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JÓZSEF HATVANY DOCTORAL SCHOOL FOR

INFORMATION SCIENCE, ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MATERIALS HANDLING AND LOGISTICS

ANALYSIS OF GENERIC FOOD SUPPLY CHAIN: THE CASE OF OLIVE OIL INDUSTRY IN TURKEY

PhD Thesis

by

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ABSTRACT

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The structure, design and management of supply chains vary in different industries based on the industry-specific requirements. Food sector is one of the industries that has distinctive characteristics. Accordingly, food supply chain, such as olive oil supply chain, has to be managed based on the requirements of the particular industry. The aim of this thesis is to optimize the distribution network of olive and olive oil supply chain of Tariş Olive and Olive Oil Company (Tariş), operating in the olive oil industry in Turkey. For this aim, a generic model is provided for a food supply chain. In addition, a specific model is developed for Tariş. Current distribution system of Tariş is analyzed and a mathematical programming model is developed to provide a distribution design for the company to maximize its profits.

Keywords: *Supply Chain, Food Supply Chain, Olive-oil Industry, Distribution Network Optimization.*

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INTRODUCTION

Effective supply chain management is the main source of sustainable competitive advantage for companies. Therefore, the concepts of supply chain and supply chain management have received attention from many practitioners and academicians, especially in the recent years. However, most of the emphasis of academic research on supply chains has been conducted in general manner. Although potential positive outcomes that will occur after the successful implementation of supply chain management practices, there are not enough studies on industry specific supply chain models and practices. Meanwhile, food industry has become one of the leading sectors that affect social and economic environment especially in the recent years. Accordingly, supply chain practices in the food industry have become more critical for food companies' competitiveness. Therefore, the supply chain system in food industry should be designed and managed according to the requirements and constraints of the sector due to the special characteristics of the food product. Hence, food supply chain research would be valuable both for researcher and practitioners of the field. In this context, this thesis aims to examine food supply chains by a mathematical model and application of it in olive oil industry.

The main objective of this thesis is, to investigate the generic food supply chain and mathematical description of it. The model is implemented and tested in the olive oil industry, based on the data gathered from Tariş Olive and Olive Oil Company (hereafter Tariş).

This thesis has five chapters. An overview of the contents is as follows:

Chapter 1 presents a literature review on supply chain and supply chain management. In the first chapter, the concepts of 'supply chain', 'supply chain management' and "food supply chain" are explained.

Chapter 2 presents the main characteristics of olive oil industry and olive oil supply chain. Chapter 2 also gives a brief summary of Tariş which is one of the focal companies in food supply chains in Turkey.

Chapter 3 mainly presents a distribution network model for a generic food supply chain.

Chapter 4 presents data required for the application and analysis.

Chapter 5 provides the company application including distribution network model. Results of the analysis are also presented in Chapter 5.

Finally **Conclusion and Recommendations for Future Studies** is presented.

CHAPTER 1[1]: LITERATURE REVIEW

This chapter aims to provide a detailed review of literature basically on supply chain and supply chain management concept. Firstly, the concept of supply chain is explained and secondly supply chain management concept is presented in this chapter.

The concepts of supply chain and supply chain management first appeared in the literature in the recent decades. The field of supply chain management has become extremely important for companies operating in an increasingly competitive global marketplace. Accordingly, supply chain management has turned into the main source of business success and sustainable source of competitive advantage [1]. Therefore, there has been an extensive amount of research on supply chain management.

1.1. THE CONCEPT OF SUPPLY CHAIN

The term "supply chain" may be used interchangeably with the terms "value chain" and "demand chain". Although the importance of supply chain concept is recently being mentioned, supply chains, in fact, have always existed throughout the economic history.

Global competition forced companies to collaborate and cooperate with their suppliers and distributors. Thus, managers of the companies recognized that the outcomes of suppliers and customers may become significant inputs or resources for their companies [2,3,4]. In this context, to facilitate competitive advantage, companies along the supply chain become inevitably interdependent. Therefore, being a member of an effective supply chain turned into the critical source of business success. Accordingly, it was recognized that a single firm

1 This chapter is a part of *PhD thesis of O. Yurt(2007) entitiled " The Impact of Services Supply Chain Orientation on Perceived Industrial Service Quality: An Empirical Analysis".*

cannot control the materials flow form point of origin to point of consumption in whole [2,4,5,6,7]. Beside these factors; increasing tendency on global sourcing, emphasis on changing competition rules, increasing environmental uncertainty are some other reasons for the increasing importance of supply chain concept [8]. Regarding to its significance, both academicians and practitioners emphasized on the definition and scope of supply chain concept. Especially, from the early 90's, the concept has gained more attention.

Supply chain has been accepted as just "a chain or cycle of business with one to one; business to business relationships" for many years [9,10]. However, many definitions of a supply chain have been offered in the literature especially in the recent years. Simply, a supply chain is a network of facilities and distribution options that performs the functions of procurement of materials; transformation of these materials into intermediate and finished products; and distribution of these finished products to customers [11]. Some examples of alternative supply chain definitions from the literature that were offered in recent years:

> *"...the network of organizations that are involved, through upstream and downstream linkages, in different processes and activities that produce value in the form of products and services in the hands of ultimate consumer"* [12].

> *"...is a network of facilities that performs the functions of procurement of material, transformation of material to intermediate and finished products, and distribution of finished products to customers"* [13].

> *"...encompasses every effort involved in producing and delivering a final product, from the supplier's supplier to the customer's customer. Four basic processes-plan,*

source, make, deliver- broadly define these efforts, which include managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer" [14].

"... a set of three or more entities(organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer" [8].

"...consists of the series of activities and organizations that materials move through on their journey from initial suppliers to final customers" [15].

Today, the definition of supply chain is clearer among the academics and practitioners than the definition of 'supply chain management' [8, 9, 16, 17].

1.2. THE CONCEPT OF SUPPLY CHAIN MANAGEMENT

Especially after 90's, both practitioners and academicians are interested in supply chain management notion. They firstly focused on the concept of cooperation in network relations and the evaluation of basic supply chain practices. Then, the businesses were managed according to the requirements of their supply chain system. Accordingly, companies emphasized on the best supply chain practices increase their efficiencies. Basic objectives of supply chain management were recognized as the "cost competitiveness" and "effective inventory management" [18,19]. Although, supply chains were identified as just the chains of companies during those years, in time, the nature of supply chain management changed as the management of multi-tier and collaboration based network [19].

Starting from the 20th century, the need for effective supply chain management has increased due to the need of companies for greater efficiency and lower total cost. Therefore, when a company is isolated from the other members of supply chain, gaining competitive advantage will be impossible for that company [14].Supply chain management is an effective tool for companies to improve their customer satisfaction levels by reducing total cost of logistics and increasing market share, sales revenue and effectiveness of customer relations[20]. Consequently, an effective supply chain management creates competitive advantage for the companies by increasing the level of value delivered to customers [21]. In this context, Porter's study [22] on value chain, in which the conceptualization of the value chain and value system were identified, is critical for supply chain management literature. Porter's generic value chain is depicted in Figure 1.

