

OPTIMIZATION OF THE PRODUCT DELIVERY SYSTEM FOR A COMPANY IN
THE BUILDING MATERIAL SECTOR

by

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ABSTRACT

OPTIMIZATION OF THE PRODUCT DELIVERY SYSTEM FOR A COMPANY IN THE BUILDING MATERIAL SECTOR

Effective management of logistics activities is crucial for companies. Previous studies have shown that transportation costs constitute an important part of the overall expenses. Therefore, companies solely focusing on new customer acquisition and product portfolio enlargement realize that not paying the necessary attention to manage the operational processes, in particular logistics activities, threaten their existence.

Eczacıbaşı İntema has recently adopted the strategy of providing service through its retail channel which consists of its own stores. Aiming at growing through this new distribution channel required to review its old business attitudes and to reorganize its internal processes in a way to support customer-driven business making. During this switch period, the company noted that end customers' complaints and problems are now a part of their business as a result of building direct relationship with customers. Therefore, the review of customer order patterns, current sales in the cities per customers and per stores as well as detection of improvement domains became a priority. Upon the request of the company, we initiated this study to examine the company's current situation with the problems and challenges coming from the business and to develop solutions and improvements regarding cost cutting possibilities and customer satisfaction. In this study, we make an effort to solve the real-world problem by developing a model to satisfy the needs of İntema, i.e., reducing the cost, increasing the customer satisfaction and effective use of resources. With the focus on the product delivery system, a detailed current situation analysis is performed to define the challenges and the constraints preventing İntema to move ahead confidently. Then, a delivery planning model is proposed. This suggested model produces better results compared to the existing business model under the assumptions given in the study and ensures some important cost savings.

ÖZET

YAPI MALZEMELERİ SEKTÖRÜNDEKİ BİR ŞİRKETİN ÜRÜN SEVKİYAT SİSTEMİNİN İYİLEŞTİRİLMESİ

Lojistik faaliyetlerin etkin yönetimi şirketler için son derece hayatidir. Geçmiş çalışmalar taşıma maliyetlerinin toplam giderler içinde azımsanmayacak bir ağırlığa sahip olduğunu işaret ediyor. Bu nedenle, şirketler şimdiye kadar sadece yeni müşteri edinimi ve ürün gamı genişletme öncelikleriyle hareket ederken operasyonel faaliyetlere dikkat etmemenin varlıklarını tehdit edecek çok ciddi sonuçları olduğunun farkına varmaya başladılar.

Yakın zamanda perakende kanalında hizmet sağlama stratejisini benimseyen Eczacıbaşı İntema, bu yeni dağıtım kanalında büyümek için öncelikle şirketin, eski iş yapış modellerini gözden geçirilmesi ve süreçlerini müşteri odaklı iş yapmayı destekleyici şekilde yeniden oluşturması gerektiğine karar verdi. Bu geçiş döneminde, son müşteri ile doğrudan ilişki içinde olan şirket artık müşteri problem ve şikayetlerinin de işlerinin bir parçası olduğunun farkına vardı. Bu sebeple, müşteri sipariş davranışları, şehir, mağaza ve müşteri kırılımında satışlar ve iyileştirme noktalarının tespiti şirket öncelikleri arasında yer alır oldu. Şirketin talebi üzerine başlatılan bu çalışma, şirketin mevcut durumunu, karşılaştığı problem ve zorlukları resmedip gider yönetimi açısından fırsat yaratma ve müşteri memnuniyetini arttıracak çözümler geliştirmek amacındadır. Bu çalışmada, gerçek hayat zorlukları konu hakkında yapılan teorik çalışmalarla bütünleştirilerek İntema'nın ihtiyaçlarını karşılayacak, maliyetleri düşürecek, müşteri memnuniyetini arttıracak ve etkin kaynak kullanımını sağlayacak uygulanabilir bir çözüm geliştirilmeye çalışıldı. Ürün sevkiyat sistemi bakışıyla, öncelikle mevcut durum analizi yapılarak İntema'nın karşılaştığı zorluk ve kısıtlar ortaya kondu ve bir sevkiyat planlama modeli önerisi geliştirildi. Önerilen model, mevcut iş modeli sonuçlarıyla karşılaştırıldığında belirtilen varsayımlar altında daha iyi sonuçlar vererek ciddi tasarruf fırsatları sağladığı gözlemlenmiştir.

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1. INTRODUCTION

One of the important tasks of a logistics manager dealing with the retail distribution is designing a distribution network to serve every single customer of the company. When the company is large and has thousands of customers in different regions and locations, the problem becomes complex. Depending on the size of regions and the number of customers, a poor design might result in hundreds of hours of overtime and delivery trucks' traveling thousands of extra kilometers each day, with a corresponding increase in costs and decrease in competitiveness. The efficient movement of goods in order to increase and meet market demands often emphasized as a business strategy. It is agreed that distribution costs account for an important percentage of the firm's revenues and of the total cost.

Eczacıbaşı İntema is one of the biggest companies in Building Materials sector in Turkey. Historically, the company has deep business knowledge on managing the relationship with its dealers and performing deliveries through this channel. However, welcoming final customers directly through the retail channel will be a new experience for the company. Small order volumes, one-to-one customer satisfaction and promises of delivering orders up to customer houses are new challenges faced by the company. Recently, outsourcing its transportation to Ceva Logistics, İntema wants to analyze its current delivery performance and take some initiatives to improve its delivery processes and resource usages as well as being able to evaluate the performance of the third-party logistics company. Therefore, the analysis of the current activities, the determination of the constraints and facts, development of strategies to handle daily operational issues and improvement of some performance measures like capacity usage and the number of vehicles in use are the focus of this thesis.

The first chapter includes the literature survey about vehicle routing problems, real-world examples in the related field and the real-world constraints faced in delivery operations. In the second chapter, the presentation of the problem is given. In the subsequent chapter, an analysis of the current situation is provided. In the fourth chapter, the scope of the study is determined and in the following chapter, the details and the assumptions regarding the transportation model are provided. Afterwards, results of the

proposed model and the comparison of the current and proposed business models are introduced. Finally, the conclusions and suggestions for future studies are given.

2. LITERATURE SURVEY

In this chapter, a brief review of the literature on transportation and delivery problems is given. As the problem we tackle is the delivery planning of products of a company, our study environment is related to shipment scheduling. Moreover, as sold items are dispatched by some vehicles, our domain of interest covers “capacitated” problems. Additionally, as each item sold departs from one storage area to a location – herein from the warehouse up to the customer house – our study expands to “Vehicle Routing Problems (VRP)” as well. Therefore, this chapter focuses on VRP depending on the similarity of the practical problem that we deal with. Some information on “Traveling Salesman Problem” and “Pick-up and Delivery Problem” is provided as well. Our review mainly focuses on the practical applications where some approaches have been developed for real-world problems.

It is a common practice to model new problems as instances of an existing classical problem [1]. Classical models of combinatorial problems play a key role in optimization as they allow theoretical and empirical work to focus on core issues of problem solving performance. However, classical models are a simplified version of real-life problems that do not fit easily into a simplified version of a known combinatorial optimization problem. Then, the decision of either ignoring or accepting the specific problem characteristic becomes the issue to face. Simplification approach puts the representation of the solution related to the real-world situation in question whereas in case complicating factors remain in tact, predicting the effect of removing a simplifying assumption on the performance of standard solution methodologies gets difficult.

The complexity of the problem held in this study comes from the fact that we deal with a real-world problem. During the analysis and solution development, this literature review will build an investigation platform helping us determine our scope, assumptions and constraints to respect in our model. Especially, we seek for studies applied in different industries in the related field – transportation – to expand our vision and consolidate different approaches.

Finding efficient vehicle routes is a representative logistics problem which has been studied for the last 40 years. A typical VRP aims to find a set of tours for several vehicles from a depot to a set of customers and return to the depot without exceeding the capacity constraints of each vehicle at minimum total cost. Since the customer combination is not restricted to the selection of vehicle routes, VRP is considered as a combinatorial optimization problem where the number of feasible solutions for the problem increases exponentially with the number of customers increasing [2]. It is among the most widely studied combinatorial optimization problems as well as the traveling salesman problem (TSP). Since the delivery routes consist of any combination of customers, these problems belong to the class of NP-hard problems. First studies on VRP were initially published by Dantzig and Ramser [3] and Clarke and Wright [4]. Ever since Dantzig and Ramser [3] first studied the VRP in 1959, researchers have spent a lot of time and effort on developing methods to tackle this problem. This is due to the fact that the VRP plays a central role in distribution management. Many heuristics algorithms such as simulated annealing, genetic algorithms, tabu search and ant colony optimization are used for solving VRP [5]. Fisher [6] describes the history of the development of solution approaches for the basic VRP. The first generation, roughly developed in the 1960s and early 1970s, consisted of simple heuristics such as savings and insertion methods. In the mid-1970s, the second generation started to emerge. Although still approximation methods, these approaches were based on solving one or more related problems to optimality. The third (current) generation has two main streams: artificial intelligence (AI) based heuristics and exact optimization. Some examples of third generation solution approaches for extensions of the VRP are given by Tan et al. [7], Semet [8], Chao et al. [9] and Cordeau et al. [10] where they investigated various AI heuristics for vehicle routing problems with time windows. None of these studies covered large number of real-life specific constraints. If one would like to develop an algorithm that is flexible enough to deal with many complicating constraints and which should also be able to incorporate customer-specific constraints, it may be easier to use a relatively simple heuristic instead of more sophisticated approximation and optimization methods. Flexibility is especially important when the same algorithm is going to be applied to many different extensions of the VRP. Obviously, this is the case for commercial vehicle routing systems that are to be installed at many different customers.

Generally, the solution techniques used for solving the VRP can be separated into exact methods and heuristics including metaheuristics [11].

A real problem of a fuel delivering in an agribusiness company with multiple deliveries is undertaken in a study of Önal et al. [12] where they proposed a mixed integer programming model and a dynamic programming method as an example of the exact solution approach. Although they acquired favorable results, the problem is instanced with a customer range from five to nine.

Blasum and Hochstattler [13] developed a modified version of the Branch and Cut algorithm which offers a solution for a symmetric capacitated routing problem, a simple variation of VRP. They solved some instances to optimality at the expense of high computational cost.

In their study, Toth and Vigo [14] evaluated some branch and bound approaches and reviewed some models and exact techniques. Their methods reached bigger sized instances than Önal et al.'s; however, they solely concentrated on basic VRP problems with capacity constraints.

Exact solution approaches either suffer from computational times required to obtain a solution or from the simple constraints considered. Therefore, they do not present any practical insights. Furthermore, it is not always easy to adapt integer programming models or Branch and Bound algorithms to more complicated VRP variations.

Heuristic approaches are used to overcome high computational times. Many heuristics and metaheuristics are developed in the literature related to VRP problems. One of them is by Bachem et al. [15] with promising results where they applied a general improvement heuristic. In 1996, a study of Xu and Kelly [16] was published where they used Tabu Search algorithm to solve the standard VRP. A year later, Bullnheimer et al. [17] published their work in which another metaheuristic was applied to the VRP. They took into consideration a simple VRP with a homogeneous vehicle fleet.

In the study of De Backer et al. [18], the results obtained by the use of a constraint programming paradigm and two metaheuristics are compared to Solomon's classic benchmark [19]. Van Breedam [20] compared descent search, simulated annealing and Tabu search for the classic VRP. Afterwards, in one of his later work [21], he compared a total of 10 heuristics for more complicated VRPs. Ralphs et al. [22] came with new methods of solving VRP considering a fleet of vehicles of uniform capacity.

Heuristics and metaheuristics seem to be an adequate approach for larger VRP instances to an extent; however, they may remain poor in reflecting realistic constraints. Still, there exist examples of studies dealing with real-world cases such as the work of Önal et al. [12], Tarantilis and Kiranoudis [23] and Angelelli and Speranza [24]. However, the methods proposed in these works are not easy to adapt.

Techniques appeared in the literature require a great deal of knowledge and expertise because of the existing gap between the problems considered in the literature and the real problems found in practice as noted by Desrochers et al. [25]. Many of the techniques do not provide the flexibility and responsiveness that a real logistic environment needs or do not take into consideration numerous constraints faced in real-life.

However, balancing theoretical works with real-life requirements is not easy all the time. Real-life problems often involve several non-standard constraints, i.e. constraints specific to real-world instances, some of which are never mentioned in the literature, while others are only analyzed in isolation, i.e. not in combination with other non-standard constraints. This difficulty is either caused by the diversity of the requirements or by the management policies. The second one is pointed out in the study of Jang et al. [26]:

The second objective was to balance the Lottery Sales Representatives' (LSRs) routes. Many LSRs work as much as 12 hours on some days because they would rather cover a certain geographical area in one trip than in several. This behavior does not increase the lottery's cost because all LSRs are salaried. However, the managers believe that the LSRs' working such long hours provide inferior service.

