2	5	4	6
$\boldsymbol{d_j}$	6	8	9	10	11

The EDDBF list scheduling gives for $k = 5$ i.e., iteration number, the solution as follows:

M1	**Job**	1	4	5	**M2**	**Job**	2	3
	$\boldsymbol{p_j}$	3	4	6		$\boldsymbol{p_j}$	2	5
	$\boldsymbol{C_j}$	3	7	13		$\boldsymbol{C_j}$	2	7
	$\boldsymbol{E_j}$	3	3	-2		$\boldsymbol{E_j}$	6	2

Job 5 is tardy. However, job 2 and job 5 can be interchanged such that job 2 becomes the second job of M1 and job 5 comes to the end of the row of M2. It is possible because (i) job 2 does not become tardy in this position and (ii) the job which will be processed after job 2 on M1 has an earliness greater than the processing time of job 2. The new solution is as follows:

M1	**Job**	1	2	4	**M2**	**Job**	3	5
	p_j	3	2	4		p_j	5	6
	C_j	3	5	9		C_j	5	11
	E_j	3	3	1		E_j	4	0

Assume that the schedule of M1 and M2 starts at time 0. The sequence of the jobs on M1 is $i_1, i_2, \ldots, i_k, \ldots, i_s$. Similarly, the jobs on M2 are $j_1, j_2, \ldots, j_l, \ldots, j_q$. The completion times of the jobs are as follows:

$$C_{i_k} = \sum_{t=1}^{k} p_{i_t} \quad k = 1, \ldots, s, \quad C_{j_l} = \sum_{u=1}^{l} p_{j_u} \quad l = 1, \ldots, q. \tag{4.10}$$

The earliness of the jobs are

$$E_{i_k} = max\{d_{i_k} - C_{i_k}, 0\} \quad k = 1, \ldots, s. \tag{4.11}$$

Assume that the current job is j_q which is tardy, i.e., $C_{j_q} > d_{j_q}$. To make the current job on time, job j_l is to be interchanged by job i_k where $p_{j_l} > p_{i_k}$. The change makes sense only if no new tardy job created on M1. The condition for that is that the earliness of the jobs on M1 behind job i_k is not smaller than the processing time surplus of job j_l, i.e.,

$$p_{j_l} - p_{i_k} \leq E_{i_t} \quad t = k + 1, \ldots, s. \tag{4.12}$$

The change is successful if

$$\sum_{u=1}^{q} p_{j_u} + p_{i_k} - p_{j_l} \leq d_{j_q}. \tag{4.13}$$

4.2.4.2 Algorithmic Tools of Disproving Feasibility

The simplest potential way of disproving feasibility is coded by formulas (4.14) and (4.16). If the inequality

$$max\left\{\frac{\sum_{j=1}^{k} p_j}{m}, max\{p_j: 1 \le j \le k\}\right\} > d_k, \quad (4.14)$$

holds, then there is no feasible solution of the sub-problem of iteration k.

Shavarani and Vizvári (2018) give an upper bound on the total working time of the machines (Shavarani and Vizvari 2018). Assume that the index order is the EDD order and all jobs are completed on time. Then, the total working time of the machines is at most

$$\sum_{j=n-m+1}^{n} d_j \quad (4.15)$$

It implies that the inequality

$$\sum_{j=1}^{n} p_j \le \sum_{j=n-m+1}^{n} d_j \quad (4.16)$$

is a necessary condition of the feasibility. The opposite inequality disproves the feasibility.

Lemma 2. Assume that the index order is identical to the EDD order. Let $\pi(k,j) = 1, \dots, k$ be the SPT order of the first k job, i.e.

$$\{1,2, \dots, k\} = \{\pi(k,1), \pi(k,2), \dots, \pi(k,k)\} \quad (4.17)$$

and

$$p_{\pi(k,1)} \le p_{\pi(k,2)} \le \cdots \le p_{\pi(k,k)}. \quad (4.18)$$

Let m be the number of vehicles. If $1 \le t \le k$ is an integer such that

$$\sum_{j=1}^{t} p_{\pi(k,j)} \le \sum_{j=k-m+1}^{k} d_j < \sum_{j=1}^{t+1} p_{\pi(k,j)}, \quad (4.19)$$

Then at least $k - t$ jobs are late.

Heuristic methods also give lower bounds on the makespan if the performance ratio is known. The main theorem of Graham (1969) is an exact upper bound on the performance ratio (Graham 1969).

Theorem 2. Let Q be an instance of the problem class $P||C_{max}$. In the case of m machines, its optimal value and the value obtained by the LPT list scheduling are $\nu(Q)$ and $LPT(Q)$, respectively (Graham 1969). Then

$$\frac{LPT(Q)}{\nu(Q)} \leq \frac{4}{3} - \frac{1}{3m} \tag{4.20}$$

The theorem implies that for a problem instance Q,

$$\nu(Q) \geq \frac{3mLPT(Q)}{4m - 1} \tag{4.21}$$

Graham (1969) gave an example where the performance ratio is exactly the upper bound. Dósa (2004) proved that Graham's example is the only one having this performance ratio. He gave some performance ratios for $m = 2{,}3$ better than Graham's general performance ratio for the improved version of the LPT list scheduling (Dósa 2004).

4.2.5 The Problem in a Dynamic Environment

In the post-disaster period, reports on injured persons would be received continuously. Therefore, it would be difficult to solve the exact optimization problem in the dynamic environment case since the information needed to set up the model changes continuously. The exact solution needs long CPU time, which is not acceptable as fast decisions must be made. Thus, the continuously repeated application of heuristic methods can be applied in the case of the real disaster. In many applications of dynamical systems it is important to stabilize the system, i.e., the trajectory must be moved to and kept in a certain target region (Kovács & Vizvári 2003).

4.3 Example

As a case study, Tehran city, which is the capital of Iran, is considered. Tehran is in the middle of a triangle of three geographical faults. Thus, the city is under constant threat of an earthquake. The map and hospitals of the city are acquired from ArcGIS (ESRI 2017). Two emergency vehicles (ambulances) were assumed in each hospital. The speed of 60 kilometers per hour considered as an average speed of the ambulances. We assume that 115 hospitals operate in the period of post-disaster. We generate the deadlines and places of the seriously injured patients randomly, and there are 100 seriously injured patients in each region of the city. The minimum, maximum, mean, and standard deviation of deadlines are 30, 300, 166.7 and 83.3 minutes, respectively (Figure 4.2).

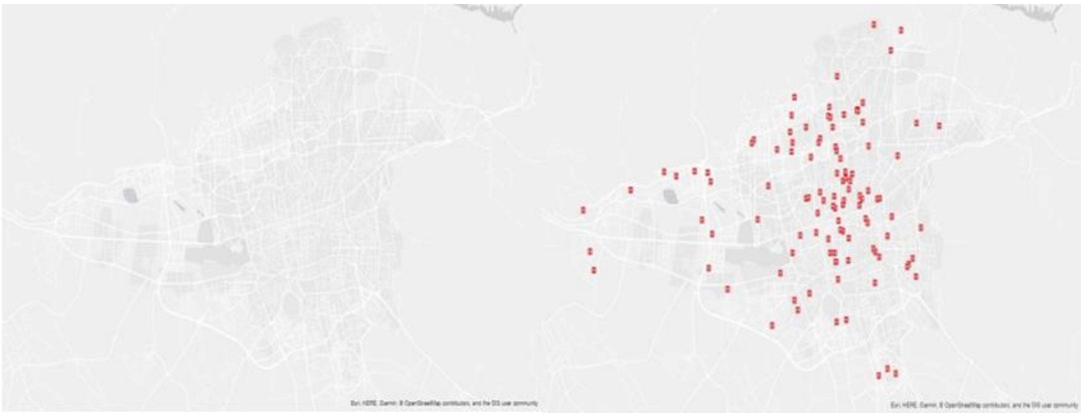

Figure 4.1: Hospitals in Tehran city

The distance calculated between any hospital and the patient in the region of the hospital is approximated by the Manhattan distance l_1, because of the high runtime required and complexity to compute the length between the patients and the hospitals. The situation is shown in Figure 4.3 where the city is divided into regions by implementing a Voronoi diagram between the hospitals of the city on the map by using ArcGIS. Divided regions have different features, as shown in Figure 4.3. The area of some of the regions is big while others are smaller. This can tell that when the covered area is huge, the problem becomes more complicated in the sense of the number of emergency vehicles in the corresponding hospital. For instance, in the center of the city, there are so many hospitals, which make the regions' area small, so if the number of patients there was huge with reasonable due date, this means with high probability the number of saved patients will be optimum with respect to the assumption that in each hospital there are two emergency vehicles.

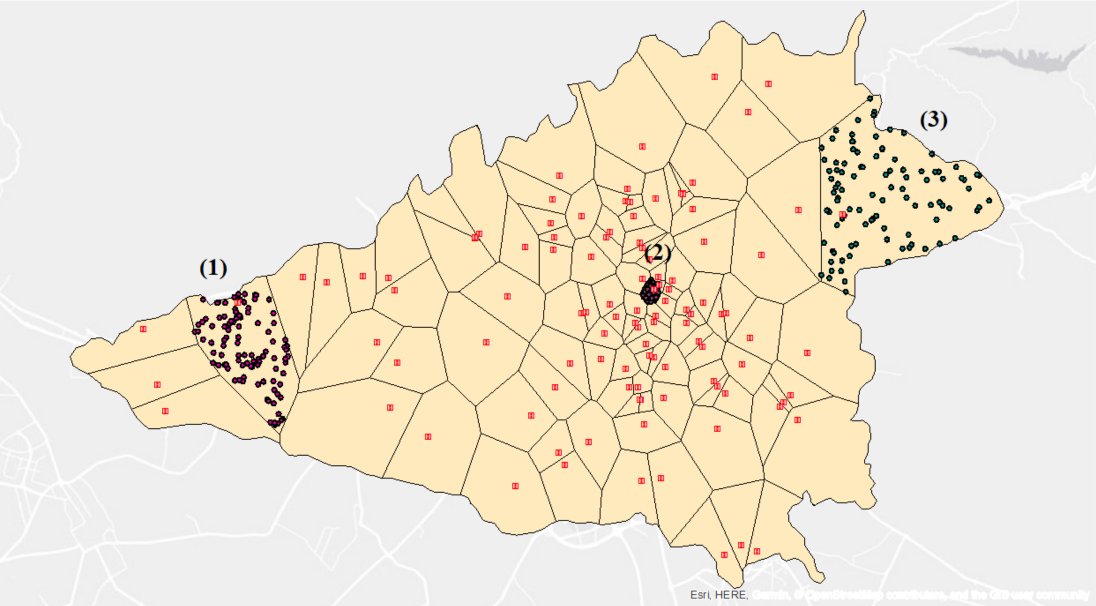

Figure 4.2: Voronoi diagram of hospitals and the three studied regions in Tehran City

4.4 Results and discussion

In this section, we report the results of the ILP model obtained by CPLEX 12.8. The proposed heuristics were implemented in C++ programming language and tested in Windows 10 with Intel(R) Core(TM) i5-5200U CPU @ 2.20 GHz with a memory of 6 GB, and their solutions were summarized. Ten different scenarios were taken for each size and compared with EDDBF, EDDWF, and LPT heuristics. The results of those scenarios are reported in Table 4.1. In the table, we indicate the number of saved patients and the computational time (in seconds) of CPLEX12.8 to find the optimal solution to the ILP problem (4.1) – (4.4). Also, let n be the number of patients considered in the simulations. The optimal solutions are performed for two vehicles and ten different scenarios for each n.

Table 4.1: Average solutions of 10 different problem instances in case of a small size problem.

Problem size (n)	**EDDBF**	**EDDWF**	**LPT**	**Opt.**	**Time (sec.)**
5	3	3	2	4	0.06
6	4	4	2	4	0.10
7	4	4	2	4	0.32
8	4	4	2	5	2.42
9	5	5	2	5	69.30
10	5	5	2	5	3078.03

As shown in Table 4.1, the computational time is increased when n increases, because of the high complexity of the problem. To find an optimal solution of size 10, the solving time is approximately fifty minutes, as shown in Table 4.1. Thus, the computational results suggest that problems of size n=10 or larger cannot be solved exactly in the case of a disaster, because of the exponential increase of the CPU time, see Figure 4.4 as well. EDDBF and EDDWF heuristics give optimal solutions in most of the instances in each size. However, in a few other instances, the results are near to optimal. Results were significantly lower than optimal in all instances solved by the LPT heuristic. It is clear that the solution has to be found immediately because of the problem environment.

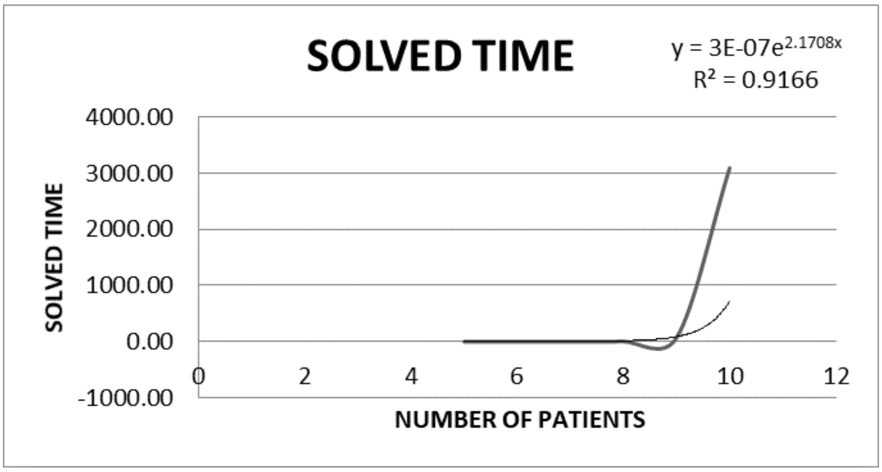

Figure 4.3: Solved time related to the problem size

The average percentage and time of the saved patients in three different regions of Tehran city are summarized in Table 4.2. Three different regions with different features 1, 2, and 3, respectively, from the left of Figure 4.3 were chosen to evaluate the performance of the methods. Also, the number of patients n=100 was fixed, with 10 random location distributions in each selected region, all data and result of one problem instances in each region can be seen in Appendix C. The upper bound of each problem instances were calculated and found in average 64, 100, and 58 patients in regions 1, 2, and 3, respectively. Thus, it was not possible to save all patients in regions 1 and 3. They show that LPT has the smallest mean percentage of saved patients of 72.4%, 77.8%, and 75.1% in regions 1, 2, and 3, respectively. EDDBF is very closely followed by EDDWF with 91.5% and 88.7% in regions 1 and 3, respectively. The results of the simulation also reveal the following: (i) EDDBF performs better than EDDWF in 100% of the test problems in region 1, performs equally in region 2, while it performs better than (worse than) EDDWF in 20% (20%) of the test problems in region 3; (ii) EDDWF and EDDBF perform better than LPT in all the test problems.

Table 4.2: The average percentage and time of the saved patients

Heuristic	Region 1		Region 2		Region 3	
	Saved Patients (%)	Completion Time (Minutes)	Saved Patients (%)	Completion Time (Minutes)	Saved Patients (%)	Completion Time (Minutes)
EDDBF	91.5	320.86	100	253.19	88.7	313.99
EDDWF	89.3	333.34	100	311.79	87.8	328.99
LPT	72.4	268.34	77.8	194.38	75.1	274.47

Table 4.3 shows the percentage of maximum, minimum, and average definite answers (YES + NO) in all problem instances by using the tools of a partial oracle. When the three heuristics EDDBF, EDDWF, and LPT and the lower bounds and upper bounds tools are used in the partial oracle, it shows that the maximum definite answer in regions 2 and 3 is 100%. However, this percentage exists in EDDBF and EDDWF in all problem instances of region 2 while it was found once in region 3 by EDDWF. It is interesting to note that region 2 has the maximum number of definite answers compared to other regions because of the small area of that region.

Table 4.3: The percentage of the definite answers of Partial Oracle

Regions	Maximum	Minimum	Average
1	98%	46%	74.73%
2	100%	51%	86.10%
3	100%	43%	66.87%

Chapter 5

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.

The emergency transportation capacity on the Asian side of Istanbul was analyzed for the case of a serious earthquake, and was shown to be much lower than the expected demand. It is therefore important to use this capacity in an efficient way. The transportation capacity and the total operating capacity of the hospitals should be approximately equal, since if one is significantly higher than the other, then the efficiency will be reduced. Transportation technology is expected to change in the near future; unmanned aerial vehicles will be able to transport injured persons (Insights 2019), and these will be faster than traditional ambulances and will be able to use more direct routes. However, the same methods can be applied to these vehicles.

Another important conclusion is that methods for decreasing the demand for transportation must be developed and applied. There are many ways to achieve this;

for instance, mobile medical teams can be used to take care of injured people on the spot, meaning that they do not need transportation.

If the measures suggested in this research can be realized, then the people of Istanbul will be in a safer position. These are important considerations, since Istanbul is situated in a region where a serious earthquake is possible at any moment. In addition, the European side of Istanbul and the other towns surrounding the city cover a large area, and the total area of the city is expected to increase in the near future, since the main airport has been moved further away, and these aspects require further investigation.