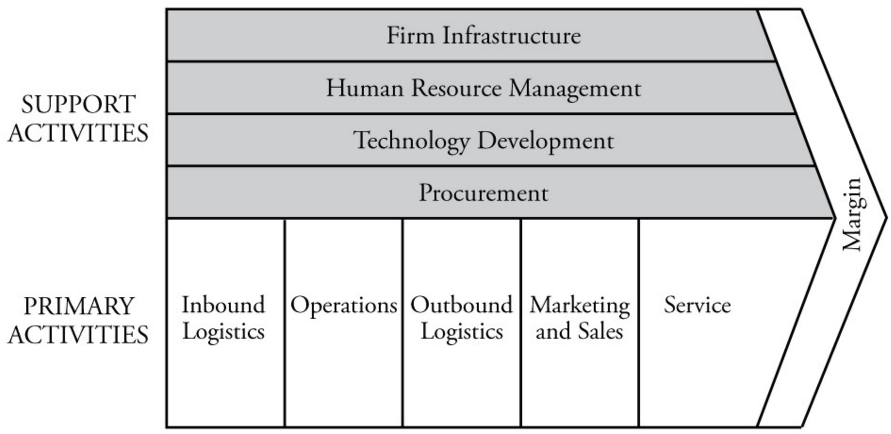


Figure 1: The Generic Value Chain

Source: [22]

Porter [22] emphasized the importance of supply chain management for competitiveness of a company by stating as the following: "…differences among competitor value chains are a key source of competitive advantage". Similarly, Christopher's [12] following statement transmitted Porter's[22] view into the supply chain management literature: "...competition takes place between supply chains rather than between individual companies"**.**

As mentioned before, companies cannot be isolated from their supply chain partners such as their suppliers and distributors. However, a particular firm can be a unit of different supply chains. Due to these reasons, supply chain management is a complex task. Although, the management of interrelationships and coordination between different departments and operations in a single company such as; production, sales, finance, marketing and distribution, in order to manage the materials flow was the main focus for companies in relatively less competitive markets, it is not enough to gain competitive advantage for the companies. The management of interdependent functions of different members in various supply chains required for business success [10]. Therefore, supply chain management is critical for all members of the entire system. In this context, the concept of supply chain management is based on the "systems approach". The systems approach was firstly proposed by [23] and [24] and it simply states that "the elements of a system affects each other, and will act differently when isolated from their environment or other components of the system". Similarly, supply chain management is the management of a system in which each firm's performance will affect the others' and the performance of the entire chain [25,26].

Based on the systems approach and accordingly supply chain management philosophy, all activities of each supply chain members should be traded-off in order to achieve the least total cost of logistics [27]. In this context, different members of supply chain should share goals, objectives and strategies of the entire system. The results of a supply chain management notion will be as the following: "customer power, long-term orientation, leveraging technology, enhanced communication across organizations, inventory control, interactivity, inter-functional and inter-organizational coordination" [28]. Beside these results, one of the important outcomes of an effective supply chain management is the creation of "synergy" within the members of supply chain. Synergy, basically refers that the outcome which is achieved by the collective effort of different components of a system will be greater than the sum of the efforts of the individual parts. It is safe to state that, if synergy creation is possible between different partners in a supply chain, there exists an effective supply chain management.

There are many different methods of approaches to supply chain management. Supply chain management is an extensive concept and a field of study that is an overlapping area of many academic disciplines. Therefore, it can be defined and examined from many different perspectives including purchasing and supply, logistics and transportation, marketing and strategic management [29]. Supply chain management is a relatively new concept and there are many different concepts which are very close to supply chain management area. Those concepts, including procurement and supply management, value-stream management, integrated purchasing, supplier integration, buyer-supplier partnership, supply base management, value added chain, network supply chain management and value chain management have turned into popular topics both for the practitioners and academicians [12,13,30,31,32]. Therefore, there are many different studies on supply chain management.

The term "supply chain management" was firstly appeared in the literature in early 80's [e.g. 33, 34] and Forrester's [35] research on 'industrial dynamics' is one of the first study that was related to supply chain management area. Besides, studies on 'least total cost concept' in physical distribution, transportation, and logistics area [36, 37] affected the development of supply chain management concept and these studies highlighted the importance of supply chain integration [38].

Some examples of alternative supply chain definitions from the literature that were offered in recent years:

> " … an integrative approach to dealing with the planning and control of the materials flow from suppliers to end users" [34].
>
> "… is an integrative philosophy to manage the total flow of distribution channel from supplier to ultimate user" [39].
>
> "…the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across business within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" [8].
>
> "…encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance and information technology" [41].

It should be noted that supply chain management concept is examined only in a few industries and especially in different divisions of manufacturing industries. In this context, Burgess and Singh [41] stated as: "Apart from a lack of consensus on the theoretical and historical determinants of SCM, there is also considerable bias toward extrapolating principles from consumer markets (most notably automotive and computer industries) to other types of supply chains." To this extent, this study focused on food supply chain, more specifically olive oil industry. Accordingly, the concept of food supply chain is presented in the following part of this chapter.

1.3. FOOD SUPPLY CHAIN[2]

Food industry has become one of the leading sectors that affect social and economic environment especially in the recent years. Accordingly, supply chain practices in the food industry have become more critical for food companies' competitiveness. Therefore, the supply chain system in food industry should be designed and managed according to the requirements and constraints of the sector due to the special characteristics of the food product. Hence, food supply chain research would be valuable both for researcher and practitioners of the field.

It should be noted that, although there are various studies on food supply chain in the literature [e.g. 42, 43, 44, 45] an important part of this research focuses on food industry [e.g. 46, 47, 48, 49, 50]. Each of these studies emphasizes one particular type of food products

2 This chapter is adapted from the following studies of the author: "*Yurt Ö., Cselenyi J., Illes, B., "Method for Evaluation of Food Supply Chain in Case of Inland Use", Conversations at Miskolc, 13-14 September 2006, pp: 77-84; Yurt Ö., Cselenyi J., Kerepeszki I., "Examination of Typical Food Supply Chain", MicroCAD-2006 International Scientific Conference, 16-17 March 2006, pp:191-197. and Yurt Ö., Cselenyi J., Kerepeszki I., "Fundamentals of Surveying Customer Satisfaction within Characteristics Food Supply Chains", 5th International Conference of PhD Students, 10-24 August 2005, pp: 217-222."*

and/or concentrated on just a few aspects of food supply chain. Thus, there is a research gap on generic and entire food supply chain.

Food supply chain concept become critical for companies performing in food industry since food industry have some distinctive characteristics such as perishable nature of products and small contribution margins in the sector [51]. Other characteristics of food industry which affects the nature of food supply chain are: “World-wide concentration of food producers, increasing power of retailers, shelf life constraints for raw materials, changes in product quality level while progressing the supply chain, recycling of materials required, long production throughput times, seasonality in production, variability of quality and quantity of supply of farm-based inputs, high volume, low variety, highly sophisticated capital-intensive machinery focusing on capacity utilization, variable process yield in quantity and quality due to biological variations, necessity to value all parts because of complementarily of agricultural input” [43]. With regard to stated characteristics of food industries velocity, flexibility, quality, cost, service and shelf life are the major drivers of food supply chain performance [52].

For supply chain performance, balancing demand and supply in food industry, especially in agri-food industry is complex task. Taylor and Fearne [53] proposed a process for synchronization demand and supply by reducing the variability of final demand and linking it to decisions in production levels. In this context, they suggested three factors affect demand in food supply chains: “demand variability, miss-alignment of demand and activity along the chain and poorly managed daily demand”. Similarly, Taylor [50] proposed that there exist some operational features of demand management which can be potential problems along the food chain: “complexity of procedures for handling demand information; data availability, accuracy and consistency: forecast proliferation, problems in sharing consumer demand data, timeliness of order transmission, lack of ‘on shelf availability’ data.