Theoretically, the VRP is the determination of the optimal routes used by a fleet of vehicles, based at one or more depots, to serve a set of customers [14]. However; in real-life applications of VRP, this description has to be enriched by many additional requirements and operational constraints imposed on the route constructions. In practice, the service provided may involve both deliveries and collections; the load along each route must not exceed the given capacity of the vehicles; the total length of each route must not be greater than a prescribed limit; the service of the customers must occur within the given time windows; the fleet may contain heterogeneous vehicles with different travel times and travel costs; precedence relations may exist between the customers; the customer demand may not be completely known in advance; the service of a customer may be split among different vehicles. Additionally according to the problem type demand and travel times may vary. Moreover;

- Multi-dimensional capacity constraints,
- Order/vehicle compatibility constraints,
- Orders with multiple pick-up, delivery and service locations,
- Different start and end locations for vehicles,
- Limited availability of the goods at the depot(s),
- Forbidden product combinations,
- Vehicle compartment to where each customer or product has to assigned,
- Limited numbers of stop,
- Minimum loading penalties for the vehicles
- Route restrictions for vehicles

can be added to the list of real-life requirements as well as visual attractiveness – a few overlapping routes – [11, 27, 28, 29].

Logistics and transportation account for a large portion of the economies of the developed countries. Therefore, governments and private companies focus their attention on developing systems that could aid logistics managers to lower costs and achieve greater flexibility. A lot of research has been performed in the field of logistics and many techniques have been already developed, from the TSP to complex dynamic routing problems. Acknowledging the importance of theoretical studies, it is also important to

generate solutions that are intuitively acceptable to managers and planners. In the literature, there are also some practical examples applied in some industries with the consideration of company and industry specific constraints. Some of these practical studies are the case study of Coca-Cola Enterprises [29] – the world’s largest marketer, producer and distributor of Coca-Cola Company products – where it is sought ways of optimizing vehicle routes for efficient product delivery; the case study of Nanta S.A. – leading Iberian feed compounder – where a Decision Support System (DSS) which will enable planners to have accuracy and speed over the route scheduling process by allowing them to improve better control on rush (urgent) orders in a very short amount of time is discussed [11]; the case of Waste Management Inc. that offers environmental services to nearly 21 million residential, industrial, municipal and commercial customers in United States, Canada and Puerto Rico, and seeks for route optimization [30].

Coca-Cola Enterprises (CCE) is the world’s biggest marketer, producer and distributor of Coca-Cola Company Products. In 2005, 20 per cent of Cola-Cola Company’s worldwide volume accounting for two billions bottles and cans are distributed over 430 distribution centers to 2.4 million final retail outlets. The CCE fleet is the second largest in United States after US Postal Service’s. Today, the company owns 54,000 vehicles. To enforce their growth and to forge ahead of their adversaries, the company needed to optimize their product delivery. In 2004, they implemented ORTEC’s – Dutch consultancy firm specialized in applied operations research – vehicle routing software namely SHORTREC Distriplanner (SDP). CCE’s focus was to obtain a route optimizer for its orders distributed from each distribution center, so-called depot, to the retail outlets. Among the constraints they face, the standard ones were vehicle capacities and the maximum route duration. Non-standard constraints might be listed as follows:

- Requirement for a specific vehicle type and equipment per order or outlet.
- Retail outlet time windows.
- Conformity with rules of Department of Transportation imposed on driver’s working and starting hours.
- Different driver’s skills. Drivers do have an appropriate commercial driving license in compliance with the products they carry.

- Traffic patterns. Rush hours in city centers and/or at the specific times of days must be considered.
- Constraints imposed by the nature of the product itself. Very specific unloading merchandising times, specific loading rules and minimum order-size requirement for certain type of vehicles are those constraints.
- Number of different drivers visiting a particular customer.

The overall objective is set as assigning all the delivery orders in the correct sequence, such that they are carried out by available resources (vehicles and drivers) at a minimum cost while respecting all constraints aforementioned and providing excellent customer service. The whole process and SDP worked in such a good manner that CCE met its objectives and saved a total of \$45 million besides improving customer service.

Nanta S.A. is the leading Iberian feed compounder with 10 production plants in Spain and one in Portugal. It has a large range of products encompassing more than 150 different articles. While its production systems blossom with the effect of its previous effort on the field, they now face challenges on the distribution subject, namely on feed compound distribution to customers. One of its production plant located in Valencia is chosen as the pilot site for an improvement study. A volume of 800,000 kg of compound feed is being distributed over 70 customers, out of a total of 700 different customers located at distances ranging from 15 to 450 km away per production plant every day. Each day, they distribute the orders placed on the day before by the vehicle fleet they rent from a third party logistics Company. Still, they deal with rush (urgent) orders placed within a range of 5 to 30 orders on daily basis. The latter ones cause a big problem because as it is not desirable to re-route current plans, they deliver these orders by single-stop trucks. Trucks have specific characteristics and different capacities. Additionally, a minimum loading capacity is applied as well. The constraints that have to be taken into consideration related with this company's specific environment are as follows:

- Minimum loading capacity should be respected in order to avoid "air" cost.
- Maximum allowed weight for the trucks cannot exceed local regulations.
- Some restrictions are applied according to truck size and weight hindering passages along roads, bridges or tunnels.

- Minimum order weight should at least equal to a capacity of one compartment.
- Maximum traveling distance for truck in single trip.
- Heterogeneous vehicle fleet differing in size, capacity and weight.
- Limited number of stop per truck.

At the end, even worst-case scenarios showed that by using DSS, the production plant located in Valencia can obtain an annual saving of 180,000€.

Waste Management, Inc. (WM) is the leading provider of comprehensive waste and environmental services in North America. Headquartered in Houston, the company's network of operations includes 293 active landfill disposal sites, 16 waste-to-energy plants, 72 landfill gas-to-energy facilities, 146 recycling plants, 346 transfer stations and 435 collection depots. These assets enable Waste Management to offer a full range of environmental services to nearly 20 million residential, industrial, municipal and commercial customers in U.S., Canada and Puerto Rico. With 26,000 collection and transfer vehicles, the company has the largest trucking fleet in the waste industry and collects over 80 million tons of garbage a year. In 1998, WM merged with USA Waste and found itself with a large fleet of vehicles in decentralized structure in terms of routing, dispatching, maintenance and management. The first decision followed by this acquisition was to switch from a decentralized organization to a centralized one and to focus on route profitability and efficiency considered that 68 per cent of its total revenue is generated by waste-collection business and a vehicle costs nearly \$120,000 in a year. Key components of operating costs encompass fixed and variable vehicle costs and labor expenses. Managers decided to give their attention to reduce number of vehicles.

WM run mainly business in three major areas: commercial, residential and industrial. These areas have their own specific characteristics and constraints. The objectives and the constraints of this case can be given as follows:

- Minimizing the number of vehicles
- Minimizing travel time
- Maximizing visual attractiveness
- Balancing workload among the vehicles

- Time windows of stops and the depot
- Vehicle capacity (volume, weight)
- Route capacity
- Routing time limit per vehicle
- Disposal trips (mandatory trips occurring when a vehicle is fully loaded and needs to go to a disposal facility)
- Driver's lunch break
- Side of street for residential route
- Turn restrictions and penalties
- Speed limits

Following the study initiated with the objective of reducing vehicle numbers, WM had its route number dramatically and provided a saving of \$44 million in 2004. In terms of customer services, they produced more consistent and reliable service.

3. DESCRIPTION OF THE PROBLEM

Eczacıbaşı İntema, officially called İntema Building Materials Marketing and Sales, is a branch of Eczacıbaşı Construction Group responsible for the marketing and sales of building materials. Among the products supplied by the company are the ceramic sanitary ware, bathroom and kitchen faucets, concealed cisterns, toilet seats, bathroom cabinets, and bathroom accessories, chemicals for cleansing and adhesion, kitchen furniture.

The trade of these products is performed through three main distribution channels: retail channel, dealers and direct shipment from manufacturer. Dealers mostly serve construction companies and architectural offices. Traditionally, this channel is the most widely used channel in this industry and İntema has a deep understanding and know-how about it. However, following the changes occurring in all almost every business area all over the world, this industry is adopting customer-driven approaches as well. The retail channel is appearing at this point. Accustomed to fix sales targets for its dealers and not to get in contact with final customers, İntema is facing new difficulties stemming from the nature of the retail channel. They are now welcoming final customers themselves and interacting with them directly. Hence, customer satisfaction becomes their duty to assure. Although the dealers comprise 70 per cent of the total sales realized, in accordance with the company's upper management strategy – that's to enforce its own stores so as to strengthen its brand name with the high quality service provided – İntema is working to assure customer satisfaction by cutting its operational expenses as much as possible through the retail channel.

Eczacıbaşı İntema drives its retail activities from its exclusive stores located in four cities in Turkey: İstanbul, İzmir, Ankara and Adana. Retail sales are either realized by customers inhabiting in these cities or by customers coming from different cities and placing orders to be shipped to their home towns.

Retail orders per city in the first six months of 2007 are as given in Table 3.1. They accounted for a total of 19,463,333 YTL.

Table 3.1. Order placement distribution per cities

| | Total order value (YTL) | Total order amount | Number of customers |
|--------------|----------------------------|--------------------|---------------------|
| İstanbul | 10,915,527 | 11,572 | 3,274 |
| İzmir | 2,512,868 | 2,137 | 691 |
| Ankara | 2,009,795 | 1,768 | 633 |
| Adana | 1,276,115 | 1,440 | 433 |
| Other cities | 2,749,028 | 1,266 | 411 |
| Total | 19,463,333 | 18,183 | 5,442 |

With respect to the growth strategy in the retail channel, İntema decided to review its operational processes including logistics activities. The company has been working with Ceva Logistics Inc. for almost a year. Formerly, the company was running its logistics activities by itself. Therefore, the company asks to have necessary and appropriate tools so as to evaluate the performance of this new logistics company instead of solely looking for new improvement opportunities in terms of services. To realize these two objectives, which will form the basis of our study, we decided to separate our study into two parts: Analysis of customers' ordering patterns and development of a mathematical model to optimize the delivery planning.

In the analysis of customers' ordering patterns, we decided to examine the order volumes and amounts, the accumulation of customers in each city and the average delivery volumes. This part will be the analysis of the current situation part of our study. Departing from that point, we will be discussing about possible improvement actions. In the second part, we will develop a mathematical model including İntema's outbound logistics activities in order to optimize the delivery planning process of the company. We will use the outcomes of the analysis of the current situation as the inputs to our model and will expose proposed conditions in terms of planning process and data storage in the information system.

4. ANALYSIS OF THE CURRENT SITUATION

Eczacıbaşı İntema uses SAP R/3 software as its Information and Operational system. In this chapter, we will base our study on data extracted from SAP R/3.

To initiate our study, we decided to analyze the first six month's sales data of 2007 with the belief that the collected data are sufficient to reflect customer's the ordering patterns. The length of this period is also determined by the availability of the data in the Information System. The data coverage is limited with the sales data that are also delivered totally to the customers. In other words, a sales data point is treated as a data in our study if this sales order is totally dispatched to the customers, meaning that the point status is switched to "CLOSED ORDER".

We selected following data types to be used as the inputs to our current situation analysis:

- Order date
- Order number
- Customer number
- Customer name
- Dispatch date
- Dispatch number
- Items included in an order and their values in price
- Items included in a dispatch
- SKU codes
- Dispatch value in price
- Order value in price
- Order quantity per item
- Dispatch quantity per item
- Dispatch volume per item
- Order volume per item

- Store name receiving the order

At first sight, we note that there is no one-to-one relationship between customers and their orders. That is to say, one customer might have many orders registered in the system with different order numbers. Furthermore, one order may be dispatched to one customer in more than one delivery. In other words, Eczacıbaşı İntema sends its trucks to the same customer address more than once. Based on the data, we found that one customer places 2.3 orders with a volume of 1.26 m³ on average.

Then, we classify customers according to the product (item) type (armatures like bathroom faucets, washing tubs, tiles and vitrified products like commode and toilet seats and so on) and the number of SKU codes placed in an order. As a result of this classification, we had three groups of behavior: customers ordering one product type defined with one SKU code (Type1), customers ordering one product type with different SKU codes (Type 2) and customers ordering many different products with different SKU codes (Type 3). The last one constitutes 51 per cent of customers, which makes 85 per cent of the total retail sales in value and 89 per cent of the dispatch volume (see Table 4.1, Table 4.2, Table 4.3).