After a disaster, a substantial number of injured persons should be transported to the hospital, and the time from the injury to arriving at the hospital plays a significant part in the result of rescue procedures. The tools which are used to get the maximum number of saved persons have been provided in this study, discussing the consequence of such choices in post-disasters. Disaster managers have been provided in this research with scheduling and obligation algorithms which were not discussed earlier.

Two methods are applied to solve the problem. Firstly, a well-known diagram (Voronoi) is used to divide the city into the regions concerning the district hospitals. Secondly, we developed a structured algorithm based on the Moore–Hodgson algorithm to solve the m identical emergency vehicles to maximize the total number of saved persons in the post-disaster period when it occurs in a metropolitan city. NP-complete is the class of problem. Thus, based on the partial oracle tool we developed three heuristic approaches. We evaluate the effectiveness of the proposed heuristics by simulation experiments. The results show that EDD patient selection rules consistently over perform the LPT rule. Concerning computational effort, the heuristics can solve large problems in a real-time environment.

In the future studies, social circumstances and morality issues will be investigated and addressed. Creating an insight into the medical staff assignment to different operating rooms in different hospitals to make these units more successful in post-disaster periods was the main aim of this study. A lot of relaxations have been assumed in this study. More detailed models can be created as an outcome of this study in the future. The dynamic environment of the post-disaster period needs further investigation and analysis.

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APPENDICES

Appendix A: Mathematical Explanation

If $P_k \leq P_{k+1} + P_{k+2} \quad k = 1,2,\ldots\ldots, n-2$

Assuming that $P_k \geq P_{k+1} \quad k = 1,2,\ldots\ldots, n-2$

Then

$$C_{max}^{LPT} - C_{max}^{OPT} \leq P_n$$

Relative error $\leq \frac{m\ min\{P_j\}}{\sum_j P_j} \leq \frac{m}{n}$ (where $\frac{m}{n}$ is very small in case of earthquake)

Appendix B: NP-Completeness

Theorem. The complexity of the problem $P||\Sigma U_j$ is at least NP-complete.

Proof. Assume that (a) the number of machines is 2, (b) the sum of the processing times is 2d, where d is a positive integer, and (c) all due dates are also d. Then, the problem is reduced to finding a subset of the jobs such that the sum of the processing times of the jobs in the subset is exactly d. This problem is the partition problem, which is one of the most well-known NP-complete problems. If a sub-problem is NP-complete, then the problem class at least NP-complete.

Appendix C: All Data Used in Tehran City

Table1: Data of the problem instance 1 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2151330	4113187	281	1525
2	2153299	4109782	880	1628
3	2148711	4112868	552	1579
4	2151317	4112633	300	1786
5	2153780	4109617	958	1781
6	2152689	4111540	596	1592
7	2153805	4108548	1089	1711
8	2149278	4112141	571	1740
9	2152198	4112255	451	1531
10	2152887	4106811	1187	1634
11	2151522	4112701	317	1579
12	2151941	4108753	841	1513
13	2154060	4108814	1088	1611
14	2154342	4107597	1268	1800
15	2150285	4112846	366	1772
16	2152163	4113728	446	1523
17	2152256	4107866	985	1725
18	2151374	4108528	800	1564
19	2149889	4112723	428	1783
20	2153959	4110365	890	1534
21	2150848	4111291	485	1533
22	2153746	4106718	1302	1503
23	2151515	4113134	297	1781
24	2148739	4112854	550	1635
25	2154292	4109233	1065	1752
26	2148628	4112607	593	1588
27	2150694	4110861	555	1501
28	2150996	4108255	831	1790
29	2150529	4108831	818	1784
30	2153834	4109062	1031	1767
31	2152421	4113748	479	1588
32	2148855	4111567	691	1718
33	2152491	4112839	416	1536
34	2151620	4113484	351	1795
35	2151776	4111735	463	1613
36	2152378	4112748	414	1635
37	2151923	4108653	851	1583
38	2151928	4112342	409	1647

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
39	2148446	4113135	584	1717
40	2151516	4110980	523	1660
41	2150690	4112156	400	1562
42	2149568	4112835	453	1563
43	2151013	4110963	504	1634
44	2151913	4108663	848	1737
45	2150778	4109968	652	1780
46	2151374	4109541	678	1573
47	2151917	4108485	870	1569
48	2152424	4110857	646	1755
49	2154069	4107747	1217	1687
50	2152277	4112831	392	1509
51	2153553	4107839	1144	1507
52	2150190	4110329	679	1670
53	2150896	4111051	508	1549
54	2153475	4107935	1123	1762
55	2149291	4111124	691	1694
56	2149689	4110162	759	1635
57	2151434	4107822	892	1588
58	2148800	4113277	559	1552
59	2152963	4108256	1023	1536
60	2152554	4113672	486	1605
61	2152778	4114110	565	1577
62	2152709	4111277	630	1540
63	2152936	4107134	1154	1536
64	2153252	4110484	790	1630
65	2149712	4111069	648	1552
66	2150064	4112579	424	1769
67	2152681	4107011	1139	1695
68	2153723	4109031	1021	1640
69	2153527	4107997	1122	1506
70	2150075	4110557	665	1527
71	2154031	4106854	1319	1502
72	2152871	4113310	480	1791
73	2151832	4112429	387	1571
74	2151230	4110825	507	1794
75	2153016	4113503	521	1646
76	2154127	4109096	1062	1777
77	2153914	4109691	965	1793
78	2153172	4112496	539	1713
79	2150596	4109938	677	1531
80	2150736	4111193	510	1560

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
81	2151772	4109418	741	1738
82	2152324	4109066	849	1562
83	2152486	4109970	760	1753
84	2150731	4111720	447	1633
85	2152290	4109167	833	1748
86	2153584	4107760	1157	1777
87	2152926	4106711	1204	1610
88	2152716	4108049	1018	1717
89	2149441	4110329	769	1720
90	2149813	4112584	454	1544
91	2150617	4109009	786	1754
92	2148569	4112842	572	1749
93	2151477	4112899	288	1504
94	2151052	4112919	265	1711
95	2151017	4111332	459	1657
96	2152321	4108856	874	1574
97	2152584	4111728	561	1509
98	2153559	4107348	1204	1724
99	2150224	4112923	364	1768
100	2150022	4109207	834	1515

Table 2: Data of the problem instance 2 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2151642	4111019	533	1782
2	2151024	4112538	314	1756
3	2152994	4111365	654	1720
4	2150731	4109240	745	1735
5	2150515	4108658	841	1644
6	2152424	4109552	803	1677
7	2154041	4109139	1046	1625
8	2152620	4107001	1133	1743
9	2150614	4108843	806	1550
10	2150977	4109606	671	1605
11	2151559	4112151	387	1543
12	2152332	4108868	874	1621
13	2153046	4110176	803	1687
14	2153886	4110232	897	1728
15	2154267	4109214	1065	1761
16	2152944	4113504	512	1649

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
17	2151974	4110648	617	1704
18	2151983	4114123	471	1592
19	2150260	4111105	577	1676
20	2153275	4111380	686	1780
21	2149524	4109919	808	1507
22	2151412	4109985	629	1652
23	2152396	4107631	1030	1507
24	2150456	4111538	502	1514
25	2152925	4107245	1140	1510
26	2148861	4111622	683	1556
27	2153823	4109961	922	1790
28	2152132	4113576	424	1786
29	2149931	4109589	799	1783
30	2153515	4108000	1120	1758
31	2151818	4108513	855	1596
32	2151511	4109650	682	1555
33	2152351	4110184	718	1519
34	2151085	4112107	358	1793
35	2152077	4110217	681	1696
36	2152191	4110649	643	1793
37	2152235	4110335	686	1649
38	2151459	4110584	563	1717
39	2154068	4106954	1312	1525
40	2152170	4110140	702	1500
41	2151654	4110843	556	1734
42	2149117	4111805	631	1619
43	2150244	4112256	441	1588
44	2150580	4112103	419	1701
45	2150636	4110178	644	1578
46	2151786	4108460	857	1605
47	2150553	4111956	440	1571
48	2150880	4112695	312	1798
49	2150750	4111909	422	1595
50	2151869	4112305	406	1501
51	2152123	4112651	395	1550
52	2150382	4110010	694	1792
53	2153203	4111457	668	1626
54	2151332	4109139	721	1508
55	2152478	4108211	970	1707
56	2152858	4106737	1193	1581
57	2154151	4107684	1234	1712
58	2153563	4108661	1046	1612

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
59	2152925	4113435	502	1608
60	2149002	4113330	541	1750
61	2152707	4107947	1029	1555
62	2150440	4111798	473	1501
63	2152865	4108633	966	1602
64	2152344	4108231	952	1591
65	2153322	4108001	1097	1781
66	2150620	4111825	448	1540
67	2149737	4110280	739	1669
68	2150719	4109084	765	1769
69	2153928	4108903	1061	1562
70	2151462	4110415	584	1705
71	2150686	4108706	814	1733
72	2154057	4109018	1063	1649
73	2150816	4110576	574	1539
74	2153381	4106023	1341	1673
75	2154168	4110045	953	1792
76	2151364	4112839	281	1640
77	2149951	4112446	454	1609
78	2154294	4107501	1273	1625
79	2153535	4110182	861	1606
80	2150004	4110596	669	1632
81	2149874	4111572	568	1547
82	2152065	4108121	932	1772
83	2151306	4109756	644	1555
84	2152623	4108805	916	1570
85	2149266	4110885	723	1671
86	2150769	4111860	426	1747
87	2151572	4108067	879	1768
88	2153024	4107826	1082	1645
89	2152976	4108301	1019	1746
90	2150719	4110114	641	1753
91	2152412	4111814	530	1767
92	2152980	4110864	712	1599
93	2151875	4113650	402	1631
94	2151024	4111568	430	1794
95	2149785	4112154	509	1555
96	2149258	4110540	766	1697
97	2149884	4112672	435	1635
98	2152857	4112425	510	1707
99	2152550	4108777	911	1608
100	2151801	4110638	598	1593

Table 3: Data of the problem instance 3 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2152748	4109538	843	1537
2	2150278	4111768	496	1631
3	2149740	4109773	800	1753
4	2153096	4112359	547	1667
5	2151207	4113052	250	1647
6	2149769	4112160	510	1612
7	2151861	4113653	400	1737
8	2152887	4106455	1230	1680
9	2152117	4111040	587	1794
10	2152470	4109019	872	1573
11	2151527	4112872	297	1548
12	2149624	4112839	446	1760
13	2151516	4112957	285	1528
14	2153784	4111235	764	1664
15	2152555	4109239	856	1574
16	2152623	4107276	1100	1531
17	2153627	4106594	1302	1521
18	2151375	4111242	474	1675
19	2150976	4112206	359	1706
20	2152178	4112500	420	1793
21	2151200	4113027	246	1767
22	2152297	4111514	552	1584
23	2149641	4112694	461	1727
24	2151610	4108619	817	1787
25	2152630	4108485	956	1576
26	2153016	4107870	1076	1709
27	2151274	4108770	759	1668
28	2153122	4107907	1084	1523
29	2153987	4106939	1304	1781
30	2150227	4112346	433	1540
31	2153444	4108789	1017	1730
32	2154251	4108453	1154	1779
33	2151036	4110162	598	1771
34	2152736	4109762	815	1632
35	2152137	4112157	456	1730
36	2149671	4111960	546	1607
37	2153191	4110452	787	1791
38	2152761	4106523	1207	1541
39	2149826	4109938	770	1705

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
40	2152100	4108541	885	1529
41	2151889	4112556	378	1598
42	2152841	4109602	847	1737
43	2152284	4113471	429	1551
44	2150933	4112108	376	1584
45	2150356	4110781	605	1755
46	2149012	4113042	505	1570
47	2152782	4108131	1016	1612
48	2153350	4106587	1270	1545
49	2151582	4110422	597	1641
50	2153409	4108736	1019	1592
51	2152492	4113660	477	1749
52	2151564	4109530	702	1799
53	2152076	4108672	867	1679
54	2151260	4112112	356	1766
55	2150279	4112627	393	1614
56	2153295	4110368	809	1670
57	2152663	4111332	618	1678
58	2153500	4110533	814	1753
59	2152721	4111892	558	1517
60	2152275	4111513	550	1582
61	2151977	4109591	745	1645
62	2151960	4113321	372	1774
63	2153418	4111592	677	1611
64	2149364	4111864	594	1565
65	2149416	4112347	530	1799
66	2151471	4111305	478	1507
67	2150886	4113070	284	1586
68	2152312	4108596	904	1673
69	2152932	4112485	512	1531
70	2152515	4107721	1034	1689
71	2153725	4106332	1345	1581
72	2150777	4110355	605	1532
73	2152806	4112897	447	1742
74	2152433	4114316	549	1633
75	2151046	4108648	778	1557
76	2150926	4110034	626	1503
77	2151848	4113003	321	1560
78	2152763	4110227	763	1560
79	2152417	4109910	759	1555
80	2152299	4112233	466	1556
81	2151691	4109371	737	1714

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
82	2151618	4111158	513	1687
83	2153187	4107719	1114	1587
84	2152231	4110617	652	1670
85	2153726	4109068	1017	1611
86	2153747	4110990	789	1556
87	2151559	4112244	376	1668
88	2152798	4112118	540	1596
89	2153640	4107707	1170	1579
90	2152898	4106249	1256	1536
91	2152442	4107318	1073	1678
92	2152593	4106944	1136	1743
93	2152002	4113442	392	1722
94	2148635	4112129	650	1743
95	2151269	4109359	687	1657
96	2153233	4108011	1085	1740
97	2152018	4107303	1024	1562
98	2152244	4107465	1032	1788
99	2151932	4108370	886	1539
100	2149465	4112677	484	1712

Table 4: Data of the problem instance 4 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2149837	4109769	789	1585
2	2148985	4112762	532	1707
3	2152489	4114248	547	1763
4	2151630	4110609	581	1714
5	2151657	4112180	395	1643
6	2151944	4113921	443	1594
7	2151954	4110521	630	1762
8	2151236	4111629	411	1729
9	2152266	4109072	842	1593
10	2150523	4108737	830	1596
11	2149195	4112946	484	1795
12	2151212	4109607	651	1643
13	2151633	4113211	320	1774
14	2152788	4111844	572	1540
15	2151684	4111986	422	1589
16	2151237	4107993	848	1607
17	2150523	4109393	751	1717

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
18	2154113	4109904	963	1682
19	2150143	4109705	760	1746
20	2151863	4107618	968	1778
21	2153240	4112111	594	1740
22	2150681	4110733	572	1794
23	2153304	4109438	922	1651
24	2152997	4108072	1049	1616
25	2152050	4110442	651	1612
26	2153324	4107072	1208	1666
27	2152793	4112814	456	1600
28	2153080	4110196	804	1781
29	2152197	4109041	837	1571
30	2150231	4112399	426	1616
31	2148810	4112076	635	1620
32	2153438	4109123	976	1742
33	2150663	4112528	358	1502
34	2150962	4108590	795	1564
35	2154524	4108528	1178	1513
36	2153604	4108283	1097	1719
37	2148774	4111481	711	1754
38	2149606	4112561	481	1756
39	2152399	4111716	540	1686
40	2150078	4109287	817	1708
41	2151277	4109550	665	1719
42	2153204	4109237	934	1778
43	2153200	4108309	1045	1677
44	2152157	4112708	392	1702
45	2153522	4111313	723	1726
46	2150309	4111847	483	1798
47	2152557	4110907	656	1676
48	2151795	4112601	362	1679
49	2152681	4114266	572	1586
50	2153905	4107820	1188	1766
51	2148892	4112909	525	1630
52	2154079	4107522	1245	1508
53	2152331	4107267	1066	1628
54	2152190	4112509	420	1621
55	2153806	4110667	835	1621
56	2149949	4109646	790	1508
57	2151119	4113125	262	1727
58	2148534	4112654	599	1717
59	2149353	4113096	471	1664

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
60	2148857	4112315	601	1710
61	2149173	4113126	496	1778
62	2153165	4111068	710	1775
63	2153138	4113182	497	1589
64	2153814	4110087	905	1656
65	2149410	4110632	736	1753
66	2151531	4108745	793	1577
67	2153724	4107700	1181	1622
68	2152662	4113525	481	1779
69	2152133	4111275	561	1766
70	2154158	4109406	1028	1545
71	2151549	4111102	512	1668
72	2150607	4111370	504	1772
73	2150457	4110126	671	1527
74	2152147	4111598	524	1671
75	2150928	4111048	504	1751
76	2152268	4112211	465	1643
77	2152886	4110621	730	1749
78	2149794	4111386	600	1776
79	2152790	4110137	777	1518
80	2150845	4109097	748	1537
81	2151119	4113358	290	1580
82	2151099	4112832	270	1648
83	2153734	4107317	1228	1624
84	2152595	4113466	466	1504
85	2153909	4107925	1176	1749
86	2152688	4112017	539	1579
87	2150500	4110472	625	1744
88	2148591	4113244	580	1676
89	2152428	4111890	523	1775
90	2152788	4112817	455	1760
91	2149279	4112795	492	1580
92	2151647	4109595	704	1530
93	2151612	4108904	783	1650
94	2152605	4107219	1105	1688
95	2152789	4110331	753	1522
96	2151464	4108288	839	1550
97	2149336	4111101	689	1792
98	2152506	4110971	642	1799
99	2153522	4108421	1070	1696
100	2151997	4111475	521	1654