Accordingly, a variety of aims for food supply chain entities include; decreasing lead-time, minimizing food waste and being agile and lean [54,55]. For the sustainable food supply chain management, these aims have to be shared by all members of the chain.

Generic food supply chain has six main participants: consumers, retailers, caterers, wholesalers, manufacturers and primary producers (e.g. agricultural producers, farmers and fishers) [56]. Other possible members of the chain are packaging suppliers, agricultural merchants, logistics service providers and other third parties. Vorst et al. [56] divided food supply chains into two as: “supply chains for fresh agricultural products such as fresh vegetables, flowers, fruits” and “supply chains for processed food products such as snacks, desserts, and canned food products”. First group of food supply chains include growers, auctions, wholesalers, importers and exporters, retailers and specialty shops in which the handling, storing, packing, transportation, and especially trading of these goods are fulfilled. In the second type of food supply chain, main members are the growers, importers, food industry, retailers and out-of home segments and their logistics service suppliers.

Since, all members of food supply chain aim to satisfy quickly changing customer demands, end users play a key role in developing the structure of the food supply chains. Changing customer demands are mainly affected by the new trends including emphasis on healthy eating and concern for ethical issues. These trends affect the entire supply chain and therefore each supply chain member adapts these issues to protect their competitiveness. Therefore, characteristics and varieties of the foods, demanded by the customers, are continuously changing. In this context, olive oil becomes one of the more demanded products in the food industry, which is the main sector we will analyze in this thesis.

In the next chapter, information on the olive and oil industry, especially in Turkey is presented.

CHAPTER 2[3]: OLIVE OIL INDUSTRY IN TURKEY AND OLIVE OIL SUPPLY CHAIN OF TARİŞ

The aim of this thesis is to optimize the distribution network of olive and olive oil supply chain for Tariş to achieve cost minimization and profit maximization. This chapter provides data on the current of olive and olive oil production and the industry especially in the Aegean Region of Turkey, as well as the supply chain system of Tariş.

2.1. OLIVE OIL IN TURKEY

In general, olive production can be separated as “for culinary” and “for olive oil”. Olive oil is a vegetable oil that is obtained after the compression of olive and the only raw material needed for olive oil is “olive”. Approximately 30% of an olive’s weight is olive oil [57].

In Turkey, olive is cultivated by 33 different countries near to Aegean and Mediterranean Regions. Olives are being compressed by a number of physical processes. No other raw material is included to these processes. Olive pressing plants have adopted more recent technologies and increased their capacities in the country. Therefore, the amount and the quality of olive oil have improved [58].

2.1.a. Classification of Olives

Olive trees are cultivated in different regions of Turkey which are: Aegean, Mediterranean, Marmara, Southeast Anatolian and Black Sea. Based on the sub-regions of the Aegean Region, different types of the olives are called as: “Ayvalik, Cakir, Cekiste, Cilli, Domat,

3 This part is mainly adapted from the following study of the author: *VALUATION OF EXISTING SUPPLY CHAIN OF OLIVE AND OLIVE OIL by Yurt, Cselenyi and Illes in MicroCad 2007.*

Edincik Su, Erkence, Izmir Sofralik, Kiraz, Memecik, Memeli, Uslu, Esek Zeytini, Hurma Karaca, Ak Zeytin, Karayaprak, Yag Zeytini, Yerli Yaglik, Asi Yeli, Tas Arasi” [59].

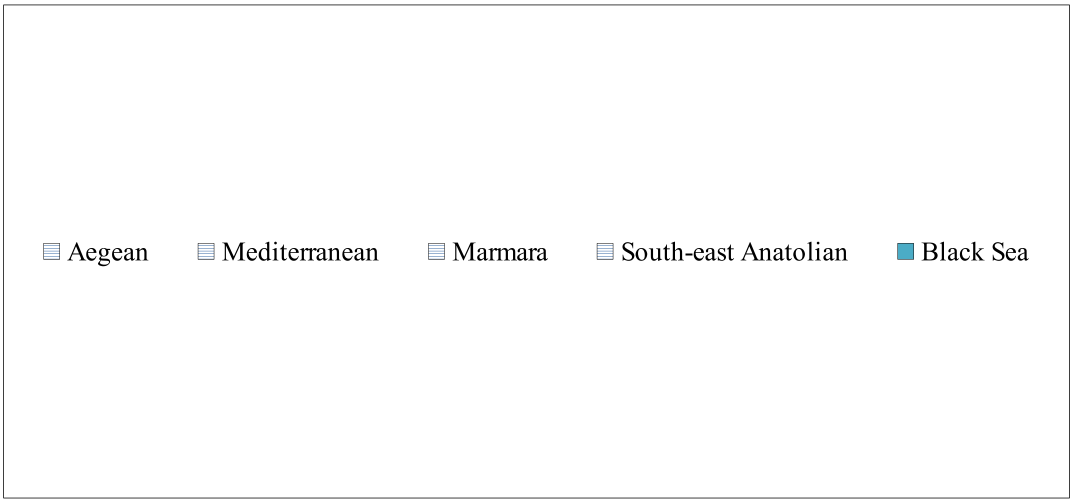


Figure 2: Olive Production According to the Regions of Turkey [60]

In Figure 2, olive production relative to the regions of Turkey is illustrated. Aegean Region is the dominant region in olive production which accomplishes the 76% of the total olive oil production of Turkey. The olive production of the Aegean Region and the Mediterranean Region reach to 90% of the Turkey’s total production. It should be noted that 70 % of the total olive production is for the aim of olive oil.

2.1. INFORMATION ON TARIŞ

Tariş Olive and Olive Oil Agricultural Sales Cooperatives Union (Tariş) is chosen from various olive and olive oil manufacturers in Turkey as a research unit since it represents enough volume, contains significant number of cooperatives, manufacturers and processing plants and produces many types of packaging modes and product types.

"There are 33 cooperatives and 27,000 producers that belong to Tariş Olive and Olive Oil Agricultural Sales Cooperatives Union. In addition, 28 modern olives pressing facilities, 14 pickling works, independent olive producing facilities, an R&D department, an internationally accredited laboratory serve for delivering most quality products and better customer services with the international quality licenses of ISO9000 and ISO9002. The cooperative union supports its partners in the following ways." [61]:

- Providing saplings appropriate for the regional conditions,
- Offering proper fertilizers,
- Helping with the prevention of diseases prevalent in olive groves,
- Providing producers with appropriate analyses,
- Increasing production in groves with the help of modern sowing techniques,
- Making sure old trees are pruned properly,
- Making sure that the newly established olive groves and existing olive groves have consistent standards,
- Giving educational opportunities to teach members how to improve the quality of olives and olive oil,
- Facilitating credit for machinery and working capital,

- Providing for cooperative functions of analysis, purchase and pressing,
- Developing new products and adding value to combined products,
- Distributing group profits to members.

2.2.a. Classification Of Olive Oil Produced By Tariş [61]

There are 5 different types of olive oil produced by Tariş. Detailed information is provided on the website of Tariş. Related information is as follows:

"The packaging depends on the quality of olive oil. Packaging of Extra Virgin Organic and Extra Virgin Special is special glass in 5.00 ml, Virgin Olive Oil is in 7.00 ml ceramic glass; Riviera Olive Oil is in 1.000 ml, 2.000 ml, 5.000 ml and 18.000 ml tin and Refined is in 1.000, 2.000 and 5.000 ml bottle and tin."