Table 4.1. Example of an order for customer type 1

| Order date | Order no | SKU code | Product type | Quantity (per Unit) |
|------------|----------|------------|-----------------------|---------------------|
| 22.01.2007 | 10274813 | 05-047-001 | Lid (for toilet seat) | 1 |

Table 4.2. Example of an order for customer type 2

| Order date | Order no | SKU code | Product type | Quantity (per Unit) |
|------------|----------|----------|-------------------------------------|---------------------|
| 11.01.2007 | 10274666 | A44538 | Bathroom accessories (soap dish) | 1 |
| 11.01.2007 | 10274666 | A44488 | Bathroom accessories (toilet brush) | 1 |

Table 4.3. Example of an order for customer type 3

| Order date | Order no | SKU code | Product type | Quantity (per Unit) |
|------------|----------|----------|----------------------|---------------------|
| 11.01.2007 | 10274934 | A41907 | Armature | 1 |
| 11.01.2007 | 10274934 | A44794 | Bathroom accessories | 1 |
| 11.01.2007 | 10274934 | A44783 | Bathroom accessories | 1 |
| 11.01.2007 | 10274934 | A44783 | Bathroom accessories | 1 |
| 11.01.2007 | 10274934 | A44787 | Bathroom accessories | 6 |
| 11.01.2007 | 10274934 | A44081 | Bathroom accessories | 1 |
| 11.01.2007 | 10274934 | A44067 | Bathroom accessories | 1 |
| 11.01.2007 | 10274934 | A44788 | Bathroom accessories | 2 |
| 11.01.2007 | 10274934 | A44789 | Bathroom accessories | 1 |
| 11.01.2007 | 10274934 | A44270 | Bathroom accessories | 2 |
| 11.01.2007 | 10274934 | A44130 | Bathroom accessories | 1 |
| 11.01.2007 | 10274934 | A44051 | Bathroom accessories | 1 |

Table 4.4. Ordering behaviors per customer type

| Customer types | # of customers | % | Total order volume (m ³) | % | Average order volume per customer (m ³) | Total order value (YTL) | % |
|----------------|----------------|-----|--------------------------------------|-----|---|-------------------------|-----|
| Type 1 | 779 | 27 | 105 | 3 | 0.13 | 255,930 | 4 |
| Type 2 | 638 | 22 | 289 | 8 | 0.45 | 831,411 | 12 |
| Type 3 | 1,472 | 51 | 3,247 | 89 | 2.27 | 6,014,209 | 85 |
| TOTAL | 2,889 | 100 | 3,641 | 100 | 1.26 | 7,101,550 | 100 |

| Customer types | # of customers | % | # of orders placed | % | Average volume per order (m ³) | # of orders placed per customer |
|----------------|----------------|-----|--------------------|-----|--|---------------------------------|
| Type 1 | 779 | 27 | 816 | 12 | 0.13 | 1.05 |
| Type 2 | 638 | 22 | 1,014 | 15 | 0.28 | 1.59 |
| Type 3 | 1,472 | 51 | 4,918 | 73 | 0.66 | 3.34 |
| TOTAL | 2,889 | 100 | 6,748 | 100 | 0.54 | 2.34 |

Following this classification, we examine the product types that are placed by Type 3 customers. We noticed that they are mainly buying vitrified products (0.9 m³ of 2.27 m³); washing tubs (0.6 m³ of 2.27 m³) and tiles (0.4 m³ of 2.27 m³). All of these products are big in volume and fragile from the transportation point of view.

Order volumes vary according to customer types. This brings the following questions: How does İntema deal with these volumes? Does the company dispatch these order volumes efficiently in terms of truck utilization and delivery frequency? Prior to

answering these questions and measuring delivery performance, we summarize the current situation as follows:

From the previous analysis results, we know that a customer orders a volume of 1.26 m³ on the average. However, we also know that different customer type's order volumes are not close to each other. Hence, we decide to classify order volumes by their frequency to see the usual order volumes and obtain following results given in Table 4.5.

Table 4.5. Order volume distribution per classes

| Class (m ³) | # of customers | % | cumulative % | Total volume (m ³) | Total order value (YTL) | Average volume (m ³) |
|-------------------------|----------------|------|--------------|--------------------------------|-------------------------|----------------------------------|
| <=1 | 2,235 | 77.4 | 77.4 | 736 | 2,193,946 | 0.33 |
| 1-2 | 198 | 6.9 | 84.2 | 385 | 826,642 | 1.94 |
| 2-3 | 132 | 4.6 | 88.8 | 391 | 665,192 | 2.96 |
| 3-4 | 118 | 4.1 | 92.9 | 469 | 735,196 | 3.97 |
| 4-5 | 59 | 2.0 | 94.9 | 291 | 497,824 | 4.93 |
| 5-10 | 102 | 3.5 | 98.4 | 733 | 1,265,542 | 7.18 |
| 10-15 | 35 | 1.2 | 99.7 | 416 | 659,204 | 11.90 |
| 15-20 | 6 | 0.2 | 99.9 | 109 | 174,997 | 18.09 |
| 20-25 | 2 | 0.1 | 99.9 | 45 | 31,735 | 22.41 |
| >25 | 2 | 0.1 | 100.0 | 67 | 51,272 | 33.33 |
| Total | 2,889 | | | 3,641 | 7,101,550 | 1.26 |

As we see, 77.4 per cent of customers order 0.33 m³ on the average, which is far below than 1.26 m³. Order volumes up to 4 m³ are covering 92.9 per cent of all customers. From Table 4.4, we already acquired the information that Type 1 and Type 2 customers' order volumes are quite small in volume; however 77.4 per cent of customers order a volume of 0.33 m³ on the average. We can then conclude that Type 3 customers' order volumes are accumulated around classes with small volumes given that this type of customer constitutes 73 per cent of all customers. Applying the same distribution approach to Type 3 customers' order volumes, we obtain that more than half of the orders of this customer type is 0.56 m³ on the average (see Table 4.6).

Table 4.6. Order volume distribution of Customer Type 3 per classes

| Class (m ³) | # of customers | % | cumulative % | Total volume (m ³) | Total order value (YTL) | Average volume (m ³) |
|-------------------------|----------------|------|--------------|--------------------------------|-------------------------|----------------------------------|
| <=1 | 874 | 59.4 | 59.4 | 493 | 1,334,658 | 0.56 |
| 1-2 | 166 | 11.3 | 70.7 | 321 | 722,082 | 1.93 |
| 2-3 | 116 | 7.9 | 78.5 | 344 | 605,126 | 2.96 |
| 3-4 | 114 | 7.7 | 86.3 | 454 | 701,408 | 3.98 |
| 4-5 | 57 | 3.9 | 90.1 | 281 | 482,864 | 4.93 |
| 5-10 | 100 | 6.8 | 96.9 | 717 | 1,250,864 | 7.17 |
| 10-15 | 35 | 2.4 | 99.3 | 416 | 659,204 | 11.90 |
| 15-20 | 6 | 0.4 | 99.7 | 109 | 174,997 | 18.09 |
| 20-25 | 2 | 0.1 | 99.9 | 45 | 31,735 | 22.41 |
| >25 | 2 | 0.1 | 100.0 | 67 | 51,271 | 33.33 |
| Total | 1,472 | | | 3,247 | 6,014,209 | 2.21 |

So far, we have investigated İntema's customer order patterns and their impact on the order volumes. We have found that products we focus on are fragile by their nature and order volumes are less than 1 m³ on the average, meaning that İntema carries a box of size 82 cm x 82 cm x 82 cm (0.56 m³) per customer.

On the other hand, when we look at the volumes transported on a daily basis, we have the views given in Figure 4.1, Figure 4.2 and Figure 4.3.

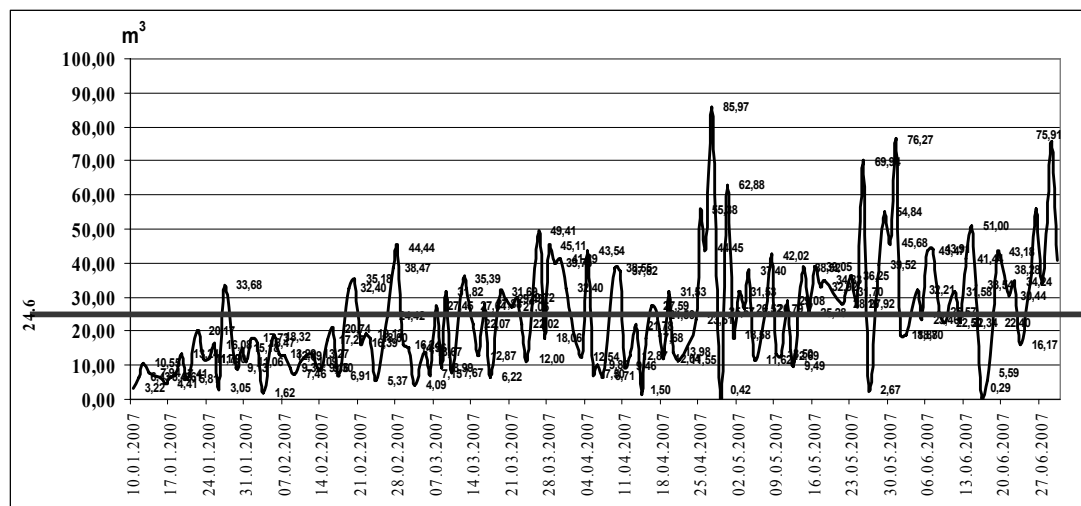


Figure 4.1. Daily delivery volumes

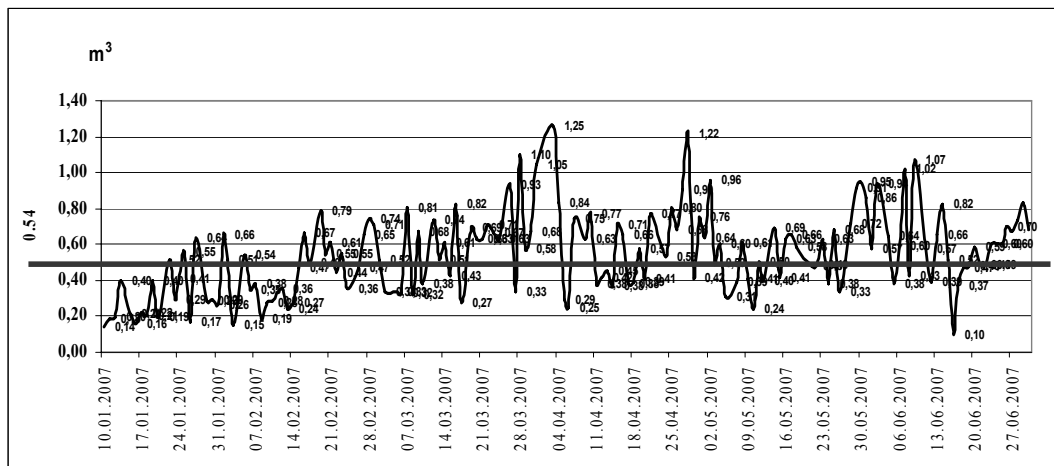


Figure 4.2. Daily dispatch volumes per customer

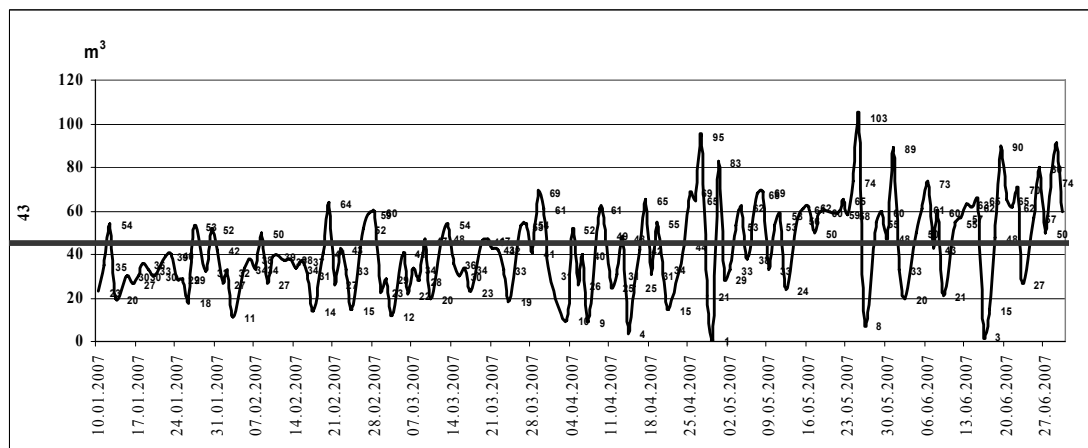


Figure 4.3. Daily number of customers visited

The average daily delivery volume transported is 24.6 m³ as seen in Figure 4.1 whereas the average daily delivery volume transported per customer is 0.54 m³ as given in Figure 4.2. The number of customers visited per day is 43 customers on the average.

Furthermore, the percentage of delivering an order to the customer at once is 83 per cent. However, as we mentioned in the earlier part, one customer might place 2.34 orders on the average. In that case, regardless of the number of orders registered in the system to the customer name, the performance of delivering all the orders altogether at once is 57 per cent. However, when we measure the performance of delivering multiple orders at once,

we note a brusque decrease to five per cent which is notably an undesirable result in an environment where a customer places 2.34 orders on the average (see Table 4.7).