Table 5: Data of the problem instance 5 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2149764	4111757	559	1578
2	2149075	4112333	572	1794
3	2153841	4108546	1094	1724
4	2152386	4109924	754	1588
5	2152364	4107968	986	1756
6	2150386	4109115	801	1690
7	2152403	4110186	724	1709
8	2153076	4113101	480	1713
9	2153408	4108522	1045	1599
10	2151246	4109256	697	1630
11	2151487	4109465	701	1607
12	2154264	4109293	1055	1598
13	2151662	4110217	632	1580
14	2148603	4113296	585	1564
15	2150679	4110431	608	1772
16	2153920	4107963	1173	1606
17	2151320	4113523	320	1587
18	2150368	4109621	743	1750
19	2152884	4109041	919	1589
20	2152756	4111971	552	1791
21	2149020	4110949	745	1573
22	2149510	4109953	806	1713
23	2153994	4106788	1323	1704
24	2151365	4108453	808	1622
25	2150131	4111765	514	1630
26	2151173	4108763	749	1613
27	2154032	4109319	1024	1550
28	2151608	4108778	798	1796
29	2153818	4107936	1164	1760
30	2154055	4109775	972	1752
31	2152318	4108234	948	1639
32	2151268	4108257	820	1649
33	2152470	4111653	556	1679
34	2151889	4111456	510	1517
35	2152669	4113841	520	1787
36	2151233	4108539	782	1670
37	2151739	4109621	712	1622
38	2149909	4112003	512	1545
39	2150059	4109620	780	1634
40	2153747	4110122	893	1507

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
41	2153936	4106615	1337	1613
42	2154059	4109945	952	1519
43	2152070	4108587	876	1557
44	2151735	4110377	621	1595
45	2150188	4109882	733	1758
46	2152118	4111189	570	1767
47	2152154	4110645	639	1759
48	2152387	4107244	1075	1784
49	2151055	4112379	329	1535
50	2149940	4109570	800	1572
51	2151893	4112946	332	1758
52	2152466	4112022	512	1593
53	2153507	4105733	1391	1770
54	2150601	4111326	510	1585
55	2151533	4112276	369	1653
56	2152571	4107585	1057	1522
57	2153833	4106710	1313	1713
58	2149736	4110562	706	1664
59	2151345	4113655	339	1672
60	2151123	4109972	610	1760
61	2150984	4108606	790	1689
62	2153807	4108560	1088	1564
63	2152170	4107180	1057	1577
64	2152153	4109185	814	1675
65	2149522	4111447	625	1622
66	2152576	4110278	734	1797
67	2149148	4111470	667	1658
68	2149107	4111034	724	1795
69	2152992	4107101	1165	1656
70	2152997	4111017	696	1537
71	2150239	4111779	499	1548
72	2152416	4112225	481	1641
73	2151101	4111590	418	1662
74	2152251	4110518	666	1593
75	2150790	4112346	365	1571
76	2148557	4112823	576	1714
77	2149684	4110356	736	1624
78	2148932	4113319	548	1661
79	2150505	4110346	639	1775
80	2149865	4109855	775	1742
81	2152623	4111316	615	1669
82	2149737	4110366	729	1561

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
83	2152174	4108448	905	1525
84	2151917	4108655	850	1747
85	2153015	4109553	874	1642
86	2149800	4110701	681	1517
87	2149338	4112990	462	1792
88	2151865	4111577	493	1565
89	2152994	4111398	650	1597
90	2148895	4111703	670	1631
91	2149532	4110564	730	1616
92	2153134	4106423	1264	1534
93	2150431	4112606	377	1514
94	2149141	4112526	541	1684
95	2152887	4110145	787	1660
96	2152562	4106727	1158	1644
97	2152360	4112004	501	1608
98	2153067	4113284	501	1608
99	2153420	4111242	720	1626
100	2153823	4109734	949	1539

Table 6 : Data of the problem instance 6 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2149732	4110528	710	1508
2	2152225	4111619	531	1779
3	2151779	4109804	695	1634
4	2152994	4107233	1150	1769
5	2151815	4107660	957	1534
6	2152210	4107211	1058	1517
7	2150236	4110386	667	1688
8	2150277	4112550	402	1733
9	2153111	4106335	1271	1633
10	2151738	4111178	525	1690
11	2153159	4109147	940	1781
12	2148711	4111722	689	1789
13	2150916	4109404	703	1513
14	2154139	4109793	980	1626
15	2150784	4110180	626	1621
16	2152174	4111056	592	1770
17	2149811	4112802	428	1537
18	2151744	4113087	318	1760

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
19	2153225	4106345	1284	1654
20	2153057	4108726	978	1617
21	2149054	4111086	724	1507
22	2153323	4107844	1116	1676
23	2149539	4111527	613	1567
24	2153820	4106772	1304	1616
25	2149931	4111935	517	1800
26	2153440	4110637	795	1500
27	2151972	4113640	412	1782
28	2151107	4112660	289	1743
29	2151636	4110735	566	1594
30	2151598	4108723	803	1619
31	2151842	4113723	407	1792
32	2152671	4114221	566	1586
33	2152126	4109214	808	1702
34	2149887	4109954	760	1577
35	2153367	4106584	1272	1790
36	2151327	4110882	512	1708
37	2152218	4108391	917	1744
38	2152875	4113230	471	1766
39	2149428	4110147	792	1655
40	2153044	4112313	546	1794
41	2152007	4112399	411	1521
42	2151213	4112093	353	1519
43	2153057	4110231	797	1511
44	2154196	4108145	1184	1792
45	2151676	4111493	480	1734
46	2153367	4111834	642	1640
47	2153143	4112658	516	1685
48	2152731	4113752	517	1619
49	2152172	4113680	441	1772
50	2153249	4110111	835	1650
51	2150601	4113169	330	1638
52	2150817	4111514	462	1526
53	2151488	4112086	386	1520
54	2152181	4107978	963	1787
55	2149384	4110538	751	1639
56	2152493	4107983	999	1516
57	2153484	4106485	1298	1590
58	2151701	4112407	374	1772
59	2150431	4109681	728	1778
60	2152829	4107581	1088	1685

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
61	2150488	4111314	525	1530
62	2153733	4109117	1012	1535
63	2152137	4111669	514	1504
64	2149757	4111777	557	1501
65	2150830	4110092	631	1763
66	2153704	4110713	817	1512
67	2149969	4111182	603	1634
68	2152925	4112763	478	1511
69	2151758	4112581	359	1510
70	2153137	4112692	512	1621
71	2151441	4112323	352	1750
72	2154139	4108094	1184	1705
73	2154215	4109310	1047	1774
74	2150061	4112956	379	1504
75	2150356	4112497	399	1547
76	2153380	4111897	636	1542
77	2154482	4108601	1164	1746
78	2149410	4112230	544	1506
79	2149210	4112519	534	1774
80	2150260	4111715	504	1612
81	2151510	4110454	585	1642
82	2151560	4110801	549	1661
83	2151410	4111247	478	1773
84	2152308	4106964	1100	1688
85	2152730	4109803	809	1640
86	2153402	4110312	829	1615
87	2153495	4111010	756	1563
88	2154041	4107392	1256	1637
89	2153785	4107809	1175	1582
90	2150819	4111422	472	1694
91	2150902	4110386	587	1627
92	2152303	4107084	1085	1683
93	2150323	4110634	626	1726
94	2153413	4111036	743	1788
95	2149962	4112836	406	1548
96	2148971	4113250	535	1799
97	2151519	4110359	597	1754
98	2154166	4109617	1004	1746
99	2152120	4112394	425	1687
100	2149600	4111254	639	1787

Table 7: Data of the problem instance 7 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2151056	4112683	293	1684
2	2154445	4108717	1146	1768
3	2148778	4112517	586	1758
4	2151971	4109225	788	1794
5	2152365	4114012	504	1639
6	2150427	4112729	363	1649
7	2152733	4107254	1116	1529
8	2149483	4112213	538	1752
9	2153535	4110830	783	1669
10	2153048	4109980	826	1696
11	2151123	4112311	329	1764
12	2153801	4111032	791	1617
13	2150453	4110750	597	1683
14	2153419	4106336	1308	1558
15	2152287	4114056	500	1686
16	2151181	4109847	618	1538
17	2151334	4112004	378	1546
18	2150081	4111442	559	1665
19	2149433	4111962	574	1680
20	2149831	4112833	422	1513
21	2152232	4110377	681	1658
22	2151902	4113765	419	1797
23	2153638	4108529	1071	1508
24	2154217	4109333	1044	1644
25	2154200	4107369	1278	1549
26	2152089	4112067	461	1513
27	2150019	4111014	617	1791
28	2152414	4107854	1005	1640
29	2152052	4110821	606	1661
30	2148937	4113303	546	1612
31	2149517	4111322	641	1613
32	2152472	4111663	555	1747
33	2152765	4110979	673	1589
34	2151132	4109439	673	1689
35	2153875	4106548	1337	1554
36	2150741	4108505	832	1672
37	2149566	4110936	681	1608
38	2152559	4113147	423	1575
39	2153511	4106237	1331	1526
40	2150534	4109144	780	1526

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
41	2153019	4113026	464	1517
42	2152296	4111552	548	1585
43	2153467	4109537	930	1792
44	2150559	4108681	832	1713
45	2153729	4109602	953	1708
46	2149893	4111270	602	1506
47	2153524	4107858	1138	1646
48	2152855	4108212	1015	1724
49	2153341	4112517	557	1510
50	2152680	4110133	764	1614
51	2151704	4110976	546	1527
52	2152436	4108192	968	1609
53	2150355	4111500	519	1759
54	2153457	4112223	606	1539
55	2153278	4111010	730	1594
56	2153001	4112645	501	1699
57	2152842	4111149	661	1596
58	2152142	4111391	548	1673
59	2154250	4108181	1187	1530
60	2154433	4108728	1143	1673
61	2153288	4109418	923	1508
62	2152721	4112226	518	1772
63	2153242	4111089	717	1750
64	2153316	4108188	1074	1752
65	2151507	4112324	360	1609
66	2153179	4108972	963	1519
67	2148875	4111936	644	1741
68	2153458	4109974	876	1732
69	2151673	4113246	329	1765
70	2153566	4109013	1005	1629
71	2152394	4106785	1131	1675
72	2149905	4111587	562	1628
73	2152729	4112327	506	1777
74	2152426	4111115	616	1665
75	2150163	4110853	619	1630
76	2152738	4113020	430	1553
77	2151146	4109843	623	1560
78	2152344	4112480	442	1587
79	2152501	4108778	905	1522
80	2153326	4106360	1294	1729
81	2150055	4110055	728	1579
82	2151772	4109162	771	1518

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
83	2152535	4114312	560	1587
84	2149778	4112074	519	1715
85	2150482	4112321	405	1671
86	2151994	4111644	500	1700
87	2153628	4107723	1167	1698
88	2152816	4113250	467	1600
89	2153813	4108589	1085	1520
90	2150904	4110095	621	1730
91	2149249	4111213	686	1566
92	2151772	4107858	928	1544
93	2153007	4111697	615	1769
94	2153582	4109367	964	1794
95	2154239	4108886	1101	1699
96	2149901	4111072	625	1768
97	2153265	4107644	1133	1606
98	2150320	4111868	479	1690
99	2151897	4110287	651	1788
100	2154049	4106944	1311	1597

Table 8: Data of the problem instance 8 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2151569	4112666	327	1532
2	2153408	4110517	805	1793
3	2150303	4111457	530	1683
4	2154240	4109428	1036	1690
5	2150976	4108201	840	1719
6	2151854	4113429	373	1552
7	2152761	4106528	1206	1754
8	2150904	4110854	530	1685
9	2153646	4111516	714	1683
10	2151765	4111848	448	1794
11	2148892	4113105	527	1702
12	2149937	4109384	823	1679
13	2151694	4110029	658	1683
14	2152438	4107845	1009	1739
15	2152395	4111763	534	1650
16	2150374	4110292	661	1610

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
17	2149063	4111989	615	1566
18	2153065	4111067	698	1519
19	2151555	4112371	360	1581
20	2151637	4112757	324	1610
21	2151903	4108463	871	1755
22	2151129	4111440	433	1545
23	2154371	4108073	1214	1537
24	2151654	4111904	428	1530
25	2150772	4112163	389	1646
26	2152184	4107301	1044	1753
27	2152693	4113345	463	1521
28	2151690	4109798	685	1579
29	2151783	4112891	325	1600
30	2152123	4112225	446	1707
31	2151483	4110732	548	1787
32	2150194	4109616	764	1756
33	2152978	4107047	1170	1676
34	2149909	4109830	773	1539
35	2154068	4108966	1070	1715
36	2151722	4113193	329	1624
37	2150653	4110399	615	1692
38	2152834	4108712	953	1502
39	2149353	4111829	599	1642
40	2150026	4112478	441	1654
41	2154353	4107814	1243	1731
42	2149464	4110947	692	1782
43	2150739	4109992	654	1702
44	2150250	4112702	387	1556
45	2153214	4109608	891	1775
46	2150392	4113038	339	1548
47	2149961	4110302	710	1757
48	2152806	4109607	842	1691
49	2151319	4111131	481	1573
50	2152915	4106345	1247	1684
51	2148847	4112923	529	1595
52	2152530	4108081	992	1665
53	2152344	4111338	579	1520
54	2151961	4113138	351	1505
55	2149147	4113115	498	1624
56	2150267	4112476	412	1592
57	2153216	4111773	631	1683
58	2152603	4113674	492	1552

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
59	2153714	4110389	857	1754
60	2152008	4112094	448	1778
61	2151299	4111107	481	1796
62	2154312	4108872	1111	1768
63	2150621	4112736	338	1788
64	2149417	4112920	461	1598
65	2154008	4108729	1092	1546
66	2150226	4112230	447	1561
67	2153512	4106054	1353	1556
68	2153968	4107972	1178	1659
69	2153419	4107009	1227	1717
70	2153370	4109909	874	1553
71	2153100	4109742	861	1659
72	2149572	4111842	572	1615
73	2150742	4111822	434	1579
74	2151689	4113681	383	1703
75	2153286	4106992	1214	1762
76	2152544	4108568	935	1526
77	2153386	4111051	738	1722
78	2150253	4112504	410	1625
79	2150464	4109474	749	1764
80	2154209	4107530	1260	1630
81	2150514	4112845	338	1702
82	2151250	4109337	688	1611
83	2152691	4107938	1029	1574
84	2150281	4113110	361	1699
85	2152566	4113345	448	1645
86	2149676	4110212	755	1765
87	2150717	4109575	706	1542
88	2151666	4113473	355	1517
89	2152043	4109385	777	1624
90	2154422	4109203	1085	1760
91	2150026	4109362	815	1754
92	2149826	4111388	596	1567
93	2149975	4110632	668	1517
94	2152978	4109799	840	1609
95	2148851	4111320	721	1612
96	2150206	4111392	550	1508
97	2151786	4107681	951	1628
98	2152345	4113327	419	1555
99	2149089	4110965	735	1596
100	2153620	4110067	885	1760

Table 9: Data of the problem instance 9 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2149858	4110162	739	1782
2	2151604	4113423	342	1650
3	2152343	4108406	931	1658
4	2150469	4109482	747	1680
5	2150501	4112939	328	1723
6	2152616	4109979	775	1741
7	2150569	4110990	554	1642
8	2152160	4113371	402	1624
9	2153225	4111813	628	1797
10	2151569	4112968	290	1715
11	2152321	4111802	521	1777
12	2150456	4110854	584	1704
13	2151362	4112131	366	1762
14	2149749	4110719	685	1661
15	2151278	4111630	416	1637
16	2153435	4106229	1323	1637
17	2152099	4109679	749	1612
18	2152360	4109801	765	1516
19	2151128	4112081	356	1524
20	2153232	4109858	863	1572
21	2151986	4110019	694	1650
22	2153597	4107671	1169	1583
23	2151580	4110033	644	1735
24	2153192	4112358	558	1731
25	2153189	4108578	1012	1558
26	2151069	4112587	303	1521
27	2150655	4109286	748	1606
28	2153032	4106289	1267	1659
29	2150138	4112947	371	1570
30	2151041	4108607	784	1634
31	2152005	4109367	775	1683
32	2153476	4106747	1266	1546
33	2150573	4109503	732	1613
34	2153238	4108087	1076	1514
35	2151258	4110012	608	1792
36	2151236	4111020	484	1540
37	2152952	4113117	467	1637
38	2152911	4111318	649	1755