Period	Production (ton)	Capacity Ratio (ton)	Capacity Usage Ratio (%)	Number of Factories
1997-1998	40.000	267.000	15	810
1998-1999	200.000	272.000	74	813

Table 1:Olive Oil Capacity-Production (Turkey) [62]

Table 1 shows the capacity and capacity usage ratio of olive oil production factories in Turkey. 98% of production capacity has already been developed in 1997-1998 time interval (the number of factories are 96,6 %) but in the pre-interval, only 15% was used. However, during the second period it has been increased to 74%, almost five times bigger.

In Turkey, there are approximately 1000 rendering plants with hydraulic press. 350 plants are with continuing centrifuge and 200 of them possess equipment that are imported from abroad. On the other hand, 150 of them possess domestic equipment [58].

Figure 3 illustrates the olive oil production in ton/season in Turkey with a larger time interval which shows 8 consecutive seasons. The figures show that the yearly production fluctuates between 40.000 ton/season and 200.000 ton/season. If the average of consecutive 2 years is calculated it is observed that the averages are 10.000 ton/ season, 117.000 ton/ season, 100.000 ton/year, and 110.000 ton/year. It should be noted that during the first two periods (1997/1998 and 1998/1999) the two year's production ratio is 5 but in the last 2 years this ratio is only 1,75, namely some kind of smoothing tendency could be visible. The causes of this additionally examination should be needed.

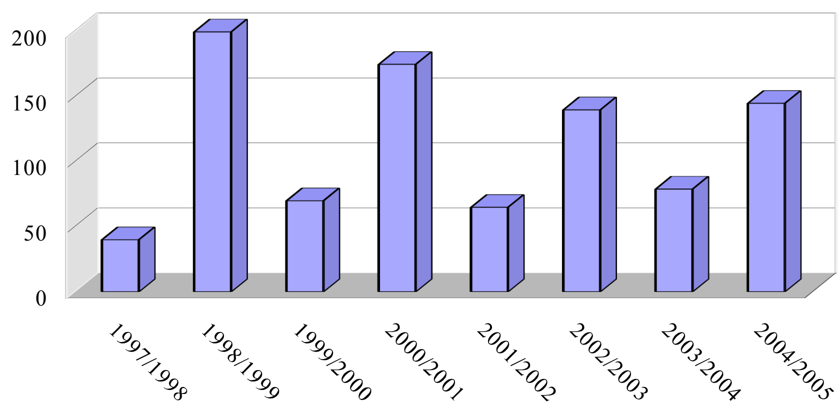


Figure 3: Olive Oil Production in Turkey *(.000 tons)* **[63]**

2.2.b. Production Figures Based on the Provinces

Table 2 shows the distribution of olive oil production between provinces in Aegean and Marmara Regions between 2005 and 2006.Table 2 illustrates that:

- At individual provinces the ratio of fruitful trees, show significant deviation from the average value (11.133.798 trees (14,2 %)): the maximum is 26,85% at Aydın and this value is only 5,23% at Çanakkale,
- The ratio of fruitful trees and non-fruitful trees also show significant deviation: 39% is at Balikesir and 3,7% is at Mugla accordance with 6,9%.
- The average number of fruitful trees for 1 ton olive oil is 14,4 trees but in Balıkesir this is 42,3 trees and 6,9 trees at Manisa.
-

Additional data collection is needed to reveal of causes of experiences.

Appendix 1 illustrates the net production and consumption of olive oil on a wider time frame. According to the data in Appendix 1, the following tendencies can be concluded in relation to 2000/01-2005/06 seasons:

- The olive oil or production area gradually increased 10% and the increasing of total number of trees is similar to it (11,1%),
- The total olive production is not showing a tendency to increase in the examined time frame but at the same time this tendency is true at the olive production for the consecutive 2 years. The volume of production is increasing as 2,6-1,81 times and the average values of 2 years are 1.200.000-1.325.000 ton/year,
- The ratio of total olive production to total olive production is fluctuating between 5 % and 80%,
- The yearly olive oil production is fluctuating between 65.000 ton and 175.000 ton, and the 2 years cycle is true for it which average is between 111,5 and 150 thousand ton/year,

- In the examined period the available amount is derived from the olive production and the starting stock, and it is seen that the ratio of export fluctuates between 33% and 62,5% and there were no import in any year,
- The season ending stock level is between 0 and 14,29% of usable amounts.

Province	Number of Trees (Fruitful)	Number of Trees (Non fruitful)	Ratio of fruitful trees to non fruitful	Olive Oil Production (ton)	Number of fruitful trees for 1 ton of olive oil production
Balıkesir	10.382.600	405.945	39,0	24.550	42,3
Canakkale	4.078.803	242.400	5,59	11.343	16,8
Manisa	8.193.385	1.173.295	14,3	10.431	6,9
Aydin	20.930.151	1.351.406	6,45	6.670	15,49
Mugla	12.795.177	475.085	3,7	3.242	26,93
Izmir	13.083.470	1.212.750	9,26	9.861	10,79
Bursa	8.468.000	525.000	6,2	2.709	16,13
Total	**77.936.586**	**5.385.881**	**6,9**	**68.788**	**14,4**

Table 2: 2005-2006/ Olive Oil Yielding Rough Table (Aegean and Marmara Regions) (adapted from [64])

Appendix 2 illustrates the production data for olive oil and olive between 1989/1990 and 2000/01 seasons. According to the data in Appendix 2:

- The number of fruitful trees increased 12% during the last 12 years,
- The increase ratio is 2 times bigger at the first 6 seasons of olive oil production and the significant production described in previously is true for the last 8 seasons,

- The increase ratio of olive for olive oil production is between 60% and 75%. The increase is 1,66 during the last 12 years which shows that the share of olive production is decreasing,
- The olive oil production has increased 66% during the 12 years, which is smaller (2 times) in comparison with olive production.

CHAPTER 3[4]: DISTRIBUTION NETWORK MODEL FOR A GENERIC FOOD SUPPLY CHAIN

In this chapter, the distribution network structure and the constructs of a general mathematical model for a generic food supply chain are presented. After this general model, specific model for distribution network optimization for olive oil supply chain will be presented in the next chapter.

In this chapter, we aim to give a conceptual framework of distribution network structure of food supply chain. For this aim, distribution network structure of a generic food supply chain is illustrated in Figure 4. It should be noted that distribution network structure may change by product.

As known, if just one supplier exists, that may also may act as manufacturer and at least one individual customer, we can say that this is the simplest form of a distribution channel. From this simplest form to the largest, structure of food supply chain can vary based on different number of echelons that will exist in the system. In this Figure 4, distribution network structure of a food supply chain is provided in the largest extent. All possible members of such a system are involved in the figure. Also, exporting activity is included at all levels.