Table 4.7. Customers and volumes covered by different transportation and order combination cases

| Cases | % of customer covered | % of volume transported |
|--------------------------------------|-----------------------|-------------------------|
| Multiple orders, single dispatch | 5 | 5 |
| Multiple orders, multiple dispatches | 43 | 80 |
| Single order, single dispatch | 52 | 15 |

Given these delivery performance metrics, we analyze the system by interviewing different people from various departments including sales and logistics to find out possible reasons that might cause the current situation. We identify the following reasons:

- (i) While preparing the delivery planning, grouping is being done on an order basis instead of a customer basis, which is causing more than one visit to the customer with small volumes of delivery.
- (ii) At the time of planning the deliveries, the total customer order might not have been ready to ship which results in partial shipments.
- (iii) Customers might have requested partial shipments.
- (iv) End of month syndrome, which is pushing sales teams to increase dispatches at the end of the months to make them align with sales targets.

We specify some areas of improvement and take some decisions to be incorporated into daily functions. These improvements will be exposed in the subsequent chapter where we will also discuss the need for a mathematical model to optimize the delivery planning process.

5. SCOPE DETERMINATION

Within the period of six months, 2,889 customers are served and a total volume of 3,641 m³ products is transported. In fact, 6,800 customers are visited due to the partial shipments. As mentioned before, a truck visits seven customers per day on the average. Some figures summarizing the current view are given in Table 5.1.

Table 5.1. Example of a pivot table prepared as the basis of a route plan

| | |
|---|--------------------------------|
| Daily average volume transported per customer | 0.54 m ³ |
| Number of customers visited during six months | 6,800 customers |
| Total volume transported during six months | 3,641 m ³ |
| Total number of transport realized | $6,800/7 = 971$ transports |
| Utilization of a truck per transport | $7*0.54 = 3.78$ m ³ |

Currently, the trucks in use have a capacity of 10 m³. Therefore, the truck utilization rate is 38 per cent ($= 3.78/10$). This fact leads us to increase the truck utilization. On the basis of the results regarding the current situation analysis and the Logistics Department goals in the retail channel, we formalize our objective as follows:

“Our primary target is to dispatch all the orders of a customer at once, to the right place, at the right time, with respect to the right delivery conditions (complete and undamaged)”.

The delivery promise that the company wants to meet is to ship all the orders of a customer up to the customer address, in other words all the orders must be transported from the warehouse to the customer’s house. In our study, we develop a delivery planning model which is aligned with the aforementioned objective. We try to increase the current usage rates to ameliorate the efficiency of the shipment processes.

The current situation reveals that trucks are not used efficiently in terms of their capacities and due to the partial shipments. Based on this fact, we intuitively decide to decrease the numbers of dispatches and increase the utilization rates per dispatch.

Melting in the pot all these facts and problems that the system has, several decisions are taken:

- (i) Delivery planning will not be made on order basis and partial shipment will be avoided. Plans will be essentially based on the customer.
- (ii) Partial shipment is possible in case the orders of the customers are not ready to be shipped at the customer requested delivery date.
- (iii) Delivery planning horizon must be expanded in order to avoid low truck usage and partial shipments.
- (iv) For each order collected, a “customer requested delivery date” data must be created and this data must be used while planning deliveries.

In addition to these decisions, İntema aims at growing through the retail channel in the cities where it has its own retail shops. Therefore, the company wants to focus on serving customers in these four cities (İstanbul, Ankara, Adana and İzmir) rather than developing a retail network covering the whole country. In parallel to this strategy and given that these four cities cover 85 per cent of all the orders collected, İntema adopted the approach to charge all deliveries to cities except these four.

Stepping forward with the aim of providing better service quality, İntema targets to cut its operational expenses down while increasing customer satisfaction by delivering goods on time, in a complete and undamaged manner. Right and efficient usage of available resources plays a critical role to achieve this target. A well structured and expanded planning will avoid the situation of visiting customers numerous times for little packages instead of shipping goods as soon as they are ready-to-ship in the warehouse. This planning approach will also ensure carrying larger volumes by consolidating orders

on customer basis and dispatching them at the date customers prefer. In the current information and order collection process, a “customer requested delivery date” data is not assigned to orders. This in turn complicates constructing a delivery plan. This missing data cause late deliveries or excessive inventory usage because of not tracking dispatches on customer requested delivery date basis. Due to this lack of follow-up, customers reach call to call centers to inquire about their orders. These calls and search of order’s current status slow down daily operations and require continuous reworks.

In our study, remaining within the framework shaped by the company’s strategies and constrained by the facts surrounding the system, we will erect a planning model based on an extended planning horizon larger than one-day length with the aim of raising truck utilizations and abolishing “urgent needs” for supplementary vehicles which are expensive compared to vehicles rented by contracts. Currently, although all trucks are not loaded up to their capacities, lack of customer requested delivery date and a solid plan covering a long period causes additional payment for theses spare vehicles.

Following the meeting we had with the management in the company, it is decided to constraint the study coverage by the orders collected in İstanbul by taking into consideration that 60 per cent of the total orders are submitted by the customers inhabiting in this city.

6. TRANSPORTATION MODEL

In this chapter, we construct a mathematical model by taking into account the following characteristics of İntema's outbound logistics.

- the promise to deliver up to the house of customers
- “in town” (referring to deliveries in İstanbul) shipments
- Fragile and heavy products in weight
- Heavy traffic in İstanbul hindering shipments to different districts and locations

İntema's challenge is the daily consolidation of orders to be delivered from a central depot (warehouse) to the premises of customers. Transportation was outsourced to a third party logistics company, namely Ceva Logistics, a year ago. The depot and the vehicles are rented from this Logistics Company. The depot is located in Gebze, a district of Kocaeli which is one hour far from İstanbul. Vehicle contracts may be revised bi-weekly in case a change is needed.

The outsourced staff work in Gebze depot and they are responsible of the construction daily loading and routing plans. Currently, these planners make their daily delivery plans manually. İntema uses SAP R/3 to manage its operations and to store its data whereas Ceva operates with a Warehouse Management System developed by a Turkish Software Providing Company. Every day, operators in İntema Logistics Department get a report from their system regarding the orders which have to be delivered the next day. They send this report over an ftp interface to Ceva's planners. This report encompasses the orders confirmed until 15:30 each day. Orders confirmed after this cut-off time are included by the next day's report and delivered on the following day. This report contains the following information:

- Customer number
- Customer name
- Customer address, written in text format manually by the dealer
- City and district information entered by the dealer manually

- Order entry date
- Dealer code
- Dealer name that placed the order
- Sales representative's name
- Article code (SKU code)
- Article name
- Product group of the article
- Order quantity
- Quantity unit (kg, m² etc.)
- Unit cost of the article
- Total cost of the order

Once the planner receives the report, he does a quick check of information availability and consistency. He controls the availability of city and district information. If this information is missing, he looks at the address row and then fills in this information. For consistency, he reviews the match of column name and the information given under the related column to detect any errors that may occur while the file transfers. Afterwards, he separates İstanbul orders from those of other cities. Then, he groups the remaining orders depending on the district information and begins to assign vehicles to those orders row by row by just considering the intuitional proximity of the districts. Once the assignment is complete, a pivot table of the report (see Table 6.1) is prepared:

Table 6.1. Example of a pivot table prepared as the basis of a route plan

| | | | | | | | | UNIT | | |
|----------------|----------|---------------|------------------|-----------------------|-----------------------|------------|---------------|-------|----|----------------|
| Vehicle Number | District | Customer Name | Customer address | Order Delivery Number | Customer Order Number | Sales rep. | Product Group | PIECE | KG | M ² |
| TRUCK1 | Üsküdar | Cust. 1 | XXXX | 12345 | 98765 | XXXXXX | Ceramic | 0 | 0 | 4.5 |
| | Kadıköy | Cust. 2 | XXXX | 12346 | 98764 | XXXXXX | Bath Tub | 3 | | |

Route planner sums up the total load volume per truck based on the associated unit such as piece, kg, m² and product group information. He roughly estimates the volume and weight of the orders; then fine-tunes his plans and assigns excessive orders to another truck which will pass nearby or to a new empty truck. He then initiates the handling of the orders according to the delivery plan and the next day. After the loading operation, drivers dispatch the orders assigned to their vehicles. If any rush order comes out, it is either assigned to the trucks if there is any place or a new empty truck is used to dispatch this order. Rush orders generally happen because of the confirmation instructions sent to the planner by order basis. In the suggested model, this challenge will be overcome by consolidating orders by customer name. Secondly, in the current way plans are prepared considering one day period as the planning horizon. In our model, consideration of customer requested delivery date and weekly planning horizon will avoid rush orders to a great extent.

In our proposed model, we highly depend on the customer requested delivery date and on the order volume information which are not currently used within the company. Therefore, we performed a study to fill in these fields of information. With a group of three people, we went over the product range and measured their volumes one by one. Even though the necessity of having product volumes in the system is obvious, this information was not available in SAP R/3. Therefore, we also conducted a volume measuring study and then went over the whole product range and measured the volumes.

The second study was to assign a customer requested delivery date to each order. After discussing the unavoidable need for this information, the manager of Logistics Department made an announcement to all sales representatives to ask for a customer requested delivery date while collecting orders. Then, he asked weekly reports to check the availability of this information and as soon as any order is detected without the customer requested delivery date, operators called the relevant sales representative to contact with the customer and agree on the date. Furthermore, sales representatives are evaluated according to their cooperation. Moreover, a weekly report pointing out their collaboration is published.

The third work we intended to initiate was to determine the weight of each product. However, due to the unavailability of resources and work intensity, we had to suspend this part. Still, as we were bound to respect the weight constraint, we reduced the available load capacity of vehicle by one third of its real capacity. With this reduction, the sub-optimality caused by loading and packaging is thereby incorporated into our model.

In the proposed model, we respected the daily service time constraint by limiting the number of locations to be visited. Additionally, as the driver's region knowledge is appreciated by the management, it is decided that Asia and Europe continents were considered separately in the model. Another prominent outcome of our "Current Situation Analysis Study" which is also a pre-requisite for our model was the confirmation of orders per customer, not per order. This is assured in two ways. The first one is the assignment of the customer requested delivery date. If a customer has more than one order and if he does not deliberately ask for distinct delivery dates, the same date is assigned for his orders. The second way of assuring customer-based consolidation is guaranteed while confirming and sending orders to the planners at the depot. If any part of an order is not ready (present) in the warehouse, the status of the orders for that customer is switched to "pending" rather than "ready to ship" if there is no pre-signalized situation for that customer. And the planning horizon is expanded in a way that the planner will produce weekly plans rather than daily plan looking over larger period than a week's duration to fulfill the vehicles up to the limit. Orders may be delivered earlier than the customer requested delivery date if customers confirm.

As mentioned earlier, Intema outsourced its transportation to Ceva Logistics. The contract of transportation cost is calculated over the fixed cost of vehicles, the driver's wages, the payment for the spot vehicles that are provided on demand and the mileages run by vehicles. According to the management decision, any saving concerning the mileages caused by routing will be subject to another study due to the intractability of drivers at the moment, in city traffic density and lack of qualified personnel who can handle route plans. Furthermore, in the first plan, savings that can be recorded by reducing number of vehicles in use will save the company from vehicle's fixed costs, additional spot vehicle need and the driver's wage which is the voluminous item compared to gas consumptions in the invoice. Additionally, as mentioned in the "Presentation of the problem" part, business

partnership with Ceva started a year ago and the company is able to evaluate this third party logistics company and revise its contract accordingly. Any cost savings in terms of vehicles will augment Intema's bargaining power against Ceva.

From the very first day of this study, the objective was to look for ways of increasing the efficient use of available resources (trucks, stuff etc,) and decreasing, if possible, the transportation expenses. Our analysis shows that the main source in transportation costs is the wages of the drivers. Neither the fixed cost of vehicles nor the variable cost occurring per kilometer affects the transportation expenses as drivers do. Considering this fact, we decide to build a model that will diminish the number of trucks used on each day. This model not only decreases the number of vehicles, it also ensures an increase at truck utilization rates. Consequently, the two objectives of this study will be satisfied.

The aim of this transportation model is to plan five-day shipments so as to minimize the number of trucks necessary while guaranteeing the average truck utilization rate per day meets the target. This model includes in-city-traffic conditions and restricts visiting all customers inhabiting on different continents sides of the city within a day. The length of the planning horizon is determined in cooperation with the logistics team in Intema. Only goods existing in warehouse that are ready-to-ship are taken into consideration in delivery plans.

6.1. Assumptions and Constraints

We develop a model which is capable of handling a variety of real-life requirements under the following assumptions:

- A tour of a truck starts and ends at the warehouse passing all locations belonging to each transportation request assigned to the vehicle. The depot is not visited within the day unless it is considered as start or end point. Any truck tour starts from the depot in the morning and following the completion of the deliveries; the truck returns to the depot and completes its tour. Therefore, a tour consists of a sequence of delivery points starting from depot and ending at the depot without any returning

back to the depot within the day. Any truck solely makes one complete tour in a day.