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
39	2151251	4109731	641	1639
40	2152641	4108559	948	1611
41	2153942	4110523	869	1775
42	2149274	4110896	721	1791
43	2149846	4109592	809	1559
44	2151553	4108794	789	1713
45	2151723	4109577	716	1634
46	2148820	4111325	724	1588
47	2153997	4109955	943	1592
48	2153420	4107866	1125	1636
49	2152246	4113362	412	1559
50	2151487	4109458	702	1520
51	2150129	4109466	790	1570
52	2149276	4113128	484	1692
53	2151481	4108562	809	1690
54	2153207	4107342	1162	1711
55	2149776	4111634	572	1581
56	2152310	4109481	798	1594
57	2153710	4106471	1327	1624
58	2152855	4107546	1095	1567
59	2150474	4112163	425	1737
60	2153169	4110777	745	1636
61	2153338	4109262	947	1598
62	2150419	4110547	625	1574
63	2153861	4109612	968	1673
64	2150949	4111844	406	1587
65	2150183	4112115	466	1609
66	2152914	4107464	1112	1799
67	2153268	4106145	1313	1557
68	2149019	4111726	652	1773
69	2151102	4112436	317	1523
70	2150732	4111766	442	1714
71	2153631	4106410	1325	1507
72	2149243	4111874	607	1563
73	2149003	4111345	700	1625
74	2153268	4106270	1298	1766
75	2153856	4110870	817	1659
76	2153732	4109009	1025	1794
77	2151021	4113246	289	1672
78	2152761	4110216	764	1591
79	2151772	4112397	383	1689
80	2153823	4110468	861	1712

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
81	2151936	4109413	761	1688
82	2152158	4113134	374	1691
83	2153569	4108401	1078	1504
84	2151304	4112238	346	1500
85	2153906	4110320	889	1635
86	2152412	4109665	788	1679
87	2149439	4112039	564	1667
88	2151231	4113408	295	1545
89	2150685	4111558	472	1733
90	2151809	4112641	358	1733
91	2151301	4108639	778	1503
92	2150829	4111919	412	1762
93	2151204	4110701	519	1536
94	2150302	4110035	701	1619
95	2151205	4113086	254	1799
96	2151359	4113090	273	1523
97	2150468	4111606	492	1712
98	2150056	4112927	383	1592
99	2153852	4109810	943	1661
100	2150698	4111434	485	1655

Table 10: Data of the problem instance 10 in Region 1

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2149386	4111875	590	1660
2	2154381	4109302	1068	1797
3	2152834	4109094	907	1657
4	2153210	4110546	778	1526
5	2153329	4108385	1052	1769
6	2152442	4113746	481	1619
7	2151523	4109846	659	1652
8	2151111	4108462	793	1662
9	2153021	4109784	847	1754
10	2151731	4111593	475	1707
11	2151321	4110218	591	1506
12	2151888	4113058	332	1556
13	2151592	4108936	777	1558
14	2150819	4112718	317	1557
15	2148751	4112461	596	1716
16	2154004	4109541	994	1608

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
17	2151929	4112675	369	1667
18	2152524	4107186	1099	1593
19	2153763	4107394	1223	1612
20	2153251	4109066	960	1678
21	2148598	4112326	630	1540
22	2150965	4109219	719	1675
23	2152801	4113925	546	1735
24	2150826	4111959	407	1690
25	2154142	4107163	1296	1650
26	2153216	4106168	1304	1633
27	2149747	4110731	684	1603
28	2149401	4111728	606	1696
29	2149615	4111793	572	1748
30	2149179	4111210	695	1755
31	2153511	4111050	754	1589
32	2149309	4112325	545	1657
33	2151213	4111420	433	1782
34	2153192	4111332	681	1545
35	2154028	4107926	1190	1646
36	2152049	4112437	412	1796
37	2151038	4108984	739	1746
38	2151352	4110723	534	1574
39	2152781	4114249	582	1752
40	2152376	4110923	633	1635
41	2149680	4110439	727	1673
42	2152479	4108919	885	1795
43	2151935	4112085	440	1583
44	2153381	4107486	1166	1580
45	2151452	4111418	462	1637
46	2153909	4108475	1110	1791
47	2153440	4106529	1288	1792
48	2151599	4112754	320	1682
49	2153266	4107552	1144	1778
50	2152768	4112379	505	1683
51	2152839	4109813	821	1744
52	2151106	4109851	626	1568
53	2152794	4107178	1132	1770
54	2152612	4113118	426	1652
55	2153630	4111688	691	1681
56	2149238	4111840	612	1578
57	2153761	4110644	832	1567
58	2150630	4111733	458	1633

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
59	2149704	4112688	454	1799
60	2153707	4107045	1258	1661
61	2152548	4107346	1082	1501
62	2152577	4108757	917	1551
63	2152691	4111668	581	1778
64	2151838	4112713	353	1738
65	2153382	4112259	593	1595
66	2153922	4106670	1328	1603
67	2153304	4107660	1136	1516
68	2152961	4113346	496	1536
69	2149232	4111046	708	1584
70	2151940	4107399	1003	1790
71	2153162	4108830	978	1773
72	2151477	4113607	349	1555
73	2149852	4110554	693	1728
74	2149539	4110570	728	1502
75	2151492	4112291	362	1770
76	2150207	4110128	701	1512
77	2151924	4113923	440	1785
78	2149305	4112629	509	1618
79	2149021	4111018	737	1553
80	2150802	4111563	457	1574
81	2153425	4106767	1257	1576
82	2152999	4107802	1082	1533
83	2149874	4112646	439	1646
84	2149110	4112850	506	1709
85	2150508	4108847	819	1616
86	2152767	4107400	1102	1757
87	2153541	4111531	699	1762
88	2152298	4112109	481	1636
89	2152968	4107681	1093	1676
90	2152426	4114000	510	1675
91	2149600	4111610	596	1740
92	2150793	4111316	488	1650
93	2153063	4110677	745	1626
94	2150282	4111289	553	1565
95	2148798	4111362	722	1663
96	2150985	4108356	820	1745
97	2150495	4109143	785	1788
98	2150727	4110767	562	1770
99	2151569	4110549	581	1775
100	2153718	4108896	1037	1788

Table 11: Data of the problem instance 1 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174127	4113535	289	1576
2	2174369	4113555	264	1514
3	2173992	4113611	296	1583
4	2174125	4113486	295	1734
5	2174154	4113340	309	1705
6	2174156	4113622	275	1634
7	2174274	4113205	311	1573
8	2173785	4113460	339	1792
9	2174025	4113720	279	1582
10	2174143	4113757	267	1771
11	2174373	4113440	279	1652
12	2174020	4113096	355	1610
13	2174504	4113787	266	1526
14	2174007	4113272	335	1622
15	2173842	4113211	362	1751
16	2174528	4113657	271	1652
17	2174639	4113470	307	1527
18	2174501	4113608	274	1798
19	2174082	4113683	277	1743
20	2174140	4113482	294	1784
21	2174202	4114106	302	1787
22	2174367	4113829	255	1640
23	2174057	4113917	297	1799
24	2174161	4114237	322	1725
25	2174012	4113707	282	1616
26	2174055	4113531	298	1591
27	2173876	4113578	314	1502
28	2173813	4113535	327	1500
29	2174127	4113649	276	1526
30	2174590	4113344	316	1598
31	2174431	4113231	311	1734
32	2174495	4113698	262	1676
33	2174148	4113955	290	1587
34	2173995	4113008	368	1643
35	2174170	4113470	292	1582
36	2173996	4113823	293	1754
37	2173798	4113492	334	1706
38	2174479	4113437	292	1516

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
39	2173854	4113330	347	1563
40	2174008	4113864	296	1697
41	2174479	4113237	316	1520
42	2174276	4113669	255	1628
43	2174120	4113050	348	1605
44	2174375	4113119	317	1703
45	2174097	4113903	290	1571
46	2173848	4113633	311	1699
47	2174123	4114111	312	1750
48	2173913	4113203	355	1540
49	2174082	4113205	334	1684
50	2174140	4113969	293	1754
51	2174100	4114127	317	1733
52	2174128	4113928	289	1629
53	2173754	4113530	335	1616
54	2174171	4113637	272	1535
55	2174035	4113410	315	1721
56	2174379	4113391	285	1739
57	2174021	4113429	315	1709
58	2174057	4113859	290	1764
59	2173922	4113720	292	1538
60	2174052	4113678	281	1598
61	2174119	4113261	323	1641
62	2173985	4113621	296	1697
63	2174321	4113222	304	1632
64	2174042	4113453	309	1682
65	2174077	4113944	297	1662
66	2174319	4113953	269	1618
67	2174227	4113011	340	1591
68	2174630	4113520	300	1782
69	2174004	4113638	292	1629
70	2174073	4113447	306	1629
71	2173956	4113336	334	1566
72	2173906	4113244	351	1778
73	2174017	4113996	311	1788
74	2174348	4114031	277	1640
75	2174011	4112986	369	1625
76	2174096	4113868	286	1767
77	2174008	4113085	358	1634
78	2174292	4113139	317	1576
79	2174181	4113096	336	1730
80	2173865	4113259	354	1795

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
81	2174016	4113412	317	1512
82	2174513	4113724	261	1552
83	2174041	4113686	282	1771
84	2174513	4113310	311	1704
85	2173920	4113720	292	1702
86	2174018	4113222	340	1626
87	2174103	4113408	307	1750
88	2174499	4113557	280	1688
89	2174117	4113178	333	1607
90	2174010	4113116	354	1745
91	2173765	4113265	365	1661
92	2174160	4113876	279	1715
93	2174366	4113931	267	1740
94	2174208	4114071	297	1631
95	2174257	4113360	295	1596
96	2173831	4113226	362	1711
97	2174250	4113223	312	1725
98	2174410	4113356	293	1515
99	2174464	4113628	267	1584
100	2174309	4113467	276	1699

Table 12: Data of the problem instance 2 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174284	4113435	282	1584
2	2174367	4113162	311	1535
3	2174045	4113669	283	1565
4	2173908	4113217	354	1500
5	2174061	4113435	309	1580
6	2173907	4113191	357	1599
7	2174003	4113311	331	1601
8	2174318	4113056	324	1740
9	2174158	4113116	336	1560
10	2174313	4113289	297	1720
11	2173918	4113134	363	1741
12	2174180	4113764	263	1797
13	2174182	4114064	299	1528
14	2174084	4113003	358	1666
15	2173808	4113538	327	1504
16	2174329	4114036	278	1548
17	2174008	4113337	327	1782

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
18	2174634	4113498	303	1707
19	2173968	4113180	351	1743
20	2174288	4113209	309	1766
21	2174367	4113306	294	1736
22	2174020	4113092	355	1773
23	2174185	4113113	333	1714
24	2173898	4113322	342	1511
25	2174000	4113060	362	1772
26	2174340	4113439	275	1569
27	2174239	4113545	275	1522
28	2174204	4113889	276	1786
29	2174534	4113679	269	1778
30	2174493	4113785	265	1682
31	2174215	4113862	271	1600
32	2174131	4113762	269	1660
33	2173991	4113191	347	1787
34	2173975	4113616	298	1601
35	2174251	4113387	292	1572
36	2174129	4113119	339	1687
37	2174354	4113726	242	1601
38	2173907	4113716	294	1602
39	2174212	4113903	276	1654
40	2174180	4113996	291	1669
41	2173778	4113385	349	1689
42	2174066	4113810	283	1779
43	2174278	4113756	251	1659
44	2173943	4113709	291	1642
45	2174225	4113378	296	1748
46	2174400	4113197	311	1745
47	2174514	4113498	289	1538
48	2174464	4113555	276	1521
49	2174139	4113378	307	1733
50	2174310	4113206	307	1613
51	2173815	4113319	353	1707
52	2174211	4113471	287	1752
53	2173899	4113669	301	1556
54	2174294	4113698	250	1674
55	2174302	4114037	282	1714
56	2173899	4113539	316	1757
57	2174086	4112992	359	1779
58	2174414	4113345	295	1711
59	2174096	4113191	334	1692

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
60	2174501	4113777	265	1694
61	2174029	4113730	278	1723
62	2174054	4113083	352	1568
63	2174198	4113857	272	1755
64	2174639	4113461	308	1633
65	2174154	4114199	319	1636
66	2174407	4113862	264	1560
67	2174028	4113691	282	1774
68	2174229	4113087	331	1549
69	2174249	4113500	279	1768
70	2174233	4113937	278	1649
71	2174151	4113910	284	1515
72	2173810	4113317	354	1733
73	2174362	4113075	321	1722
74	2174093	4113650	280	1621
75	2173877	4113252	353	1621
76	2173902	4113575	312	1622
77	2174177	4113162	328	1647
78	2174234	4114189	308	1557
79	2173983	4113788	290	1620
80	2174418	4113198	313	1500
81	2173776	4113494	336	1519
82	2174019	4113550	300	1615
83	2173853	4113589	316	1642
84	2173891	4113779	300	1511
85	2174399	4113894	266	1757
86	2174524	4113594	278	1567
87	2174561	4113314	316	1711
88	2174324	4113271	297	1747
89	2173867	4113535	321	1701
90	2174264	4113234	309	1769
91	2174553	4113508	292	1575
92	2174378	4113285	298	1609
93	2174390	4113243	304	1630
94	2174050	4113927	299	1513
95	2173871	4113253	354	1600
96	2173836	4113200	364	1680
97	2174064	4113063	354	1620
98	2174429	4113460	283	1641
99	2174386	4114025	281	1724
100	2173832	4113263	357	1754

Table 13: Data of the problem instance 3 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174277	4113970	276	1791
2	2174296	4113273	300	1579
3	2174022	4113545	301	1701
4	2174315	4113749	245	1735
5	2174136	4113872	282	1782
6	2174485	4113234	317	1659
7	2173743	4113362	356	1700
8	2174069	4113145	343	1531
9	2174450	4113414	291	1636
10	2173951	4113615	301	1505
11	2174576	4113325	317	1588
12	2174324	4113556	263	1571
13	2174310	4113469	275	1708
14	2174196	4113073	336	1679
15	2174041	4113155	345	1500
16	2173996	4113696	286	1772
17	2173964	4113817	296	1579
18	2173958	4113494	315	1637
19	2174550	4113602	280	1718
20	2174482	4113506	284	1579
21	2174362	4114034	279	1538
22	2174414	4113432	285	1624
23	2173746	4113363	356	1680
24	2174202	4114085	299	1709
25	2174070	4113608	287	1559
26	2174173	4113211	323	1516
27	2173969	4113777	290	1728
28	2174063	4113384	315	1717
29	2174317	4113935	267	1679
30	2174201	4113533	281	1676
31	2174547	4113320	314	1566
32	2174368	4113819	254	1771
33	2173874	4113221	357	1746
34	2174119	4113654	276	1689
35	2174441	4113856	267	1510
36	2174497	4113759	262	1679
37	2173943	4113706	291	1645
38	2174206	4113691	261	1796
39	2174511	4113337	308	1664
40	2173952	4113853	301	1567

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
41	2174357	4113698	246	1716
42	2173856	4113652	308	1518
43	2173971	4113059	365	1739
44	2174267	4114032	285	1699
45	2174304	4113592	261	1555
46	2174065	4113979	303	1504
47	2174190	4113704	261	1703
48	2174384	4113364	289	1685
49	2174196	4113035	341	1761
50	2174374	4113989	275	1779
51	2174362	4113058	323	1704
52	2174298	4114126	293	1734
53	2174121	4113465	298	1611
54	2173999	4113806	290	1621
55	2174273	4113170	316	1603
56	2174345	4113924	264	1800
57	2173873	4113408	335	1667
58	2174078	4113671	279	1770
59	2174227	4113570	273	1541
60	2174505	4113733	260	1653
61	2174340	4113365	284	1621
62	2174298	4113267	301	1505
63	2173965	4113485	315	1707
64	2174435	4113704	254	1542
65	2174127	4113262	322	1599
66	2174106	4113443	303	1588
67	2174188	4113825	270	1590
68	2174147	4113237	323	1542
69	2174231	4114044	291	1764
70	2174523	4113241	321	1670
71	2174528	4113259	319	1733
72	2174336	4113369	284	1556
73	2174317	4113372	286	1599
74	2174124	4113683	272	1633
75	2174219	4113718	256	1733
76	2174161	4114090	305	1617
77	2174566	4113304	318	1605
78	2173994	4113610	296	1543
79	2174043	4113996	308	1772
80	2173905	4113310	343	1542
81	2174306	4113547	266	1800
82	2174436	4113651	261	1781

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
83	2174349	4113180	307	1738
84	2174320	4113517	268	1505
85	2174411	4113511	275	1559
86	2174528	4113471	294	1664
87	2173865	4113459	330	1776
88	2174102	4113812	279	1724
89	2173888	4113308	345	1579
90	2173998	4112996	369	1707
91	2174413	4113949	275	1633
92	2174217	4114095	299	1775
93	2174222	4113740	255	1731
94	2173781	4113590	324	1781
95	2174564	4113654	276	1642
96	2174127	4113331	314	1521
97	2174367	4113424	280	1765
98	2174370	4113075	322	1549
99	2174058	4113466	306	1757
100	2174632	4113392	315	1638