4 This chapte is mainly adapted from the following study of the author: *Yurt Ö., Cselenyi J., Illes, B., "Method for Evaluation of Food Supply Chain in Case of Inland Use", Conversations at Miskolc, 13-14 September 2006, pp: 77-84.*

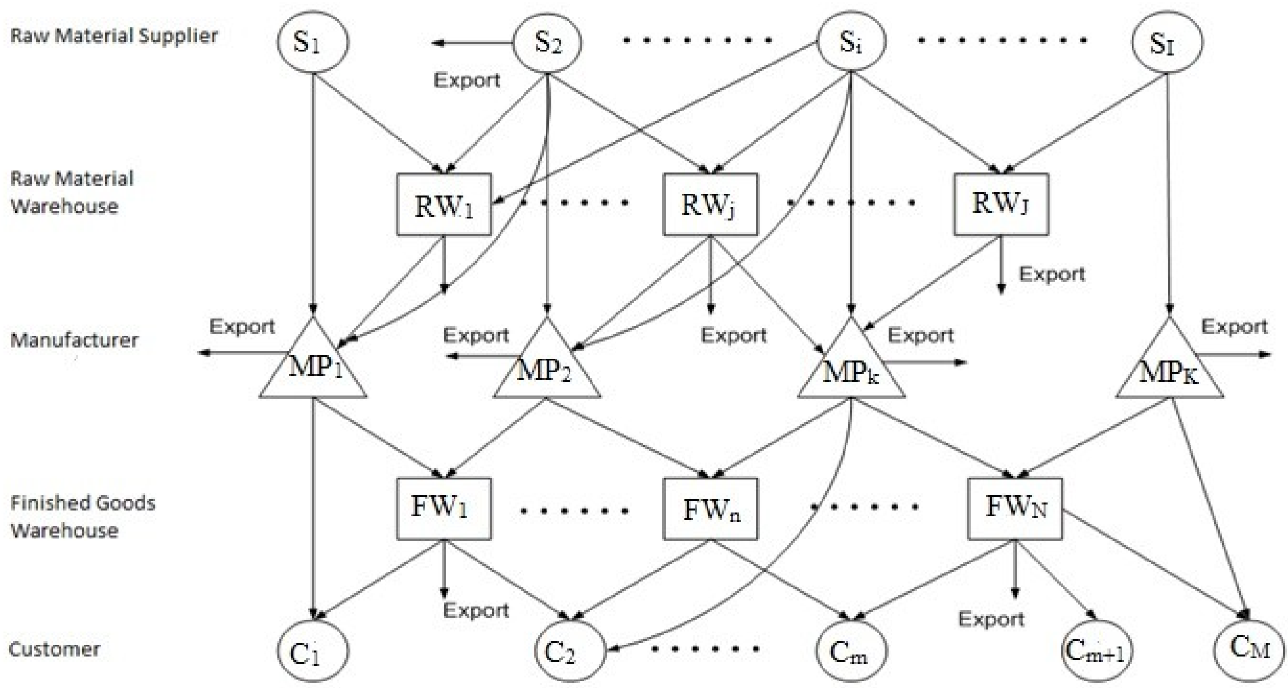


Figure 4: Distribution Network Structure of a Generic Food Supply Chain

Members of the generic food supply chain are represented as follows:

Raw material supplier: $S_i i = \{1, \ldots, I\}$

Raw material warehouse: $RW_j j = \{1, \ldots, J\}$

Manufacturing plant: $MP_k k = \{1, \ldots, K\}$

Finished goods warehouse: $FW_n n = \{1, \ldots, N\}$

Customers: $C_m m = \{1, \ldots, M\}$

Processes of generic food supply chain model are represented as follows:

Raw material distribution:

- **Direct:** $S_i \rightarrow MP_k$
- **Indirect:** $S_i \rightarrow RW_j \rightarrow MP_k$

Finished goods distribution:

- **Direct:** $MP_k \rightarrow C_m$
- **Indirect:** $MP_k \rightarrow FW_n \rightarrow C_m$

Exported raw materials:

- **Direct:** $S_i \xrightarrow{A_w^1} E$
- **Indirect:** $RW_j \xrightarrow{A_w^2} E$

Exported finished goods:

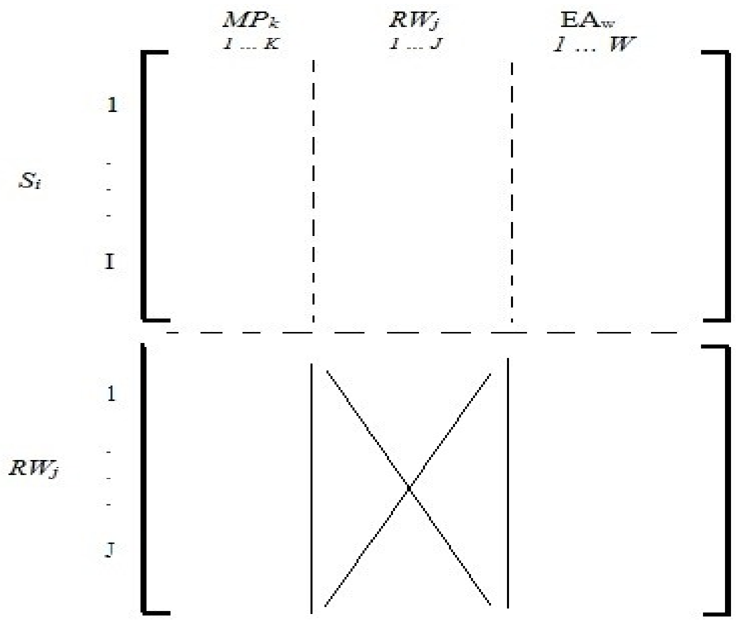
- **Direct:** $MP_k \xrightarrow{B_z^1} E$
- **Indirect:** $FW_n \xrightarrow{B_z^2} E$

Destination of exported raw materials: $w = \{1, \ldots, W\}$

Destination of exported finished goods: $z = \{1, \ldots, Z\}$

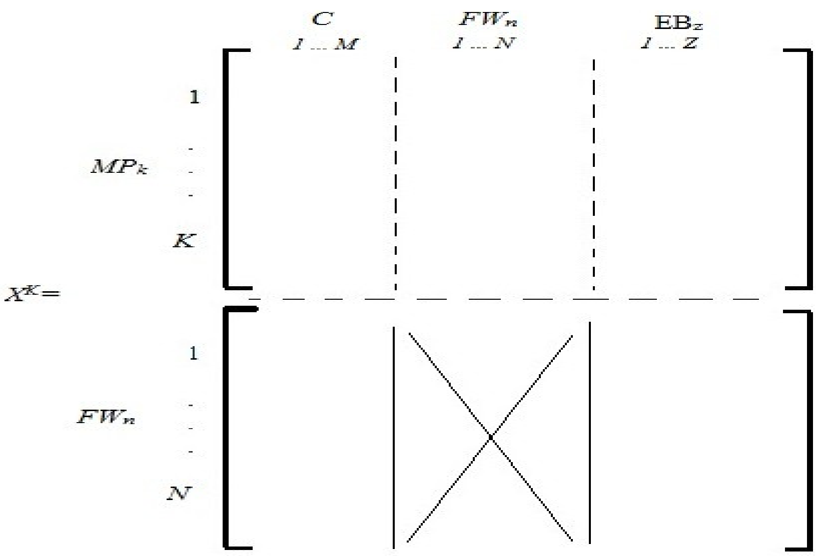
Distribution network structure and possible assignments between supply chain members are represented by X^A and X^K matrices.

a) Raw materials distribution matrix (X^A):



X^A matrix shows that raw materials are distributed either from the supplier or the raw material warehouse. From the supplier, raw materials are shipped to the manufacturing plant, raw material warehouse or they can be exported. From the raw material warehouse, raw materials are either shipped to the manufacturing plant or exported.

b)Finished goods distribution matrix (X^K):



Matrices X^A and X^K represent the structure of the distribution network and the possible distribution activities. If X takes value 1, then this means that the distribution activity occurs. Otherwise, there is no distribution activity between the mentioned parties.

Packaged products are produced by using different raw materials and packaging alternatives. There are different raw materials. From each raw material different finished goods can be manufactured. Also each finished good may be offered to the market in various packaging alternatives. Thus, the production process and the product tree are represented as follows and illustrated in Figure 5:

Raw materials: **r = {1, …, R}**

Finished goods: **f = {1, …, F}**

Packaging type: **p = {1, …, P}**

Logistics activities within and between different members of supply chain are represented in Figure 6.