- Time windows are not taken into account within the model. The reason of discarding this constraint is that Intema does not even work with an agreement on delivery date.
- There exists a homogeneous fleet of trucks. According to the supplementary research conducted with the Logistics Department, we see no point of hiring a fleet of heterogeneous vehicles because of fuel consumptions and route restrictions.
- Any order can be assigned to any truck. Namely, there is no compatibility problem between orders and vehicles.
- Any mixture of the items may be loaded onto a vehicle.
- Multi-dimensional capacity constraints are discarded as well. However, the total capacity of trucks is decreased by 30 per cent with respect to the loading reality which is out-of scope from the perspective of this study and the maximum allowed weight for the trucks by local regulations. The second reason of reducing the volume by 30 per cent is to reflect the weight dimension of the problem. Due to the unavailability of the weight of any product in the system, this dimension is not included in the model.
- Sequencing of delivery locations is not presented in this study due the traffic density. This issue is assumed to be optimized by the driver's expertise.
- Working hours are between 09:00-18:00, Intema is not accountable of overtime workings. The vehicles are supposed to be available within this period.
- A customer can be only visited on the week days.

- A “Customer Requested Delivery Date” is assigned to each order to propose a planning model.
- Order volumes are consolidated by customer name and by customer requested delivery date. Therefore, orders cannot be dispatched partially given that their customer requested delivery dates are identical.
- The main expense item is identified as driver’s wages. Thus, travel costs are not reflected into the objective function of the model developed.
- Any truck tour starts from the depot in the morning and following the completion of the deliveries; the truck returns to the depot and completes its tour. Therefore, a tour consists of a sequence of delivery points starting from depot and ending at the depot without any returning back to the depot within the day. A truck makes one complete tour in a day.

6.2. Mathematical Model

Eczacıbaşı İntema operates under the “up-to your house” promise they have given to customers and deliver each order to wherever it is asked. Shipments are either in city shipments, referring to the circulation in İstanbul, or out-of-city shipments including orders collected from all over the country except İstanbul. Considering the weights of “in-city” and “out-of-city” shipments in the whole business, we have decided to focus on organizing İstanbul shipments in the first step.

The model deals with the planning of in-city shipments over a period of predefined length. Basically, we aim to propose such a delivery plan that will consolidate orders present in the warehouse in a way implying the efficient use of trucks in hand. In other words, our model will ensure that all trucks in use will be loaded at a level that meets utilization targets while minimizing the number of trucks in use.

In our model, we have considered a five-day period for planning and limited the horizon to 10 days. This means that demands of the first five days will be shipped compulsorily but we can also ship demands of the oncoming days in addition to these five days. To overcome daily transportation issues stemming from the long distances between districts located on both two sides of İstanbul, we have decided to consider the two sides separately.

The details of the proposed transportation model are given below:

Indices

| | | |
|-----|---|------------------------|
| i | refers to the number of trucks The company has 7 trucks rented. | $\{1, 2, \dots, 7\}$ |
| t | refers to the delivery day | $\{1, 2, \dots, 5\}$ |
| v | refers to the customers in İstanbul | $\{1, 2, \dots, M_v\}$ |
| u | refers to the demand horizon (days) (The length of the horizon can be changed) | $\{1, 2, \dots, 10\}$ |

Parameters

d_{vu} Demand of customer v on day u

Variables

$$X_{it} = \begin{cases} 1 & \text{if truck } i \text{ provides service on delivery day } t \\ 0 & \text{Otherwise} \end{cases}$$

$$S_{itvu} = \begin{cases} 1 & \text{if the demand on day } u \text{ of the customer } v \text{ is shipped} \\ & \text{on day } t \text{ by truck } i \\ 0 & \text{Otherwise} \end{cases}$$

$$Y_{itv} = \begin{cases} 1 & \text{if customer } v \text{ is visited on day } t \text{ by truck } i \\ 0 & \text{Otherwise} \end{cases}$$

F_{it} Load of truck i on day t

$$F_{it} = \sum_{v=1}^{M_v} \sum_{u=1}^{10} S_{itvu} d_{vu} \quad (6.1)$$

Free variables

z Total number of trucks used in five days

The goal is to minimize the number of trucks in service for five days. The following restrictions apply:

- M_v is the number of customers existing within the data set. In our case, M_v will be assumed to be equal to 173, which is the number of customers in Asia dataset and it will be considered as 349 customers for the Europe data set corresponding to the first week planning horizon.
- The capacity of any truck on any day cannot exceed 10 m^3 .
- Any order of any customer has to be transported in one truck and at a single time.
- The orders within the planning horizon must be transported. In other words, the delivery plan might include any order but it is mandatory to deliver the ones belonging to the first five days.
- Single visit for the same order to the same customer: If any demand of a customer is carried to that customer on day t by truck i , then that customer is referred to as “visited”.

- The maximum number of customers to be visited: To make our model more realistic, we limited the number that can be visited within a day by a single truck to 15 customers. This number is deduced from historical delivery data and fine-tuned with the expertise of drivers.

Mathematical model

$$\min z = \sum_{i=1}^7 \sum_{t=1}^5 X_{it} \quad (6.2)$$

$$\text{s.t.} \quad F_{it} = \sum_{v=1}^{M_v} \sum_{u=1}^{10} S_{itvu} d_{vu} \leq 10X_{it} \quad \forall i, t \quad (6.3)$$

$$\sum_{i=1}^7 \sum_{t=1}^5 S_{itvu} \leq 1 \quad \forall v, u \quad (6.4)$$

$$\sum_{i=1}^7 \sum_{t=1}^5 S_{itvu} = 1 \quad \forall v, u = \{1, \dots, 5\} \quad (6.5)$$

$$Y_{itv} \leq \sum_{u=1}^{10} S_{itvu} \quad \forall i, t, v \quad (6.6)$$

$$Y_{itv} \geq S_{itvu} \quad \forall i, t, v, u \quad (6.7)$$

$$\sum_{v=1}^{M_v} Y_{itv} \leq 15 \quad \forall i, t \quad (6.8)$$

The objective of the above given model is to minimize the number of trucks in use during five days. Constraint (6.3) ensures that the capacity of any truck in use is not exceeded. Through constraint (6.4), we make sure that any order of any customer can be transported at most once and if so can be contained in one truck. Constraint (6.5) is a modified version of the former one with the intent of assuring the transportation of demands belonging to the first five days within the delivery planning horizon. With the

remaining constraints, we aim to keep the number of customers (points) visited during a day within a threshold. In our model, this number is set as 15 customers based on the evaluation of the real-world traffic conditions and past shipment data. The model consists of $35 + 385 M_v$ variables and is constrained by a number of $70 + 350 M_v$ constraints.

7. RESULTS

For the comparison of the existing system and the proposed model, we decided to work on a ten-day period and prepare a five-day delivery plan. We will then generate our proposed plan and compare it with the actual deliveries. The performance of the proposed model will be evaluated in terms of the capacity utilization and the reduction in the number of vehicles.

7.1. Results obtained using the proposed model

In the proposed delivery plan, orders requested in the first five days have to be mandatorily delivered regardless of which day they are dispatched on. Additionally, orders whose delivery date is later than the five-day period might be delivered if necessary. We used the information related to the orders belonging to this ten-day period per side separately and ran the algorithm. Before inputting any data into the algorithm, a pre-processing step is required where the orders are consolidated on the customer basis. Then, the data set is separated into two with the respect to the Asian and European sides. Following this data processing part, the algorithm is run for Asia and Europe sides separately and the results are then consolidated. Thus, the weekly plans are obtained. The results of the planning are given in Tables 7.1-7.6 in terms of cubic meters.

Table 7.1. One week delivery plan obtained by the developed model

| Week 1 | | | | | |
|---------|-------|-------|-------|-------|-------|
| | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
| Truck 1 | 5.660 | 4.510 | 6.890 | 0.210 | 9.090 |
| Truck 2 | 7.980 | 7.850 | 8.070 | 0.360 | 0.290 |
| Truck 3 | 9.820 | 6.550 | 9.950 | 4.640 | 5.170 |
| Truck 4 | 7.840 | 9.620 | 5.250 | 4.650 | 5.720 |

Table 7.2. Delivery volumes transported on the first day of the first planning horizon per district and per customer

| Truck 1 | | | | | | | |
|----------|----------|------|------|------|------|------|------|
| District | Customer | | | | | | |
| | 78 | 98 | 100 | 106 | 111 | 112 | 115 |
| BAKIRKÖY | | | | 0.05 | | | |
| BEŞİKTAŞ | 2.64 | | | | 0.01 | 0.06 | 0.03 |
| SARIYER | | | | | | | |
| ŞİŞLİ | | 0.01 | 0.02 | | | | |

| District | Customer (Cont.'d) | | | | | | | |
|----------|--------------------|------|------|------|------|------|------|------|
| | 147 | 148 | 151 | 153 | 154 | 155 | 158 | 160 |
| BAKIRKÖY | | | | | | | | |
| BEŞİKTAŞ | | | | 0.07 | 0.09 | 0.05 | | 1.09 |
| SARIYER | 0.37 | 0.38 | 0.20 | | | | 0.61 | |
| ŞİŞLİ | | | | | | | | |

| Truck 2 | | | | | | | |
|--------------|----------|------|------|------|------|------|------|
| District | Customer | | | | | | |
| | 54 | 59 | 61 | 63 | 70 | 76 | 77 |
| AVCILAR | | | | | | | |
| BAHÇELİEVLER | | | | | | | |
| BAKIRKÖY | 0.36 | | | | | | |
| BAYRAMPAŞA | | | | | | | 0.01 |
| BEŞİKTAŞ | | 0.01 | | | 0.83 | | |
| SARIYER | | | 0.05 | 0.46 | | 0.05 | |
| ŞİŞLİ | | | | | | | |

| District | Customer (Cont.'d) | | | | | | |
|--------------|--------------------|------|------|------|------|------|------|
| | 84 | 85 | 88 | 92 | 121 | 125 | 144 |
| AVCILAR | 0.03 | | | | | | |
| BAHÇELİEVLER | | | | | 3.61 | | |
| BAKIRKÖY | | | | | | | |
| BAYRAMPAŞA | | | | | | | |
| BEŞİKTAŞ | | | 1.05 | 0.61 | | | |
| SARIYER | | | | | | | 0.84 |
| ŞİŞLİ | | 0.01 | | | | 0.06 | |

| |
|---------|
| Truck 3 |
|---------|

| | Customer | | | | | | |
|----------|----------|------|------|------|------|------|------|
| District | 20 | 25 | 26 | 30 | 57 | 64 | 69 |
| BEYKOZ | | | 2.45 | | 1.17 | | |
| GEBZE | | 0.62 | | | | | |
| KADIKÖY | 0.93 | | | 0.45 | | | 0.47 |
| TUZLA | | | | | | | |
| ÜSKÜDAR | | | | | | 0.26 | |

| | Customer (Cont.'d) | | | | | | |
|----------|--------------------|------|------|------|------|------|------|
| District | 72 | 81 | 87 | 92 | 108 | 109 | 117 |
| BEYKOZ | | | | | | | |
| GEBZE | | | | | | | |
| KADIKÖY | 0.06 | | 0.11 | 0.12 | 1.20 | | |
| TUZLA | | | | | | 0.30 | 1.31 |
| ÜSKÜDAR | | 0.35 | | | | | |

| |
|---------|
| Truck 4 |
|---------|

| | Customer | | | | | |
|----------|----------|------|------|------|------|------|
| District | 17 | 19 | 34 | 36 | 37 | 39 |
| BEYKOZ | | 0.05 | | | | |
| KADIKÖY | | | | 0.47 | 1.42 | 0.61 |
| TUZLA | | | 0.42 | | | |
| ÜSKÜDAR | 1.71 | | | | | |

| | Customer (Cont.'d) | | | | | |
|----------|--------------------|------|------|------|------|------|
| District | 40 | 52 | 113 | 114 | 118 | 123 |
| BEYKOZ | | | | | | |
| KADIKÖY | | 0.19 | 0.18 | 0.41 | 1.04 | 0.82 |
| TUZLA | | | | | | |
| ÜSKÜDAR | 0.52 | | | | | |

