

A LOGISTICS SYSTEM DESIGN FOR FAST MOVING CONSUMER GOODS

by

Atılım Oluk

B.S., Management Engineering, Istanbul Technical University, 2003

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Industrial Engineering
Boğaziçi University

2006

ACKNOWLEDGEMENTS

I am very grateful for my advisor, Professor Ali Rıza Kaylan for his supports and guidance. Master study in Boğaziçi University is a stressful journey; especially when you have to maintain it with work life, indeed. Without his patience, it would be impossible to reach for a satisfactory result. I am also indebted to other committee members, Professor Tülin Yazgaç and Associate Professor Taner Bilgiç for their kind efforts.

There are too many friends to name, who have helped and encouraged me; especially my respectable colleagues Ari Köroğlu, and Ceren Sungu Kutlay. Whenever I had felt it is impossible to finish this thesis, they have never let me to lose my faith and made insightful comments and suggestions.

Finally, my beloved parents, Aysel and Oktay Oluk, and my aunts Assistant Prof. Necmiye Karataş and Assistant Prof. Günseli Görür, they have always been and will always be a tremendous source of inspiration and encouragement for me.

ABSTRACT

A LOGISTICS SYSTEM DESIGN FOR FAST MOVING CONSUMER GOODS

This research addresses to a logistics system design for fast moving consumer goods. Within the context of the thesis, the distribution system of cold products starting from the ordering process and ending with the placement of the product on the chain store shelf considering storage, preparation, loading and delivery operations for T. Group in Istanbul was studied. The purpose was focusing on ways to improve the current program with a systematic approach and industrial engineering tools. The primary performance indicators are distribution time and costs, stock- out occurrences, and the ratio of fresh products on the shelves. Thus, the ultimate goal is to increase retailer and consumer satisfaction.

After problem characterization and suggestions to improve the current system operations, two major problems, “Storage System Design” and “Vehicle Routing Problem” were discussed. A new layout design that depends on the compromise of dedicated storage policy with full turnover storage policy and a new in-truck layout and loading procedure is offered in order to maximize the utilized volume of the trucks. For vehicle routing problem, savings algorithm with Yellow’s (1970) modification was assigned.

After the design of the distribution system, a decision support system was offered in order to respond for future changes related to the current system. Lastly, the designed program was run for different scenarios and their results were analyzed. In light of these runs, it has been proved that an excessive amount of improvement is possible in the current system.

ÖZET

HIZLI TÜKETİM MALLARI İÇİN LOJİSTİK SİSTEM DİZAYNI

Bu tezde, hızlı tüketim malları üreticisi olan T. Gıda'nın lojistik sisteminin yeniden modellenmesi ele alınacaktır. Bu bağlamda, T. Gıda'nın soğuk zincir dağıtım ağının, sipariş prosesinden ürünün zincir mağaza rafına yerleştirilmesine kadar olan sürecinin, iş akış planı ve sistem modelleme ile performans, maliyet ve kalitesinin iyileştirilmesi amaçlanmıştır. Tez kapsamı içinde asıl hedeflenen, mevcut dağıtım ağının sistem yaklaşımı ve endüstri mühendisliği araçlarıyla iyileştirilmesidir. Başlıca performans göstergeleri dağıtım zamanı ve maliyeti, stoksuz kalma durumu ve raftaki taze ürün oranı olarak belirlendiğinden, bu çalışmayla asıl hedeflenen perakendecinin ve müşterinin tatminini arttırmak olmuştur.

Mevcut problemlerin tanımlanması ve mevcut sistem operasyonlarını iyileştirici önerilerin yapılmasından sonra, iki ana problem, depolama sistemi dizaynı ve araç rotalama problemi olarak belirlenmiştir. Depolama sistemi dizaynıyla ilgili olarak “*dedicated storage policy*” ve “*full turnover*” yaklaşımları beraber düşünülerek modelleme yapılmıştır. Araç rotalama probleminin modellenmesi için de Yellow'un (1970) geliştirilmiş “*savings algorithm*” yaklaşımı kullanılmıştır.

Mevcut sistem yeniden modellendikten sonra, dinamik yapıdaki sisteme tam anlamıyla hakim olabilmek için bir karar destek sistemi geliştirilmiştir. Bu sistemden elde edilen sonuçlarla mevcut yapıda önemli büyüklükte iyileştirmelere gidilebileceği kanıtlanmıştır.

TABLE OF CONTENTS

ACKNOWLEDGEMENT.....	iii
ABSTRACT.....	iv
ÖZET.....	v
TABLE OF CONTENTS.....	vi
LIST OF FIGURES.....	ix
LIST OF TABLES.....	xi
1. INTRODUCTION.....	1
1.1 Purpose of the Study	1
1.2 Literature Review	2
1.3 Methodology	5
2. CURRENT DISTRIBUTION SYSTEM.....	7
2.1 Suppliers.....	7
2.2 Warehouses.....	7
2.3 Products & Distribution System.....	9
2.4 Customers and Distribution Channels.....	10
2.4.1 Hot Sales	10
2.4.2 Regular Orders.....	11
2.5 Activity Modelling.....	12
2.5.1 As-Is Modelling.....	13
2.6 Symptoms and Problem Definition.....	13
2.6.1 Unstructured Warehouse Operations.....	14
2.6.2 Unbalanced Truck Loads.....	14
2.6.3 Long and Unequal Distribution Times and Distance Travelled by Trucks.....	17
2.6.4 Static Routing.....	18
2.6.5 Costly and Ineffective Distribution System.....	18

2.6.6	Door Keeper Phenomenon.....	19
2.6.7	Other Symptoms.....	20
2.7	Problem Characterization and Proposed Solutions.....	20
2.8	To-Be Model.....	25
3	MAJOR PROBLEMS.....	27
3.1	Storage System Design Problem.....	27
3.1.1	Mathematical Model for Assignment Problem.....	29
3.1.2	Alternative Policies.....	31
3.1.3	Results and Evaluation of Alternatives.....	32
3.1.3.1	Single vs. Double Entrance.....	32
3.1.4	Procedures for Loading Operations.....	33
3.2	Vehicle Routing Problem.....	34
3.2.1	Heuristic Methods.....	35
3.2.1.1	Determination of the Parameters.....	35
3.2.1.1.1	Market Locations and Distances	35
3.2.1.1.2	Service Time and Travel Time.....	36
3.2.1.1.2.1	Regression Analysis for Service Times.....	36
3.2.1.1.2.2	Regression Analysis for Travel Times.....	37
3.2.1.1.3	Demand of Markets.....	37
3.2.1.1.4	Weights and Volumes of the Products.....	37
3.2.1.1.5	Capacity of Trucks.....	38
4	DECISION SUPPORT SYSTEM.....	39
4.1	Need for DSS.....	39
4.2	Decision of the Development Tools.....	39
4.3	The Program: Istanbul Intercity Distribution System.....	40
4.3.1	Database Operations.....	40
4.3.2	VRP Solver.....	40

4.4	Programming the Selected Algorithm.....	41
5	RESULTS OF THE MODEL.....	44
5.1	Results for Current Depot.....	44
5.1.1	Anatolian Side.....	45
5.1.2	European Side.....	46
5.2	New Depot at M. Tuzla Facility	47
5.2.1	Anatolian Side	47
5.2.2	European Side	48
5.3	New Depot at S. Yenibosna Facility.....	48
5.3.1	Anatolian Side	49
5.3.2	European Side.....	49
5.4	New Depot in Topkapı	50
5.4.1	Anatolian Side	50
5.4.2	European Side	50
5.5	Evaluation of the Alternatives.....	51
5.5.1	One – Depot System.....	52
5.5.2	Two – Depot System.....	56
6	CONCLUSION	60
	APPENDIX A: AS-IS SCHEMAS.....	63
	APPENDIX B: TO-BE SCHEMAS.....	68
	APPENDIX C: LAYOUTS FOR PROPOSED ALTERNATIVES.....	70
	REFERENCES.....	75
	REFERENCES NOT CITED.....	77

LIST OF FIGURES

Figure 2.1. Assigned loads to trucks 14 and 23 in June.....	15
Figure 4.1. 2-opt exchange between routes.....	43
Figure 4.2. 2-opt exchange within one route.....	43
Figure 5.1. Performance of alternatives for one – depot model.....	55
Figure 5.2. Performance figures of current system and alternative depot locations.....	55
Figure 5.3. Performance of alternatives for two – depot model.....	57
Figure A.1. Chain store ordering.....	62
Figure A.2. Charcuterie ordering-delivering process.....	63
Figure A.3. Milk-yogurt ordering-delivering process.....	64
Figure A.4. Fresh meat-chicken ordering-delivering process.....	64
Figure A.5. S. milk-yogurt distribution process.....	65
Figure A.6. M. fresh meat-chicken distribution process.....	65

Figure A.7. D. charcuterie distribution process.....	66
Figure B.1 Chain store ordering.....	67
Figure B.2. S. products ordering-delivering process.....	67
Figure B.3. M. products ordering-delivering process.....	68
Figure B.4. D. distribution process.....	68
Figure C.1 Proposed alternative for room 1.....	69
Figure C.2. Proposed alternative for room 2.....	70
Figure C.3. Proposed alternative for room 3.....	71
Figure C.4. Proposed loading operation 1.....	72
Figure C.5. Proposed loading operation 2.....	73

LIST OF TABLES

Table 2.1. Average revenue, sales and return data for all trucks.....	16
Table 2.2. Averages of distance travelled and total time spent by some trucks.....	17
Table 2.3. Distribution system details.....	19
Table 2.4. Time schedule of D. delivering-distributing process.....	24
Table 3.1. Number of pallets needed for each product group.....	29
Table 3.2. Capacity of vehicles.....	38
Table 5.1. Results of current route and improved route for current depot alternative.....	46
Table 5.2. Total results of current route and improved route for current depot alternative.....	47
Table 5.3. Results for M. and current improved alternative.....	48
Table 5.4. : Results for S. and current improved alternative.....	50
Table 5.5. : Results for Topkapı and current improved alternative.....	51

Table 5.6. Program results for Anatolian Side and alternative depot locations.....	52
Table 5.7. Program results for European Side and alternative depot locations.....	53
Table 5.8. Total results for all alternatives.....	54
Table 5.9. Delivery cost figures for current system and alternatives.....	58

1. INTRODUCTION

In the highly competitive market of retailing, distribution of Fast Moving Consumer Goods (FMCG) and logistical arrangements are very important factors to achieve maximum customer satisfaction while keeping the business running smoothly, efficiently and more profitably. According to Kasilingam, “logistics represents a collection of activities that ensures the availability of the right products in the right quantity to the right customer in the right time. This requires focus and information on products, people and goods” (Kasilingam, 2000).

Since transportation costs typically account for 2.88 percent of sales (Davis et al., 1996), and it is the largest component of logistics cost and represent 40 percent of that cost, in recent years, due to increasing competition, wider markets, large variety of goods and more conscious consumers, companies are urged to put more and more emphasis on distribution in their attempts to reach more customers more frequently with lower costs (Kasilingam, 2000).

In the beginning of 2003, K Group decided to merge its food producing companies, M., S., P., T. and the sales and distribution company D., under the name T. to become one of the leading food producers in Turkey. The main aim was to take advantage of the synergy that would occur after this merge. Although much was expected from the merger, in terms of increased sales, effective marketing and ease of distribution, the fact that certain problems would arise, especially during the adjustment period, were also anticipated.

1.1. Purpose of the Study

Every single day, new approaches, algorithms and methods are developed in order to deal with real-life and industrial problems. However, only a few of these approaches are really

used in order to pass over the problems, whereas most of them cannot be more than a drop in the literature ocean.

As a member of T. Konserve, and a graduate student, the probability of a possible intersection of a real life problem and industrial engineering discipline is extremely attractive. In order to prove to the company that there exist optimal and profitable solutions for their current system and at the same time in order to deal with the problems faced in industry under the concept of a master thesis, the general concept and goal of the thesis was shaped.

After a careful investigation of the system weaknesses and drawbacks, this study intends to design the distribution system of cold products starting from the ordering process and ending with the placement of the product on the chain store shelf in Istanbul considering storage, preparation, loading and delivery operations in an efficient and effective manner in order to reduce costs and increase sales while keeping customer satisfaction.

The primary performance indicators are distribution time and costs, stock-out occurrences, and the ratio of fresh products on the shelves. Thus, the ultimate goal is to increase retailer and consumer satisfaction.

After the design of the distribution system, a decision support system (DSS) will be offered in order to respond for future changes related to the current system.

1.2. Literature Review

Since the thesis covers major problems such as system re-modelling, warehouse layout design and vehicle routing problem (VRP), extensive literature review has been conducted for each subject.

In order to come up with a satisfactory solution for the warehouse design problem, which is complicated by variety of products, fluctuating demand and required storage space, some policies such as random storage, closest open location storage, dedicated storage, full turnover storage and class-based storage may be applied according to Larson et al., 1996. For random storage, each pallet is assigned to a randomly selected place. The second policy, closest open storage is a policy that the first available slot or space of the warehouse is assigned. However, if pallets are full, both of these policies may perform similarly. Another possible policy is dedicated storage where a store is reserved for a single product. Next, full turnover storage is an option for governing warehouses. This policy makes products to be located in warehouse depending on their turnover rate. (Koster et al., 2006). Lastly, class based policy, which is an extension of randomized and dedicated storage may be applied for determining warehouse layout. Products are assigned into classes depending on size, demand, or product type, and each class is assigned to a fix location. However, within this location products are stored randomly. (Larsson et al., 1996). Moreover, in this study, Francis et al., 1992 is referred for some methods.

On the other hand, several different variants of VRP have been reported in many studies. The main variants are *multiple depot VRP*, where the customers get their deliveries from several depots, *stochastic VRP*, if any component of the system has random behaviour, *periodic VRP*, if the delivery is completed in a few days, *split delivery VRP*, if several vehicles serve a customer, *VRP with backhauls*, if the vehicle must pick something up from the customer after all deliveries are done and lastly *VRP with pickups and deliveries*, if the vehicle picks something up and delivers it to the customer.

VRP received a lot of attention during last four decades and many algorithms were proposed to solve this problem. Generally, the algorithms are separated into two major branches, *exact algorithms* and *heuristic algorithms*. Three broad categories of exact algorithms are *direct tree search methods*, *dynamic programming* and *integer linear programming*. Due to the computational complexity in solving VRP to optimality, exact

algorithms are not preferred widely. Many heuristic methods are employed to solve VRPs. As Frostic (1987) stated in his essay *Heuristic* “those who share ideas without the necessity of infallible certitudes, and enjoy the wonder on confusion”, heuristic methods have wider usage ratios.

Laporte and Semet (2002) proposed a classification of the published heuristics into two main groups: *classical heuristics* and *meta-heuristics*. They divide classical heuristics into three sub groups: *constructive heuristics*, *two-phase heuristics* and *improvement heuristics*. The two-phase heuristics are also divided into two categories called *cluster first-route second* and *route first-cluster second* heuristics. The most important constructive heuristic is Clarke and Wright’s savings algorithm (1964). Yellow (1970), Gaskell (1967) and Golden, Magnanti, Nguyen (1977) made some developments to this algorithm.

On the other hand, Gendreau, Laporte and Potvin, divides meta-heuristics into six types (1997, 2002) as *simulated annealing*, *deterministic annealing*, *tabu search*, *genetic algorithms*, *ant systems* and *neural networks*.

Due to the structure of the problem dealt in the thesis and the need for high computing time, an exact algorithm, especially an IP modelling is not appropriate for such large and complex vehicle routing problems. However, it is found useful to present an IP model of the problem for both clarification of the problem constraints and objective.

The complete formulation of IP model problem is mainly derived from the original formulation of Fisher and Jaikumar (1981). Moreover, two heuristic models, Bramel and Simchi-Levi (1995)’s *Location Based Heuristic*, and Fisher and Jaikumar (1981)’s *Generalized Assignment Heuristic* models were presented.

1.3. Methodology

In the first part of the study, current distribution system and its participants were evaluated. This part covers suppliers, current situation of warehouses, products & distribution system, and finally customers & distribution channels. After the description of the current system, the As-Is schemas, which identify the individual elements of the business process, as they exist currently, were composed. Since the company is not very sure whether the actual performance of the system approaches to its potential, system was analyzed, data were gathered from the companies D. and T. and they were combined with the ones collected with distance time observation forms. As a result of these data analyses, symptoms like unstructured warehouse operations, unbalanced truckloads, long and unequal distribution times and distance travelled by trucks, static routing, and ineffective distribution system, were observed and decided as proofs to the existence of a problem in the current system.

The next part consists of problem characterization and numerous suggestions to improve the current system operations. The problems were defined as “Storage System Design” and “Vehicle Routing Problem” whereas the suggestions are related to standardization, time schedule and information handling system. With the help of the aforementioned suggestions, the To-Be schemas were formed in such a way that they show how our processes should be and thereafter, major problems were discussed.

Storage system design, which includes activities as storage layout design, loading and unloading procedures of products, in-truck layout design, was the first major problem that was held in the study. Within the scope of this part, a new layout design that depends on the compromise of dedicated storage policy with full turnover storage was offered. Moreover, a new in-truck layout and loading procedure is offered in order to maximize the utilized volume of the trucks and prevent the disorders and confusions considering the ergonomics aspects.