R_{μ}^{ik} is the μ th logistics activity in the *i*-*k* relation, which are shown as subset of

The R_{μ}^{iv} **subset**

R_{μ}^{iv} is the subset of L_{TS} union

$R_{\mu}^{ik}=\{L_{TS}\}$

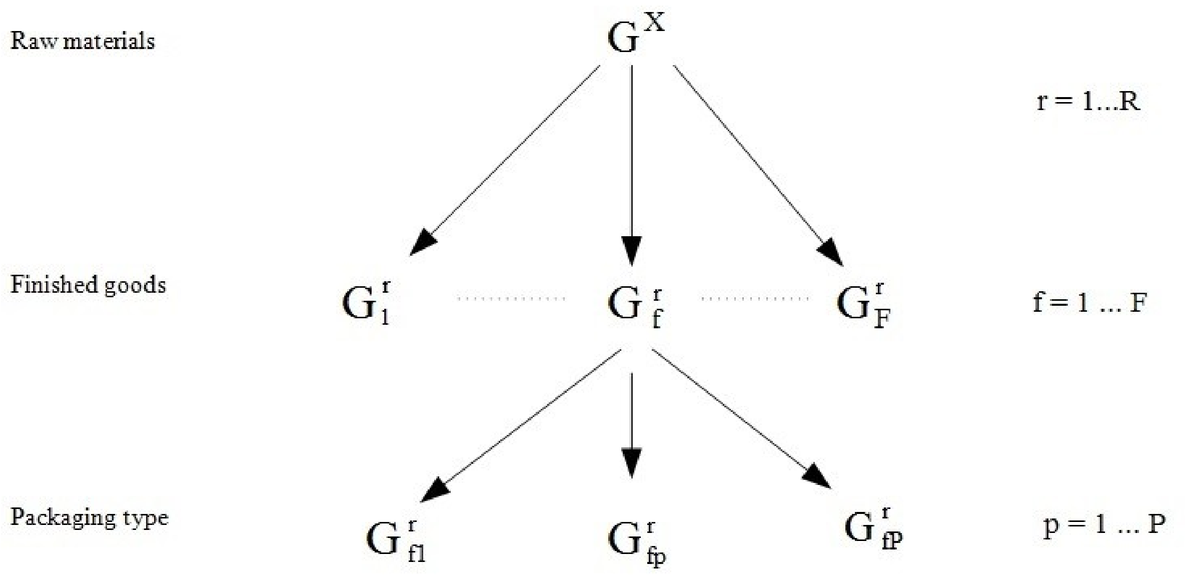


Figure 5: Production process

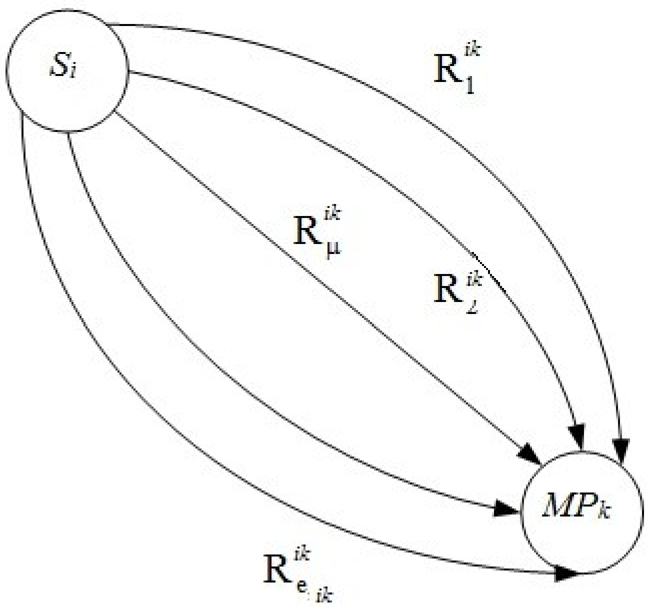


Figure 6: **Logistics activities fulfilled along the supply chain**

Where T means sequence of the logistics operation and s refers to typical logistics operations:

s=1 road transportation

s=2 rail transportation

s=3 ship transportation

s=4 air transportation

s=5 dispatching

s=6 stocking

s=7 customs clearance

As an example, direct road transportation is a possible logistics activity between an *(i-k)* pair.

Then the R_{μ}^{ik} contains the item L_{11} in which $T=1$ and $s=1$. $T=1$ means the sequence of the logistics activity is 1, in other words direct. $s=1$ means the selected logistics activity is road transportation.

Based on the generic model presented in this chapter, Chapter 6 provides a specific model for a firm, Tariş, operating in the olive and olive oil industry in Turkey. Data collection process, required for the specific model, is presented in the next chapter.

CHAPTER 4[5]: DATA COLLECTION

Data is collected is through observation and face to face interviews with Tariş managers and workers. Also, information on the Tariş's [6] website is used to support data collection. Face to face interviews are conducted by a semi-structured questionnaire. Questions are as follows:

1. Please provide information about your sector, your company and your operations.
2. What is the number of production centers? Where are they positioned?
3. How many suppliers do you have?
4. What is the number of raw materials and semi finished goods that you use? How can you classify them?
5. How can you classify your suppliers? Where are they positioned?
6. Which transportation mode(s) is/are used during distribution activities between suppliers and production centers? What are the usage percentages?
7. How can we classify manufacturers in your sector?
8. Do you outsource transportation activity to a third party logistics firm?
9. What is the total production volume (weekly, monthly and annually)?
10. How many different types of finished goods do you produce?
11. How many warehouses and/or distribution centers do you use? What are the capacity levels?
12. What are the raw materials and finished goods inventory replenishment times in warehouses and/or distribution centers?
13. Do you outsource packaging activity to a third party firm?

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5 Data is provided by TARIŞ staff.

6 http://www.tariszeytinyagi.com/ http://www.ta-ze.ca/ca/en/default.aspx

14. How many different packaging types do you use?

15. What is the final industrial distribution channel member?

4.1. DATA ON RAW MATERIALS

Raw materials used in production can be classified as;

a. Basic raw material: Natural-extra virgin olive oil.

b. Packaging materials: There are different types of raw materials that are used in packaging process. These are: tin can, tin cap, card board box, glass bottle, glass bottle cap, cork, label, plastic bottle and plastic bottle cap.

c. Other raw materials: Adhesive for card board box and nylon used for shrink-wrapping.

4. 2. DATA ON SUPPLIERS

a. All domestic glass bottles are supplied from Anadolu Cam Sanayii, which is the leader glass producer company in Turkey.
b. Imported glass bottles, glass bottle cans and corks are supplied from the manufacturers in other countries.
c. Plastic bottles, plastic bottle cans, labels and card board boxes are supplied from various manufacturers in Turkey.
d. Natural-extra virgin olive oil is supplied from different cooperatives located in north part of Aegean Region.
e. Tin cans are supplied from suppliers in Kocaeli.

Suppliers of Tariş are located in different regions of Turkey. They can be classified as:

a. Raw materials suppliers are located in the Aegean region.
b. Packaging materials suppliers are located in the following cities: İzmir, İstanbul, Mersin, Kocaeli.
c. Suppliers of others work in process materials suppliers are located in the following cities: İstanbul, Kocaeli, İzmir.