Table 14: Data of the problem instance 4 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174214	4113600	271	1500
2	2174174	4113945	286	1566
3	2174128	4113979	295	1625
4	2174138	4113793	272	1794
5	2174429	4113722	252	1796
6	2174216	4114102	300	1579
7	2173908	4113278	346	1527
8	2174261	4113061	330	1649
9	2173886	4113132	367	1604
10	2174280	4113186	313	1538
11	2174300	4114073	286	1525
12	2174126	4114160	317	1735
13	2174512	4113282	314	1550
14	2174308	4113402	284	1543
15	2174083	4113957	298	1786
16	2174438	4113858	267	1541
17	2174340	4113720	242	1637
18	2173918	4113546	313	1599

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
19	2174381	4113352	290	1648
20	2174428	4113494	279	1576
21	2174356	4113215	304	1697
22	2173936	4113511	315	1668
23	2174071	4113836	285	1695
24	2174119	4113205	330	1511
25	2174325	4113990	273	1579
26	2174616	4113517	299	1592
27	2173847	4113480	330	1619
28	2174460	4113669	262	1555
29	2173986	4113841	296	1693
30	2174229	4114096	297	1702
31	2174356	4113228	302	1757
32	2173740	4113524	337	1600
33	2173948	4113401	327	1800
34	2174351	4113217	303	1739
35	2174120	4114029	302	1541
36	2174641	4113436	311	1654
37	2174189	4113424	295	1547
38	2174588	4113556	291	1770
39	2173959	4113516	312	1606
40	2174067	4113933	297	1616
41	2173983	4113312	333	1653
42	2174313	4113425	280	1651
43	2174033	4113899	297	1593
44	2174438	4113198	315	1686
45	2174022	4113780	284	1740
46	2174099	4113318	319	1718
47	2174438	4113647	262	1587
48	2174390	4113130	318	1567
49	2173920	4113485	320	1552
50	2174252	4113107	326	1765
51	2173714	4113331	363	1607
52	2174355	4113757	245	1658
53	2174350	4113164	309	1734
54	2174037	4113208	339	1515
55	2173971	4113289	338	1618
56	2174198	4113462	290	1705
57	2173936	4113248	347	1689
58	2174133	4113974	294	1708
59	2174150	4113347	309	1666
60	2174041	4113116	350	1514

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
61	2173948	4113614	301	1792
62	2174191	4114157	309	1770
63	2174129	4114049	304	1681
64	2173826	4113304	353	1701
65	2174222	4113089	331	1781
66	2174360	4113614	256	1521
67	2174150	4113774	268	1687
68	2174450	4113496	281	1765
69	2174496	4113681	264	1565
70	2173960	4113347	332	1558
71	2173846	4113240	358	1666
72	2174598	4113637	282	1630
73	2174463	4113486	284	1590
74	2174106	4113177	335	1762
75	2173731	4113434	349	1572
76	2174468	4113304	306	1612
77	2174319	4113902	263	1643
78	2173984	4113109	358	1632
79	2174338	4114092	284	1758
80	2174167	4114172	314	1525
81	2174054	4113336	322	1533
82	2174224	4113394	295	1720
83	2174356	4113303	293	1790
84	2174163	4113473	292	1761
85	2174231	4113264	309	1581
86	2174085	4113864	287	1526
87	2174639	4113553	297	1771
88	2174385	4113108	320	1579
89	2174500	4113691	264	1679
90	2174262	4113716	251	1635
91	2174448	4113534	276	1535
92	2174594	4113568	290	1739
93	2174324	4113571	261	1629
94	2174119	4113352	312	1671
95	2174338	4113792	248	1718
96	2174177	4113125	333	1643
97	2173896	4113362	338	1566
98	2174222	4113133	326	1751
99	2173867	4113306	348	1643
100	2174293	4114073	287	1626

Table 15: Data of the problem instance 5 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174008	4113737	281	1755
2	2174276	4113795	256	1582
3	2174372	4113713	246	1787
4	2174238	4113995	284	1723
5	2174221	4113695	259	1568
6	2174016	4113982	309	1545
7	2173979	4113136	355	1797
8	2174262	4114164	302	1734
9	2174147	4113103	339	1737
10	2174202	4114090	300	1627
11	2173786	4113282	361	1637
12	2174275	4113348	294	1754
13	2173894	4113508	321	1744
14	2173759	4113472	341	1723
15	2174141	4114147	314	1782
16	2173815	4113549	325	1549
17	2174581	4113504	296	1752
18	2174117	4113630	279	1515
19	2174249	4113700	255	1695
20	2173992	4113495	310	1676
21	2174037	4113303	328	1540
22	2173880	4113219	357	1794
23	2174036	4113917	299	1530
24	2174474	4113527	280	1623
25	2174109	4113077	346	1524
26	2174394	4113260	303	1652
27	2174461	4113732	254	1712
28	2174260	4113806	259	1688
29	2173910	4113293	344	1504
30	2174232	4113313	303	1791
31	2173989	4113294	335	1718
32	2173799	4113588	322	1589
33	2174016	4113370	322	1563
34	2174296	4113068	325	1555
35	2174266	4113566	269	1539
36	2173869	4113663	305	1632
37	2173989	4113618	296	1593
38	2174468	4113262	311	1685
39	2174086	4113311	321	1526
40	2174015	4113661	288	1666

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
41	2174108	4113567	288	1674
42	2174271	4113586	266	1510
43	2174617	4113466	305	1718
44	2174025	4113303	329	1786
45	2174226	4113868	270	1587
46	2173993	4113049	364	1533
47	2174031	4113550	299	1694
48	2173959	4113482	316	1707
49	2173957	4113487	315	1566
50	2174396	4113969	275	1619
51	2173895	4113703	297	1744
52	2174036	4113529	301	1755
53	2174338	4113175	307	1545
54	2174255	4114129	298	1723
55	2174365	4113114	317	1591
56	2174022	4113467	310	1784
57	2174588	4113322	319	1767
58	2174222	4113794	262	1602
59	2173831	4113332	349	1682
60	2174111	4113868	284	1747
61	2174378	4113139	315	1701
62	2174203	4113171	324	1619
63	2174552	4113722	266	1630
64	2174317	4113088	320	1689
65	2174180	4113324	308	1721
66	2174450	4113142	324	1745
67	2173932	4113815	299	1611
68	2173910	4113533	316	1506
69	2174251	4113237	310	1724
70	2174275	4113097	324	1513
71	2174316	4113836	256	1596
72	2174218	4113659	264	1615
73	2174282	4113535	271	1590
74	2174516	4113577	279	1518
75	2174345	4113492	269	1781
76	2173809	4113535	327	1588
77	2174212	4113991	287	1756
78	2174211	4113049	338	1507
79	2174182	4113793	267	1669
80	2174223	4113966	282	1695
81	2174137	4113720	266	1706
82	2174068	4113762	277	1724

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
83	2174618	4113547	295	1788
84	2174127	4113451	299	1557
85	2174360	4114002	275	1519
86	2174103	4114118	315	1529
87	2174069	4113405	312	1710
88	2174298	4113447	279	1649
89	2174427	4113521	275	1553
90	2173921	4113345	337	1553
91	2173982	4113573	302	1571
92	2174370	4114077	285	1558
93	2174338	4113772	245	1536
94	2174095	4113467	301	1781
95	2174195	4114111	303	1506
96	2173991	4113900	302	1736
97	2173857	4113711	301	1772
98	2174251	4113825	262	1728
99	2174206	4113154	326	1611
100	2174331	4113900	262	1502

Table 16: Data of the problem instance 6 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174396	4113189	312	1641
2	2174180	4113571	279	1637
3	2174031	4113321	327	1758
4	2174505	4113513	286	1696
5	2174107	4113566	288	1736
6	2174510	4113220	321	1788
7	2174338	4113679	247	1558
8	2174153	4113626	275	1794
9	2173925	4113304	341	1751
10	2174455	4113220	315	1616
11	2174478	4113855	271	1692
12	2174087	4113690	276	1597
13	2174638	4113471	307	1699
14	2173934	4113335	336	1800
15	2174147	4113854	278	1791
16	2174480	4113478	287	1581
17	2174064	4113056	354	1688
18	2174036	4113426	313	1679

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
19	2174149	4113277	318	1668
20	2174022	4113113	353	1650
21	2173998	4113345	328	1712
22	2173984	4113832	295	1786
23	2174053	4113586	292	1796
24	2174309	4113445	278	1537
25	2174035	4112993	365	1521
26	2174262	4113403	289	1773
27	2174216	4114191	310	1605
28	2174446	4113382	294	1672
29	2173932	4113586	307	1551
30	2174323	4113909	264	1648
31	2174238	4113688	258	1578
32	2174535	4113342	310	1549
33	2174408	4113164	316	1788
34	2174084	4113989	302	1589
35	2174077	4113541	295	1573
36	2174381	4113422	282	1539
37	2173986	4113030	367	1660
38	2174279	4113004	335	1712
39	2174465	4113719	256	1603
40	2174489	4113249	315	1666
41	2174531	4113391	303	1632
42	2174086	4114027	306	1609
43	2174144	4113347	310	1585
44	2174604	4113364	315	1573
45	2174216	4113851	270	1633
46	2173900	4113360	338	1747
47	2174404	4113537	271	1522
48	2173932	4113401	329	1529
49	2174412	4113985	279	1628
50	2174081	4113931	295	1756
51	2173996	4113001	369	1713
52	2174232	4113443	288	1722
53	2174244	4113199	316	1606
54	2174290	4114064	286	1795
55	2174186	4113488	288	1691
56	2174204	4113642	267	1759
57	2174073	4113406	311	1787
58	2174009	4113516	306	1663
59	2173908	4113675	299	1615
60	2174132	4113251	323	1507

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
61	2174111	4113085	345	1693
62	2174052	4113851	289	1720
63	2174418	4113294	302	1733
64	2174146	4113185	329	1605
65	2174547	4113699	268	1722
66	2174079	4113368	315	1622
67	2174218	4113147	325	1626
68	2174399	4114004	280	1798
69	2174175	4114010	294	1516
70	2174466	4113805	264	1693
71	2173868	4113190	362	1678
72	2174394	4113269	302	1628
73	2174019	4113353	324	1635
74	2174347	4113378	283	1659
75	2174270	4113044	331	1701
76	2174149	4113374	306	1729
77	2173979	4113333	331	1535
78	2174549	4113696	269	1577
79	2174277	4114045	285	1795
80	2174277	4113132	320	1669
81	2173770	4113316	358	1622
82	2174232	4113985	284	1725
83	2173975	4113041	367	1758
84	2174466	4113714	257	1597
85	2174515	4113737	261	1559
86	2174584	4113639	280	1737
87	2174538	4113623	276	1597
88	2174187	4113429	295	1714
89	2173912	4113738	292	1560
90	2174242	4113963	280	1630
91	2173939	4113449	322	1735
92	2173880	4113431	331	1798
93	2174351	4113249	299	1752
94	2174274	4113191	313	1576
95	2174234	4113864	269	1602
96	2174458	4113708	257	1551
97	2174052	4113790	282	1680
98	2173919	4113689	296	1706
99	2173913	4113599	307	1763
100	2174543	4113348	310	1744

Table 17: Data of the problem instance 7 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174252	4113141	322	1617
2	2173911	4113190	357	1586
3	2173957	4113728	287	1711
4	2174028	4114002	310	1613
5	2173921	4113114	365	1570
6	2174589	4113495	298	1505
7	2173941	4113611	303	1759
8	2174124	4114040	303	1720
9	2174361	4113838	255	1580
10	2174305	4113591	261	1574
11	2173748	4113430	347	1681
12	2174321	4113916	265	1787
13	2174242	4113835	264	1693
14	2173863	4113555	319	1694
15	2174150	4113683	269	1577
16	2174367	4113595	259	1697
17	2174118	4113842	280	1751
18	2174605	4113558	292	1591
19	2173974	4113896	304	1657
20	2173882	4113232	355	1796
21	2173985	4113619	296	1782
22	2174163	4113256	318	1524
23	2174080	4113370	315	1676
24	2174034	4113398	317	1633
25	2174555	4113619	279	1610
26	2174117	4113323	316	1566
27	2174225	4114158	305	1584
28	2173765	4113350	355	1800
29	2174166	4114043	299	1704
30	2173999	4113056	362	1549
31	2173999	4113474	312	1562
32	2174000	4113005	368	1529
33	2174450	4113204	316	1712
34	2174162	4114093	305	1650
35	2174456	4113160	322	1716
36	2174322	4113938	267	1735
37	2174433	4113570	270	1563
38	2174051	4113117	349	1721
39	2174556	4113649	276	1761
40	2174381	4113975	274	1646

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
41	2173809	4113555	325	1535
42	2174405	4113682	253	1667
43	2173996	4113015	367	1745
44	2174164	4113633	273	1659
45	2173993	4113543	304	1733
46	2174079	4113438	307	1787
47	2174561	4113630	278	1692
48	2174405	4113091	324	1524
49	2174361	4113510	269	1654
50	2174313	4114066	284	1612
51	2173999	4113206	344	1659
52	2173968	4113305	336	1537
53	2174066	4113199	337	1557
54	2174385	4113333	293	1646
55	2173986	4113873	300	1779
56	2174379	4113958	272	1523
57	2174211	4114205	313	1774
58	2173939	4113294	341	1617
59	2174070	4113668	280	1730
60	2174256	4113819	261	1710
61	2174353	4113774	246	1540
62	2174304	4113393	285	1794
63	2174021	4113887	297	1596
64	2174220	4113037	338	1586
65	2174373	4113192	308	1611
66	2174532	4113323	312	1645
67	2173785	4113265	363	1652
68	2173898	4113354	339	1572
69	2174043	4113975	305	1759
70	2174340	4113482	270	1533
71	2174361	4113120	316	1501
72	2173857	4113546	320	1559
73	2174165	4114070	302	1707
74	2174204	4114082	299	1687
75	2174566	4113459	300	1556
76	2173891	4113216	356	1706
77	2174169	4113254	318	1675
78	2174591	4113497	298	1667
79	2174350	4114015	275	1724
80	2174058	4113755	277	1733
81	2174235	4113084	330	1636
82	2174118	4113670	274	1754

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
83	2174261	4113885	268	1578
84	2173774	4113357	353	1779
85	2174205	4114035	293	1703
86	2174311	4114063	284	1622
87	2173865	4113723	298	1536
88	2173972	4113680	291	1666
89	2173860	4113551	319	1587
90	2174477	4113232	316	1717
91	2174242	4113902	273	1665
92	2174042	4113457	309	1584
93	2174195	4112997	346	1529
94	2174151	4113859	278	1721
95	2173907	4113214	354	1760
96	2174339	4113755	243	1728
97	2174438	4113740	253	1757
98	2174245	4113188	317	1634
99	2174004	4113685	286	1677
100	2174084	4113379	313	1625

Table 18: Data of the problem instance 8 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2173927	4113381	332	1715
2	2174633	4113414	313	1739
3	2173904	4113508	319	1680
4	2174124	4113938	291	1583
5	2174248	4113401	291	1783
6	2174325	4113422	279	1684
7	2174544	4113419	302	1704
8	2174380	4113325	293	1524
9	2174027	4113999	310	1526
10	2174112	4113861	283	1739
11	2174426	4113152	320	1704
12	2174096	4113311	320	1607
13	2174143	4113353	309	1555
14	2174258	4113753	253	1701
15	2174151	4114046	301	1659
16	2173836	4113291	354	1659
17	2174175	4113090	337	1704
18	2174345	4113165	308	1517
19	2174102	4113562	289	1549

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
20	2174435	4113149	321	1574
21	2174251	4113180	317	1671
22	2174448	4113570	272	1504
23	2174185	4113808	268	1580
24	2174211	4113609	270	1685
25	2174413	4113610	263	1597
26	2174129	4113557	286	1575
27	2174374	4113872	261	1577
28	2174349	4113773	246	1514
29	2174365	4113259	299	1517
30	2173928	4113618	303	1738
31	2174410	4113608	263	1691
32	2174388	4113197	310	1565
33	2174205	4114129	304	1582
34	2174141	4113177	331	1627
35	2173931	4113781	295	1798
36	2174285	4113347	293	1762
37	2174151	4113469	294	1674
38	2174374	4113496	272	1532
39	2174151	4114121	310	1603
40	2173830	4113623	314	1504
41	2174013	4112993	368	1617
42	2173945	4113321	337	1693
43	2173962	4113538	309	1563
44	2174116	4113994	299	1711
45	2174050	4113956	302	1581
46	2174095	4113065	350	1614
47	2174317	4113438	278	1633
48	2174032	4113889	296	1512
49	2174255	4113014	336	1576
50	2174419	4113880	267	1770
51	2174667	4113485	309	1653
52	2174101	4113550	291	1771
53	2173681	4113354	365	1757
54	2173965	4113614	299	1639
55	2174330	4113828	253	1586
56	2173889	4113553	316	1601
57	2173939	4113626	301	1551
58	2174430	4113634	262	1588
59	2174484	4113265	313	1584
60	2173884	4113230	355	1795
61	2174106	4113570	288	1768