Table 7.3. Delivery volumes transported on the second day of the first planning horizon per district and per customer

| |
|---------|
| Truck 1 |
|---------|

| | | | | | | | | |
|----------|----------|------|------|------|------|------|------|------|
| - | Customer | | | | | | | |
| District | 6 | 25 | 31 | 35 | 37 | 72 | 82 | 101 |
| BAKIRKÖY | 1.08 | | | | 0.01 | | | |
| BEŞİKTAŞ | | | 0.02 | | | | | 0.03 |
| EYÜP | | | | | | | | |
| FATİH | | 0.84 | | | | | | |
| SARIYER | | | | 0.18 | | | 0.48 | |
| ŞİŞLİ | | | | | | 0.01 | | |

| | | | | | | | | |
|----------|--------------------|------|------|------|------|------|------|------|
| | Customer (Cont.'d) | | | | | | | |
| District | 109 | 123 | 129 | 136 | 142 | 156 | 161 | 175 |
| BAKIRKÖY | | | | | | | | |
| BEŞİKTAŞ | | | | | | 1.05 | 0.03 | |
| EYÜP | | | | | | | | 0.01 |
| FATİH | | | | | | | | |
| SARIYER | 0.06 | | 0.23 | 0.29 | 0.13 | | | |
| ŞİŞLİ | | 0.07 | | | | | | |

| |
|---------|
| Truck 2 |
|---------|

| | | | | | | | |
|----------|----------|------|------|------|------|------|------|
| | Customer | | | | | | |
| District | 3 | 5 | 7 | 8 | 9 | 10 | 14 |
| BAĞCILAR | | | | | | | |
| BAKIRKÖY | | 0.02 | | | | | |
| BEŞİKTAŞ | 0.62 | | | | 2.64 | 0.04 | 0.06 |
| SARIYER | | | 0.02 | | | | |
| ŞİŞLİ | | | | 0.05 | | | |

| | | | | | | | |
|----------|--------------------|------|------|------|------|------|------|
| | Customer (Cont.'d) | | | | | | |
| District | 15 | 16 | 18 | 19 | 22 | 86 | 90 |
| BAĞCILAR | 0.06 | | | | | | |
| BAKIRKÖY | | | | | | 3.09 | |
| BEŞİKTAŞ | | | | 0.21 | | | 0.07 |
| SARIYER | | | | | | | |
| ŞİŞLİ | | 0.95 | 0.01 | | 0.01 | | |

Truck 3

| Customer | | | | | | | | |
|----------|------|------|------|------|------|------|------|------|
| District | 23 | 26 | 27 | 56 | 79 | 80 | 81 | 89 |
| BEŞİKTAŞ | 0.63 | 0.60 | | | 3.08 | | | 0.32 |
| BEYOĞLU | | | | | | | | |
| EMİNÖNÜ | | | | | | | | |
| FATİH | | | 0.52 | | | | | |
| SARIYER | | | | | | 0.02 | 0.28 | |
| SİLİVRİ | | | | 0.17 | | | | |
| ŞİŞLİ | | | | | | | | |

| Customer (Cont.'d) | | | | | | | | |
|--------------------|------|------|------|------|------|------|------|------|
| District | 94 | 96 | 104 | 107 | 110 | 134 | 143 | 159 |
| BEŞİKTAŞ | | 0.22 | | | 0.03 | | | |
| BEYOĞLU | | | 0.03 | | | | | |
| EMİNÖNÜ | 0.27 | | | | | | | |
| FATİH | | | | | | | | |
| SARIYER | | | | 0.05 | | | 0.22 | |
| SİLİVRİ | | | | | | | | |
| ŞİŞLİ | | | | | | 0.04 | | 0.09 |

Truck 4

| Customer | | | | | | | |
|----------|------|------|------|------|------|------|------|
| District | 21 | 27 | 38 | 41 | 42 | 44 | 47 |
| KADIKÖY | 0.05 | | | | | | |
| KARTAL | | | | | | | |
| MALTEPE | | | | | | | 0.04 |
| TUZLA | | 0.31 | | | | | |
| ÜSKÜDAR | | | 3.92 | 0.10 | 0.12 | 0.08 | |

| Customer (Cont.'d) | | | | | | | | |
|--------------------|------|------|------|------|------|------|------|------|
| District | 56 | 60 | 88 | 110 | 115 | 116 | 119 | 124 |
| KADIKÖY | | 2.84 | 0.15 | 0.12 | | 0.10 | 0.06 | 0.23 |
| KARTAL | | | | | 0.06 | | | |
| MALTEPE | | | | | | | | |
| TUZLA | | | | | | | | |
| ÜSKÜDAR | 1.45 | | | | | | | |

Table 7.4. Delivery volumes transported on the third day of the first planning horizon per district and per customer

Truck 1

| District | Customer | | | | | | |
|----------|----------|------|------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| BEYKOZ | 0.39 | | | | | | |
| GEBZE | | | | 0.20 | | | |
| KADIKÖY | | | | | | | |
| MALTEPE | | | | | 0.09 | | |
| PENDİK | | | | | | | |
| ŞİLE | | | | | | | |
| ÜMRANIYE | | | | | | | 0.55 |
| ÜSKÜDAR | | 0.26 | 1.37 | | | 0.96 | |

| District | Customer (Cont.'d) | | | | | | | |
|----------|--------------------|------|------|------|------|------|------|------|
| | 8 | 9 | 12 | 13 | 61 | 102 | 121 | 132 |
| BEYKOZ | | | | | | | | |
| GEBZE | | | | | | | | |
| KADIKÖY | | 0.25 | | | 0.48 | | | |
| MALTEPE | | | | | | | | |
| PENDİK | | | | | | | | 0.08 |
| ŞİLE | | | | 0.74 | | | | |
| ÜMRANIYE | 0.72 | | | | | | | |
| ÜSKÜDAR | | | 0.01 | | | 0.72 | 0.08 | |

Truck 2

| District | Customer | | | | | | | | | |
|----------|----------|------|------|------|------|------|------|------|------|------|
| | 18 | 23 | 24 | 31 | 35 | 66 | 67 | 80 | 84 | 107 |
| KADIKÖY | | | 0.06 | 0.01 | 0.20 | | | | | 0.65 |
| MALTEPE | | 0.47 | | | | 0.33 | | | | |
| ÜSKÜDAR | 2.72 | | | | | | 1.43 | 1.95 | 0.26 | |

Truck 3

| District | Customer | | | | | | |
|----------|----------|------|------|------|------|------|------|
| | 1 | 21 | 32 | 60 | 66 | 87 | 91 |
| BAĞCILAR | | | | 0.01 | | | |
| BAKIRKÖY | | | | | | | |
| BEŞİKTAŞ | | | | | | 0.06 | |
| EYÜP | | | | | | | |
| SARIYER | | | 2.03 | | 4.59 | | 0.10 |
| SİLVİRİ | 0.12 | | | | | | |
| ŞİŞLİ | | 0.78 | | | | | |

| Customer (Cont.'d) | | | | | | | | |
|--------------------|------|------|------|------|------|------|------|------|
| District | 95 | 113 | 117 | 120 | 126 | 133 | 140 | 165 |
| BAĞCILAR | | | | | | | | |
| BAKIRKÖY | | | | 0.17 | | | | |
| BEŞİKTAŞ | 0.06 | 1.53 | | | | 0.03 | | |
| EYÜP | | | 0.30 | | | | | |
| SARIYER | | | | | | | 0.11 | |
| SİLVİRİ | | | | | 0.05 | | | |
| ŞİŞLİ | | | | | | | | 0.01 |

| |
|---------|
| Truck 4 |
|---------|

| Customer | | | | | | | | |
|--------------|------|------|------|------|------|------|------|------|
| District | 12 | 17 | 24 | 42 | 58 | 62 | 103 | 105 |
| BAKIRKÖY | | 0.01 | | | | | | |
| BEŞİKTAŞ | | | 0.06 | | | | | |
| BEYOĞLU | | | | | | | 0.58 | |
| BÜYÜKÇEKMECE | | | | | 2.11 | | | |
| SARIYER | | | | | | | | |
| ŞİŞLİ | 0.01 | | | 0.01 | | 0.01 | | 0.02 |

| Customer (Cont.'d) | | | | | | | | |
|--------------------|------|------|------|------|------|------|------|------|
| District | 116 | 130 | 135 | 146 | 149 | 152 | 163 | 170 |
| BAKIRKÖY | | | | | | | | |
| BEŞİKTAŞ | 0.01 | | 0.01 | | | | 0.08 | 0.10 |
| BEYOĞLU | | | | | | | | |
| BÜYÜKÇEKMECE | | | | | | | | |
| SARIYER | | | | 0.56 | 1.29 | 0.41 | | |
| ŞİŞLİ | | 0.04 | | | | | | |

| |
|---------|
| Truck 2 |
|---------|

| | Customer | | | | | | |
|----------|----------|------|------|------|------|------|------|
| District | 11 | 46 | 51 | 53 | 54 | 58 | 65 |
| KADIKÖY | 0.04 | 0.03 | 0.02 | 0.01 | 0.02 | | |
| KARTAL | | | | | | 0.01 | |
| TUZLA | | | | | | | 0.03 |
| ÜSKÜDAR | | | | | | | |

| | Customer (Cont.'d) | | | | | | |
|----------|--------------------|------|------|------|------|------|------|
| District | 68 | 75 | 85 | 89 | 90 | 91 | 93 |
| KADIKÖY | 0.01 | 0.01 | 0.03 | | 0.02 | 0.01 | 0.01 |
| KARTAL | | | | | | | |
| TUZLA | | | | | | | |
| ÜSKÜDAR | | | | 0.04 | | | |

| |
|---------|
| Truck 3 |
|---------|

| | Customer | | | | | | |
|--------------|----------|------|------|------|------|------|------|
| District | 20 | 29 | 30 | 34 | 36 | 38 | 41 |
| BAĞCILAR | | | 0.13 | | | | |
| BAKIRKÖY | | | | | | | |
| BEŞİKTAŞ | | 0.01 | | | | 0.49 | |
| BÜYÜKÇEKMECE | | | | | | | 0.12 |
| SARIYER | 3.04 | | | | | | |
| ŞİŞLİ | | | | 0.08 | 0.45 | | |

| | Customer (Cont.'d) | | | | | | | |
|--------------|--------------------|------|------|------|------|------|------|------|
| District | 43 | 48 | 49 | 52 | 67 | 119 | 122 | 139 |
| BAĞCILAR | | | | | 0.06 | | | |
| BAKIRKÖY | | | | | | 0.08 | | |
| BEŞİKTAŞ | 0.03 | 0.12 | | | | | | |
| BÜYÜKÇEKMECE | | | | | | | | |
| SARIYER | | | 0.10 | 0.35 | | | | |
| ŞİŞLİ | | | | | | | 0.05 | 0.06 |

| |
|---------|
| Truck 4 |
|---------|

| District | Customer | | | | | |
|----------|----------|------|------|------|------|------|
| | 33 | 40 | 44 | 51 | 53 | 74 |
| BEŞİKTAŞ | | 0.04 | | 0.10 | | 0.36 |
| BEYOĞLU | 0.04 | | | | | |
| SARIYER | | | | | | |
| ŞİŞLİ | | | 0.24 | | 1.49 | |

| District | Customer (Cont.'d) | | | | | | |
|----------|--------------------|------|------|------|------|------|------|
| | 83 | 97 | 118 | 127 | 131 | 145 | 157 |
| BEŞİKTAŞ | | 0.32 | | | 0.22 | | 1.05 |
| BEYOĞLU | | | | | | | |
| SARIYER | 0.05 | | 0.91 | | | 0.45 | |
| ŞİŞLİ | | | | 0.07 | | | |

The current plan prepared by Ceva planners for the same period, namely the first five days is given in Table 7.7.

Table 7.7. Actual vehicle utilization within the first five days of the planning horizon

| | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
|-----------------------------------|-------|-------|-------|-------|-------|
| Truck 1 (m ³) | 1.53 | 1.45 | 2.76 | 4.72 | 2.15 |
| Utilization rate (%) | 15 | 14 | 28 | 47 | 21 |
| Truck 2 (m ³) | 10.00 | 6.31 | 3.98 | 10.00 | 3.97 |
| Utilization rate (%) | 100 | 63 | 40 | 100 | 40 |
| Truck 3 (m ³) | 0.81 | 1.87 | 3.42 | 6.09 | 2.47 |
| Utilization rate (%) | 8 | 19 | 34 | 61 | 25 |
| Truck 4 (m ³) | 5.41 | - | 4.44 | 8.93 | 4.37 |
| Utilization rate (%) | 54 | 0 | 44 | 89 | 44 |
| Truck 5 (m ³) | 7.10 | - | 3.55 | 4.31 | 2.29 |
| Utilization rate (%) | 71 | 0 | 36 | 43 | 23 |
| Truck 6 (m ³) | 5.19 | - | 3.00 | - | 2.98 |
| Utilization rate (%) | 52 | 0 | 30 | 0 | 30 |
| Truck 7 (m ³) | 5.19 | - | 0.17 | - | 2.37 |
| Utilization rate (%) | 52 | 0 | 2 | 0 | 24 |
| Spare vehicle 1 (m ³) | - | - | 2.42 | - | - |
| Utilization rate (%) | 0 | 0 | 24 | 0 | 0 |
| Total | 35.22 | 9.63 | 23.76 | 34.04 | 20.60 |

We then decided to run the model for a total of eight five-day periods (see Table 7.8) with the belief that if a better vehicle utilization rate is obtained with fewer vehicles, we

can suggest a contract review with Ceva given that vehicle contracts may be revised bi-weekly.