VRP, which is a policy maker for an efficient routing policy while minimizing the travel distance and time with lowest possible number of vehicles, is the other major problem that was held. Since exact methods would not guarantee to find the solution in a considerable amount of time, heuristic methods were considered as solution alternative. Moreover, since the type of heuristics such as cluster first route second methods, which operates with the principle of adding the nearest node to the routes, needs more improvement than the other types, constructive method was chosen to apply. The savings algorithm with Yellow's modification, which is an important member of constructive class, was assigned.

After the determination of parameters with the help of the data that were gathered from the companies D. and T. and the ones collected with distance time observation forms, a DSS was developed.

The last part deals with the results of the model. In this section, the program was run for different depot locations scenarios and their results were analyzed.

2. CURRENT DISTRIBUTION SYSTEM

In this section the current distribution system of T. group products, which is carried out by D. will be described. Since the thesis covers the Istanbul distribution system of cold products, more emphasis will be given to these products. The system can be described by focusing on its components such as the suppliers (production facilities), warehouse, distribution channels & processes and customers.

2.1. Suppliers

D. carries out the distribution activities not only for T. group companies, but the main concern will be the distribution of M. and S. products.

M.'s production facility is located in Tuzla whereas S.'s dairy products factory was used to be in Yenibosna, Istanbul. However, it was moved to Mustafakemalpaşa, Bursa a year ago. Products of these facilities are delivered to D.'s warehouse daily, which will be described in more detail in the following parts.

2.2. Warehouses

Both of D.'s warehouses, durable products' warehouse and cold products' warehouse, are located at Sultançiftliği. The warehouse that is dedicated to durable products such as tomato paste, ketchup, pasta, bottled fresh water is in the form of a classical warehouse, where the 4-level shelf system is organized in a neat order. A specific barcode system is used and forklifts are utilized so that the information system can easily keep the arrival and departure

data of the goods while search time for any good in the warehouse is minimized. Moreover, the racks are organized in such a way that the products, which have higher turnover rate, are located closer to the gates and also, the relatively heavier products are not stored on the higher shelves. Although there are some problems associated with this part of the warehouse, the main focus of the thesis is the other part, which is called as the cold warehouse. This is due to the fact that the problems associated with cold warehouse are more serious since the goods stored and transferred are much more vulnerable.

Cold warehouse consists of three rooms; one serves as a storage area for the returned cold goods (returned goods storage room), another serves as the chain store distribution system (chain store storage area) and the last one serves for smaller store's distribution system (free placer storage area).

The products stored in chain store storage area are distributed to the chain supermarkets; and the distributions of the products are entirely controlled by D. The chain store storage area is divided in itself to three parts with respect to the type of products stored. These are chicken products, the piece meat, and processed meat. However, where to locate each product type is not clearly identified and mostly they are located randomly. Besides, there is neither shelf system in this part of the cold warehouse nor bar coding system for inventories since the time between inwards and outwards loading actions of cold products are short, namely in hours.

On the other hand, free placer storage area is reserved for free placers who work as independent agents between D. and small markets. The free placers having their own trucks purchase products such as milk in glass bottles and yogurt at the distribution centre and sell them to the grocers and small markets, which are not, included on the routes of D.'s distribution trucks. In addition to these, the loading processes are not carried out by personnel of D. but by the free placers.

2.3. Products & Distribution System

The products that are stored in the cold warehouse are *dairy products*, such as milk, yogurt, ayran, butter and *butchery products* such as carcass, piece meat, processed meat, chicken, and charcuteries. As the name implies, these goods should be kept in specific temperature ranges in order to prevent spoilage. Moreover, since the lifespan of these products are short and many consumers give significant attention to the production date and freshness, delivery time is extremely important.

Cold products' distribution occurs daily and the process consisting of the arrival of the products from the production facilities to the delivery points through the warehouse is called "cold chain". The cold chain starts with the arrival of the first truck from S.'s production facility to cold warehouse at about 12:00. One more truck carrying S.'s dairy products arrive to the distribution facility around 17:00, and in some cases, another truck arrives around 22:30 when the order volume is relatively higher.

On the other hand, everyday, two trucks come from M.'s Tuzla production facility to the warehouse. The trucks carrying meat and charcuterie products come around 22:30 while another one usually arrives at 24:00. As soon as the trucks arrive, the goods are immediately taken to the cold rooms where the temperature is kept below 4°C. Over the night, the products, which are allocated to the chain markets, are loaded to the corresponding trucks until 6:00 AM. The fleet used to consist of 29 trucks (15 going to European, 14 going to Asian side of Istanbul), which are owned and operated by a subcontracted logistics company, and the markets that each truck will visit on each day are fixed regardless of the volume of daily demand.

Each truck has a capacity of 3 tons in refrigerated storage areas. In addition to the driver, one placer – sector specific terminology that will be described in the following sections - is assigned to each truck. While the driver is an employee of logistic company, the placer works for D. The trucks depart between 6:00 - 6:30 A.M and follow their specific route. The timelines of the departures quite important especially for the trucks going to the European side, since the trucks are forbidden to pass across the Bosphorus bridges after 7:00 AM.

2.4. Customers and Distribution Channels

In the current system, daily and non-durable products of the facilities are delivered to chain stores by plants' own vehicles. All the activities, starting from the ordering process till the placing the product on the shelf, are held by the facilities' own sales team. D. is only responsible from delivering the long lasting cold products such as cheese, butter, meat and chicken charcuterie. The sales team of D. orders these products from S. and M.; and keeps them in its own cold warehouse until a sales order comes from a chain store

D.'s distribution fleet visits around 500 chain stores situated in various locations in Istanbul including the chain stores of Migros, ŞOK, Dia, Gima, Tansaş, Carrefour, Metro. Sales to those points are carried out in two main channels, which can be identified as “*Hot Sales*” and “*Regular Orders*”.

2.4.1. Hot Sales

“*Hot Sales*” process is only used in the sales of dairy products such as milk and yogurt that are cheaper than meat, chicken and charcuterie. Everyday, the placer determines the amount of each product to be placed on the shelves of the store. There is no pre-ordering. Once the store representative and the placer reach the agreement, the placer prints out the associated receipt from the printer located in the truck and delivers to the store representative.

In order to load the right amount to the trucks everyday, the placers need to predict the order amount precisely one day in advance.

2.4.2. Regular Orders

Meat, chicken and charcuterie sales are done through orders placed by the store managers. Migros, Şok and Tansaş charcuterie orders are received via Internet by B2B connections while the other orders are received through fax or telephone a day in advance.

The orders of daily products are sent directly to S. and M. from the customers. As it is impossible to keep a stock, each product is produced daily by the facilities. After production that takes 1-2 days, the products are loaded to the vehicles and delivery starts at 6:30 A.M. On the other hand, D. collects the charcuterie orders and loads its vehicles provided that there is enough stock in the warehouse. If not, then D. prepares an order and sends it to S. or M. by fax.

Generally, it can easily be seen that three vehicles visit each store.

- S. Vehicles Visiting 25 stores/day (Only milk products)
10-11 hours/day
Store Visiting Frequency: Everyday
- M. Vehicles Visiting 30 stores/day (Only meat products)
9-10 hours/day
Store Visiting Frequency: Twice a week
- D. Vehicles Visiting 30 stores/day (Only charcuterie products)
9-10 hours/day
Store Visiting Frequency: Twice a week

After the sales activities are completed at each store, the placers take the returns. The main reason for the returns that are taken back is the exceeding of expiration dates. The returned goods are sent back to S. and M. facilities. The documentation of return procedure takes significant time. Furthermore, each returned product is a waste of capacity and capital. Therefore the placer should minimize the return rates by predicting the daily sales more precisely.

2.5. Activity Modeling

Activity modelling is a technique, which assists in understanding how a business process really works. Activity modelling, which is used to describe how things are, called “*As-Is*” modelling, and how they are wanted to be, based on redesign criteria, called “*To-Be*” modelling.

In activity modelling, a business process is decomposed step-by-step into activities that make up the process. This comes out in a multi-level diagram that corresponds to the way the work is done.

Each activity is shown in a diagram, complete with the inputs to that activity, the outputs of that activity, the controls or constraints on the way that the activity is performed, and the mechanisms or factors of production consumed by the activity in transforming inputs to outputs (Business Process Reengineering Fundamentals, www.brint.com).

2.5.1. As-Is Modelling

As-Is model is a business process model that is used to identify and quantify the individual elements of a business process, creating a clearly defined model of the supply chain partner interfaces, as they exist today. This model reflects the results of extensive research at every level of the supply chain and is then analyzed to identify any misalignments or inefficiencies.

The As-Is model is reflected in figures for processes chain store ordering, charcuterie ordering-delivering, milk-yogurt ordering-delivering, fresh meat-chicken ordering-delivering, S. milk-yogurt distribution, M. fresh meat-chicken distribution process, D. charcuterie distribution process. The figures are found in Appendix A. In these figures, it can be seen that, except D.'s system, the ordering process starts from chain store by fax, which is a manual operation, and each company is responsible from its own ordering and distribution process.

After producing and delivering the products to the warehouses, distribution process starts at each facility. Distribution system is similar to each other, except the amount of vehicles/placers, visited stores and invoice/waybill operations. S. and M. placers use hardcopies and fill them in handwriting. On the other hand, D. placers use pocket pc for this operation.

2.6. Symptoms and Problem Definition

According to Ballou (1992), "Problem of logistics system design arises under two situations. The first case is when a new logistic system has to be redesigned. The second one is when the existing system has to be redesigned to accommodate certain changes that occur in service, demand, product characteristics, cost and pricing policy".

After the merging of four companies, Istanbul Distribution System should have been redesigned. Even though a cost and benefit analysis was performed and it was seen that the new system designed led to increased sales while keeping the distribution costs nearly constant, the company is not very sure about if the actual performance of the system approaches to its potential, since there may be several distinct factors leading to sales increase. In order to find out whether there is indeed a problem or not, the system was analyzed, data were gathered from the companies D. and T. and they were combined with the ones collected with distance time observation forms. As a result of these data analyses, the following symptoms were observed.

2.6.1. Unstructured Warehouse Operations

As mentioned at the beginning of Section 2, there are three parts within the cold warehouse. One is for products sold to free placers; one is used to keep returned products and the last one, which is the largest, is allocated to serve the daily distribution of cold products to chain store demand points. The most active one is the largest part, where all cold products coming from the factories are kept until loading and prepared according to the routes. Since the preparation time is very limited and all trucks must be ready before 6:00 A.M., the warehouse should be organized efficiently. However, during the busiest period of the warehouse, congestion and untidiness were observed. There is neither a systematic operation procedure -like the one in the classical warehouse - nor a well-defined shelf or placement system. This situation of the cold warehouse can be considered both as a symptom and a cause of a problematic distribution system.

2.6.2. Unbalanced Truck Loads

The daily demand data, which actually consists of 30,000 entries according to the chain market and cold product type (yogurt, milk, ayran, chicken) for a past month, was accessed. These data was organized in such a way that it shows exact figures for each chain

market and specific routes followed by the trucks. Results were striking in the sense that there were tremendous differences between the truckloads. As seen in Table 2.1, truckloads fluctuate within a range of 232.04 kg and 1472.69 kg.

Besides the variation in the assigned truckload observed, an interesting situation is also seen for route 14. According to Figure 2.1, it can be seen that, on June 1st, 18th, 20th, and 22nd, assigned loads exceed the truck capacity, 3,000 kg. The company might either have used additional trucks or divided the load of route 14 to others. Hence, unbalanced truckloads can be considered as a significant symptom of the problem.

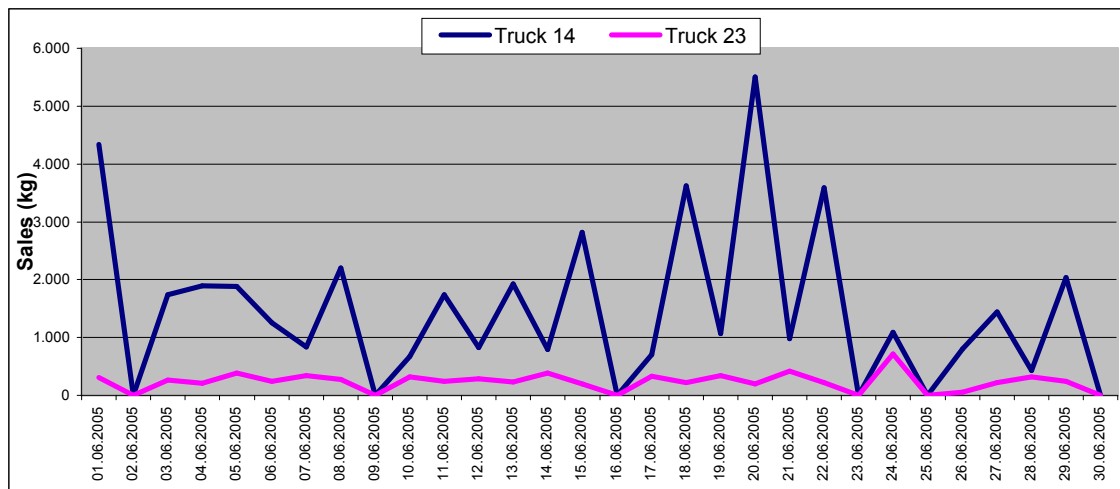


Figure 2.1. Assigned loads to trucks 14 and 23 in June

Table 2.1. Average daily revenue, sales and return data for all trucks

Route	Revenue (YTL)	Sales (kg)	Returns (kg)	Return Rate (%)
1	5,653	882	56	6.40%
2	9,239	1,107	46	4.16%
3	4,187	841	85	10.11%
4	4,909	780	39	5.00%
5	1,091	339	29	8.67%
6	3,076	552	38	6.83%
7	2,724	644	39	6.05%
8	913	273	28	10.09%
9	3,194	603	61	10.12%
10	3,433	674	74	10.95%
11	3,589	608	74	12.25%
12	5,872	907	76	8.43%
13	4,588	718	68	9.54%
14	8,728	1,473	61	4.17%
15	6,480	931	57	6.11%
16	3,701	615	56	9.03%
17	1,564	414	63	15.20%
18	2,767	587	53	8.97%
19	1,746	364	41	11.23%
20	3,704	657	58	8.88%
21	4,647	1,030	39	3.74%
22	6,748	1,114	50	4.45%
23	828	232	37	16.02%
24	1,210	375	58	15.44%
25	2,371	760	43	5.64%
26	1,314	329	41	12.34%
27	1,164	280	78	27.78%
28	6,174	1,072	94	8.75%
29	3,318	613	40	6.45%
Averages	4,512	755	56	7.35%
Standart Dev	2.275	302	17	0.0488983

2.6.3. Long and Unequal Distribution Times and Distance Travelled by Trucks

There were no data available on the distance travelled and time spent by trucks during distribution in D.'s information system. On the other hand, such information would assist a lot in problem definition. For this reason, these parameters were obtained using forms that were filled by placers during the distribution process. 29 Placers filled the distance-time observation forms for six consecutive days. Substantial amount of data, which covers 1878 individual, is obtained. In order to gain useful information from this study, it should be performed more frequently but the data shown on Table 2.2 can still be useful to comment on.

Table 2.2. Averages of distance travelled and total time spent by specific trucks

Truck	Travel Distance (km)	Total Time (min)	Travel Time (min)	Service Time (min)	Ratio for Travel %	Ratio for Point %
1	123	495	199	296	40.2	59.8
3	128	530	200	330	37.7	62.3
13	144	491	224	267	45.6	54.4
14	283	480	236	244	49.2	50.8
15	174	544	257	287	47.2	52.8
16	67	361	125	236	34.6	65.4
18	53	371	106	265	28.6	71.4
20	63	375	95	280	25.3	74.7
22	57	429	125	304	29.1	70.9
27	43	358	82	276	22.9	77.1
28	76	365	145	220	39.7	60.3

Several results can be deducted from Table 2.2. First of all, there exist obvious differences with respect to time and distance between trucks. This can be considered as a symptom of inefficient distribution system. Second, there are some trucks that have long travelling times. For example, truck 15 spends more than 9 hours on routes, which means that some products are delivered with undesirable delays to some chain markets resulting in customer dissatisfaction and profit lost. Finally, it can be seen that the major part of the time spent is the service time. This may be a symptom of problems occurring during the placement of orders to the customers.

2.6.4. Static Routing

Demand of the customers fluctuate throughout the year due to several reasons, such as seasonality, promotions, weather conditions, competitor activities and economic conditions. As a result, routes of trucks should be flexible enough to correspond to these fluctuations. However, currently the routes are fixed, and each truck follows the same route every day regardless of the demand amount. As a result, this may cause some trucks' load to exceed or to fall well below its capacity while the demand fluctuates.

2.6.5. Costly and Ineffective Distribution System

The current distribution system costs more than reasonable amounts since each facility's vehicles are visiting the same stores. This leads to increase total travelling distance hence, the fuel and vehicle cost.

During January- June 2005, 6 vehicles are assigned to D. delivery process with monthly cost of 21,400 YTL, whereas 20 vehicles are assigned to S. with monthly cost of 40,498 YTL and 8 vehicles are assigned to M. with monthly cost of 16,200 YTL. The total amount of vehicles and placers should be lowered in order to decrease maintenance costs.

Moreover, since S. and M. plants are located far from the city, this situation causes additional transportation cost.

Next, M. and D. vehicles visit the stores twice a week. Because of this low frequency, penetration decreases and tracking of the products/competitors become unsuccessful. Besides, returns should be taken within a few days before their expiration date in order to be reworked. However, low penetration causes more spoiled products that cannot be reworked.