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
62	2174580	4113636	280	1779
63	2174042	4113503	303	1620
64	2173982	4113290	336	1759
65	2174203	4113649	267	1654
66	2174260	4113185	315	1698
67	2174125	4113073	345	1640
68	2174035	4113579	295	1682
69	2174327	4113132	314	1645
70	2174258	4113427	287	1555
71	2173977	4113515	310	1673
72	2174022	4113473	309	1757
73	2174207	4113431	292	1606
74	2174387	4113262	302	1707
75	2174035	4113352	322	1518
76	2174432	4113418	288	1551
77	2174197	4113302	309	1692
78	2174560	4113419	304	1733
79	2174149	4113943	289	1695
80	2174411	4113864	264	1768
81	2174086	4114053	309	1788
82	2174574	4113331	316	1730
83	2174556	4113525	290	1643
84	2174303	4113423	282	1561
85	2174006	4113445	315	1523
86	2174149	4113328	312	1576
87	2174339	4113778	246	1520
88	2174271	4113675	255	1798
89	2174319	4113868	259	1561
90	2173811	4113543	326	1600
91	2173865	4113604	312	1611
92	2174559	4113414	304	1509
93	2173768	4113374	352	1606
94	2174180	4113623	272	1596
95	2174394	4113928	270	1648
96	2174371	4113348	289	1701
97	2174422	4113499	277	1691
98	2174132	4113232	325	1662
99	2173751	4113373	354	1634
100	2173843	4113402	339	1758

Table 19: Data of the problem instance 9 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174607	4113570	291	1739
2	2173944	4113328	336	1791
3	2173907	4113192	357	1766
4	2174151	4113816	273	1783
5	2174230	4113454	287	1725
6	2174186	4113575	277	1612
7	2174276	4113163	316	1735
8	2173788	4113347	353	1716
9	2173961	4113710	288	1714
10	2173959	4113190	351	1597
11	2174155	4113806	271	1640
12	2174385	4113317	295	1626
13	2174108	4113810	278	1663
14	2174499	4113534	282	1560
15	2174322	4113394	283	1550
16	2174297	4113512	272	1515
17	2174503	4113289	312	1644
18	2173957	4113603	302	1614
19	2174080	4113709	274	1799
20	2174202	4113328	305	1503
21	2173922	4113582	308	1590
22	2174323	4112993	331	1717
23	2173944	4113341	335	1576
24	2173810	4113276	358	1572
25	2174016	4113554	300	1746
26	2174510	4113403	300	1724
27	2174352	4113260	298	1518
28	2174005	4113935	305	1687
29	2173874	4113696	300	1743
30	2174195	4113149	327	1534
31	2174412	4113154	318	1783
32	2174428	4113239	309	1703
33	2174092	4113961	298	1593
34	2173746	4113380	354	1590
35	2174091	4113300	322	1516
36	2174042	4113481	306	1547
37	2174335	4113281	295	1682
38	2174059	4113764	278	1703
39	2174337	4113653	250	1745
40	2174201	4113749	259	1690

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
41	2173954	4113560	307	1522
42	2174207	4113616	270	1674
43	2174120	4113087	344	1533
44	2173829	4113547	324	1571
45	2174209	4113912	278	1531
46	2174059	4113619	287	1636
47	2174323	4113013	328	1784
48	2174276	4113514	274	1694
49	2174102	4113662	277	1700
50	2174250	4113890	270	1789
51	2173845	4113623	313	1661
52	2173972	4113565	304	1563
53	2174076	4114101	316	1580
54	2174289	4113092	323	1675
55	2174071	4113470	304	1739
56	2174535	4113696	267	1524
57	2174329	4113177	308	1633
58	2174391	4113430	282	1541
59	2173920	4113808	300	1780
60	2173977	4113365	328	1776
61	2174141	4113418	302	1585
62	2174259	4113081	328	1699
63	2174285	4113990	278	1787
64	2174190	4113192	323	1647
65	2173812	4113365	348	1709
66	2174091	4113659	279	1510
67	2174261	4113684	255	1659
68	2173977	4113279	338	1685
69	2174532	4113304	314	1616
70	2174447	4113409	291	1709
71	2174529	4113329	311	1636
72	2173787	4113412	345	1530
73	2174487	4113566	277	1654
74	2173893	4113435	329	1711
75	2174585	4113352	315	1570
76	2174341	4113981	270	1758
77	2174459	4113762	258	1687
78	2174342	4113777	246	1552
79	2174175	4113523	285	1615
80	2174488	4113368	301	1785
81	2174585	4113553	291	1798
82	2174450	4113695	257	1679

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
83	2173964	4113024	370	1673
84	2174012	4113959	307	1643
85	2174138	4113870	281	1796
86	2174051	4113213	337	1688
87	2174190	4113861	274	1589
88	2174065	4113533	297	1626
89	2174392	4113222	307	1641
90	2174205	4113663	265	1538
91	2174231	4113694	258	1622
92	2174562	4113308	317	1611
93	2174327	4113404	281	1729
94	2174253	4113162	319	1682
95	2174288	4113711	249	1530
96	2174086	4113238	330	1700
97	2174129	4113922	288	1614
98	2174013	4113977	309	1501
99	2174447	4113672	260	1627
100	2174181	4113899	279	1534

Table 20: Data of the problem instance 10 in Region 2

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2174083	4113112	345	1545
2	2174391	4113987	277	1731
3	2174434	4113192	316	1729
4	2174370	4113660	252	1772
5	2174153	4113073	342	1573
6	2174474	4113285	309	1710
7	2173814	4113281	357	1552
8	2173996	4113574	300	1645
9	2174154	4114145	312	1746
10	2173949	4113189	352	1508
11	2174076	4113194	336	1641
12	2173889	4113724	295	1586
13	2173765	4113366	353	1719
14	2173765	4113539	332	1734
15	2174200	4113637	268	1680
16	2173908	4113301	344	1728
17	2173996	4113554	303	1757
18	2174431	4113393	291	1735

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
19	2174035	4113603	292	1507
20	2174064	4113053	355	1720
21	2174250	4114023	286	1538
22	2174161	4112998	350	1625
23	2174206	4114087	299	1582
24	2173994	4113154	351	1705
25	2174296	4113621	259	1592
26	2174287	4113643	257	1769
27	2174527	4113441	297	1724
28	2174644	4113404	315	1750
29	2173941	4113733	288	1653
30	2173777	4113549	330	1678
31	2173895	4113217	355	1724
32	2174577	4113425	305	1675
33	2174333	4113359	286	1699
34	2173975	4113277	339	1772
35	2174236	4113244	311	1613
36	2173973	4113301	336	1594
37	2174387	4113971	274	1657
38	2174124	4113452	300	1727
39	2174365	4113573	262	1574
40	2174388	4113528	270	1628
41	2173849	4113628	312	1765
42	2173971	4113049	366	1773
43	2174402	4113346	293	1517
44	2174362	4113880	260	1768
45	2174459	4113181	320	1703
46	2174525	4113584	280	1738
47	2174199	4113873	274	1770
48	2174158	4113443	297	1558
49	2174249	4113522	276	1518
50	2173934	4113598	305	1681
51	2174414	4113695	253	1663
52	2174245	4113763	255	1631
53	2174167	4114139	310	1578
54	2174215	4113796	263	1680
55	2173935	4113837	302	1772
56	2173845	4113487	329	1666
57	2174236	4113462	285	1572
58	2174014	4113285	333	1698
59	2174445	4113837	265	1724
60	2174228	4114095	297	1736

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
61	2173695	4113349	363	1607
62	2174315	4113393	284	1651
63	2174326	4114100	286	1763
64	2174401	4113831	259	1670
65	2174534	4113560	284	1522
66	2173969	4113513	311	1565
67	2174311	4113822	255	1543
68	2174226	4114046	292	1549
69	2174035	4113025	362	1745
70	2174332	4113274	296	1791
71	2173988	4113655	292	1527
72	2173983	4113478	313	1651
73	2174131	4114143	315	1697
74	2174148	4113744	265	1767
75	2174518	4113528	285	1739
76	2173969	4113408	324	1528
77	2174202	4113761	260	1748
78	2174550	4113344	311	1672
79	2173767	4113480	339	1521
80	2174273	4113744	250	1715
81	2174129	4113034	349	1662
82	2174441	4113172	319	1722
83	2174450	4113355	298	1743
84	2174180	4113223	320	1703
85	2174591	4113598	286	1550
86	2174098	4113865	285	1686
87	2174128	4113595	282	1763
88	2174275	4113997	280	1576
89	2174343	4113814	250	1747
90	2174215	4113170	323	1674
91	2174067	4114071	314	1523
92	2174356	4113057	323	1525
93	2173907	4113754	295	1501
94	2173900	4113651	303	1710
95	2174297	4114093	289	1594
96	2174621	4113425	310	1789
97	2173953	4113682	293	1647
98	2174026	4113691	283	1795
99	2173807	4113472	335	1528
100	2174480	4113277	311	1704

Table 21: Data of the problem instance 1 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2190713	4117996	954	1717
2	2187580	4120681	900	1746
3	2185008	4120835	610	1666
4	2189844	4117418	898	1709
5	2190100	4120315	1159	1679
6	2185714	4120511	656	1717
7	2185211	4113754	782	1712
8	2185835	4116804	491	1790
9	2189257	4118356	823	1743
10	2187031	4120835	853	1735
11	2187389	4122271	1068	1568
12	2185305	4123000	906	1664
13	2188303	4119469	842	1695
14	2188134	4119137	782	1646
15	2192915	4118290	1254	1703
16	2188466	4116239	874	1597
17	2191648	4119805	1283	1789
18	2190637	4116624	1089	1747
19	2184301	4119815	534	1680
20	2191799	4118406	1134	1747
21	2184165	4117926	324	1514
22	2187535	4120633	889	1591
23	2187362	4121855	1015	1560
24	2185378	4113698	809	1790
25	2189054	4118897	863	1703
26	2191377	4119523	1217	1724
27	2187546	4115715	827	1633
28	2185939	4121611	815	1616
29	2189090	4121139	1137	1797
30	2189566	4116614	961	1795
31	2188876	4121056	1101	1684
32	2188365	4120580	982	1570
33	2183888	4118061	374	1554
34	2192051	4118122	1130	1610
35	2193414	4118801	1375	1637
36	2192086	4120141	1376	1635
37	2185902	4118952	492	1709
38	2188503	4122364	1213	1559
39	2189988	4120687	1190	1752
40	2190668	4116371	1123	1598

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
41	2184060	4118106	358	1502
42	2184238	4122321	843	1795
43	2184983	4123243	896	1769
44	2183851	4119173	511	1711
45	2186812	4119248	636	1500
46	2189787	4120148	1101	1582
47	2186991	4119463	684	1615
48	2185318	4117147	388	1684
49	2189941	4120214	1128	1513
50	2187742	4120286	872	1749
51	2184733	4119488	443	1691
52	2184825	4120040	499	1507
53	2190139	4116607	1031	1569
54	2190103	4118038	886	1652
55	2186650	4118274	500	1675
56	2187837	4121628	1045	1562
57	2185603	4119823	560	1631
58	2189473	4119889	1032	1703
59	2190047	4117195	949	1501
60	2185276	4118814	400	1603
61	2187219	4118180	557	1583
62	2183724	4121482	804	1795
63	2190519	4120449	1225	1693
64	2183842	4121060	739	1713
65	2189282	4120388	1069	1692
66	2189192	4117434	818	1774
67	2187709	4118472	651	1567
68	2184833	4114919	601	1547
69	2184251	4119629	518	1582
70	2185617	4114611	728	1677
71	2186950	4120466	799	1539
72	2188874	4117277	799	1536
73	2185170	4114251	717	1525
74	2188604	4118849	803	1768
75	2192959	4117828	1223	1579
76	2188609	4117206	776	1575
77	2187717	4118706	680	1787
78	2186420	4119071	568	1667
79	2186447	4121703	887	1550
80	2183805	4117176	453	1672
81	2185400	4114590	704	1596
82	2184830	4121367	657	1570

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
83	2184636	4122486	815	1793
84	2189683	4118305	868	1791
85	2192021	4118906	1220	1563
86	2185111	4115642	543	1797
87	2184395	4120013	547	1794
88	2188617	4118807	800	1653
89	2183633	4120030	640	1782
90	2188382	4116507	832	1544
91	2185871	4114854	729	1633
92	2190010	4117873	864	1651
93	2184956	4113943	729	1782
94	2191549	4120624	1370	1600
95	2185387	4119664	515	1578
96	2186361	4117399	483	1760
97	2185825	4119943	601	1527
98	2186729	4120522	779	1540
99	2187093	4118680	602	1546
100	2188766	4117357	776	1500

Table 22: Data of the problem instance 2 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2188984	4116664	886	1739
2	2187601	4119099	713	1650
3	2189978	4118338	907	1522
4	2184376	4115769	554	1584
5	2189551	4121316	1213	1647
6	2187409	4119669	758	1683
7	2184237	4117051	416	1654
8	2184686	4118094	282	1514
9	2189533	4121322	1212	1779
10	2187157	4119000	648	1653
11	2191526	4119120	1187	1632
12	2186066	4116948	501	1785
13	2186081	4119768	611	1592
14	2183682	4117579	420	1670
15	2192477	4117199	1241	1697
16	2185244	4113480	819	1653

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
17	2185113	4114177	720	1738
18	2186540	4117209	527	1544
19	2186981	4118702	591	1563
20	2188203	4119791	868	1658
21	2184647	4116538	429	1719
22	2191694	4117602	1098	1787
23	2187003	4120416	799	1764
24	2184163	4116367	507	1654
25	2184664	4120825	612	1525
26	2191796	4118503	1145	1566
27	2184300	4121357	720	1547
28	2191092	4118022	1003	1664
29	2190866	4119671	1173	1682
30	2183786	4119805	595	1528
31	2192119	4118598	1195	1527
32	2187989	4122280	1141	1728
33	2188710	4115760	961	1716
34	2189215	4119925	1006	1634
35	2185763	4115875	594	1554
36	2185266	4120382	587	1642
37	2185828	4120350	650	1635
38	2189600	4118060	828	1635
39	2187000	4115591	776	1746
40	2188236	4118730	745	1670
41	2184877	4115494	533	1637
42	2183927	4120550	668	1746
43	2191282	4117915	1013	1504
44	2186235	4120133	673	1765
45	2186850	4117666	509	1529
46	2183967	4116193	552	1684
47	2187018	4119887	738	1717
48	2187260	4116445	705	1691
49	2184216	4114702	701	1549
50	2184897	4122192	760	1631
51	2187297	4118948	658	1577
52	2184548	4120601	599	1684
53	2192549	4118325	1214	1680
54	2189389	4121296	1191	1588
55	2191895	4119885	1323	1503
56	2188715	4117119	799	1591
57	2192881	4118214	1240	1727
58	2185167	4121653	727	1565

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
59	2191485	4119581	1237	1626
60	2191649	4119225	1214	1788
61	2185693	4123045	958	1663
62	2189799	4121115	1219	1631
63	2185326	4121203	693	1574
64	2184194	4117388	381	1501
65	2185124	4116030	498	1788
66	2183732	4114879	738	1626
67	2185847	4116924	478	1611
68	2187980	4119778	840	1716
69	2190623	4116519	1100	1744
70	2191378	4117971	1031	1541
71	2191561	4118189	1079	1705
72	2189028	4116096	959	1588
73	2185958	4121638	821	1651
74	2185139	4120242	555	1545
75	2184205	4113910	797	1514
76	2187540	4119292	729	1527
77	2185373	4115386	606	1706
78	2186789	4116498	642	1542
79	2188180	4121843	1112	1573
80	2188956	4117194	819	1639
81	2190131	4120669	1205	1539
82	2184895	4118946	370	1782
83	2185796	4119059	492	1626
84	2184291	4119647	516	1572
85	2190614	4120221	1209	1588
86	2188370	4122046	1159	1648
87	2188055	4119778	849	1629
88	2185063	4119981	514	1778
89	2187094	4119706	725	1502
90	2186160	4123923	1119	1602
91	2187225	4115143	857	1630
92	2188778	4118096	734	1562
93	2186213	4117355	470	1670
94	2188925	4117768	746	1536
95	2186398	4123173	1058	1602
96	2190535	4118718	1019	1799
97	2186238	4115661	676	1790
98	2184490	4117875	287	1762
99	2192668	4119495	1369	1592
100	2190858	4120367	1256	1573