Table 7.8. Two months delivery plan suggested by the developed model

| Vehicle capacity=10; Number of customers=15 | | | | |
|---|----------------|-------------|-------------|--------------|
| | Proposed Model | | | |
| | Week 1 | Week 2 | Week 3 | Week 4 |
| Number of vehicles in use | 4 | 4 | 6 | 4 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 5 out of 20 | 3 out of 20 | 4 out of 30 | 13 out of 30 |
| Average utilization rate per truck | 60% | 67% | 64% | 89% |
| Total volume delivered (m ³) | 120.12 | 113.89 | 165.12 | 152.00 |
| Volume that must be delivered within the week | 120.09 | 113.9 | 165.2 | 152 |

| | Proposed Model (Cont'.d) | | | |
|---|--------------------------|-------------|-------------|-------------|
| | Week 5 | Week 6 | Week 7 | Week 8 |
| Number of vehicles in use | 4 | 4 | 3 | 4 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 2 out of 20 | 4 out of 20 | 8 out of 20 | 3 out of 20 |
| Average utilization rate per truck | 92% | 91% | 81% | 80% |
| Total volume delivered (m ³) | 165.12 | 145.75 | 97.07 | 135.7 |
| Volume that must be delivered within the week | 165.1 | 145.7 | 97 | 135.7 |

The actual values computed by Ceva planners were are given in Table 7.9.

Table 7.9. Actual values obtained in two months

| | Actual | | | |
|---|-------------|-------------|-------------|-------------|
| | Week 1 | Week 2 | Week 3 | Week 4 |
| Number of vehicles in use | 7 | 7 | 7 | 7 |
| Number of spare vehicles used | 1 | 0 | 2 | 4 |
| Number of times a vehicle is not used | 6 out of 35 | 6 out of 35 | 2 out of 35 | 4 out of 35 |
| Average utilization rate per truck | 41% | 42% | 46% | 35% |
| Total volume delivered (m ³) | 123.26 | 122.24 | 163.21 | 122.6 |
| Volume that must be delivered within the week | #N/A | #N/A | #N/A | #N/A |

| | Actual (Cont.'d) | | | |
|---|------------------|-------------|-------------|-------------|
| | Week 5 | Week 6 | Week 7 | Week 8 |
| Number of vehicles in use | 7 | 7 | 7 | 7 |
| Number of spare vehicles used | 3 | 6 | 7 | 2 |
| Number of times a vehicle is not used | 4 out of 35 | 3 out of 35 | 1 out of 35 | 6 out of 35 |
| Average utilization rate per truck | 46% | 39% | 41% | 29% |
| Total volume delivered (m ³) | 156.24 | 147.16 | 168.18 | 91.11 |
| Volume that must be delivered within the week | #N/A | #N/A | #N/A | #N/A |

The volume that must be delivered within the corresponding week information is given as “Not Applicable” for the current situation because of the lack of “customer requested delivery date” information. As a result, it is not possible to accept any quantity as “must-be delivered” volume.

The proposed model is developed by considering the environment in which the company runs business and incorporating the findings of the company’s current operations. Therefore, it ensures that any order of a customer will be delivered within a week if the requested delivery date coincides with the planning period. Furthermore, according to the proposed model, it is sufficient to have four trucks to deliver all the orders of the first and the second week. Based on the fact that the renting contract might be reviewed bi-weekly, the number of vehicles needed might be decreased to four trucks for these two weeks. For the following two weeks, namely third and fourth week, it is sufficient to have six vehicles. In weeks five and six, Intema might decrease the number of vehicles contracted to four vehicles, and in the following two-week periods, four vehicles are again sufficient to deliver all the orders. Hence, the same contract might be adopted without any change in terms of the vehicle number. In conclusion, the company would have needed three less

trucks in the first two-week period, one less truck in the third and the fourth weeks, whereas the savings would be three trucks in the remaining two-week periods resulting in a decrease of 44 per cent in value throughout the eight-week period. Assuming that the monthly cost of a contracted truck is 5,000 YTL for İntema and a spare vehicle daily rent cost is 400 YTL excluding variable costs, the proposed model ensures savings of 35,000 YTL in the eight-week period by decreasing the number of vehicles contracted. Moreover, the “consolidation of customer orders” and the “usage of customer requested delivery date” will be the factors affecting customer service in a good way.

7.2. Results obtained using the Bin Packing Heuristic

The similarity of the problem with the class of bin-packing problems presented in the literature encouraged us to conduct a supplementary analysis. We decided to apply the first fit heuristic as a solution approach for our problem. The results derived from this approach are given in Table 7.10.

Table 7.10. Results of the bin packing heuristic

| Vehicle capacity=10; Number of customers=15 | | | | |
|---|-------------|-------------|-------------|-------------|
| | Week 1 | Week 2 | Week 3 | Week 4 |
| Number of vehicles in use | 5 | 4 | 5 | 4 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 9 out of 20 | 3 out of 20 | 1 out of 25 | 8 out of 25 |
| Average utilization rate per truck | 56% | 72% | 66% | 92% |
| Total volume delivered (m ³) | 116.61 | 121.63 | 158.76 | 155.79 |
| Volume that must be delivered within the week | 120.09 | 113.9 | 165.2 | 152 |
| | Week 5 | Week 6 | Week 7 | Week 8 |
| Number of vehicles in use | 4 | 3 | 3 | 4 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 4 out of 20 | 5 out of 20 | 9 out of 20 | 3 out of 20 |
| Average utilization rate per truck | 96% | 92% | 83% | 93% |
| Total volume delivered (m ³) | 153.79 | 137.82 | 91.11 | 158.47 |
| Volume that must be delivered within the week | 165.1 | 145.7 | 97 | 135.7 |

When we compare the results obtained by the proposed model and the bin packing heuristic, we note that there is no significant difference in terms of the number of vehicles used, the truck loads, the number of times a vehicle is not used, and especially in the value of savings. However, the run time comparison shows that Bin Packing Heuristic performs faster than solving the proposed model to optimality. Both algorithms are run on the computers with a core duo processor. However the processor speeds of these computers are different. The Bin Packing Heuristic is run on a computer with a processor speed of 1.83 GHz and with a RAM of 1.00 GB whereas the optimal algorithm is run on a computer with a processor speed of 2.4 GHz and a RAM of 3.92 GB. The duration of having results using First Fit heuristic is no more than two seconds whereas the proposed model to optimality lasts at least one minute. Therefore, the use of First Fit Heuristic seems to be more appropriate for solving this problem.

8. SENSITIVITY ANALYSIS

8.1. Effect of the vehicle capacity

With the aim of analyzing the effect of the vehicle capacity on the results, we run our model by taking the capacity constraint of the vehicles equal to eight cubic meters. All the remaining parameters are kept the same. Results are given in Table 8.1:

Table 8.1. Results when the capacity is eight cubic meters

| Vehicle capacity=8; number of customers=15 | | | | |
|---|----------------|-------------|-------------|--------------|
| | Proposed Model | | | |
| | Week 1 | Week 2 | Week 3 | Week 4 |
| Number of vehicles in use | 4 | 4 | 6 | 4 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 0 out of 20 | 3 out of 20 | 3 out of 30 | 10 out of 30 |
| Average utilization rate per truck | 60% | 67% | 61% | 76% |
| Total volume delivered (m ³) | 120.12 | 113.89 | 165.12 | 152.0 |
| Volume that must be delivered within the week | 120.09 | 113.9 | 165.2 | 152 |

| | Proposed Model (Cont'.d) | | | |
|---|--------------------------|-------------|--------------|-------------|
| | Week 5 | Week 6 | Week 7 | Week 8 |
| Number of vehicles in use | 5 | 4 | 3 | 5 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 3 out of 25 | 6 out of 25 | 11 out of 25 | 4 out of 25 |
| Average utilization rate per truck | 75% | 77% | 69% | 65% |
| Total volume delivered (m ³) | 165.12 | 145.75 | 97.07 | 135.7 |
| Volume that must be delivered within the week | 165.1 | 145.7 | 97 | 135.7 |

According to the results, we need more vehicles compared to the case where the vehicle capacity is equal to 10. As Intema reviews the contract bi-weekly, it is sufficient to have four trucks to deliver all the orders of the first and the second week and six vehicles for the following two weeks, as in the higher capacity case. We can say that the number of the contracted vehicles will be the same for the first four weeks. But for the last four

weeks, Intema would need one more contracted vehicle compared to the case where the capacity is equal to 10 to deliver all the orders. If we compare the average utilization rate per truck, we note lower ratios for the last four weeks because of the increase in the number of the trucks. As the model proposes the same number of vehicles for the first four weeks, the average utilization rates per truck are close to the case where the capacity is higher. In both cases, we have not used any spare vehicle. Therefore, it is evident that both cases are better than the actual situation. If we examine the total number of times a vehicle is not used for both of the cases, the idle capacity of the vehicles is lower when we use vehicles which have higher capacity.

In conclusion, the company would be saving eight trucks in total resulting in a decrease of 25 per cent in value through the eight-week period. The proposed model ensures a saving of 20,000 YTL in the eight-week period by decreasing the number of contracted vehicles, which is 15,000 YTL lower than the previous results in which the capacity is equal to 10. The sensitivity analysis shows that using vehicles with a capacity of 10 m³ generates better results in terms of total cost, the number of vehicles in use, the number of spare vehicles used, the number of times a vehicle is not used and the average utilization rate per truck.

8.2. Effect of the number of customers visited per trip

The number of customers that the vehicles should visit also affects the number of vehicles used. If we decrease this number, it is expected to use more vehicles. We will conduct a sensitivity analysis on the number of customers that the vehicles should visit. To this end, we will run our model while the number is equal to 12. We again keep all the remaining parameters the same. Results are given in Tables 8.2-8.4.

Table 8.2. Results when the number of customers visited per trip is 12

| Vehicle capacity=10; Number of customers=12 | | | | |
|---|----------------|--------------|-------------|--------------|
| | Proposed Model | | | |
| | Week 1 | Week 2 | Week 3 | Week 4 |
| Number of vehicles in use | 6 | 4 | 7 | 4 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 4 out of 30 | 11 out of 30 | 4 out of 35 | 17 out of 35 |
| Average utilization rate per truck | 46% | 60% | 53% | 84% |
| Total volume delivered (m ³) | 120.32 | 114.09 | 165.32 | 152.20 |
| Volume that must be delivered within the week | 120.09 | 113.9 | 165.2 | 152 |

| | Proposed Model (Cont'.d) | | | |
|---|--------------------------|-------------|-------------|-------------|
| | Week 5 | Week 6 | Week 7 | Week 8 |
| Number of vehicles in use | 4 | 4 | 3 | 4 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 1 out of 20 | 2 out of 20 | 6 out of 20 | 3 out of 20 |
| Average utilization rate per truck | 87% | 81% | 69% | 79% |
| Total volume delivered (m ³) | 165.32 | 145.95 | 97.27 | 134.23 |
| Volume that must be delivered within the week | 165.1 | 145.7 | 97 | 135.7 |

Table 8.3. Results when the number of customers visited per trip is eight

| Vehicle capacity=10; number of customers=8 | | | | |
|---|----------------|-------------|-------------|-------------|
| | Proposed Model | | | |
| | Week 1 | Week 2 | Week 3 | Week 4 |
| Number of vehicles in use | 7 | 6 | 7 | 6 |
| Number of spare vehicles used | 3 | 0 | 14 | 0 |
| Number of times a vehicle is not used | 0 out of 35 | 9 out of 35 | 0 out of 35 | 9 out of 35 |
| Average utilization rate per truck | 32% | 44% | 34% | 58% |
| Total volume delivered (m ³) | 120.12 | 113.89 | 165.12 | 152.00 |
| Volume that must be delivered within the week | 120.09 | 113.9 | 165.2 | 152 |

| | Proposed Model (Cont.'d) | | | |
|---|--------------------------|-------------|-------------|-------------|
| | Week 5 | Week 6 | Week 7 | Week 8 |
| Number of vehicles in use | 6 | 5 | 5 | 6 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 2 out of 30 | 5 out of 30 | 8 out of 30 | 4 out of 30 |
| Average utilization rate per truck | 59% | 58% | 44% | 52% |
| Total volume delivered (m ³) | 165.12 | 145.75 | 97.07 | 135.7 |
| Volume that must be delivered within the week | 165.1 | 145.7 | 97 | 135.7 |

Table 8.4. Results when the number of customers visited per trip is six

| |
|--|
| Vehicle capacity=10; Number of customers=6 |
|--|

| | Proposed Model | | | |
|---|----------------|-------------|-------------|-------------|
| | Week 1 | Week 2 | Week 3 | Week 4 |
| Number of vehicles in use | 7 | 7 | 7 | 7 |
| Number of spare vehicles used | 17 | 2 | 26 | 0 |
| Number of times a vehicle is not used | 0 out of 35 | 0 out of 35 | 0 out of 35 | 1 out of 35 |
| Average utilization rate per truck | 23% | 31% | 27% | 45% |
| Total volume delivered (m ³) | 120.12 | 113.89 | 165.12 | 152.00 |
| Volume that must be delivered within the week | 120.09 | 113.9 | 165.2 | 152 |

| | Proposed Model (Cont.'d) | | | |
|---|--------------------------|-------------|-------------|-------------|
| | Week 5 | Week 6 | Week 7 | Week 8 |
| Number of vehicles in use | 7 | 7 | 6 | 7 |
| Number of spare vehicles used | 0 | 0 | 0 | 0 |
| Number of times a vehicle is not used | 0 out of 35 | 2 out of 35 | 7 out of 35 | 0 out of 35 |
| Average utilization rate per truck | 47% | 44% | 35% | 39% |
| Total volume delivered (m ³) | 165.12 | 145.75 | 97.07 | 135.7 |
| Volume that must be delivered within the week | 165.1 | 145.7 | 97 | 135.7 |

These results will be referred to alternative scenarios in the following analysis and the base scenario will refer to the case when the number of customers that can be visited by a truck per trip is equal to 15. The following table (Table 8.5) shows the results of the algorithm for the base and the alternative scenarios together.