Table 2.3. Distribution system details

Facility	Vehicle Amount	Amount of placers	Distance from the city centre (km)	Amount of	Route time per day (Hours/day)	Visiting Frequency (Times/week)	Return Ratio (%)
				stores visited per day (Stores/day)			
S.	20	20	15	25	10	6	8
M.	6	6	40	30	9	2	15
D.	8	8	20	30	9	2	5

2.6.6. Door Keeper Phenomenon

Generally, daily fresh cold products, like milk and yogurt are sold early in the morning. The concept of doorkeeper in Turkey has a great effect on sales of daily products. Doorkeepers visit stores between 7:00 –10:00 A.M. and housewives visit usually between 10:00 – 12:00 A.M. As a result, if the products are not placed on the chain store shelf between these hours, sales decreases and this causes customer dissatisfaction. In the current system, all the vehicles start their route at 6:30 AM, but they finish their routes about 16:00 PM., because, in current route, they have to visit too many stores. This means that many stores receive daily

milk and yogurt late in the afternoon, which could stay on shelf for only about four hours because of their expiration date.

2.6.7. Other Symptoms

There is no standardization and control on the sales team of each facility that reduces service quality. Moreover, the information platform and programs used in S. and M. are focused on production processes, not on sales processes. Without any sales analysis reports, it is hard to improve the performance and quality. Besides this production- focused structure, the orders are being collected by fax or hardcopy. This manual ordering causes too many mistakes and errors. Also, it leads to a long time gap between ordering, production and delivering of the needed products. As everything is kept on hardcopy, huge paperwork occurs that leads to data lost.

2.7. Problem Characterization and Proposed Solutions

After a careful investigation of the system weaknesses and drawbacks, this study intends to design the distribution system of cold products in Istanbul considering storage, preparation, loading and delivery operations in an efficient and effective manner in order to reduce costs increase sales while keeping customer satisfaction.

The primary performance indicators are distribution time and costs, stock- out occurrences, and the ratio of fresh products on the shelves. Thus, the ultimate goal is to increase retailer and consumer satisfaction.

There are several constraints related to the aforementioned problem. First of all, Board of Directors does not want to consider any investment for new warehouses. Only small changes, requiring low investment costs are acceptable. Also, the products included in this study reflect certain characteristics. Dairy products such as milk, yoghurt, ayran, butter and

butchery products such as carcass, piece meat, processed meat, chicken, and charcuterie products are identified as “cold products”. As the name implies, these goods should be kept in specific temperature ranges in order to prevent spoilage. Moreover, some of these products such as daily milk and yoghurt are perishable goods. That is, their lifespan may be as short as one day. Then, the maximum loading capacity of the vehicles must be 3.5 tons. Bigger vehicles are not suitable for narrow Istanbul streets during distribution. Lastly, chain stores are external partners. Change or improvement in their system is beyond the scope of this study.

In order to accomplish the objectives of the thesis and to cover the system as a whole, the problems stated in the previous sections are divided into some minor problems that cover system operations and two major problems in order to facilitate reaching to an effective and efficient solution while keeping systems approach and thinking. The major problems are identified as “*Storage System Design*” and “*Vehicle Routing Problem*”.

The storage system design deals with the processes starting with the arrival of trucks coming from production facilities and ending with the departure of in-city distribution trucks. These activities include storage layout design, loading and unloading procedures of products, in-truck layout design and a simple workforce allocation.

In order to come up with a satisfactory solution for storage layout design, a compromise of dedicated storage policy with full turnover storage, which distributes products over the storage area according to their turnover into fixed locations, was applied. This may be summarized as a store is reserved for a single product whereas the products with higher turnovers must be placed near I/O points. (Koster et al., 2006).

The next major problem, Vehicle Routing Problem, aims to improve the processes that start with the departure of the trucks, continue with the delivery of the customer orders and ends with their arrival back to the warehouse. The main issue in this part is to determine an

efficient routing policy, which minimizes the travel distance and time with lowest possible number of vehicles.

After examining all approaches to VRP, the type of the problem may be decided as “capacitated vehicle routing problem with time windows”. However, time windows are only applicable for the depot, not for the route, because time window for customers adds substantial complexity to the problem and exists only for a few customers. Our major concern about time requires that the distribution process must start and end within predetermined time period.

Due to the structure of the problem, and the need for high computing time, an exact algorithm, is not appropriate for such large and complex vehicle routing problems. As a result, two heuristic methods cluster first – route second and constructive methods were discussed as solution alternative. The first alternative, cluster first – route second methods give reliable solutions for general assignments of customers to routes. However, in this case, since the customer demands are very small compared to the vehicle capacity, large number of customers is assigned to each vehicle. This assignment violates depot’s time constraint and reforming clusters requires excessive amount of corrections. Consequently, cluster first – route second methods would not be appropriate for this case. On the other hand, the savings algorithm suggested by Clarke and Wright (1964) is the most important member of constructive class.

However, in order to place grater emphasis on the distance between points, rather than position relative to the depot in selecting an addition to a route, a modification seems reasonable to assign. Since, the proposed DSS will be structured in such a way that it will find the feasible routes, not the optimum place of the depot, Yellow’s (1970) modification was chosen to apply. In this modification, a route shape parameter, “ γ ” is multiplied with d_{ij} which is the distance between demand points i and j is as follows:

$$S_{ij} = d_i + d_j - \gamma d_{ij} \quad (2.1)$$

Moreover, tests made by Golden, Magnanti and Nguyen (1977) show that $\gamma=0.4$ or $\gamma=1$ yield good results. Hence, γ will be taken as 0.4 in calculations. After finding a feasible solution with savings algorithm, improvements can be made with tabu search with 2-opt exchange methods to this current algorithm.

Since IP Formulation would not be appropriate for this case because of its high computation time need and the solutions created by cheapest insertion heuristics would need substantial improvement, it was decided to implement Yellow's savings algorithm.

Apart from these two major problem areas that will be held in next section, there are numerous suggestions to improve the current system operations. They are related to standardization, time schedule and information handling system.

First of all, standardization of vehicles and the placers' job definitions would help to control the sales process and might be attractive and satisfactory for the customer stores. The old vehicles and unproductive placers could be eliminated, also, the old vehicles might be replaced by new 3.5-ton vehicles and placers might be dressed up in a common uniform and equipment. As a result of such standardization, improvement in service quality would certainly affect the sales in a positive manner.

Limited human resources and space in the main warehouse causes difficulties and chaos in the system. To solve this problem, a systematic ordering-delivering plan was prepared with optimum scheduled operations.

Table 2.4. Time schedule of D. delivering-distributing process

Time	Operation
15:00 – 21:00	Three S. truck arrive and unload at the warehouse
16:00 – 22:00	Loading S. products and preparing routing plans
23:00 – 00:00	One M. truck of meat and charcuterie arrives and unloads
01:00 – 02:00	One M. truck of chicken and charcuterie arrives and unloads
02:00 – 04:00	Loading M. products and preparing routing plans
04:00 – 05:00	Preparing the waybills for the vehicles
05:00 – 06:00	Placers arrive and load their vehicles
06:00 – 06:30	Taking the waybills and vehicle departures
06:30 – 14:00	Distribution
14:00 – 14:30	Unloading the returns
14:30 – 15:00	Invoice operations

Manual operations in the system have negative effects on the response time to the customers and furthermore they are open to human errors. Removing the manual operations can be done by process automation.

Moreover, the information system of S. and M. has no communication with other systems, so every single data from outside is entered manually, whereas D. information system can communicate with most of the chain stores through data transferring (B2B). The solution should be using D.'s information system as the single order collector of the process, which transfers them to the production facilities.

Centralizing the data entering system would facilitate data control operations. All three facilities are using Oracle Databases with different versions, programs and interfaces. After collecting the orders, information might be converted into text format and transferred to the

production facilities. The converter software that is installed on the system could send demand orders directly to the logistics staff of T. As T's system is directly connected to the production facilities and is using the same host and databases, the order info can be evaluated and send to the production department. When there is no fax and manual entry, error ratio and human resource cost could considerably be minimized.

Removing the manual ordering system would not be sufficient to respond the customers in time. Replacing the manual process of the placers with an IT integrated process would shorten the distribution period. In the old system, placers were preparing the invoices manually. After supplying pocket PC's to the placers, the operation period would decrease considerably. By optical reader, barcode of the products could be entered to the pocket PC and the invoice could be prepared and printed immediately. Same process would be applied to the returned goods.

2.8. To-Be Model

As the As-Is model was formed in order to describe the current data environment, the To-Be model should be formed in such a way that it shows how our processes should be. The desired processes are mostly automated and standardized. The flowchart of the attributes of the Business Process Redesign is found in APPENDIX B.

As it is seen in Figures, all the orders are collected by D collects all the orders and, transfer them to T., and T., distributes them to the production facilities.

To-Be Model shows that, manual operations like order letters and waybills have been eliminated. Moreover, by designing standard processes which were stated as chain store ordering, charcuterie ordering-delivering, milk and yoghurt ordering-delivering, fresh meat and chicken ordering- delivering, S. milk and yoghurt distribution, M. meat and chicken

distribution, D. charcuterie distribution, the processes were reduced into chain store ordering, S. ordering-delivering, M. ordering-delivering and D. distribution processes. Three processes were removed from As-Is Model. These removals result in standardization and facilitation of data control operations.

3. MAJOR-PROBLEMS

The major problems that have to be dealt in order to accomplish the objectives of the thesis are identified as Storage System Design and Vehicle Routing Problem. In this section, these problems will be held separately. After a brief introduction about each problem, solution alternatives will be discussed.

3.1. Storage System Design Problem

According to Kasilingam, facilities' planning addresses two major logistics decisions: facilities location and facilities layout. The first one is concerned with the selection of the best locations. Facilities at the macro level may include warehouses, plants, stores, cross-docking facilities, whereas micro level facilities are smaller components of larger facilities'. (Kasilingam et al., 2000).

In order to deal with storage system design problem, firstly, it was decided to work on the layout of the storage rooms. Then carrying out a proper assignment of product types and ratio of the required space to the order frequency over this area in order would be appropriate. For this layout assignment, initial step was the determination of the average *volume/mass* ratios for each product group (i.e. different yoghurt types are grouped under *yoghurts* title). Total volume of each individual product type is found by multiplying total sales amount (kg) of that type with its own *volume/mass* ratio. These results are then used for assessing the pallet needs, which will be the main determinant of layout decision. After that, the space requirement is transformed into a base area requirement assuming that the height of the pallet

load should be approximately “1” meter. “1” meter was derived considering the height of the pallet, which is around 20 cm’s, and suitable lifting height for warehouse workers.

Another consideration is that the cardboard boxes (i.e. boxes for delicatessen) should not be squeezed when piled up. In the warehouse all pallets employed for this purpose were identical and had dimensions of 120x80 cm’s.

In calculations, 95 per cent service level for each product group is used since the demands for the product groups are random variables.

Also, different replenishment intervals for each of individual product groups were assumed. For example “1” replenishment day for daily goods, “2” replenishment day for delicatessen, and “5” replenishment day for durable products were used in the calculations.

For an individual product, the required storage slots (pallets) are found as follows (Francis et al, 1991).

$$q_j = \left\lceil \mu_j + z_{0.05} \cdot \sigma_j \right\rceil \quad (3.1)$$

where;

μ_j = mean daily demand

σ_j = st.dev of daily demand

$z_{0.05}$ = 1.645 probability parameter

Table 3.1. Number of pallets needed for each product group

Product	Number of Pallettes
Sausages	9
Garlic Flavored Sausage	6
Salamis	4
Other Delicatessen	1
Chick Plate	16
Lamb Package	63
Water	1
Cheese	1
Butter	1
Durable Milk	18
Daily Milk	4
Ayran	4
Yoghurt	52
Salep	7

3.1.1. Mathematical Model for Assignment Problem

The next step was the assignment of products to these storage locations. To achieve a satisfactory result, a compromise of full turnover storage policy and dedicated storage policy was employed. With this policy, products are assigned to storage/retrieval locations in such a way that the time required to perform storage/retrieval operations is minimized. Francis McGinnis and White's (1991) formulation of the assignment problem is as follows:

$$\text{minimize} \quad f(x) = \sum_{i=1}^m \sum_{j=1}^n \sum_{k=1}^s \frac{T_j}{S_j} p_{ij} t_{ik} x_{jk} \quad (3.2)$$

subject to

$$\sum_{j=1}^n x_{jk} = 1, \quad k = 1, \dots, s \quad (3.3)$$

$$\sum_{k=1}^s x_{jk} = S_j, \quad j = 1, \dots, n \quad (3.4)$$

$$x_{jk} = \{0,1\} \quad \text{for all } j \text{ and } k$$

where;

s = number of storage slots or locations

n = number of products to be stored

m = number of input/output (I/O) points

S_j = storage requirement for product j , expressed in number of storage slots

T_j = throughput requirement or activity level for product j , expressed by the number of storage/retrievals performed per unit time

p_{ij} = percent of the storage/retrieval trips for product j that are from/to input/output (I/O) point i

t_{ik} = time (distance) required to travel between I/O point i and storage/retrieval location k

$x_{jk} = 1$, if product j is assigned to storage/retrieval location k

0, otherwise

$f(x)$ = expected time required to satisfy the throughput requirement for the system

As a result, it is easy to see that the algorithm tries to position family members at locations with similar distances to the input-output (entrance) point. This leads to dispersion around the central point, which is undesirable. Within this solution alternative, positioning of a specific product, on each of the four loading lines in any room is possible. This creates

difficulty both to remember places of the individual product types and to perform loading/picking operations. Therefore, for the sake of a logical and practical result, the solution should be modified.

3.1.2. Alternative Policies

The warehouse is operated as a cross-dock centre rather than a classical one. Therefore, it is not possible at all to introduce a standardized system such as bar-coding or multiple-level shelf system. Nevertheless, the cold-warehouse is still not a typical cross-dock centre since replenishment intervals of some of the product groups are more than one day. Hence, after determining the positions of the slots, it was decided to open a second door (input/output point) to the east side of Room 3 of the cold warehouse as an alternative solution.

The full turnover storage policy model had been changed by modifying p_{ij} and t_{ik} parameters for this alternative. With this slight change, it might be experienced that the model tries to assign daily products, meat whose replenishment intervals are one day- near to the input/output (entrance) points as much as possible. That means *Cold Room 1* and *Cold Room 3* are allocated for these products while delicatessen and durable goods are assigned to *Cold Room 2* where the distances to the input/output points are more.

These results brought the evidence that the warehouse rooms, Room 1 and Room 3 can be further differentiated as European and Anatolian sub-rooms without changing the current allocation because the ratio of the aggregate demands of Europe to Anatolia was approximately the same as that of available storage slots of Room 1 to Room 3 ($\cong 5/7$). For this alternative, Room 3 was entirely allocated to the Anatolian demand points, similarly, Room 1 to Europe. The products in Room 2 can pass through either 1st or 2nd I/O points.

Therefore, considering the distance between truck parking slots and I/O points may alter the calculation of t_{ik} . The proposed layout alternatives may be found in Appendix C

3.1.3. Results and Evaluation of Alternatives

Although, there is not enough data to compare the current storage system, with the proposed ones numerically, the comparisons can be made between single and double-entrance alternatives and the proposed alternatives with the current one theoretically.

3.1.3.1. Single vs. Double Entrance: The main reason for opening a new door to the warehouse is to shorten the total distance. Total distance can be calculated by using the t mentioned above as

$$\sum_{i=1}^m \sum_{j=1}^n \sum_{k=1}^s T_j t_{(altered) ik} x_{jk} \quad (3.5)$$

where each product assumed to travel to the entrance one by one. When the sum for both cases was calculated, it was found that the total distance as 4789.75m for single-entrance and 2965.56m for double-entrance alternatives. That means that the total distance travelled, or the total travel time spent for the storage system will decrease by 38.1per cent.

Opening a second door may raise the heat loss in the warehouse, which may negatively affect the cold chain of the products and also causes a slight increase in electric consumption. However, since this alternative shortens the time spent outside the cold warehouse when loading the trucks, it can be determined as a more effective solution to prevent spoilage.

Other weakness of opening a new door is the cost of construction and the time loss during this process. Actually, construction will not probably prevent the routine activities

carried out in the warehouse because it can be performed in the morning or noon when the depot is nearly inactive.

3.1.4. Procedures for Loading Operations

In order to design the logistic system of T., not only the routing problem should be solved, but also the other components of the system such as warehouse operations, layout procedures, packaging and loading of the products should be revised.

One of the main components of an effective logistic system is loading the packages into the trucks in minimum time and with minimum effort. From this point of view, a new in-truck layout and loading procedure is offered in order to maximize the utilized volume of the trucks and prevent the disorders and confusions considering the ergonomics aspects. Although there are several types of the packages from each product, four main were classified. These types are one for milk, one for meat, and two for delicatessen. Actually here are more than four types, however these four dimensions have more numbers regarding to others. The dimensions in centimetres are 50x37 for Milk, 60x40 for meat, 46x 23 for Delicatessen type 1, and 40x31 for Delicatessen type 2.

In order to provide enough space to perform loading and unloading operations inside of a truck comfortably, the minimum corridor width is decided as 75cm. According to the new plan, it is recommended that the packages of milk and meat are placed at the opposite sides of the corridor and the leaned sides are the short edges for these package types. In other words, if a route has both milk and meat products and the milk packages are placed on one side; the meat packages should be placed to the opposite side of the truck body. Similarly each type of delicatessen packages is placed oppositely. It is recommended that the leaned sides are the long edges for these package types. With this way, two packages for both types of

delicatessen can be placed side by side without violating the minimum corridor width constraint. Furthermore, the plan requires that the Delicatessen type 1 packages and the milk packages may be placed at the same side of the inner body of the truck while the ones for the Delicatessen type 2 and meat be placed to the other side. In addition, the delicatessen packages, which are smaller comparing the ones of milk and meat, are loaded to the back part of the truck body. Since loading small packages is easier than the big ones, this method will ease and accelerate the loading operations. The sample layouts of this plan can be found in Appendix C.