4.3. DATA ON PRODUCTION

Tariş Olive and Olive Oil Agricultural Sales Cooperatives Union has just one manufacturing plant. Other producers in the sector are profit oriented legal entities. Production volumes are given on the monthly basis in Appendix 3, Appendix, Appendix 5 and Appendix 6. Capacity of the production plant is 45.000 lt/month.

Final Products:

There are 10 different versions of natural extra virgin olive oil packages that are offered to the market. 6 of them are different types of tin boxes, 4 of them are different types of glass bottles.

Tin box packages are: 1 lt tin can natural virgin olive oil, 1.5 tin can natural virgin olive oil, 2 lt tin can natural virgin olive oil, 3 lt tin can natural virgin olive oil, 5 lt tin box natural virgin olive oil, 18 lt tin can natural virgin olive oil.

Glass bottle packages are: 250 ml glass bottle (maraska type) natural virgin olive oil, 500 ml glass bottle (maraska type) natural virgin olive oil, 750 ml glass bottle(maraska type) natural virgin olive oil, 1000 ml glass bottle(bertolli type) natural virgin olive oil.

4.4. DATA ON TRANSPORTATION

The only transportation mode that is used to carry raw materials to production plant is road transport. Raw materials are transported by trucks, centipede trucks and heavy goods vehicles.

Road transportation is outsourced to a third party logistics firm, called Ceva Logistics, in truck load(TL) less than truck load(LTL) basis.

LTLs can be classified as:

1)1-100 kg

2)101-1000 kg

3)1001 kg and more

TLs can be classified as:

1) Truck load(6-15 ton)

2) Centipede truck load (15-19 ton)

3)Heavy goods vehicle load(19 ton and more)

As mentioned before, Tariş divides Turkey into 5 geographical zones according to their distances to Izmir:

1st Zone: Interior Izmir

2nd Zone: (For instance Denizli is 236 km far away from Zone 1)

3rd Zone: (For instance Istanbul is 600 km far away from Zone 1)

4th Zone: (For instance Adana is 939 km far away from Zone 1)

5th Zone: (For instance Erzurum is 1466 km far away from Zone 1)

Transportation costs

The rate of transportation costs to total turnover was roughly 1, 8% in 2007 and it was 2% in 2008.

The amounts and costs of TLs and LTLs are given according to different regions in the following Table 3 and 4. The rates are same for 2007 and 2008.

REGION	**SAMPLE PROVINCE**	**TL**		
		Truck 6-15 ton	Centipede truck 15-19 ton	Heavy goods vehicle 19 ton
INTERIOR IZMIR	İZMİR	12	20	25
1st Zone	DENİZLİ 236 KM	35	41	52
2nd Zone	İSTANBUL 600 KM	70	89	109
3rd Zone	ADANA 896 KM	100	121	153
4th Zone	ERZURUM 1466 KM	188	237	295

Table 3: Truck Load Freights

As shown in Table 7, transporting 15 tons of truck load to anywhere in Zone 1 is 35 unit whereas transporting same truck to somewhere in Zone 3 increases to 100 units.

In Table 8, it is seen that transporting 50 kg of less than truck load freight to anywhere in Zone 1 is 1,6 units whereas transporting same less than truck load freight to somewhere in Zone 4 costs 2.3 units.

REGION	**SAMPLE PROVINCE**	**LTL**		
		50 Kilos	500 Kilos	5000 Kilos
INTERIOR IZMIR	İZMİR	1,6	13	26
1st Zone	DENİZLİ 236 KM	1,6	13	29
2nd Zone	İSTANBUL 600 KM	1,8	13	66
3rd Zone	ADANA 896 KM	2,1	14	74
4th Zone	ERZURUM 1466 KM	2,3	14	126

Table 4: Less than Truck Load Freights

4. 5. DATA ON WAREHOUSES AND DISTRIBUTION CENTERS

There is 1 distribution center and there are 3 different types of warehouses. The capacities of the warehouses are as follows:

a. Finished product warehouse (distribution center) : 1.100 euro-pallet

b. Raw materials warehouse 1 : 40.000 ton

c. Raw materials warehouse 2 : 5.000 ton

d. Packaging materials warehouse: 1850 euro-pallet

4.6. DATA ON INVENTORY MANAGEMENT

- Average finished goods inventory level is: 300 ton.
- Average raw materials inventory level is: 8000 ton.
- Finished goods inventory replenishment period is approximately 1 day.

4. 7. DATA ON PACKAGING ACTIVITIES

Packaging activities are handled by "filling and packaging" unit of Tariş.

Different types of packages are as mentioned above. Two main packaging materials are tin and glass. Tin cans and glass bottles are covered by card board boxes in appropriate dimensions. Tin cans and glass bottles are put in card board boxes during filling and packaging process. Then, card board boxes are orderly stacked on wooden pallets. Finally, pallets are firstly sent to warehouses management centre and then card board boxes are dispatched to retailers or stores.

4. 8. DATA ON THE DELIVERY TO END USERS

National and international chain stores, supermarkets, grocery stores, sales stores and franchise stores of Tariş are the final destination of finished products for costumers buy them.

CHAPTER 5: MODEL FOR TARİŞ OLIVE OIL SUPPLY CHAIN AND APPLICATION

Based on the data gathered, distribution network model for TARİŞ, analysis, solution and results are presented in this chapter.

5.1.THE MODEL

Distribution network of Tariş is illustrated in Figure 7.

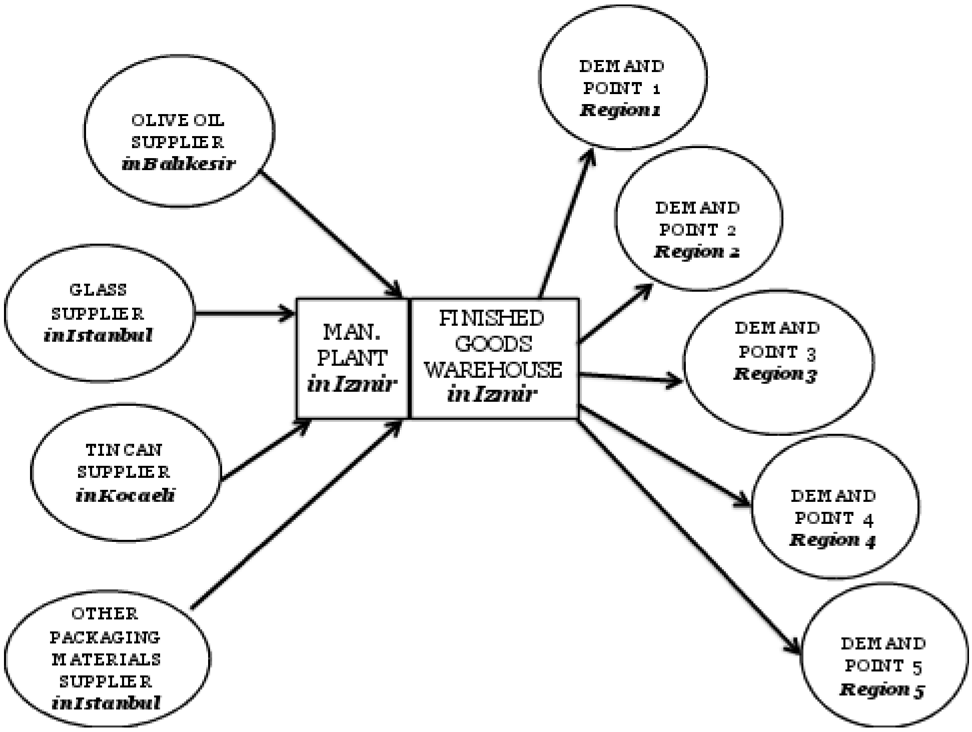

Figure 7: Olive Oil Network Model of Tariş in Turkey

As shown in the network model, there are 4 suppliers, 1 manufacturer (which is the focal company) and 5 demand points. Manufacturing facility basically acts as olive oil bottling company, which is located in Izmir. It has 2 main divisions: plant and finished goods warehouse. Raw materials warehouses are excluded from the model since they may not be used in all operations.