Table 8.5. Results of the base and the alternatives scenarios

| | | Base Scenario | Alternative Scenarios | | |
|------------------------------|---------------------------------------|---------------------|-----------------------|--------|--------|
| | | Number of customers | | | |
| | | 15 | 6 | 8 | 12 |
| W1 & W2 | Number of vehicles in use | 4 | 7 | 7 | 6 |
| | Number of spare vehicles used | 0 | 19 | 3 | 0 |
| | Number of times a vehicle is not used | 8 | 0 | 9 | 15 |
| | Average utilization rate per truck | 63% | 27% | 38% | 53% |
| | Savings in value (YTL) | 7.900 | -7.200 | -800 | 7.900 |
| W3 & W4 | Number of vehicles in use | 6 | 7 | 7 | 7 |
| | Number of spare vehicles used | 0 | 26 | 14 | 0 |
| | Number of times a vehicle is not used | 17 | 1 | 9 | 21 |
| | Average utilization rate per truck | 76% | 36% | 46% | 68% |
| | Savings in value (YTL) | 4.900 | -8.000 | -3.200 | 2.400 |
| W5 & W6 | Number of vehicles in use | 4 | 7 | 6 | 4 |
| | Number of spare vehicles used | 0 | 0 | 0 | 0 |
| | Number of times a vehicle is not used | 6 | 2 | 7 | 3 |
| | Average utilization rate per truck | 91% | 45% | 58% | 84% |
| | Savings in value (YTL) | 11.100 | 3.600 | 6.100 | 11.100 |
| W7 & W8 | Number of vehicles in use | 4 | 7 | 6 | 4 |
| | Number of spare vehicles used | 0 | 0 | 0 | 0 |
| | Number of times a vehicle is not used | 11 | 7 | 12 | 9 |
| | Average utilization rate per truck | 80% | 37% | 48% | 74% |
| | Savings in value (YTL) | 11.100 | 3.600 | 6.100 | 11.100 |
| Total Savings in value (YTL) | | 35.000 | -8.000 | 8.200 | 32.500 |

To assess the effect of the change in the number of customers, several criteria are evaluated for the base and the alternative scenarios in the Table 8.6. The evaluation is first presented in the two-week periods and then at the bottom of the table, the marginal savings of the scenarios compared to the base scenario is given.

Table 8.6. Effect of the “number of customers” parameter

| | | Base Scenario vs. Actual | Alternative Scenarios vs. Base Scenario | | |
|------------------------------|---------------------------------------|--------------------------|---|-------|------|
| | | Number of customers | | | |
| | | 15 | 6 | 8 | 12 |
| W1 & W2 | Number of vehicles in use | -75% | 75% | 75% | 50% |
| | Number of spare vehicles used | -1 | 19 | 3 | - |
| | Number of times a vehicle is not used | -50% | -100% | 13% | 88% |
| | Average utilization rate per truck | 54% | -57% | -40% | -16% |
| | Savings in value (YTL) | 44% | -191% | -110% | 0% |
| W3 & W4 | Number of vehicles in use | -1 | 17% | 17% | 17% |
| | Number of spare vehicles used | -6 | 26 | 14 | - |
| | Number of times a vehicle is not used | 150% | -94% | -47% | 24% |
| | Average utilization rate per truck | 90% | -53% | -39% | -11% |
| | Savings in value (YTL) | 25% | -263% | -165% | -51% |
| W5 & W6 | Number of vehicles in use | -75% | 75% | 50% | - |
| | Number of spare vehicles used | -9 | - | - | - |
| | Number of times a vehicle is not used | 10% | -67% | 17% | -50% |
| | Average utilization rate per truck | 112% | -51% | -36% | -8% |
| | Savings in value (YTL) | 53% | -68% | -45% | 0% |
| W7 & W8 | Number of vehicles in use | -75% | 75% | 50% | - |
| | Number of spare vehicles used | -9 | - | - | - |
| | Number of times a vehicle is not used | 60% | -36% | 9% | -18% |
| | Average utilization rate per truck | 129% | -54% | -40% | -8% |
| | Savings in value (YTL) | 53% | -68% | -45% | 0% |
| Total Savings in value (YTL) | | 44% | -123% | -77% | -7% |

The values written in the columns of the Table 8.6 indicate the change obtained for the five criteria in two-week periods relative to the base scenario. According to these results, we note that the decrease in the number of customers visited by truck on a trip has

a negative influence on the total savings as well as the total number of vehicles needed in the two-week periods and the average utilization rate per truck. However, we see that decreasing the number of customers result in an increase in the number of the spare vehicles used. The reason behind this behavior might be explained with the constraint on the allowed number of customer per truck applied on the truck capacity. In other words, even if there is still a carriage capacity in the trucks, the model does not allow loading more packages into the vehicles because of the constraint on the number of customers. Thus, more vehicles are used to deliver all the required orders. As a result, the total savings decreases in parallel to the decrease in the number of customers. Moreover, it points out that a decrease to six customers results in a loss compared to the actual situation.

9. CONCLUSION

In this thesis, we focus on a joint project with Eczacıbaşı İntema. After several meetings held with İntema's Logistics Department to define the problem within the context of the strategic targets and business environment of the company, studies have been initiated. In the early stage of the analysis studies, the need for separating the whole context into two main streams is determined: analysis of customer's ordering patterns and solution development.

In the analysis of customer's ordering patterns, the main concern was to acquire an overall view of customer's ordering patterns and the problematic processes. The first remark shared with the company was the lack of current situation analysis. Afterwards, focusing on both customer's attitudes and the current operations, a series of findings are obtained. These findings are then presented to the top management, the channel managers and the store managers iteratively in face-to-face meetings. Although the thesis scope is constrained with the product deliveries in İstanbul, the current situation analysis is performed over all orders collected in the first six months of 2007. The prominent findings with critical effects on the continuation of the study are the existence and the usage of a "customer requested delivery date" for all orders submitted in the operational system, the consideration of deliveries per customer and the availability of weight and volume information of products in the system. Although the demand forecasting and the inventory management are not within the scope of this thesis, the criticality of these subjects are underlined during the meetings for the health of the overall system improvement. Analysis of sales data are performed with Microsoft Excel features.

In the second part, namely the solution development, outcomes of the current situation analysis are analyzed. After determining the real-world constraints the company faces, a mathematical model is developed to provide a basis for a new planning approach. Although it was not possible or worth to incorporate some constraints into the model evaluating the usability or information availability, it is decided that the performance of the solution developed will be evaluated over the capacity usage and the reduction in the number of vehicles. The latter has a cost cutting effect on operational expenses.

Additionally, in the solution development the adopted planning approach was enlarging the planning period to a week in contrast to the current daily planning approach. This approach combined with the availability of the customer requested delivery date and volume/weight information decreases the need for additional vehicles to contracted ones; thus it will have a cost reduction effect.

Comparing the current situation and the proposed model, savings up to 44 per cent in value are generated using the sample data of eight weeks. The number of vehicles is decreased from seven to four resulting in a decrease of 75 per cent in the first two-week period, to six vehicles in the second two-week period and to four vehicles again in the remaining four weeks. In the sensitivity analysis chapter, several scenarios are presented by changing the values assigned to the parameters and the gain and loss are also discussed. Additionally, the run time performance issue is analyzed by comparing the optimal and the heuristic approach used.

Additionally, it is noteworthy to emphasize that the proposed model is highly dependent on the order volumes. Since the number of customers that can be visited within a day by a truck is a constraint incorporated into the model with the intent of reflecting the city traffic conditions, order volumes must not be too small. This precondition is also discussed in the analysis of the current situation chapter where the main reasons of this issue are given. To avoid such a circumstance, the consolidation of orders at the time of order submission, the production planning and the inventory management must be closely monitored and improved.

As a future work, it may be interesting for İntema to include time-window constraints into the model and focus on the route construction in İstanbul. It may be also worthwhile to examine deliveries outside of İstanbul and determine delivery frequencies for those cities.

APPENDIX A: VBA CODE OF THE FIRST FIT HEURISTIC APPLIED TO THE PROBLEM

```
Sub binpacking()  
  
Dim custnum As Integer  
custnum = 173  
Dim sef As Integer  
sef = 35  
ReDim data(1 To custnum, 1 To 3) As Double  
ReDim bincap(1, 1 To sef) As Integer  
ReDim binload(1, 1 To sef) As Double  
ReDim binload2(1, 1 To sef) As Double  
ReDim binremcap(1, 1 To sef) As Double  
ReDim binremcap2(1, 1 To sef) As Double  
ReDim points(1, 1 To sef) As Integer  
ReDim status(1 To custnum, 1) As String  
Dim maxpoints As Integer  
Dim numbinused As Integer  
Dim totalload As Double  
Dim truckused As Integer  
Dim avloadper As Double  
Dim capacity As Integer  
  
'DETERMINATION OF PARAMETERS  
  
maxpoints = 15  
capacity = 10
```

'DATA READING

```
For i = 1 To custnum
  For j = 1 To 3
    data(i, j) = Cells(i + 1, j)
  Next
Next
```

```
For i = 1 To sef
  bincap(1, i) = Cells(2, i + 8)
Next
```

'INITIAL VALUE ASSIGNMENT

totalload = 0

```
For i = 1 To sef
  binload(1, i) = 0
  binremcap(1, i) = capacity
  points(1, i) = 0
Next
```

```
For i = 1 To custnum
  status(i, 1) = "undelivered"
Next
```

'MAIN

```
For i = 1 To custnum
  If data(i, 3) = 1 Then
    If status(i, 1) = "undelivered" Then
      For j = 1 To sef
        If points(1, j) < maxpoints Then
```

```

        If data(i, 2) <= binremcap(1, j) Then
            binload(1, j) = binload(1, j) + data(i, 2)
            binremcap(1, j) = binremcap(1, j) - data(i, 2)
            points(1, j) = points(1, j) + 1
            status(i, 1) = "delivered"
            binload2(1, j) = binload(1, j)
            binremcap2(1, j) = binremcap(1, j)
            GoTo SKIP
        End If
    End If
Next
End If
Else
    For j = 1 To sef
        If binremcap2(1, j) < capacity And binremcap2(1, j) > 0 Then
            If status(i, 1) = "undelivered" Then
                If points(1, j) < maxpoints Then
                    If data(i, 2) <= binremcap2(1, j) Then
                        binload2(1, j) = binload2(1, j) + data(i, 2)
                        binremcap2(1, j) = binremcap2(1, j) - data(i, 2)
                        points(1, j) = points(1, j) + 1
                        status(i, 1) = "delivered"
                        GoTo SKIPJUMP
                    End If
                End If
            End If
        End If
    End If
Next
GoTo SKIP
End If
SKIP:
    If status(i, 1) = "delivered" Then
        totalload = totalload + data(i, 2)
    End If

```

```

        End If
    Next
    'NUMBER OF BIN USED

    numbinused = 0
    For i = 1 To sef
        If binload(1, i) <> 0 Then
            numbinused = numbinused + 1
        End If
    Next

    truckused = Int(numbinused / 5) + 1
    avloadper = Round(totalload / (numbinused * capacity), 2) * 100

    'PRINTING

    Cells(12, 9) = numbinused
    Cells(13, 9) = Round(totalload, 2)
    Cells(14, 9) = truckused
    Cells(15, 9) = avloadper
    For i = 1 To sef
        Cells(5, i + 8) = binload(1, i)
        Cells(3, i + 8) = binremcap(1, i)
        Cells(4, i + 8) = points(1, i)
        Cells(6, i + 8) = binload2(1, i)
        Cells(7, i + 8) = binremcap2(1, i)
    Next
    For i = 1 To custnum
        Cells(i + 1, 4) = status(i, 1)
    Next
    End Sub

```

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