Table 23: Data of the problem instance 3 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2185764	4119645	558	1573
2	2191633	4120051	1311	1784
3	2183843	4121939	844	1675
4	2185913	4122791	954	1758
5	2186226	4115651	676	1699
6	2184609	4119493	459	1558
7	2191491	4116826	1167	1692
8	2191561	4119288	1211	1729
9	2189201	4121539	1198	1587
10	2187899	4117781	621	1664
11	2193035	4118029	1237	1725
12	2192157	4118659	1207	1790
13	2186951	4119491	682	1614
14	2185350	4118537	375	1785
15	2187094	4118824	619	1659
16	2184356	4117163	389	1652
17	2187142	4120658	845	1522
18	2188324	4119051	794	1583
19	2187278	4115218	854	1508
20	2191919	4120394	1387	1684
21	2187882	4118224	642	1750
22	2191006	4118082	1000	1588
23	2191999	4117933	1101	1661
24	2187274	4120312	819	1580
25	2185094	4114422	688	1748
26	2186273	4123230	1049	1656
27	2184720	4113688	762	1745
28	2184797	4120176	518	1658
29	2184183	4116397	501	1790
30	2185800	4123250	995	1627
31	2190336	4119647	1107	1752
32	2188259	4115780	905	1554
33	2187321	4120288	822	1677
34	2187640	4115397	876	1721
35	2189428	4115742	1050	1592
36	2190198	4118589	963	1515
37	2189246	4117836	776	1800
38	2184368	4117132	391	1741

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
39	2185788	4122823	942	1549
40	2183847	4118011	372	1719
41	2186390	4122094	927	1510
42	2186450	4119472	620	1560
43	2188741	4116498	876	1571
44	2185202	4117116	378	1594
45	2186793	4119928	716	1633
46	2190342	4117620	934	1635
47	2183655	4118436	447	1641
48	2185225	4119522	479	1597
49	2188270	4122445	1195	1642
50	2184428	4115253	609	1520
51	2187724	4118537	660	1624
52	2188951	4120676	1064	1619
53	2188291	4121517	1086	1659
54	2187264	4121586	971	1768
55	2184437	4119267	452	1548
56	2187090	4117024	615	1520
57	2190197	4117122	976	1507
58	2184394	4122556	852	1533
59	2193568	4118531	1361	1522
60	2184589	4115508	559	1750
61	2187077	4121974	995	1545
62	2184800	4117955	251	1596
63	2183817	4119027	498	1691
64	2193108	4119269	1394	1540
65	2192821	4119745	1417	1612
66	2188497	4118752	779	1602
67	2184888	4117095	342	1634
68	2191416	4117644	1060	1793
69	2185636	4119569	534	1726
70	2193130	4119183	1387	1548
71	2189912	4118658	937	1611
72	2188736	4117645	738	1771
73	2183964	4120357	640	1602
74	2186056	4120806	732	1719
75	2186022	4119228	539	1609
76	2184167	4117915	323	1717
77	2187409	4117461	601	1526
78	2184996	4120995	628	1739
79	2190343	4116917	1018	1763
80	2188138	4120097	897	1696

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
81	2184208	4114572	717	1774
82	2189518	4116526	966	1777
83	2187810	4116148	807	1754
84	2187276	4118693	625	1648
85	2187823	4121688	1050	1553
86	2190051	4117984	873	1570
87	2192753	4117806	1201	1775
88	2188611	4116875	816	1641
89	2189824	4121080	1218	1502
90	2187815	4117719	619	1679
91	2189667	4116849	945	1642
92	2183840	4115491	651	1524
93	2191391	4119546	1221	1593
94	2187853	4118492	670	1735
95	2185689	4118181	373	1714
96	2188165	4115910	878	1575
97	2185019	4117691	287	1708
98	2186781	4116897	593	1632
99	2184491	4116989	393	1614
100	2189669	4119772	1042	1609

Table 24: Data of the problem instance 4 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2184199	4117946	322	1799
2	2188614	4116406	872	1722
3	2186918	4118644	576	1553
4	2184826	4122114	747	1674
5	2186803	4123771	1178	1651
6	2188122	4115762	890	1788
7	2184109	4116466	502	1509
8	2184348	4116701	445	1764
9	2188265	4116653	801	1585
10	2189561	4119429	988	1767
11	2184556	4121913	756	1570
12	2184306	4122099	808	1590
13	2191562	4116619	1200	1761
14	2189699	4116527	988	1656
15	2186980	4118173	527	1604
16	2188456	4120256	954	1741

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
17	2184562	4121747	735	1784
18	2193067	4117532	1271	1620
19	2184435	4119452	475	1760
20	2192680	4118826	1290	1708
21	2186443	4117045	535	1695
22	2184481	4121429	707	1781
23	2185710	4121792	809	1753
24	2187518	4120049	817	1582
25	2187503	4119506	750	1569
26	2187049	4121900	983	1588
27	2184156	4121110	707	1766
28	2192473	4117330	1224	1746
29	2188995	4120353	1031	1708
30	2185572	4121102	710	1517
31	2185619	4121159	722	1528
32	2187375	4116821	674	1755
33	2187557	4115453	860	1576
34	2188384	4119624	870	1733
35	2187248	4122328	1058	1582
36	2185193	4117203	366	1656
37	2186245	4124064	1146	1637
38	2189262	4117985	779	1716
39	2184576	4115376	577	1655
40	2186540	4121413	863	1603
41	2189489	4116218	1000	1638
42	2186113	4115639	664	1714
43	2186818	4123804	1184	1614
44	2184175	4116241	521	1554
45	2191031	4120317	1271	1505
46	2187492	4121006	929	1566
47	2187503	4118446	623	1779
48	2185404	4114389	729	1609
49	2188644	4115759	953	1565
50	2192637	4119224	1332	1610
51	2189447	4118984	921	1581
52	2187674	4116016	806	1695
53	2188266	4122181	1163	1700
54	2186320	4120687	750	1794
55	2184016	4118678	432	1691
56	2190492	4120691	1251	1765
57	2185658	4120644	665	1705
58	2184891	4115732	506	1542

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
59	2183821	4116118	578	1546
60	2184824	4118748	344	1544
61	2189616	4120398	1111	1751
62	2184225	4119784	540	1558
63	2191980	4118811	1204	1529
64	2190802	4120388	1252	1782
65	2187441	4121607	995	1559
66	2188761	4121576	1149	1744
67	2186421	4114986	779	1660
68	2185639	4120832	686	1642
69	2189311	4116359	961	1798
70	2186765	4120219	747	1673
71	2190921	4120773	1312	1614
72	2192678	4117737	1200	1619
73	2187490	4120232	836	1719
74	2185169	4118446	343	1723
75	2192829	4119205	1353	1589
76	2187104	4118220	548	1589
77	2192574	4119196	1321	1631
78	2183906	4117008	461	1553
79	2184402	4121052	671	1771
80	2187368	4118084	563	1674
81	2183724	4120413	675	1526
82	2186877	4115329	793	1514
83	2183930	4120679	683	1565
84	2189591	4117742	829	1531
85	2191143	4118968	1122	1523
86	2191305	4118383	1072	1668
87	2191344	4117858	1026	1568
88	2184698	4114889	621	1594
89	2191753	4119442	1252	1694
90	2190271	4119141	1038	1781
91	2188787	4118714	809	1675
92	2188134	4120168	905	1626
93	2184422	4120341	583	1595
94	2184584	4115790	526	1554
95	2188432	4119949	915	1562
96	2183752	4119944	616	1752
97	2184249	4118869	427	1579
98	2190709	4117580	983	1621
99	2189250	4121463	1195	1775
100	2184496	4119201	437	1723

Table 25: Data of the problem instance 5 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2184858	4115987	472	1781
2	2184660	4118858	377	1618
3	2188849	4120539	1036	1627
4	2184630	4119353	440	1643
5	2191575	4120448	1352	1602
6	2186294	4119562	612	1532
7	2190663	4120501	1249	1514
8	2186959	4122035	988	1598
9	2191168	4118582	1079	1652
10	2187994	4122502	1169	1689
11	2192114	4117042	1216	1799
12	2185375	4116586	462	1776
13	2185945	4120895	730	1508
14	2184895	4115772	502	1783
15	2185012	4121171	651	1705
16	2188460	4115867	918	1588
17	2186385	4119795	651	1777
18	2189503	4120164	1069	1747
19	2186131	4115788	648	1533
20	2186324	4123016	1030	1585
21	2192061	4120556	1423	1779
22	2184342	4115366	606	1597
23	2187534	4115833	811	1781
24	2189950	4116085	1071	1692
25	2191773	4117988	1080	1622
26	2184475	4116600	442	1535
27	2188613	4120488	1001	1695
28	2193266	4118425	1312	1613
29	2185301	4118644	382	1608
30	2191445	4117030	1137	1685
31	2190594	4117675	957	1701
32	2190518	4116305	1113	1584
33	2185727	4117020	452	1701
34	2185111	4122308	799	1654
35	2187901	4118978	735	1777
36	2189761	4119843	1062	1765

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
37	2189958	4119757	1075	1611
38	2184663	4117248	342	1773
39	2191739	4119111	1211	1629
40	2184617	4118605	351	1512
41	2192727	4119536	1381	1534
42	2189587	4116091	1027	1649
43	2186488	4123455	1102	1720
44	2186898	4117755	504	1654
45	2186164	4120305	685	1554
46	2186798	4121866	949	1583
47	2186007	4123395	1037	1562
48	2189351	4118117	805	1544
49	2186035	4118090	404	1702
50	2186914	4120765	831	1800
51	2187956	4118720	710	1554
52	2191382	4116901	1145	1587
53	2190236	4117767	903	1615
54	2184136	4115719	588	1679
55	2184208	4119715	534	1612
56	2186918	4122436	1032	1682
57	2191825	4120404	1377	1668
58	2186703	4116511	630	1726
59	2190042	4116532	1028	1755
60	2187681	4120769	923	1572
61	2184915	4121053	625	1704
62	2187297	4118370	589	1681
63	2189746	4116325	1018	1756
64	2185543	4116036	548	1760
65	2184659	4120155	532	1711
66	2189195	4120381	1058	1726
67	2186460	4121032	808	1508
68	2185320	4118323	346	1502
69	2185210	4119778	508	1647
70	2190848	4117450	1015	1760
71	2190726	4118119	970	1662
72	2189992	4118997	988	1755
73	2187804	4116100	812	1565
74	2191552	4116738	1185	1612
75	2188722	4116049	928	1576
76	2184924	4115194	575	1648
77	2183959	4114366	772	1528
78	2187829	4118258	639	1620

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
79	2188832	4116287	913	1510
80	2192426	4118374	1205	1536
81	2190920	4120063	1227	1734
82	2185775	4115416	650	1751
83	2187547	4120548	880	1558
84	2184516	4116494	450	1594
85	2190378	4117730	925	1754
86	2183898	4115091	692	1566
87	2190728	4120742	1285	1581
88	2184905	4118127	273	1641
89	2187839	4120955	964	1509
90	2188423	4115698	934	1542
91	2185285	4116498	462	1783
92	2187554	4120084	826	1507
93	2185015	4114846	627	1601
94	2189442	4118946	916	1561
95	2189943	4118234	890	1708
96	2190446	4116281	1107	1523
97	2186603	4123356	1104	1506
98	2184689	4122787	845	1548
99	2186278	4118754	513	1534
100	2191363	4119885	1259	1795

Table 26: Data of the problem instance 6 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2189304	4118971	902	1678
2	2190250	4119876	1124	1700
3	2191146	4117854	1002	1631
4	2187705	4121938	1066	1515
5	2189565	4117469	859	1520
6	2192801	4117329	1264	1662
7	2189494	4121500	1228	1731
8	2184195	4120628	645	1652
9	2187223	4119733	744	1581
10	2183786	4118145	396	1673
11	2188763	4120106	973	1786
12	2189883	4118763	947	1788

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
13	2189462	4115728	1055	1730
14	2190099	4118131	897	1569
15	2188866	4118934	845	1694
16	2185187	4122873	876	1527
17	2183745	4121817	841	1524
18	2189795	4120972	1201	1719
19	2189810	4121254	1237	1786
20	2191247	4118859	1122	1722
21	2191439	4120626	1357	1672
22	2191514	4117575	1080	1587
23	2188158	4119857	871	1785
24	2185190	4120919	642	1531
25	2189242	4116154	978	1530
26	2191823	4119826	1307	1651
27	2184113	4114324	759	1585
28	2188079	4122420	1169	1501
29	2191035	4116937	1099	1730
30	2189087	4115703	1013	1562
31	2185648	4115784	591	1800
32	2191911	4118350	1140	1734
33	2183739	4117747	393	1748
34	2185109	4116178	479	1789
35	2189950	4117743	872	1728
36	2187974	4119266	778	1641
37	2184393	4120894	653	1692
38	2191004	4119256	1140	1548
39	2184318	4121694	758	1520
40	2187457	4119475	741	1587
41	2188860	4116053	944	1576
42	2190005	4116206	1063	1686
43	2188970	4117895	736	1578
44	2190728	4118740	1045	1568
45	2185458	4113484	844	1777
46	2186947	4116287	686	1632
47	2184006	4118671	433	1620
48	2185398	4117348	373	1621
49	2187621	4121827	1043	1617
50	2186197	4116174	610	1545
51	2183859	4115100	696	1751
52	2190052	4120132	1131	1566
53	2190565	4117994	936	1755
54	2191342	4118628	1105	1716

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
55	2192571	4117549	1210	1753
56	2185068	4119367	441	1687
57	2184876	4121511	675	1696
58	2191197	4120205	1277	1545
59	2185172	4122854	872	1698
60	2184572	4118409	333	1500
61	2185028	4121753	723	1594
62	2186601	4119832	681	1703
63	2190090	4119022	1002	1510
64	2186791	4120000	724	1710
65	2186881	4117732	505	1639
66	2187479	4121148	944	1554
67	2189810	4120731	1174	1684
68	2189943	4121157	1241	1649
69	2188058	4118442	689	1741
70	2189423	4117346	856	1530
71	2184787	4115721	510	1777
72	2186297	4121174	806	1521
73	2185669	4115737	599	1649
74	2186541	4115974	675	1768
75	2183934	4117739	370	1754
76	2185627	4117263	411	1685
77	2186252	4116900	529	1659
78	2185620	4115304	645	1570
79	2186830	4116905	598	1650
80	2187301	4120367	829	1740
81	2190780	4118895	1070	1548
82	2188166	4119345	810	1668
83	2186757	4118761	571	1679
84	2191186	4116579	1160	1586
85	2192644	4117344	1243	1630
86	2188513	4121585	1121	1512
87	2189175	4118460	825	1792
88	2190257	4119445	1073	1786
89	2187301	4122047	1031	1771
90	2186673	4116311	651	1787
91	2186520	4119054	578	1672
92	2183985	4118551	421	1723
93	2191989	4119825	1327	1543
94	2185827	4120825	707	1612
95	2191951	4118168	1123	1527
96	2188238	4116844	774	1768

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
97	2186654	4119376	633	1678
98	2188328	4120026	912	1777
99	2185970	4118712	471	1503
100	2189181	4117457	814	1644

Table 27: Data of the problem instance 7 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2185004	4113986	729	1638
2	2187851	4117064	702	1524
3	2185173	4123217	916	1581
4	2190753	4116613	1104	1672
5	2187672	4115361	885	1749
6	2184139	4114671	714	1559
7	2192328	4119537	1333	1537
8	2184099	4116574	490	1723
9	2187322	4117984	546	1760
10	2185098	4114677	658	1608
11	2191565	4117787	1061	1745
12	2191430	4117817	1041	1686
13	2190969	4120356	1268	1759
14	2184953	4121341	664	1788
15	2189433	4121518	1223	1717
16	2190473	4119108	1059	1584
17	2187615	4116814	703	1779
18	2188888	4116207	929	1511
19	2191189	4119838	1232	1637
20	2191362	4117237	1102	1707
21	2185523	4121087	702	1727
22	2184509	4118881	397	1600
23	2188217	4116642	796	1588
24	2186418	4119698	643	1693
25	2193554	4118053	1302	1502
26	2187050	4118596	587	1686
27	2185744	4115411	647	1731
28	2186380	4119982	672	1573
29	2184647	4121618	709	1596
30	2187733	4117154	677	1546
31	2189659	4116434	994	1665
32	2186286	4120062	671	1698

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
33	2191494	4117838	1046	1653
34	2191607	4117647	1082	1582
35	2183885	4121931	838	1620
36	2185299	4123307	942	1648
37	2189117	4119384	929	1786
38	2186420	4121467	855	1759
39	2191149	4117515	1043	1735
40	2189871	4118070	862	1728
41	2192206	4120410	1423	1507
42	2190773	4116587	1110	1519
43	2186218	4123655	1094	1748
44	2190236	4120643	1215	1619
45	2193327	4117669	1286	1548
46	2183876	4115495	646	1668
47	2191846	4119651	1289	1686
48	2184968	4118229	293	1543
49	2192959	4119227	1371	1681
50	2189277	4119637	979	1517
51	2186788	4116321	663	1693
52	2190844	4118945	1084	1563
53	2187175	4115030	865	1593
54	2185154	4122343	809	1697
55	2188931	4120972	1097	1642
56	2185971	4117997	385	1743
57	2191163	4119044	1134	1616
58	2185901	4121638	814	1774
59	2186625	4121173	845	1796
60	2193132	4117327	1304	1732
61	2186316	4119998	667	1644
62	2186924	4118574	569	1599
63	2188959	4119697	948	1629
64	2189982	4120820	1205	1637
65	2189650	4118473	884	1742
66	2189698	4120889	1179	1752
67	2184218	4113901	797	1501
68	2191049	4119904	1223	1529
69	2183919	4120706	687	1776
70	2185983	4120663	707	1655
71	2186565	4117800	459	1762
72	2187394	4115796	799	1519
73	2186321	4116575	577	1520
74	2191987	4116987	1207	1647