Since the main aim is designing a system, different scenarios for truckloads may also be considered in order to achieve more flexible in-truck layout and package positioning. For instance, if a route does not have any milk demand, the recommended layout policy suggests that the meat packages are placed oppositely while no changes will occur in the placing method for both Delicatessen types. The maximum height for loading the trucks is found as 150 cm to prevent the possible difficulties and time losses during the unloading operations. As a result, the utilizable volume capacity is calculated as 5.814 m^3 .

In order to prevent the packages to tumble to the floor when the truck travels in the city, an elastic cargo strap can be used, which is very easy to use and adjustable to any size of packages.

3.2. Vehicle Routing Problem

The vehicle routing problem (VRP) is a complex combinatorial optimization problem, which may be defined as the merge of two well-known problems; travelling salesman (TSP) and the bin packing (BPP) problems. It can be described as follows. Given a fleet of vehicles with uniform capacity, a common depot and several customer demands whereas the objective is to find the set of routes with overall minimum route cost that services all demands. The

route must be designed in such a way that, all the routes start and end at the depot, each customer is served only once and just by one vehicle, and some side constraints are satisfied. The most common side constraints include:

- (i) *capacity restrictions*: a non-negative weight is assigned to each city and the total weight of any route may not exceed the vehicle capacity
- (ii) *total time restrictions*: the length of the route can not exceed a predetermined value
- (iii) *time windows*: any city must be visited within the time interval
- (iv) *precedence relations*: any city may be visited before/after another city depending on choices.

3.2.1. Heuristic Methods

As stated before, heuristic methods are employed widely to solve VRPs since exact algorithms require computational complexity in solving VRP to optimality. Within the context of the study, two heuristic models will be presented; *cluster first route second* and *constructive algorithm*.

3.2.1.1. Determination of the Parameters. In order to apply the selected algorithm for the vehicle routing problem, market locations, distances between markets and warehouse, the relation coefficient of the service time spent in a market with the demand data and the relation coefficient of traveling time spent between two points on a route with the rectilinear distance must to be determined. Since the accuracy of input data for any solution approach is extremely important, substantial amount of time was spent in order to obtain enough data.

3.2.1.1.1. Market Locations and Distances: D. has 209 customers on the Anatolian Side and 236 customers on the European Side of Istanbul. In order to determine the location of these points, the largest and the most detailed Istanbul map, which is in fact a book with 583 pages,

was used. Each page is a detailed map of adjacent clusters numbered from 1 to 583 showing different parts of the city and represents a rectangular area of 1.771 km², which has dimensions of 1125m and 1575m. Furthermore, each cluster is divided into grids horizontally indexed as A to D, and vertically indexed as 1 to 6, each having dimensions of 281.25m to 262.50m respectively.

With the help of the address data provided by the company, the grid that belongs to each market, and the X and Y coordinates of the grids were found. Demand points and the depot are assigned to the same coordinate plane by considering the grid they are in. As a result, data become stable for distance and time computations.

3.2.1.1.2. Service Time and Travel Time. In order to find out the actual spent time and the actual travel distance, the placers filled “*Distance-Time Observation Form*” during a week.. With the help of the data obtained by the implementation of these forms, regression analysis was carried out for service time and travel time predictions.

3.2.1.1.2.1. Regression Analysis for Service Times. 29 Placers with 29 vehicles filled the distance-time observation forms for six consecutive days. Substantial amount of data, which covers 1878 individual observations showing the time spent in each market, is obtained. These data were combined with the demand data obtained from D.’s Information System. With the help of Minitab, linear, cubic and quadratic regressions were conducted and it was seen that cubic regression has the best result. The model resulted from cubic regression is as follows;

$$\begin{aligned} \text{“Service Time (min)} &= 7.58908 + 0.315003 * (\text{Demand in kg}) - 0.0003341 * (\text{Demand in kg})^2 \\ &+ 0.0000001 * (\text{Demand in kg})^3\text{”} \end{aligned} \quad (3.6)$$

3.2.1.1.2.2. Regression Analysis for Travel Times. The data obtained from the distance-time forms are also used to find the relation between travel time and rectilinear distances among markets. Since traffic loads, complexity of streets and roads differ on each side, separate analysis was conducted for each side of Istanbul. The result of the analysis proved that the linear regression is best fitted.

The resulted equation for European side is as follows;

$$\text{“Travel Time (min) = 4.23439 + 1.91201 * (Rectilinear Distance in km)”} \quad (3.7)$$

The model for Anatolian region was found as;

$$\text{“Travel Time (min) = 2.49930 + 1.68341 * (Rectilinear Distance in km)”} \quad (3.8)$$

3.2.1.1.3. Demand of Markets. In order to construct a model to solve the problem, demand figures of markets are needed. Hence, demand data obtained for July by taking the average of demands observed each day in this month were used.

3.2.1.1.4. Weights and Volumes of the Products. While the weights of the products are known, there were no data about their dimensions or volumes. Thus, the dimensions of boxes and cases that are used to carry products have been measured. The aim of this calculation is to determine an appropriate density coefficient, which can be used to convert the weight of the products into volume figures. This single constant is obtained by analyzing the demand data for the months June - July 2005, and turned out to be $0.0029675 \text{ m}^3/\text{kg}$. This constant is believed to be reliable since these two months' data involve huge amount of entries and reflects the share of each product well.

3.2.1.1.5. Capacity of Trucks. As mentioned in Section 2, the trucks are identical. Weight capacity of these vehicles is already known as 3000 kg. Moreover, volume capacity of the trucks has been determined by measuring the inner dimensions of truck body. The results can be summarized as follows:

Table 3.2. Capacity of vehicles

Width (m)	1.85
Length (m)	3.90
Height (m)	1.95
Volume Capacity (m³)	14,069
Weight Capacity (kg)	3,000

While the truck volume is roughly found to be 14.069 m³, the usable volume should be much lower than this value, since there must be a free space for placers' movement within the truck's body and the number of cases and packages to be placed in the truck would be limited in order to prevent smash or falling of the boxes while traveling. As a result of the calculations made in the Section 3, where in-truck layout recommendations are made, the usable truck volume capacity is found to be 5.8 m³.

4. DECISION SUPPORT SYSTEM

4.1. Need for a DSS

The need for such a DSS arose from certain features. First of all, the system is quite dynamic such that new markets enter to the customer portfolio commonly, while some of the existing ones leave frequently. Also, the demands of the markets tend to change in time. In order to deal with this considerably fast alteration of demand points and their respective demands, the customer data (required for routing computation) should be easily changed, and thus updated.

Next, the distribution system decisions need to be standardized and centralized because of the reasons summarized in Section 3. A computerized system provides standard procedures for data alteration operations. Moreover, a simple database that facilitates the storage of market data provides the data consistency and integrity.

4.2. Decision of the Development Tools

The DSS might be programmed in one of many alternative platforms. However, because it offers easy and fast coding, handles database operations with ease, and has familiar visual options with Windows, which facilitates easy running and usability of the DSS, it was decided to develop DSS in *Visual Basic 6.0 (VB)*. Besides, the market data is stored in a simple database that was formed by using VB in Microsoft Access 7.0. Lastly, C-code that performs the algorithmic operations for vehicle routing is also enabled to run under the VB platform.

4.3. The Program: Istanbul Intercity Distribution System

The Program includes two execution steps, database operations and vehicle routing problem solver.

4.3.1. Database Operations

The first database operation is the addition of new markets. This is performed through an interface that includes all the necessary data fields for routing calculations. The new market is added to the database and its data is updated as the solver is used for the first time.

Another operation is market data change. This operation is required when a market is wrong, or when an existing market is has left the customer portfolio. This is performed through searching the database with the *unique* market code and changing the required data fields or deleting the found market from the database.

Final group of database operations is the changing of program parameters. This requires new data analysis, which was currently carried out in Section 3, and formulation of the relation between time, distance and demand. There is also a constant that transforms the volume to weight, which may also be changed through this menu.

4.3.2. VRP Solver

The solver that is developed by using the C-programming language is executed under VB through this interface. The data that is not stored in the database, but should be entered as decision parameters is entered here. After that, the whole dataset is updated and the program is run leading to the presentation of the outcomes.

The output is presented in text format. This text file provides a complete list of routes with calculated statistical parameters and expected time data.

4.4 Programming the Selected Algorithm

Coding the selected algorithm consists of two phases, programming the initial solution construction (Yellow's Savings Algorithm) and programming the improvement phase (2-opt exchange). Since it is among the most powerful coding languages, C is decided to use for coding the algorithms.

The program uses the customer coordinate information in the format of the page number and grid indexes, e.g. 252 A 3, and calculates the distance matrix between all customers and the depot. The distance type to be calculated is chosen by the user between two options of the rectilinear distance: *Manhattan* or *Euclidean*. Manhattan distance is the distance between two points measured along axes at right angles. In a plane with p_1 at (x_1, y_1) and p_2 at (x_2, y_2) , it is $|x_1 - x_2| + |y_1 - y_2|$. On the other hand, Euclidian distance is the straight-line distance between two points. In a plane with p_1 at (x_1, y_1) and p_2 at (x_2, y_2) , it is $\sqrt{((x_1 - x_2)^2 + (y_1 - y_2)^2)}$ (National Institute of Standards and Technology, www.nist.gov).

Consequently, by using the formula obtained by regression analysis that has been explained at Section 3, the predicted travel time matrix is found. Next, predicted service time for each customer is calculated by the demand data of each customer in kg's. Additionally, in order to check feasibility of demand data in kg's with respect to volume constraint, the volume of each customer's demand will be computed with the parameter found in Section 3. Moreover, it is also possible to make manual entrance of the constant that is used to estimate the volume data of demand from the weight data.

Then, the user is asked to enter which side of Istanbul he/she wishes to run the program for, since the program deals with each side as two separate problems. Also, the time limit and at what time the trucks will depart the depot is asked to the user. Finally, the user is asked to enter the number of iterations for the 2-opt exchange phase. Since this iteration number limits the actual number of improvement (i.e. exchanges performed) a number in the range of 0-100 would be reasonable. Although the coefficients found by regression analysis are set as default inputs to the program, it is also possible to change these values at the initiation of the program.

After creating the distance matrix and every other parameter that is required by the algorithm, the code starts building the routes as described before about Yellow's Savings Algorithm. Once the initial solution is found, the code starts the improvement phase, in which it calculates the possible savings of exchanging any two arcs. After sorting these savings in a non-increasing order, it starts checking from the top if the constraints are satisfied when the proposed exchange is performed, and if it turns out to satisfy all the constraints the exchange is done and the routes are updated. Until there is no feasible positive saving is possible or the iteration number is reached, the algorithm iterates. The exchanges performed may be of two types; namely exchange within one route or exchange between two routes. Visually, both can be seen in Figure 4.1. and 4.2.

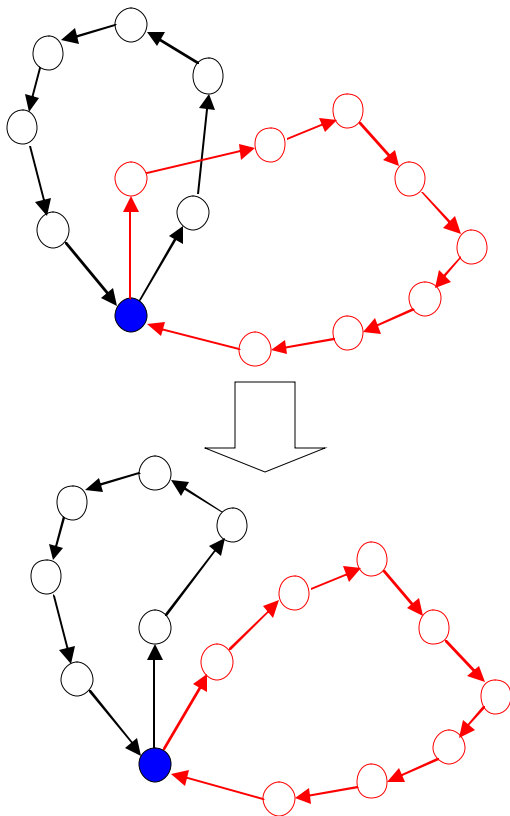


Figure 4.1. 2-opt exchange between routes

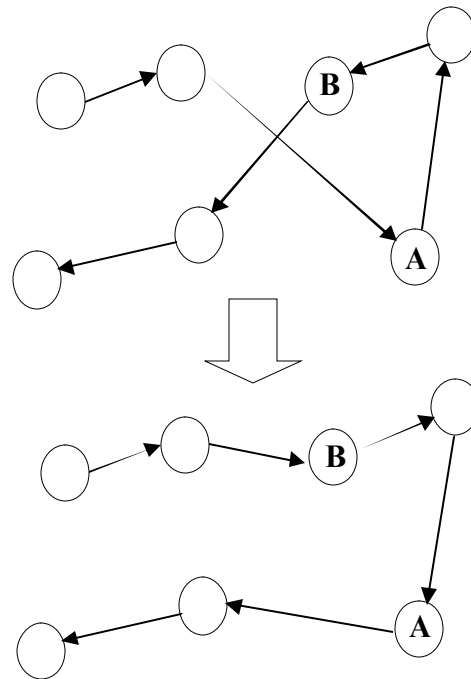


Figure 4.2. 2-opt exchange within one route

After completing the improvement phase, the program produces the output file which shows the routes with customer numbers and names, predicted arrival and departure times, amounts to be delivered, individual route durations, distances, weights, volumes and their overall appropriate statistics. Additional to the output file, the program generates the distance matrix in MS Excel datasheet form of desired computation type (rectilinear or euclidean) and some other text files which are to be used by the DSS for visualization purposes.

5. RESULTS OF THE MODEL

The program was run for different depot locations scenarios and their results were analyzed. Instead of solving a facility location problem, which will probably locate the new depot in central regions of Istanbul that would not be feasible to locate a warehouse due to renting cost, alternative depot locations' performances that were provided by the management were compared with the help of program code. The alternative depot locations include

- (1) Current Depot
- (2) New Depot at M. Tuzla Facility
- (3) New Depot at S. Yenibosna Facility
- (4) New Depot at Topkapı region.

Among these scenarios, M. Tuzla Facility alternative has another importance that it has been seriously considered by D. management to conduct the delivery operations of Istanbul from this facility instead of current depot.

Daily average demand value data for July 2005 was used in all the runs that were conducted. In the following sections, the results obtained from the model by running for different scenarios will be explained.

5.1. Results for Current Depot

As stated in Section 2, D.'s current warehouse is located at Sultançiftliği region that is a developing low-income residential and industrial area on the Şile Highway. It has very fast and easy connections to TEM and E-5 motorways, which is a critical feature for such a

warehouse. Although Sultançiftliği seems far away from the city centre, it actually has more advantages than the other alternatives.

The results of the code will be explained under two different headings according to the side of the city below.

5.1.1. Anatolian Side

Input parameters for both Anatolian Region and European Region, calculations were set as follows.

- Truck Weight Capacity: 3,000 kg
- Truck Volume Capacity: 5.8 kg
- Departure Time of Trucks: 6:30 AM
- Arrival Time of Trucks: 3:00 PM
- Number of Iterations for 2-OptExchange: 50

The resulting routing has twelve routes, which is two lower than the actual routing. The statistical information such as the average distance traveled, average delivery weight and average duration are all improved. Numerically, the program output lowered the average distance by 31.0 per cent, total distance by 40.9 per cent, total delivery time by 10.1 per cent and increased the average truckloads (truck utilization) by 16.7 per cent. Additionally, the standard deviations of the performance measures of the routes are lowered. This can be considered as an indication of balancing placers' workloads, which is an important issue for management since unbalanced workloads create problems during evaluating placer performances and determination of bonuses to be given. Numerically, the standard deviation of distance traveled is lowered by 38.9 per cent, whereas for delivery time, it is reduced by 86.4 per cent.

Table 5.1. Results of current route and improved route for current depot alternative

Region	Route Type	Number of Routes	Statistic	Number of Customers per Route	Route Length		Vehicle Load	
					Distance (km)	Time (min)	Weight (kg)	Volume (m ³)
Anatolian Side	Current	14	Mean	14.93	69.07	472.97	779.84	2.31
			Std Dev	2.34	43.15	121.48	324.20	0.96
	Improved	12	Mean	17.42	47.66	495.98	909.90	2.70
			Std Dev	3.50	26.37	16.52	220.95	0.66
European Side	Current	15	Mean	15.73	81.73	579.30	1030.61	3.06
			Std Dev	2.46	30.14	99.08	474.24	1.41
	Improved	16	Mean	14.75	64.96	521.05	966.20	2.87
			Std Dev	3.73	19.42	38.43	394.41	1.17

5.1.2. European Side

The input parameters were kept as the same as Anatolian Side except the departure time which was set as 6:00 A.M., in order to be sure that the trucks arrive FSM Bridge before 7:00 A.M. After the program is run for European Side, it was seen that the resulting routing has 16 routes, which is 1 more than actual routing in July 2005. Compared with the July 2005 routes, average route distance has fallen to 64.959 km from 81.730 km (by 20.5 per cent), total distance has fallen from 1,225 km to 1,039 km (by 15.2 per cent) and the average route time has fallen to 521.05 minutes from 579.3 minutes (by 10.0 per cent). Additionally, the standard deviations of route distance, route time and vehicle load weight has fallen by 35.6 per cent, 61.1 per cent and 16.8 per cent respectively, which means that the workload among the placers is more balanced.

To sum up, total number of vehicles, total distance traveled, total time traveled, standart deviation figures decreased in the new system with drastic amounts.

Table 5.2. Total results of current route and improved route for current depot alternative

Route Type	Number of Routes	Statistic	Route Length		Vehicle Load	
			Distance(km)	Time(min)	Weight(kg)	Volume(m ³)
Current	29	Sum	2193	15,311	26,378	80.35
		Mean	75.62	527.97	909.55	2.77
		Std Deviation	36.88	121.18	421.32	1.27
Improved	28	Sum	1611	14,289	26,378	80.35
		Mean	57.55	510.31	942.07	2.77
		Std Deviation	23.85	33.04	327.29	0.97

5.2. New Depot at M. Tuzla Facility

As mentioned at the beginning of Section 5, D. management thinks about moving the current warehouse to M.'s Tuzla facility. In this section the effects of such a change is evaluated using the model constructed.

5.2.1. Anatolian Side

The number of routes turned out to be 13, which is one more than that of current improved system. Due to the higher distances between this facility and the customers compared to the current one, total delivery time has increased, which also increased the required number of vehicles. Numerically, compared to current improved routes, average route distance would increase by 53.4 per cent, whereas total distance traveled would increase by 66.2 per cent. The increase in total delivery time would be 9.8 per cent. Since the number of trucks needed has been increased by 1, the truck utilization has decreased by 7.7 per cent compared to the improved results of Sultançiftliği alternative.

5.2.2. European Side

In the program output, the number of routes came out as 20. This is much higher than other alternatives, which is a result of the time that would be spent traveling all the way from Tuzla to the European side. Additionally, the total distance to be traveled would increase by 92.3 per cent, while average distance would increase by 53.8 per cent. Since it turned out to have higher number of routes, the average delivery time would be reduced by 2.3 per cent, while the total delivery time would increase by 22.2 per cent. Furthermore the truck utilization rates would be lowered considerably by 20 per cent.

Table 5.3. Results for M. and current improved alternative

Region	Depot Location	Number of Routes	Statistic	Number of Customers	Route Length		Vehicle Load	
					Distance (km)	Time (min)	Weight (kg)	Volume (m3)
Anatolia	M.	13	Sum	209	951	6,535	10,919	32.4
			Mean	16.08	73.13	502.70	839.91	2.49
			Std Deviation	3.23	25.20	5.36	203.76	0.60
	Current Improved	12	Sum	209	572	5,952	10,919	32.4
			Mean	17.42	47.66	495.98	909.90	2.70
			Std Deviation	3.50	26.38	16.52	220.95	0.66
European	M.	20	Sum	236	1,999	10,188	15,459	46
			Mean	11.80	99.93	509.40	772.96	2.29
			Std Deviation	3.00	15.57	46.21	344.17	1.02
	Current Improved	16	Sum	236	1,039	8337	15,459	46
			Mean	14.75	64.96	521.05	966.20	2.87
			Std Deviation	3.73	19.42	38.43	394.42	1.17

5.3. New Depot at S. Yenibosna Facility

S.'s facility is located at Yenibosna, which is an industrial region on the European side. Everyday, dairy products produced in these facilities are transported to D.'s Sultançiftliği

warehouse, which makes up a long distance to travel. Therefore, the management wants to analyze the system whether a new warehouse might be opened on the European Region. The possible locations for a new warehouse are S.'s Yenibosna Facilities and an open lot in Topkapı, which is more central location. The results for S. Yenibosna depot will be analyzed in this section, whereas Topkapı alternative will be held in the next section.

5.3.1. Anatolian Side

Although it is not seriously considered to make the deliveries of Anatolian side from the depot located on European side unless the current depot is shut down, in order to have a basic insight of the results of a possible change, the output of the program was analyzed. A similar case will be held for European deliveries as it was mentioned for European deliveries from Sultançiftliği, such as the trucks must depart so early that they would be able to reach the FSM Bridge before 7:00, after which trucks are not allowed to cross the bridge. Therefore departure time is set to 6:00 A.M. and the trucks are required to return to the depot before 3:00 P.M. The resulting routing would have 12 routes with higher route length parameters, such as 32.8 per cent higher average route distance and 5.3 per cent higher route time. The vehicle utilization rate would stay same since there would be no change in the number of vehicles required.

5.3.2 European Side

When the program is run for the European Side and a depot located at S.'s Yenibosna facility, the following results are obtained: the number of routes would be 15, which is 1 lower than that of improved version of current system, average distance would be 43.3 per cent lower, total distance would be 46.9 per cent lower, average delivery time would be 5.3 per cent lower and truck utilization rate would be higher be 6.7 per cent. Additionally, the standard deviation values for route length values would be lowered but truckload values would have higher standard deviation figures.

Table 5.4. Results for S. and current improved alternative

Region	Depot Location	Number of Routes	Statistic	Number of Customers	Route Length		Vehicle Load	
					Distance (km)	Time (min)	Weight (kg)	Volume (m3)
Anatolia	S.	12	Sum	209	759	6,267	10,919	32
			Mean	17.42	63.29	522.28	909.90	2.70
			Std Deviation	3.78	40.11	39.13	238.57	0.71
	Improved	12	Sum	209	572	5,952	10,919	32
			Mean	17.42	47.66	495.98	909.90	2.70
			Std Deviation	3.50	26.38	16.52	220.95	0.66
European	S.	15	Sum	236	552	7,400	15,459	46
			Mean	15.73	36.81	493.33	1,030.61	3.06
			Std Deviation	3.49	19.21	25.91	413.22	1.23
	Improved	16	Sum	236	1,039	8,337	15,459	46
			Mean	14.75	64.96	521.05	966.20	2.87
			Std Deviation	3.73	19.42	38.43	394.42	1.17

5.4. New Depot in Topkapı

5.4.1 Anatolian Side

If the depot is located in Topkapı, which is more centrally located than Yenibosna, the following routing results would be obtained, according to the program results. There would be 12 routes with 12.4 per cent higher average route distance and 5.3 per cent higher average delivery time figures compared to the improved version of the current situation. The vehicle utilization value would be the same since there would be no change in the number of vehicles.

5.4.2 European Side

According to the program output, it was seen that, relatively better results would be obtained if the depot on European side was located in Topkapı. The number of routes required

to make the deliveries in the specified time window would be 15 and the average route distance would be 53.7 per cent lower while average delivery time would be 8.8 per cent less, when compared to the program results for the current situation. However, the standard deviation values would be higher, which means that the placer workload would not be equally distributed. Additionally, the truck utilization rate would be 6.7 per cent higher.

Table 5.5. Results for Topkapı and current improved alternative

Region	Depot Location	Number of Routes	Statistic	Number of Customers	Route Length		Vehicle Load	
					Distance (km)	Time (min)	Weight (kg)	Volume (m3)
Anatolia	Topkapı	12	Sum	209	643	6,071	10,919	32
			Mean	17.42	53.55	505.90	909.90	2.70
			Std Deviation	3.60	32.76	46.92	257.04	0.76
	Improved	12	Sum	209	572	5,952	10,919	32
			Mean	17.42	47.66	495.98	909.90	2.70
			Std Deviation	3.50	26.38	16.52	220.95	0.66
European	Topkapı	15	Sum	236	451	7,208	15,459	46
			Mean	15.73	30.07	480.51	1,030.61	3.06
			Std Deviation	3.77	16.28	64.59	408.32	1.21
	Improved	16	Sum	236	1,039	8,337	15,459	46
			Mean	14.75	64.96	521.05	966.20	2.87
			Std Deviation	3.73	19.42	38.43	394.42	1.17

5.5. Evaluation of the Alternatives

Results of the alternative depot locations mentioned in the previous sections can be evaluated for one-depot and two-depot systems as follows.

5.5.2. One – Depot System

Currently, distribution system is based on a one-depot model, which is located on the Anatolian side of the city, Sultançiftliği. Results of the computer runs show that distribution system can be improved impressively for the current depot location. In fact, Sultançiftliği gives the best results for Anatolian side compared to other alternatives. From current depot, daily orders of the customers on the Anatolian side can be distributed with only 12 vehicles with a total delivery time less than 6,000 minutes. A vehicle is expected to travel nearly 47.5 km on the average and total distance traveled turns out to be slightly more than 570 km per day. Furthermore, average truckload is estimated to be 910 kg, meaning an increase in the truck utilization compared to the current routes and it is the maximum among all alternatives. As a result, a depot in Sultançiftliği seems to perform the best among all other alternatives for Anatolian side as seen on Table 5.6. below.

Table 5.6. Program results for Anatolian Side and alternative depot locations

Depot Alternative	Number of Routes	Statistic	Number of Customers per Route	Route Length		Vehicle Load	
				Distance (km)	Time (min)	Weight (kg)	Volume (m3)
D. Sultançiftliği	12	Mean	17.42	47.66	495.98	909.90	2.70
		Std Dev	3.50	26.38	16.52	220.95	0.66
M. Tuzla	13	Mean	16.08	73.13	502.70	839.91	2.49
		Std Dev	3.23	25.20	5.36	203.76	0.60
S. Yenibosna	12	Mean	17.42	63.29	522.28	909.90	2.70
		Std Dev	3.78	40.11	39.13	238.57	0.71
Topkapı	12	Mean	17.42	53.55	505.90	909.90	2.70
		Std Dev	3.60	32.76	46.92	257.04	0.76

On the other hand, for European side, the alternative of a depot in Topkapı seems to perform the best. Daily orders of the customers in European region can be distributed with 15 vehicles with a total delivery time more than 7,200 min. Expected travel distance per vehicle is estimated as approximately 30 km and total distance traveled per day is expected to be about 451 km for a depot located in the region of Topkapı. As seen on table 5.7., performance of an alternative depot in Yenibosna is very similar with Topkapı for both Anatolian and European side of Istanbul. For both alternatives, number of vehicles is 12 for Anatolian and 15 for European. Moreover, it can be observed on the graphs and figures that the depot alternative in Tuzla (M. facility) is the worst alternative for each region of the city.

Table 5.7. Program results for European Side and alternative depot locations

Depot Alternative	Number of Routes	Statistic	Number of Customers per Route	Route Length		Vehicle Load	
				Distance (km)	Time (min)	Weight (kg)	Volume (m3)
D. Sultançiftliği	16	Mean	14.75	64.96	521.05	966.20	2.87
		Std Dev	3.73	19.42	38.43	394.42	1.17
M. Tuzla	20	Mean	11.80	99.93	509.40	772.96	2.29
		Std Dev	3.00	15.57	46.21	344.17	1.02
S. Yenibosna	15	Mean	15.73	36.81	493.33	1,030.61	3.06
		Std Dev	3.49	19.21	25.91	413.22	1.23
Topkapı	15	Mean	15.73	30.07	480.51	1,030.61	3.06
		Std Dev	3.77	16.28	64.59	408.32	1.21

To sum up, for a one – depot system, the depot location should be selected among Sultançiftliği, Yenibosna and Topkapı. Total number of vehicles needed for both sides of the city is 28 for Sultançiftliği and 27 for Topkapı and Yenibosna. Related to this, total distance travelled and total travel time (sum of European and Anatolian routes) for Sultançiftliği is higher compared to Yenibosna and Topkapı. (1,611 km – 14,289 min for Sultançiftliği, 1,312 km – 13,667 min for Yenibosna and 1,094 km – 13,278 min for Topkapı, Figure 5.1.). As a result, if number and performance of routes are taken into account, a new depot in Topkapı seems to be preferable for a

one-depot model. However, in order to reach a more reliable conclusion, the feasibility of the proposed alternative in terms of financial aspects, availability of land etc. should be evaluated.

Table 5.8. Total results for all alternatives

Depot Location	Number of Vehicles	Calculation	Route Length		Vehicle Load	
			Distance (km)	Time (min)	Weight (kg)	Volume (m ³)
Current	29	Sum	2,193	15,311	26,378	78
		Mean	75.62	527.97	909.55	2.77
		Std Deviation	36.88	121.18	421.32	1.27
Improved	28	Sum	1,611	14,289	26,378	78
		Mean	57.55	510.31	942.07	2.80
		Std Deviation	23.85	33.04	327.29	0.97
M.	33	Sum	2,949	16,723	26,378	78
		Mean	89.37	506.76	799.33	2.37
		Std Deviation	23.64	35.91	294.96	0.88
S.	27	Sum	1,312	13,667	26,378	78
		Mean	48.58	506.20	976.96	2.90
		Std Deviation	32.54	34.99	346.06	1.03
Topkapı	27	Sum	1,094	13,278	26,378	78
		Mean	40.50	491.79	976.96	2.90
		Std Deviation	27.17	57.82	348.52	1.03

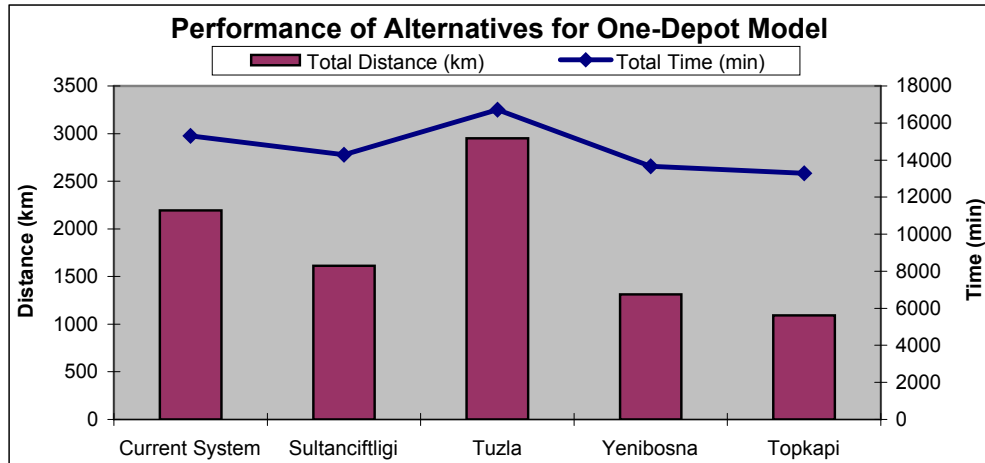


Figure 5.1. Performance of alternatives for one – depot Model

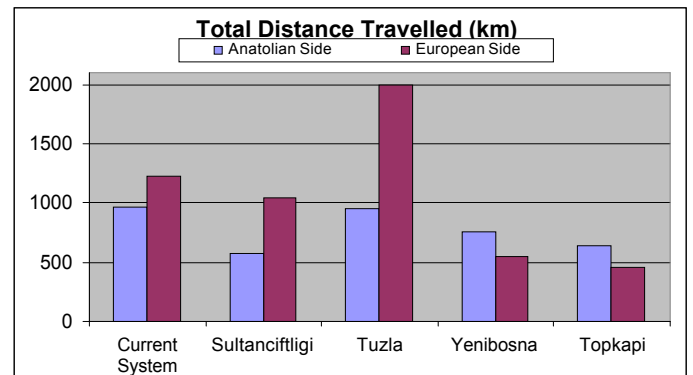
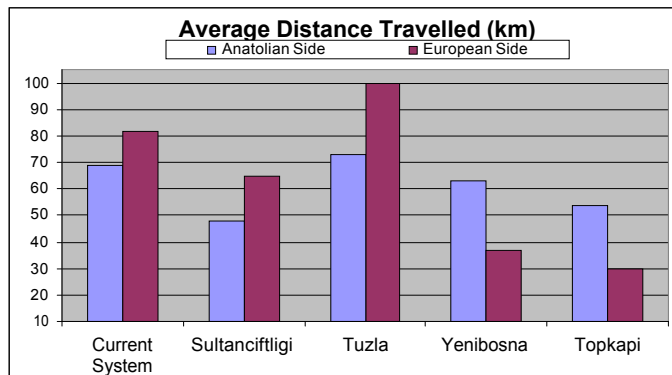
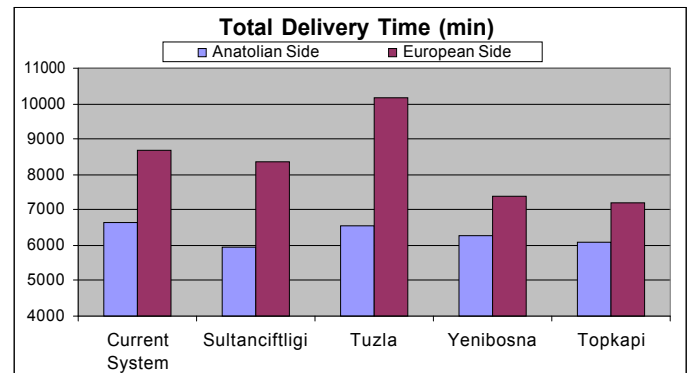
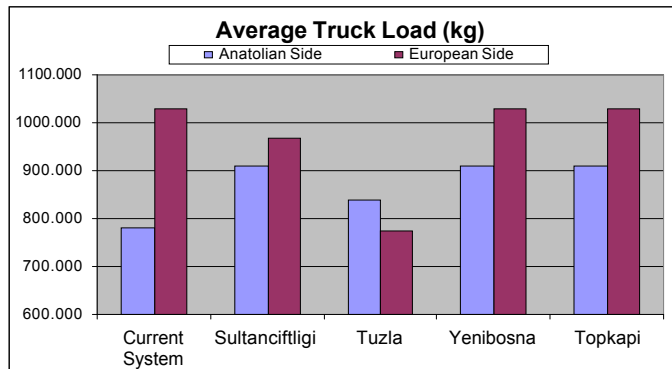


Figure 5.2. Performance figures of current system and alternative depot locations

As seen on Table 5.9., for a one-depot model, annual total cost of delivery operations (vehicle – including truck rent, fuel and driver cost – and placer) is about 1,552,000 YTL for Sultançiftliği, and 1,485,000 YTL for Yenibosna and Topkapı.