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
75	2187794	4116468	766	1723
76	2187201	4120410	822	1675
77	2186457	4123705	1128	1598
78	2188162	4117244	717	1602
79	2184106	4121065	708	1793
80	2185229	4118651	375	1503
81	2186880	4116468	657	1563
82	2188935	4121439	1154	1753
83	2187796	4121555	1031	1532
84	2189589	4120753	1150	1740
85	2188144	4119540	831	1608
86	2183908	4120381	650	1558
87	2185862	4121721	819	1710
88	2186754	4119348	641	1753
89	2183843	4114915	720	1708
90	2192024	4120226	1379	1800
91	2191192	4120425	1303	1574
92	2189616	4118181	845	1692
93	2191234	4116550	1169	1576
94	2191576	4119591	1249	1567
95	2190429	4117290	984	1501
96	2187725	4116703	730	1793
97	2188294	4117848	661	1555
98	2183652	4117791	398	1544
99	2190732	4118876	1062	1520
100	2191453	4118203	1068	1597

Table 29: Data of the problem instance 8 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2189892	4120572	1165	1683
2	2186380	4117371	488	1528
3	2184997	4117585	297	1594
4	2186700	4122379	999	1747
5	2183833	4118091	384	1569
6	2184121	4114769	704	1752
7	2184801	4119616	451	1738
8	2188163	4116206	842	1734
9	2186635	4118819	564	1513
10	2186763	4120691	804	1741

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
11	2191755	4116966	1182	1602
12	2183918	4121348	764	1517
13	2187349	4115791	794	1522
14	2184198	4116349	505	1764
15	2186515	4117395	502	1743
16	2190253	4117926	891	1795
17	2184554	4118486	345	1654
18	2186804	4117019	581	1642
19	2186480	4117402	497	1579
20	2186510	4119469	627	1777
21	2192201	4117569	1163	1663
22	2191542	4119367	1218	1693
23	2184244	4116693	459	1792
24	2184434	4116766	427	1577
25	2185042	4122779	848	1726
26	2186039	4118317	432	1712
27	2184069	4117355	400	1576
28	2184521	4122033	774	1565
29	2185236	4115582	566	1600
30	2191549	4119529	1238	1513
31	2187488	4119671	768	1617
32	2188813	4120217	993	1679
33	2184388	4116674	444	1604
34	2187931	4120268	893	1524
35	2189372	4121014	1155	1542
36	2188199	4116929	760	1753
37	2187803	4120861	949	1531
38	2193503	4118151	1308	1662
39	2187762	4117969	597	1517
40	2187907	4121348	1020	1605
41	2183716	4114370	801	1566
42	2187014	4120823	849	1714
43	2186126	4119460	579	1664
44	2188605	4117806	703	1626
45	2190058	4118007	877	1550
46	2185918	4115289	683	1526
47	2192828	4117149	1289	1759
48	2188372	4115703	927	1532
49	2185798	4118546	430	1539
50	2184618	4119840	499	1756
51	2187075	4121376	923	1662
52	2188189	4119217	798	1558

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
53	2188746	4121746	1168	1726
54	2185024	4114492	671	1704
55	2187350	4122150	1049	1735
56	2187755	4122246	1109	1695
57	2187616	4118847	685	1695
58	2185571	4122608	891	1695
59	2183917	4114637	744	1741
60	2185906	4115561	649	1603
61	2185491	4114177	765	1798
62	2189597	4117339	878	1638
63	2190890	4118390	1023	1754
64	2190509	4118618	1004	1581
65	2186035	4116587	541	1776
66	2186647	4119116	601	1781
67	2189331	4120165	1049	1706
68	2188744	4117181	795	1776
69	2190247	4118431	950	1699
70	2189819	4121112	1221	1795
71	2185269	4114256	729	1791
72	2188688	4118198	735	1515
73	2186477	4123794	1142	1543
74	2190561	4118435	989	1520
75	2185123	4121667	724	1564
76	2191499	4118703	1133	1644
77	2184339	4121357	715	1643
78	2186129	4118446	458	1797
79	2187636	4117339	643	1576
80	2184419	4115933	529	1534
81	2184425	4117038	395	1779
82	2184758	4119755	472	1780
83	2188322	4120404	956	1606
84	2190517	4116678	1068	1781
85	2191221	4116618	1160	1676
86	2183989	4122358	877	1550
87	2192126	4119743	1333	1785
88	2185979	4120946	740	1635
89	2184228	4116595	472	1772
90	2188608	4118105	715	1524
91	2184730	4117996	265	1606
92	2184001	4114527	748	1706
93	2183679	4118872	496	1687
94	2186882	4116480	655	1665

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
95	2188765	4120587	1031	1748
96	2186002	4116146	590	1691
97	2186438	4117113	526	1588
98	2183659	4121051	760	1689
99	2186066	4121523	820	1719
100	2184395	4121959	780	1662

Table 30: Data of the problem instance 9 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2185348	4120810	648	1579
2	2186395	4117024	532	1687
3	2191279	4119958	1257	1667
4	2185038	4115473	555	1689
5	2192935	4119166	1361	1595
6	2186254	4122258	930	1798
7	2193575	4118362	1341	1648
8	2189754	4117815	840	1726
9	2190015	4119530	1054	1631
10	2187131	4115895	756	1727
11	2185146	4120771	619	1748
12	2186874	4121690	937	1601
13	2188394	4120678	998	1662
14	2186260	4122312	938	1669
15	2185860	4119030	496	1757
16	2192574	4118620	1252	1738
17	2189225	4117517	812	1632
18	2184381	4116535	461	1523
19	2185197	4115987	512	1616
20	2185330	4123470	965	1512
21	2184678	4119817	489	1598
22	2189909	4120608	1171	1763
23	2189640	4120181	1088	1648
24	2191913	4116916	1207	1715
25	2189510	4121033	1174	1797
26	2187655	4121485	1006	1721
27	2188853	4117506	769	1581
28	2190748	4119275	1112	1557
29	2186489	4119099	580	1529
30	2189174	4121402	1178	1648

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
31	2190454	4117815	924	1573
32	2188280	4121730	1110	1521
33	2189101	4115609	1026	1554
34	2186225	4116123	619	1531
35	2184526	4118617	364	1505
36	2190835	4119552	1155	1664
37	2185688	4123713	1037	1777
38	2186420	4120314	717	1564
39	2184557	4114187	722	1707
40	2184504	4116216	485	1757
41	2184456	4118705	383	1755
42	2188285	4122284	1177	1598
43	2186706	4119263	625	1616
44	2188279	4121980	1140	1507
45	2186504	4120755	780	1740
46	2184665	4113960	736	1648
47	2185733	4117665	375	1722
48	2184023	4114081	798	1754
49	2189870	4116554	1005	1724
50	2188546	4118622	769	1696
51	2185531	4123049	939	1743
52	2184032	4119309	506	1769
53	2185930	4116167	579	1690
54	2187496	4116889	680	1581
55	2186355	4123904	1140	1746
56	2185833	4123534	1033	1681
57	2186881	4116565	645	1771
58	2186551	4123886	1161	1769
59	2185428	4118863	424	1542
60	2186808	4123550	1152	1782
61	2192244	4117143	1219	1774
62	2185824	4122670	928	1797
63	2191851	4120356	1374	1630
64	2189127	4116976	865	1536
65	2186984	4119930	739	1571
66	2185105	4115315	582	1725
67	2187417	4117751	567	1756
68	2186381	4121199	819	1570
69	2190297	4118211	930	1654
70	2186487	4117084	536	1557
71	2185444	4114449	727	1766
72	2189337	4117721	801	1737

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
73	2185056	4115071	605	1566
74	2184081	4119138	480	1517
75	2192493	4119009	1289	1540
76	2191773	4120300	1358	1586
77	2189382	4116859	910	1681
78	2186686	4121021	834	1731
79	2185643	4117510	383	1530
80	2184146	4118981	453	1720
81	2188226	4122347	1178	1783
82	2189501	4120362	1093	1719
83	2186598	4119926	692	1611
84	2189939	4120610	1175	1527
85	2190407	4116536	1072	1625
86	2186484	4120116	701	1589
87	2185432	4118238	349	1644
88	2186162	4120219	675	1698
89	2189127	4115713	1017	1547
90	2185317	4113827	786	1525
91	2191581	4119092	1190	1583
92	2186620	4117202	537	1523
93	2183844	4115308	673	1506
94	2186905	4116896	608	1765
95	2189418	4115724	1050	1642
96	2183948	4114177	796	1755
97	2186539	4116049	666	1697
98	2189162	4116139	970	1668
99	2187258	4119323	699	1725
100	2190024	4117216	944	1577

Table 31: Data of the problem instance 10 in Region 3.

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
1	2184605	4118759	371	1788
2	2186120	4117307	465	1588
3	2184826	4115282	558	1764
4	2187485	4120283	841	1793
5	2192445	4118247	1192	1779
6	2185433	4121908	790	1652
7	2184226	4119830	545	1509
8	2189823	4121220	1234	1568

Patient Number	X-coordinate	Y-Coordinate	Process time (Sec.)	Due-date (Sec.)
9	2186712	4122187	977	1632
10	2187058	4121470	932	1579
11	2184951	4120681	585	1731
12	2188894	4118337	777	1621
13	2184590	4119546	468	1669
14	2188388	4119920	906	1507
15	2184483	4122542	840	1743
16	2188185	4119269	804	1747
17	2186633	4123552	1131	1509
18	2183663	4114495	792	1735
19	2187557	4119358	739	1667
20	2190208	4120233	1162	1689
21	2189453	4115937	1029	1752
22	2190001	4120221	1136	1719
23	2186387	4124307	1192	1657
24	2185783	4118099	375	1635
25	2186731	4121084	847	1714
26	2184820	4117628	277	1734
27	2185474	4119971	562	1562
28	2185425	4121479	738	1746
29	2190252	4118536	964	1677
30	2185886	4120491	674	1714
31	2185342	4116110	515	1732
32	2185250	4118140	316	1716
33	2184525	4120313	567	1792
34	2184251	4114717	695	1556
35	2184307	4115803	558	1772
36	2183847	4120889	718	1724
37	2185702	4123096	965	1789
38	2184961	4117791	268	1625
39	2183810	4116280	560	1752
40	2184289	4122078	807	1583
41	2184204	4115211	641	1504
42	2187070	4118649	595	1562
43	2188197	4115950	877	1650
44	2189754	4118378	885	1558
45	2185246	4115535	573	1508
46	2186581	4123382	1105	1599
47	2185370	4122301	830	1638
48	2187060	4121532	940	1660
49	2187486	4122574	1116	1766
50	2189242	4120240	1047	1627

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
51	2186530	4117596	479	1501
52	2184093	4117992	341	1747
53	2190790	4118195	987	1648
54	2188406	4118790	773	1509
55	2192444	4120023	1405	1659
56	2188520	4116726	822	1784
57	2186510	4118939	563	1664
58	2185594	4116208	534	1684
59	2184550	4117252	355	1671
60	2185028	4113541	786	1734
61	2186732	4117766	483	1640
62	2184117	4114305	760	1723
63	2193007	4118625	1305	1711
64	2187762	4120913	950	1724
65	2183982	4118086	365	1560
66	2187376	4115208	867	1562
67	2184814	4119217	401	1621
68	2184467	4119348	459	1602
69	2190434	4119838	1142	1604
70	2184812	4120199	519	1643
71	2190254	4116221	1091	1701
72	2190406	4118348	960	1730
73	2187169	4117080	618	1766
74	2184366	4119075	438	1779
75	2184767	4114699	635	1668
76	2187257	4120063	787	1795
77	2191110	4116532	1157	1517
78	2192329	4120058	1395	1768
79	2188264	4122393	1188	1594
80	2188215	4120330	934	1719
81	2184558	4118620	360	1697
82	2189531	4119766	1025	1534
83	2191872	4119290	1248	1639
84	2184977	4114114	711	1697
85	2192331	4118064	1156	1744
86	2185664	4121319	747	1773
87	2188568	4116016	913	1760
88	2184388	4115718	558	1747
89	2191606	4119777	1275	1505
90	2185384	4121921	786	1648
91	2185962	4120478	682	1569
92	2191474	4119866	1270	1749

Patient Number	**X-coordinate**	**Y-Coordinate**	**Process time (Sec.)**	**Due-date (Sec.)**
93	2184499	4120728	620	1677
94	2187329	4116468	711	1514
95	2188687	4116181	908	1728
96	2184110	4120273	612	1520
97	2183684	4121567	819	1526
98	2191172	4120492	1309	1639
99	2190078	4117558	910	1674
100	2186459	4117539	478	1508

Table 32: Results of problem instance 1 in Region 1

Upper Bound	70					
Heuristic	**EDDBF**		**EDDWF**		**LPT**	
Number of Saved Patients	64		64		50	
Completion time (Minutes)	329.3		343.2		278.4	
	Vehicle 1	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**
	89	1	89	1	60	21
	66	37	66	37	31	72
	98	87	98	87	35	95
	82	17	82	17	42	90
	7	21	7	21	84	9
	41	83	41	83	16	19
	23	3	23	3	33	66
	15	99	15	99	38	36
	28	33	28	33	50	41
	16	72	16	72	73	15
	95	26	95	26	34	99
	42	69	42	69	4	11
	91	65	91	65	23	93
	60	9	60	9	94	71
	24	27	24	27	22	14
	92	84	92	84	10	86
	6	100	6	100	63	51
	50	13	50	13	54	13
	90	75	90	75	59	68
	18	32	18	32	88	77
	11	59	11	59	57	47
	74	8	74	8	20	44
	43	80	43	80	55	48
	35	48	35	39	70	39
	52	39	52	44	62	
	4	94	4	20	78	
	53	44	53	55		
	93	73	48			
	78	19	93			
	34	55	78			
	57		34			
	70		94			
	20		57			
	62		70			
			73			
			19			
			62			

Table 33: Results of problem instance 1 in Region 2

Upper Bound	100					
Heuristic	**EDDBF**		**EDDWF**		**LPT**	
Number of Saved Patients	100		100		78	
Completion time (Minutes)	256.9		299.8		197.3	
	Vehicle 1	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**
	89	38	89	37	94	65
	88	57	38	25	62	4
	18	23	57	12	3	95
	36	84	88	77	2	4
	95	71	23	24	98	5
	98	16	18	33	36	85
	54	35	36	43	59	69
	86	42	84	8	35	38
	9	76	95	14	45	58
	87	34	71	49	52	33
	19	61	98	6	1	76
	31	37	16	56	83	56
	25	17	54	21	25	6
	92	79	35	55	92	88
	91	12	86	75	11	9
	77	96	42	70	74	19
	82	28	76	10	1	29
	24	33	9	5	6	18
	58	43	34	59	16	54
	8	85	87	63	66	99
	14	49	19	53	1	93
	22	6	61	73	2	13
	56	21	31	1	32	82
	55	66	17	2	75	22
	75	70	92	94	96	91
	10	5	79	50	77	15
	59	63	91	81	12	48
	53	93	96	44	8	9
	3	73	82	51	43	72
	1	99	28	13	67	39
	20	2	58	68	53	8
	94	50	85	39	49	14
	74	81	22	80	78	81
	44	47	66	72	44	51
	51	11	93	65	3	41
	13	46	3	30	97	27
	68	7	99	90	46	47
	60	83	20	40	64	7
	39	67	74	48	26	68

Upper Bound	100					
Heuristic	**EDDBF**		**EDDWF**		**LPT**	
Number of Saved Patients	100		100		78	
Completion time (Minutes)	256.9		299.8		197.3	
	Vehicle 1	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**
	40	26	60	100		
	4	69	83			
	48	100	67			
	29	15	27			
	45	64	41			
	32	97	78			
	52	62	26			
			4			
			69			
			29			
			15			
			45			
			64			
			32			
			97			
			52			
			62			

Table 34: Results of problem instance 1 in Region 3

Upper Bound	59					
Heuristic	**EDDBF**		**EDDWF**		**LPT**	
Number of Saved Patients	52		53		43	
Completion time (Minutes)	330.95		353.7		274.3	
	Vehicle 1	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**	**Vehicle 1**	**Vehicle 2**
	85	75	85	53	3	99
	86	42	75	51	68	97
	53	13	86	38	57	78
	51	38	42	9	61	87
	9	56	13	56	19	86
	66	83	66	7	95	69
	7	64	93	83	44	55
	93	100	64	3	37	52
	3	8	43	57	96	8
	43	44	89	8	8	6
	89	70	88	44	33	48
	74	33	21	70	21	41
	37	16	33	37	36	35
	68	97	68	16	94	17
	73	11	97	73	39	26
	81	55	81	54	49	34
	61	78	1	61	18	4
	98	77	96	55	23	65
	65	99	77	65	22	79
	62	60	99	62	5	84
	14	80	80	60	72	14
	95	72	14	72	82	
	69	50	84	95		
	84	26	26	50		
	82	19		69		
	79	18		82		
				19		
				79		
				18		