In other words, cost of constructing a new warehouse on the European side instead of Anatolian should compensate the difference of 67,000YTL/year for a logical time period. At this point, decision should be left to the management since the value of the current warehouse and the cost of constructing a new one can not be easily compared without evaluating the reasons stated before, financial aspects, land availability.

At this point, it should be noted that there exist some implicit savings and benefits resulting from better performance of routes although they are not easily computable. These can be called as the negotiation power of D. when lease contracts are signed with the company that provides trucks, drivers and fuel. In the improved case, trucks travel significantly lower distances in shorter time periods, which reduce the fuel consumption, work hours of drivers and truck depreciation. Besides, with the improved routes, trucks arrive to the customers earlier.

5.5.3. Two – Depot System

Managements of T. and D. are seriously considering converting the current one-depot system to a new two-depot one. The main reason is to reduce the workload on the placers that serve to European side.

This brings long travel distances and times with late deliveries and unsatisfied customers. Furthermore, although all placers are paid the same wage, their workload differs depending on whether they work on a European or Anatolian route, and this creates problems between placers. Even though such problems are expected to be solved with the improved results, it is still worth to evaluate the performance of a two-depot system.

Since four different possible warehouse locations 2 on European, 2 on Anatolian side are available, and it is assumed that customers on one side of the city are served by the depot on the same side, four possible combinations were decided. These are; (1) Sultançiftliği–Yenibosna, (2) Sultançiftliği–Topkapı, (3) Tuzla–Yenibosna and (4) Tuzla–Topkapı.

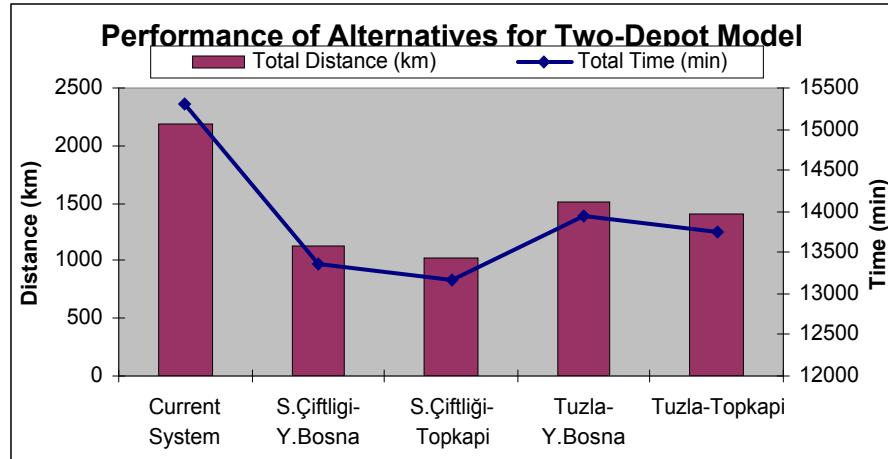


Figure 5.3. Performance of alternatives for two – depot Model

Table5.9 Delivery cost figures for current system and alternatives

Depot Alternatives	Region	Number of Routes	Daily Cost per Vehicle (YTL)	Annual Vehicle Cost (YTL)	Annual Placer Cost (YTL)	Annual Delivery Cost (YTL)	Cost Saving %
Current System	Anatolian	14	95	414,960	336,000	750,960	-
	European	15	105	491,400	360,000	851,400	-
Sultançiftliği	Anatolian	12	95	355,680	288,000	643,680	14.3
	European	16	105	524,160	384,000	908,160	-6.7
Tuzla	Anatolian	13	95	385,320	312,000	697,320	7.1
	European	20	105	655,200	480,000	1,135,200	-33.3
Yenibosna	Anatolian	12	105	393,120	288,000	681,120	9.3
	European	15	95	444,600	360,000	804,600	5.5
Topkapı	Anatolian	12	105	393,120	288,000	681,120	9.3
	European	15	95	444,600	360,000	804,600	5.5

Expected performances of the routes constructed for the four depot locations were explained in detail for both European and Anatolian side at the beginning of Section 5. It is known that M.-Tuzla alternative has worse performance than the current depot location, Sultançiftliği. Hence, the depot on the Anatolian side should be in its current location, Sultançiftliği. The reason of why M.-Tuzla should not be preferred is clearly seen on Figure 5.2. Therefore, the decision should be made between S.-Yenibosna and Topkapı alternatives. As mentioned above, it is logical to select Yenibosna because of its high feasibility in the sense of financial aspects and land availability. Under a two depot policy of Sultançiftliği and Yenibosna (S.) pair, in the light of program run results, total distance traveled by vehicles is expected to be around 1,120 km and total delivery time is estimated as approximately 13,350 min. These figures are very close to the one of Sultançiftliği and Topkapı pair, which are

about 1,020 km and 13,160 min. respectively. Besides, under both policies a fleet of 27 vehicles (12 for Anatolian, 15 for European) is necessary to satisfy the orders of customers on each side of the city.

As seen on Table 5.9 and Figure 5.3., any two –depot policy seems have extremely better performances than the current one – depot system. Thus, it may be highly desirable to open a new depot in the proposed region, S.-Yenibosna. However, explicit and implicit cost figures should be considered as much as possible. As seen on Figure 5.3., expected annual delivery cost of Sultançiftliği for Anatolian side is 643,680 YTL and the one of Yenibosna for European side is 851,400 YTL, making up a total of 1,495,080 YTL. In the current system, total annual cost of delivery operations is 1,602,360 YTL. Therefore, explicit cost saving resulting from a two – depot policy can be considered as about 110,000 YTL/year. Moreover, as seen on Figure 5.3., performance of the routes under two – depot policy increases significantly compared to the current system (total distance traveled can be reduced to 1,120 km from 2,193 km and total delivery time can be dropped to 13,350 min from 15,311 min.). These significant changes may contribute a lot to the implicit cost savings and benefits as described in the previous section.

6. CONCLUSION

T. is one of the leading companies in the food production industry. Since the merge in 2003, M., S., P. and T. brands are produced under this brand name. This has made its product spectrum spread from tomato paste to dairy and meat products. D. carries out distribution of this large product range.

For companies in the food sector, it is an essential issue to distribute products in big cities to customers on time and under the required conditions. Also the harsh market conditions and competition, companies are increasing their interest in decreasing costs of transportation.

Within the context of the thesis, the distribution system of cold products for T. Group in Istanbul was studied. The purpose was focusing on ways to improve the current program with a systematic approach and industrial engineering tools.

According to Kasilingam, the process of logistics systems analysis may be grouped into four phases. The first phase is concerned with defining the problem, the second one is related to data analysis, the third consists of analyzing the problem, and the final phase includes user testing and actual implementation of the refined logistics system. (Kasilingam, 2000). The background of this thesis was implemented according to these steps.

In the first phase of the thesis, several observations were made and data related to the current system were collected. In the light of these observations and the information gathered, symptoms and some of the possible causes of problem areas were identified. The problem has

been stated as evaluating and designing the distribution system of cold products in Istanbul considering storage, preparation, loading and delivery operations into an efficient and effective manner with the base goal of reducing costs and increased sales alongside customer satisfaction. Then, the problem has been handled with suggestions to improve the current system operations and two major separate sub-problems of storage system design and vehicle routing. After a detailed survey, mathematical models were used in developing the solution and the parameters necessary for the construction of models were determined. Among these data, some parameters were derived from the data provided by the company, while some others were determined from specific studies and observations. Determination of market locations and rectilinear distances between them, service time at customer locations and travel time between customers (result of regression analysis), product dimensions and distance covered by each product group and some other findings were all determined by result of detailed studies.

The last step of the thesis can be considered as a solution for the models and determination of alternative policies for both vehicle routing and storage systems. In the storage system design, the layout of the warehouse has been changed according to the determined space requirements of product groups. Also, construction of a new door has been recommended for the simplification and acceleration of loading and unloading operations. Finally, allocations of the current workforce in the new system and vehicle loading procedures have been specified and the expected results of the changes have been justified. In the vehicle routing system, several trial runs of the computer code written have been performed for the current depot and 3 alternative depot locations.

In light of these runs, it has been proved that an excessive amount of improvement is possible in the current system regarding to the number of vehicles used and performance of routes. Furthermore, using a one-depot system, it has justified that the current location of the depot should be expected to perform the best when financial aspects are also considered. On

the other hand, for a two-depot system, the Yenibosna region, in which the S. facility was located, is suggested for a second depot location. Besides, it can be proven that any two-depot system will perform delivery activities much better than the current single one.

In addition to the studies described above, a DSS has been proposed for the purpose of simplifying the use of adaptive computer program writing. With the help of this system, the user can add new customers and delete existing ones in the integrated database. They can also change customer information, update decision variables and even parameters used within the program code.

APPENDIX A: AS-IS SCHEMAS

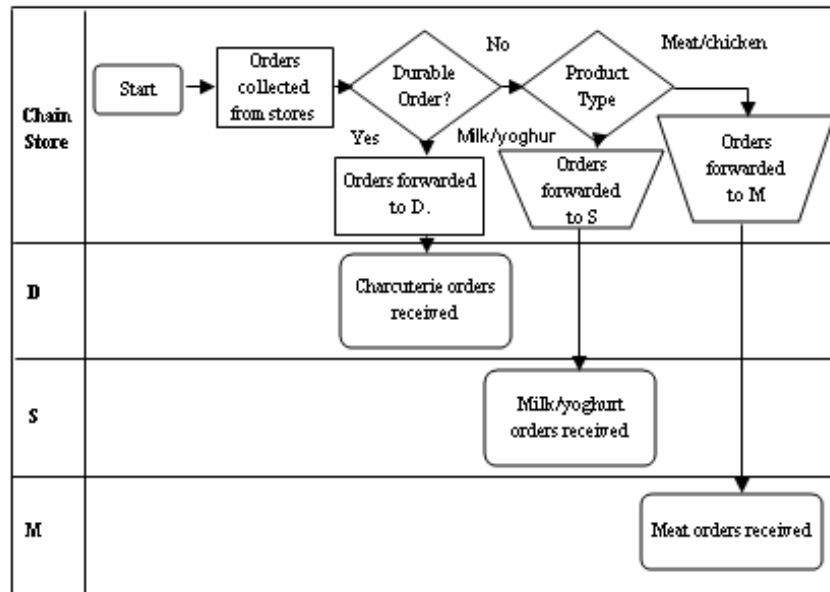


Figure A.1. Chain store ordering

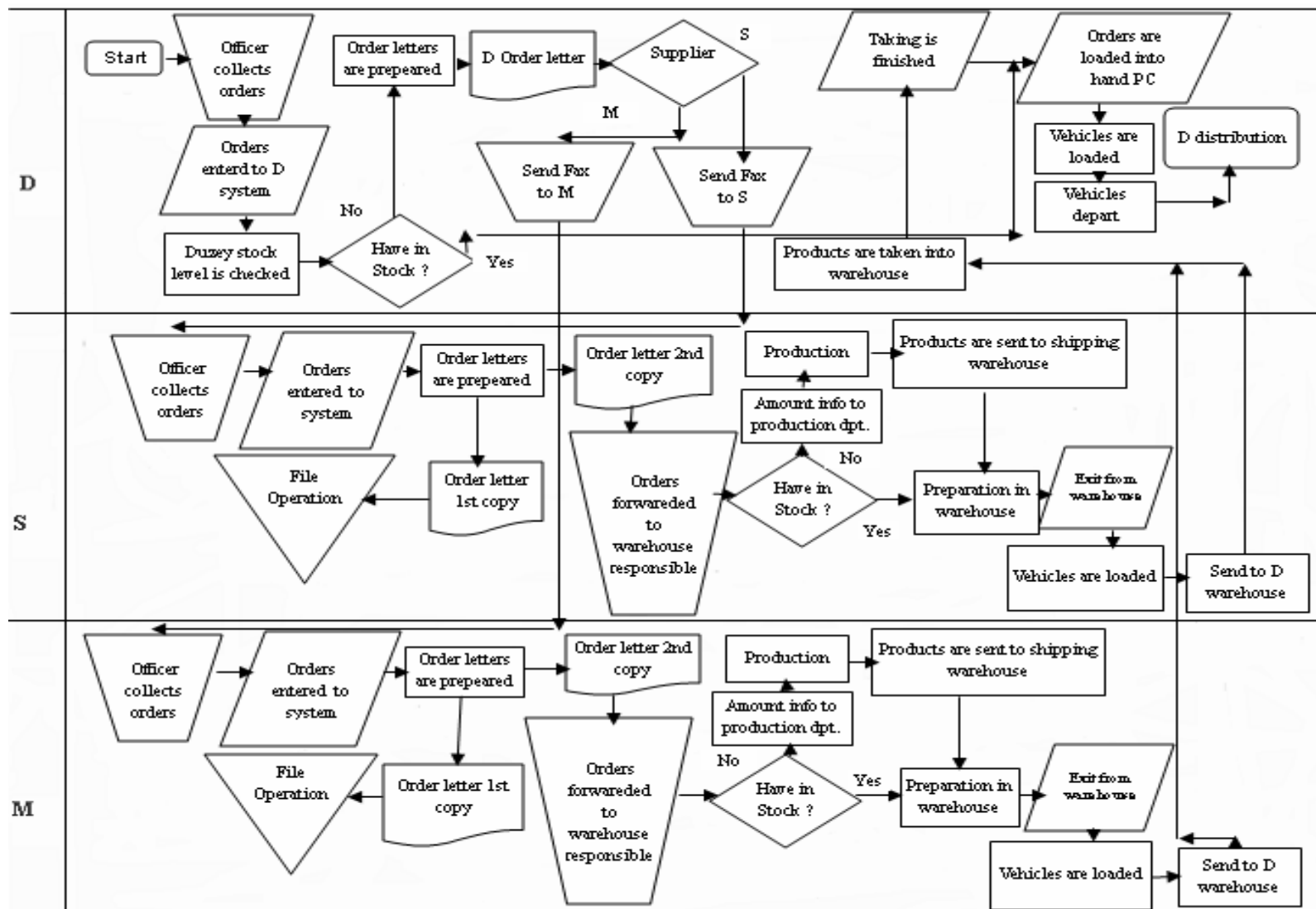


Figure A.2. Charcuterie ordering-delivering process

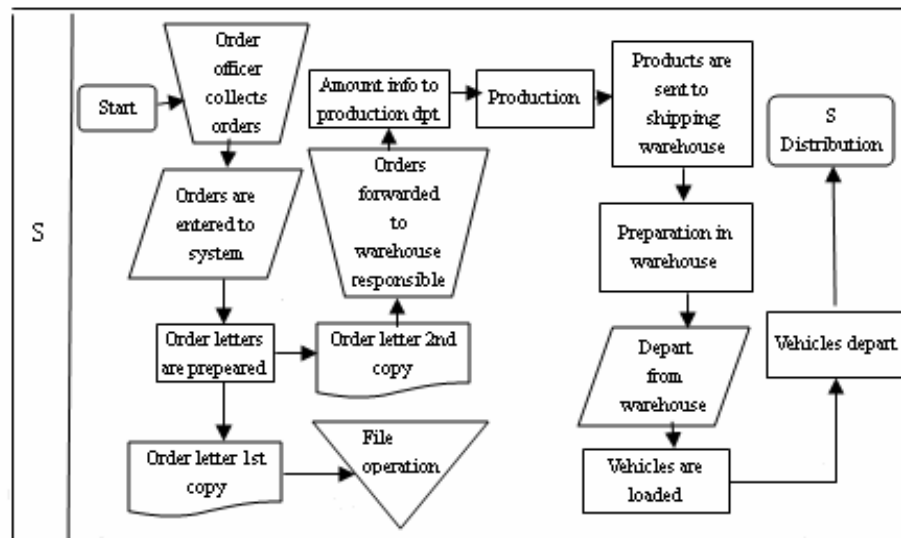


Figure A.3. Milk/yoghurt ordering-delivering process

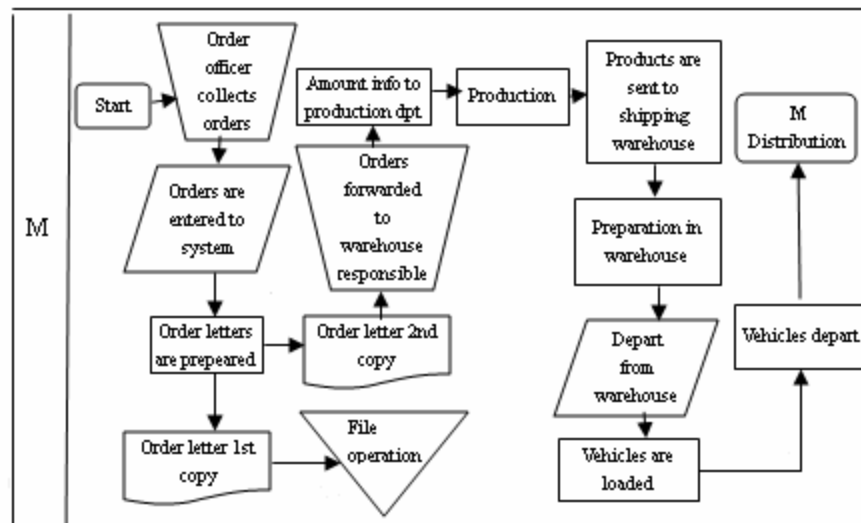


Figure A.4. Fresh meat/chicken ordering-delivering process

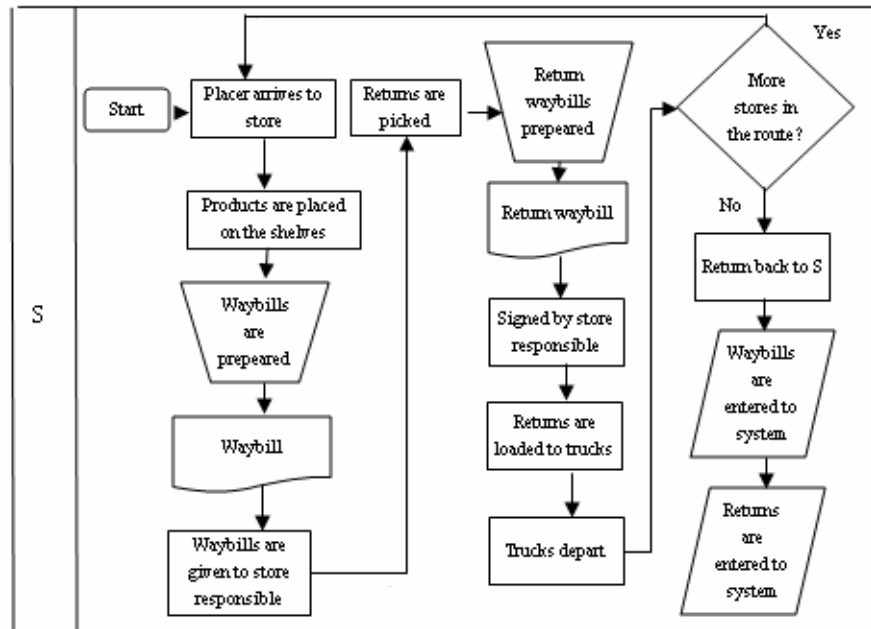


Figure A.5. Milk/yoghurt distribution process

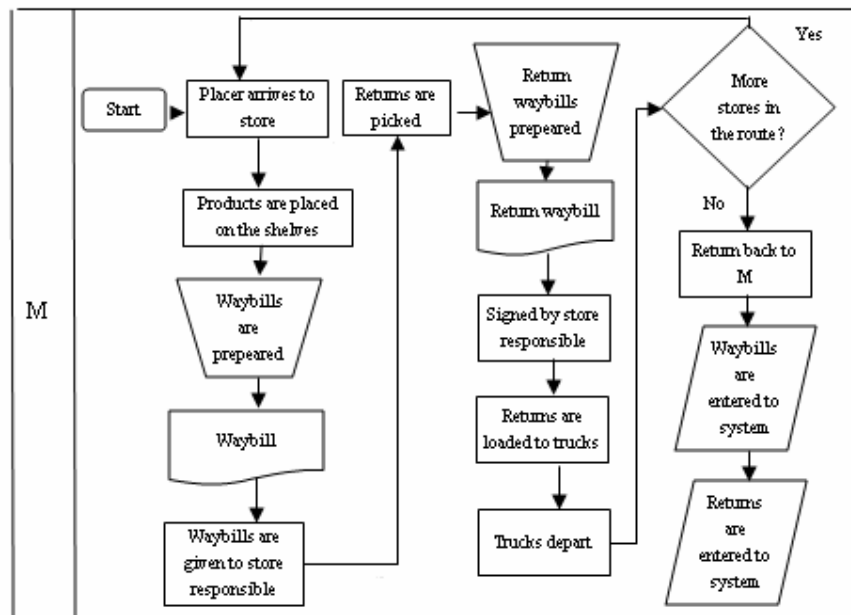


Figure A.6. Fresh meat/chicken distribution process

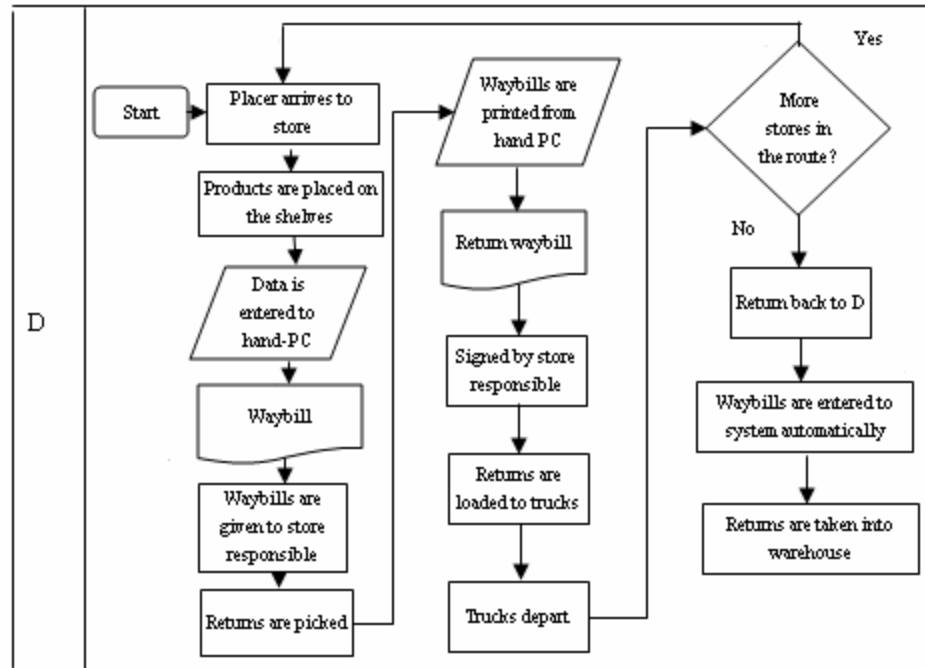


Figure A.7. Charcuterie distribution process

APPENDIX B: TO-BE SCHEMAS

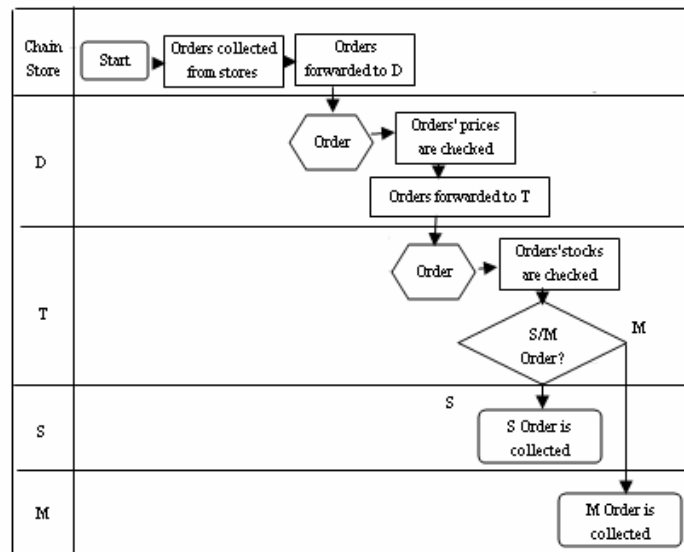


Figure B.1. Chain store ordering

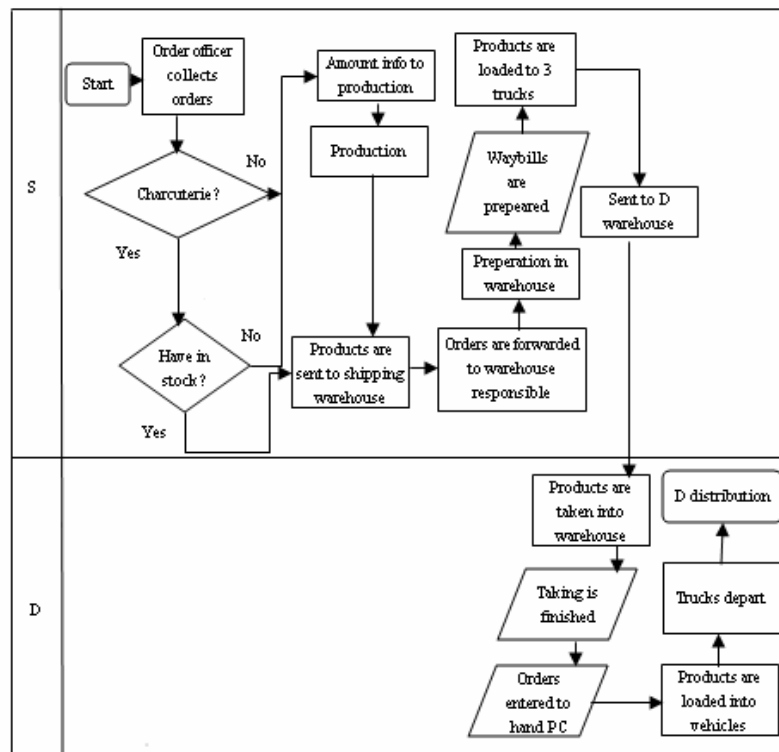


Figure B.2. S products ordering-delivering process

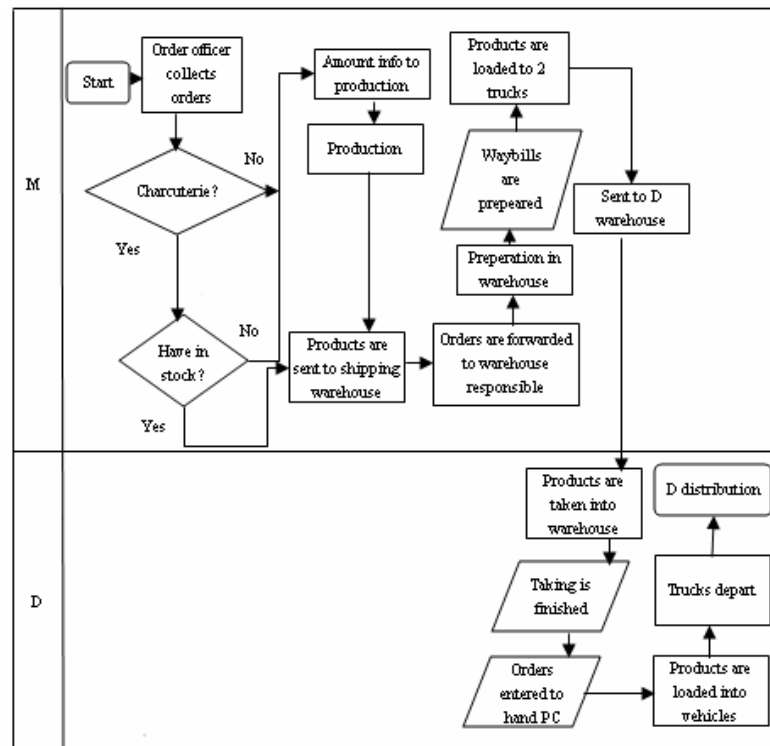


Figure B.3. M products ordering-delivering process

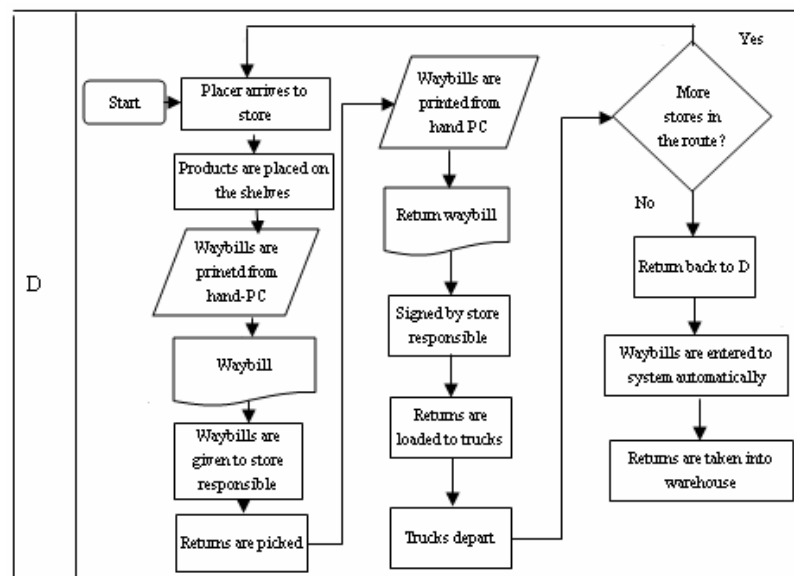


Figure B.4. D. distribution process

APPENDIX C: LAYOUTS FOR PROPOSED ALTERNATIVES

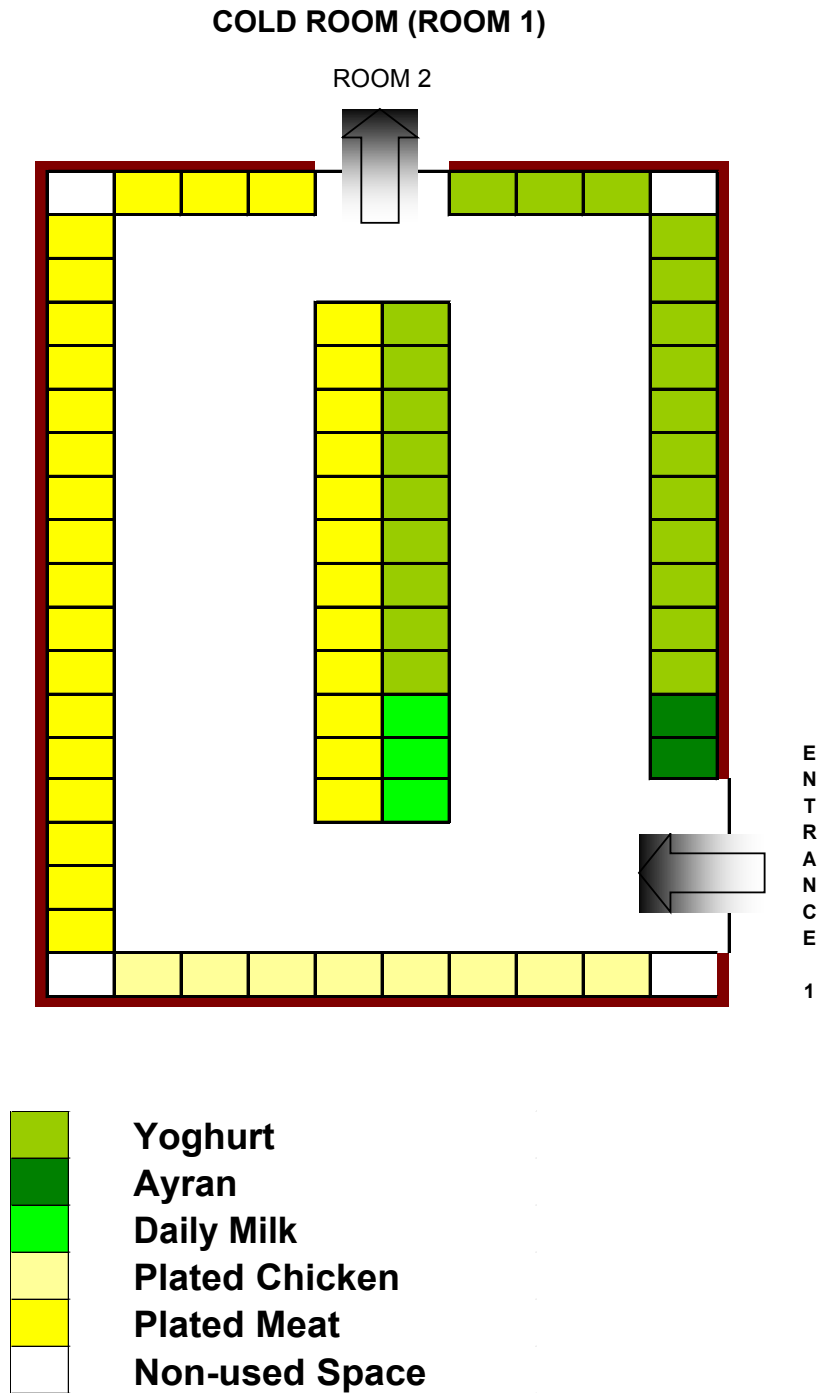


Figure C.1. Proposed alternative for room 1

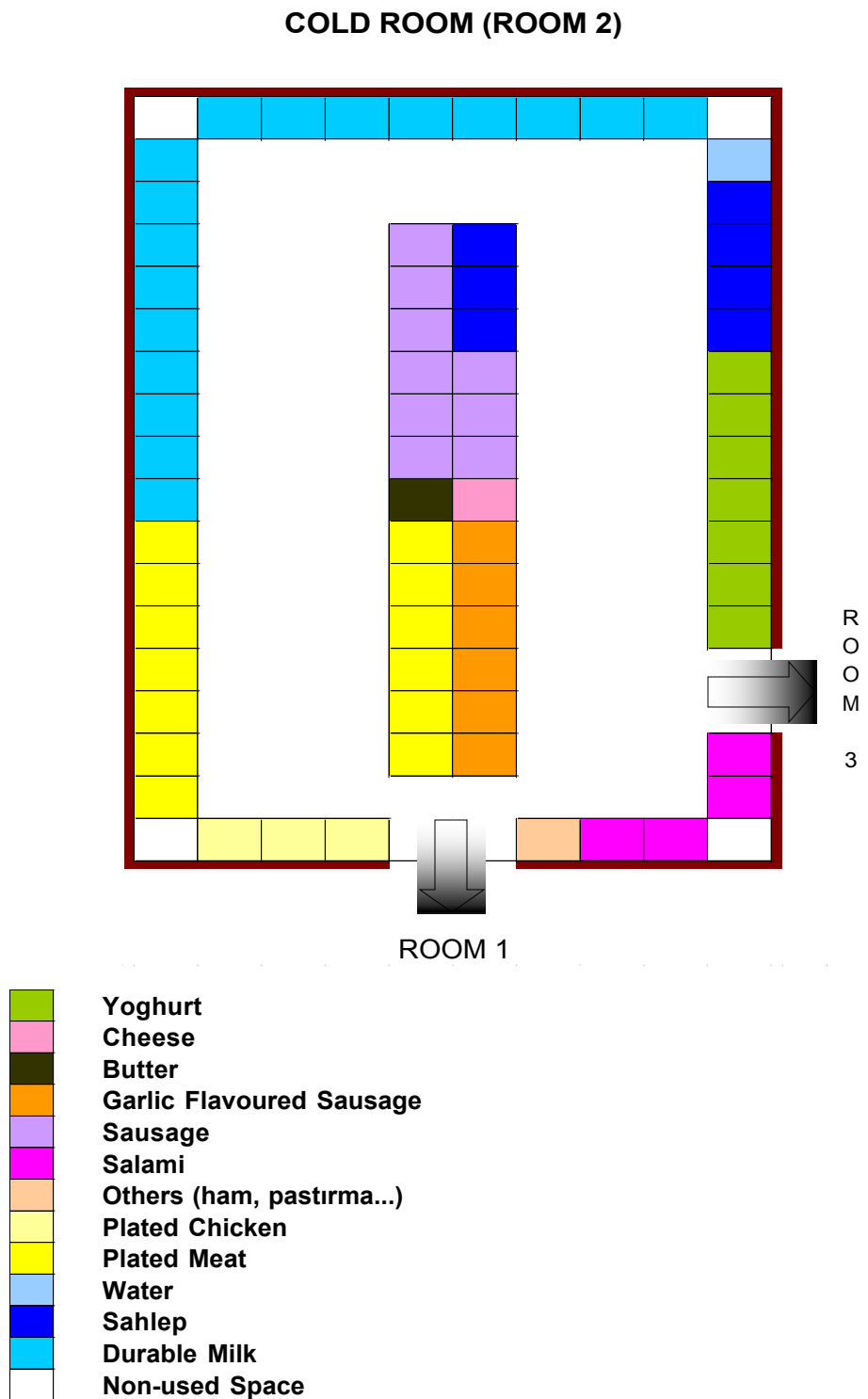


Figure C.2. Proposed alternative for room 2

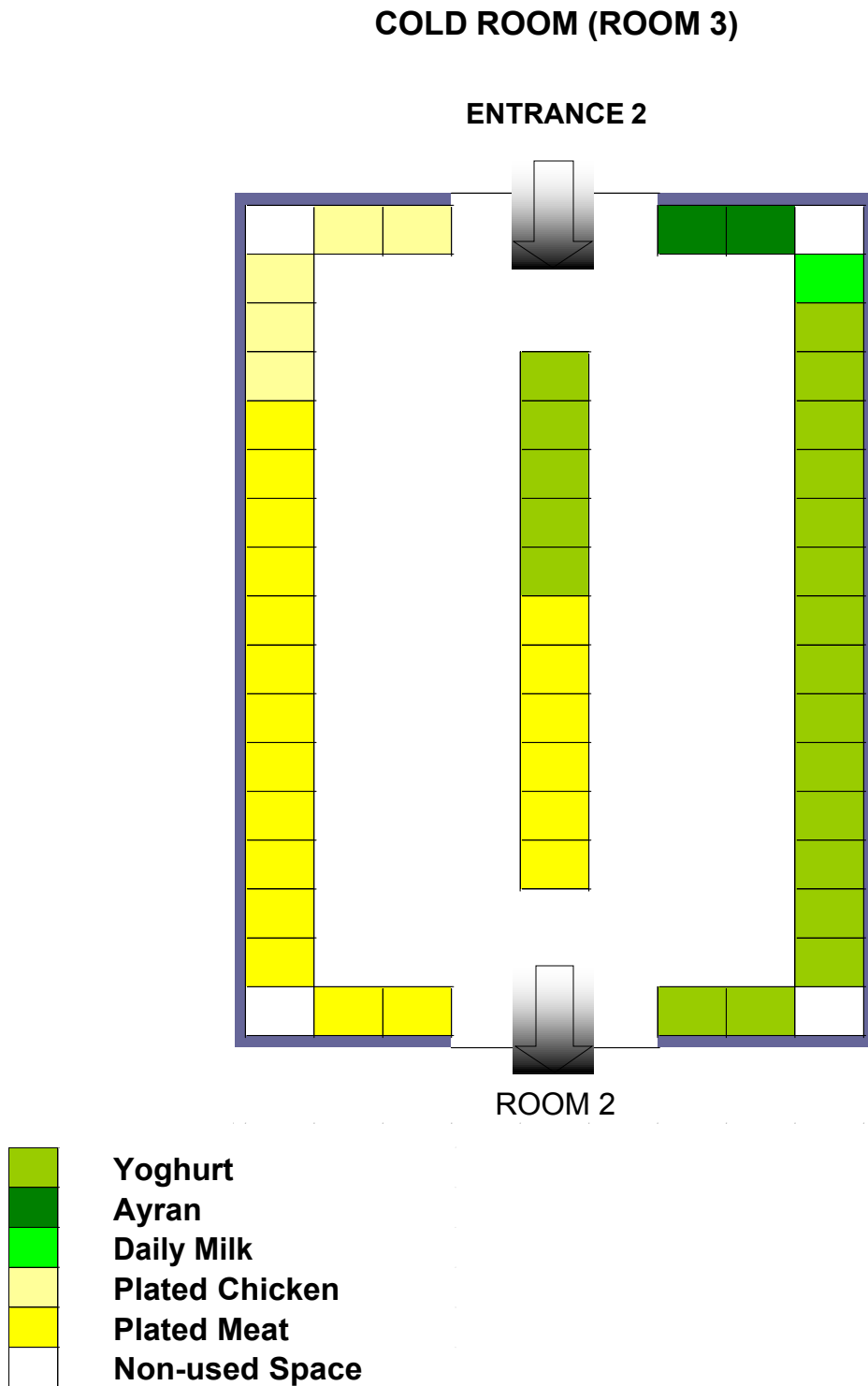


Figure C.3. Proposed alternative for room 3

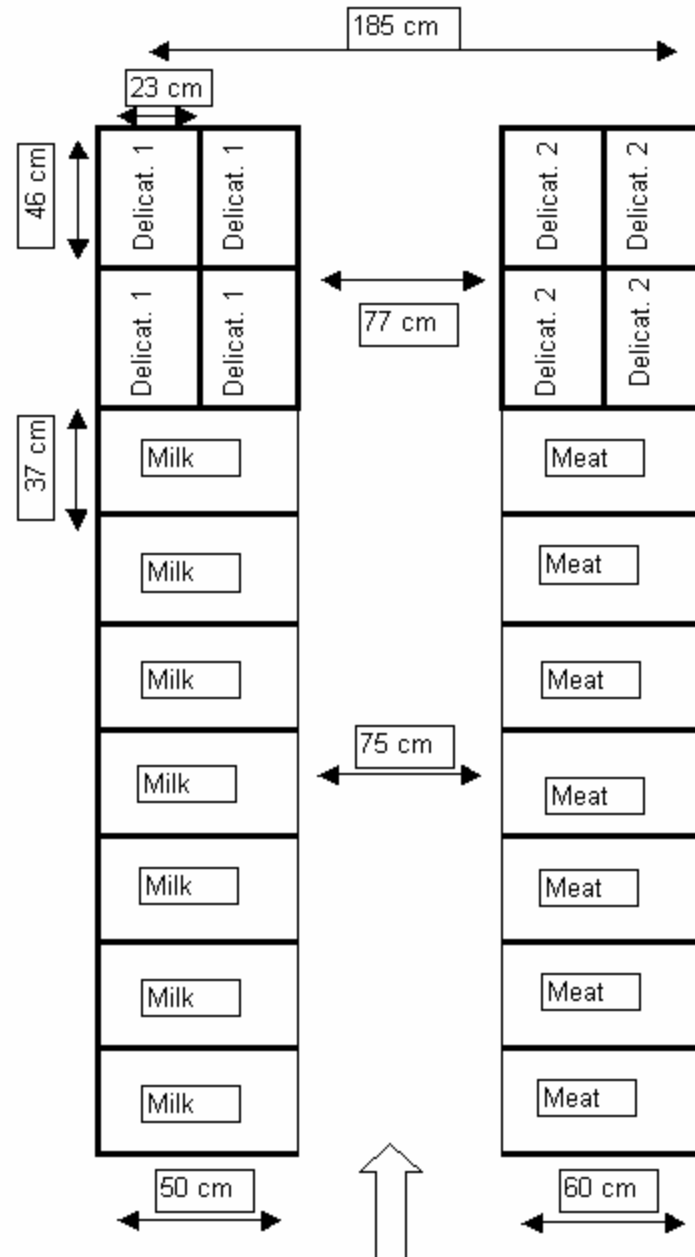


Figure C.4. Proposed loading operation 1

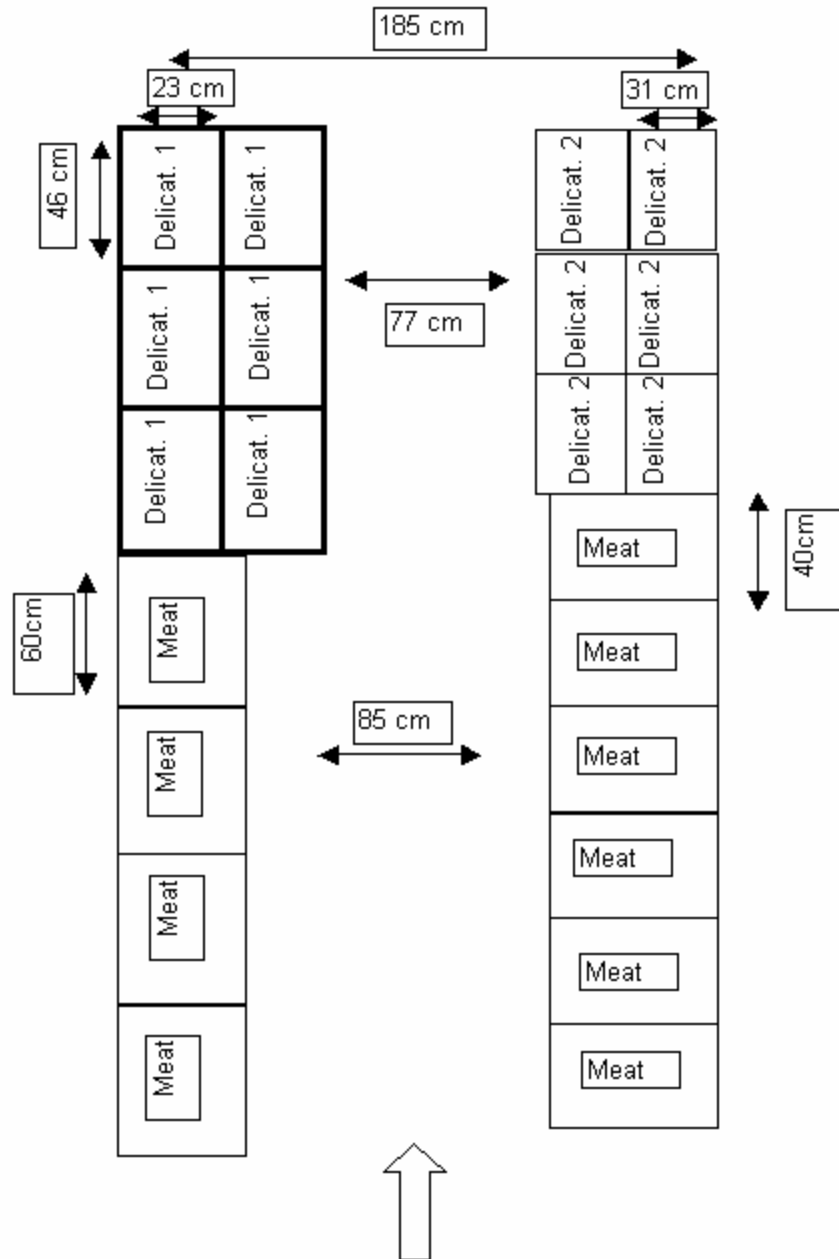


Figure C.5. Proposed loading operation 2

REFERENCES

- Ballou, R.H., 1992, *Business Logistics Management*, Prentice- Hall.
- Bramel J., Smichi-Levi D., 1994, *The Logic of Logistics: Theory, Algorithms, and Applications for Logistics Management*, Springer.
- Bramel J., Smichi-Levi D., 1995, "A Location Based Heuristic for General Routing Problems", *Operations Research*, 43, 649-660.
- Clarke G., Wright W., 1964, "Scheduling of Vehicles from a Central Depot to a Number of Delivery Points", *Operations Research*, Vol 12, 568-581
- Davis H.W., Drumm W.H., 1996, "Logistics Costs and Customer Service Levels". *Council of Logistics Management Annual Conference Proceedings*.
- Fisher M. L., Jaikumar R., 1981, "A Generalized Assignment Heuristic for Vehicle Routing.", *Networks*, Vol.11, No. 2 pp. 109-124.
- Frostic G., 1987, *Heuristic, 1st ed. Presscraft Papers*.
- Francis R.L., McGinnis Jr. L.F., White J.A. 1992, *Facility Layout and Location: An Analytical Approach*. Prentice-Hall.
- Gaskell T J., 1967, "Bases for Vehicle Fleet Scheduling", *Operational Research Quarterly*, 18,281-295.
- Gendreau, Laporte and Potvin, 1997, "Vehicle Routing: Modern Heuristics", *Local Search in Combinatorial Optimization*, Wiley, 311-336 2001.

- Gendreau, Laporte and Potvin, 2001, "Metaheuristics for the Capacitated VRP", *The Vehicle Routing Problem*, 129-154.
- Golden B., Magnanti T., Nguyen H., 1977, "Implementing Vehicle Routing Algorithms", *Networks*, 7, 113-148.
- Laporte, 1991, "The Vehicle Routing Problem: An Overview of Exact and Approximate Algorithms", *European Journal of Operational Research*, 59, 345-358
- Laporte and Semet, 2002, "Classical Heuristics for the Capacitated VRP", *The Vehicle Routing Problem*, 109-238.
- Larsson T., March H., Kusiak A., 1996, "A Heuristic Approach to Warehouse Layout with Class-based Storage", *IIE Transactions*, 29, 337-348.
- Magnanti T.L., 1981, "Combinatorial Optimization and Vehicle Fleet Planning: Perspectives and Prospects", *Networks*, Vol 11, 179-213.
- Kasilingam R. G., 2000, *Logistics and Transportation, Design and Planning*, Kluwer Academic Publishers.
- Koster R., Le-Duc T., Rodgenberg K., 2006, "Design and Control of Warehouse Order Picking: A Literature Review", *ERIM Report Series in Management*, ERS-2006-005-LIS.
- Yellow P. C., 1970, A Computational Modification to the Savings Method of Vehicle Scheduling, *Operational Research Quarterly*, 21, 281-283.

REFERENCES NOT CITED

- Blecha C., Goetschalck M., “The Vehicle Routing Problem with Backhauls: Properties and Solution Algorithms”, *Georgia Tech Research Corporation, Atlanta*, 1992.
- Bodin L., and Golden B., “Classification in Vehicle routing and Scheduling”, *Networks*, 11, 97—108, 1981.
- Braysy O., Gendreau M., “Vehicle Routing Problem with Time Windows”, *Transportation Science*, Vol 39, 104-118, 2005.
- Caron F., Marchet G., Perego A., “Routing Policies and COI- based Storage Policies in Picker-to-part Systems”, *Int. J. Production Research*, Vol 36, 713-732, 1998.
- Croes A., “A Method for Solving Traveling Salesman Problems,” *Operations Research*, Vol. 5, 1958.
- Girard S., Renaud J., Boctor F., *A Simple efficient Perturbation Heuristic to Solve the Vehicle Routing Problem*, Network Organization Technology Research Center, 2005.
- Golden, B., Assad, A., Levy, L., Gheysens, F., “The Fleet Size and Mix Vehicle Routing Problem”, *Computers and Operations Research*, 1, 49-66, 1984.
- Golden B., Assad A., “Perspectives on Vehicle Routing: Exciting New Developments”, *Operations Research*, Vol 34, 803-810, 1986.

- Heragu S., Huang J., Mantel R.J., Schuur, P., “A Mathematical Model for Warehouse Design and Product Allocation”, *International Journal of Production Research*, Vol 43, 327-338, 2005.
- Katayama K., Narihisa H., “An Efficient Hybrid Genetic Algorithm for the Travelling Salesman Problem”, *Electronics and Communications in Japan*, 3, Vol 84, 2001.
- Van den Berg J., Zijm W., “Models for Warehouse Management: Classification and Examples“, *International Journal of Production Economics*, Elsevier, 519-528, 1999.