For production process, 4 groups of materials are needed: olive oil, glass, can and other packaging materials. Each group of materials is provided by different suppliers in Turkey. Therefore, there are 4 suppliers in the model. Olive oil is provided by a single supplier in Balıkesir, glass (bottles) are provided by a supplier in Istanbul, can (bottles) are provided by a supplier in Kocaeli, and other supporting packaging materials are provided by a supplier in Istanbul.

As mentioned before, Tariş sells finished goods to 5 main distribution regions in Turkey. In Figure 7, distribution regions are shown as demand points. 5 regions are determined based on their distances to Izmir. As an example; Denizli is 236 km to Izmir and accepted as in the2nd region. Similarly, Istanbul (600 km to Izmir) is in the 3rd region, Adana (939 km to Izmir) is in the 4th region, Erzurum (1466 km to Izmir) is in the 5th region.

In this thesis, we utilized optimization techniques, which are widely used for different types of problems including network design, manufacturing plants and design structures [65]. For this model, we use minimum – cost network flow minimization formulation in our mathematical model. General multi-commodity minimum cost flow formulation is shown and explained by Ghiani et al. [66] as follows:

"Let O(k), k $\in$ *K, be the set of origins of commodity k; D(k), k* $\in$ *K, the set of destinations of commodity k; T(k), k* $\in$ *K, the set of transshipment points with respect to commodity k;* o_i^k *, I* $\in$ *O(k), k* $\in$ *K, the supply of commodity k of vertex i;* d_i^k *, i* $\in$ *D(k), k* $\in$ *K, the demand of commodity k of vertex i;* $u_{ij}^{\square}$ *, (i,j)* $\in$ *A, the capacity of arc (i,j) (i.e. the maximum flow that arc (i,j) can carry);* u_{ij}^k *, (i,j)* $\in$ *A, k* $\in$ *K, represent the flow of commodity k on arc (i,j). Moreover,*

let C_{ij}^{k} *(* x_{ij}^{k} *), (i,j)* $\in$ *A, k* $\in$ *K, be the cost for transporting* x_{ij}^{k} *flow units of commodity on arc (i,j)."*

Minimize

$$\sum_{k\in K}\sum_{(i,j)\in A} C_{ij}^{k} x_{ij}^{k}$$

subject to

$$\sum_{\{j\in V:(i,j)\in A\}} x_{ij}^{k} - \sum_{\{j\in V:(j,i)\in A} x_{ji}^{k} = \begin{cases} o_i^k, if\ i\in O(k), \\ -d_i^k, if\ i\in D(k), \\ 0, if\ i\in T(k), \end{cases} (1)$$

$$x_{ij}^{k} \le u_{ij}^{k}, (i,j)\in A, k\in K, (2)$$

$$\sum_{k\in K} x_{ij}^{k} \le u_{ij}, (i,j)\in A, (3)$$

$$x_{ij}^{k} \ge 0, (i,j)\in A, k\in K, (4)$$

"The objective function is the total cost, constraints correspond to the flow conservation constraints holding at each vertex i $\in$ V and for each commodity *k* $\in$ *K. Constraints impose that the flow of each commodity k* $\in$ *K does not exceed capacity* u_{ij}^{k} *on each arc (i,j)* $\in A$ *. Constraints (bundle constraints) require that,*

for each (i,j) $\in A$ *, the total flow on arc (i,j) is not greater than the capacity* u_{ij} *.”*

In order to optimize distribution and production system of Tariş by minimizing cost and maximizing profit, we propose the following mathematical model.

Notations used in the model proposed in this study are as follows:

i**:** product types, $i = \{1, \ldots, I\}$

k**:** sales regions, $k = \{1, \ldots, K\}$

p_i**:** sales price of product *i*

oil_i**:** amount of oil required to produce product *i*

oc**:** unit cost of oil

t**:** unit transportation cost of oil from Kuzey Ege (Balikesir) to the factory

toil**:** total amount of oil available for production

pc_i**:** packaging cost of product *i*

tc_i**:** unit transportation cost of packaging material for product *i* from suppliers to the factory ***(can from Kocaeli, glass from Istanbul)

c_{ik}**:** cost of transportation for product *i* from factory to sales region *k*

d_{ik}**:** demand of sales region *k* for product *i*

Decision Variables:

$\boldsymbol{X_i}$**:** number of product *i* produced

$\boldsymbol{Y_{ik}}$**:** number of product *i* shipped to sales region *k*

Mathematical Model:

Maximize

$$p$$
$$¿$$
$$¿\, i - c_{ik} ¿\, Y_{ik} - \sum_{i=1}^{I} (oc * oil_i - pc_i) X_i - t * toil$$
$$¿$$
$$¿$$
$$\sum_{k=1}^{K} ¿$$
$$\sum_{i=1}^{I} ¿$$

Subject to:

$$X_i \leq \sum_{k=1}^{K} Y_{ik} \; \forall i \; (1)$$

$$\sum_{i=1}^{I} oil_i X_i \leq toil \; (2)$$

$$Y_{ik} \leq d_{ik} \; \forall i, k \; (3)$$

$$X_i \geq 0 \; \forall i \; (4)$$

$Y_{ik} \geq 0 \forall i, k (5)$

The objective function aims to **maximize the total profit.** Constraint set 1 shows that the amount of product i shipped to customer region k must be less than or equal to the amount produced. Constraint set 2 limits the number of products by the total available olive oil. Constraint set 3 states that the demand of each region may not be fully met. Constraint sets 4 and 5 state that decision variables are positive integers.

In Chapter 5 and in the Appendices, production data gathered from the company is presented. Notations used in the model are explained below.

In the model, products types are represented by *i* which are given in Table 5.

i	**Type of the final product**
1	1 litre tin can
2	1.5 litre tin can
3	2 litre tin can
4	3 litre tin can
5	5 litre tin can
6	18 litre tin can

7	250 ml tin can
8	500 ml tin can
9	750 ml tin can
10	1000 ml bertolli glass bottle

Table 5: Final Products of Tariş

Since, precise demand data is not available, demand volume is assumed as equal to the population. In other words, it is assumed that, all people will have a demand for olive oil. Therefore, in order to generate demand data, all provinces in Turkey are listed in Appendix 7. Their distances to Izmir and population data are included in the list.

Provinces are sorted in the ascending order based on "their distances from Izmir". Izmir is considered as Region 1. Provinces that are not more than 300 km away from Izmir are considered as the 2nd region. Between 300 and 600 km away from Izmir are considered as the 3rd region. Between 600 and 900 away from Izmir are considered as the 4th region and more than 900 km away from Izmir are considered as the 5th region. In the analysis, we used population data and assumed that the whole population is located in the center of the provinces. The distances used in the model are calculated according to these centers.

From each region we selected 3 densely populated provinces. We assumed that Tariş delivers final products to these selected provinces. These provinces are represented with *k* in the model. In Table 6, related data is provided.

k	**Provinces**	**Region**	**Distance to Izmir**	**Population**

1	İZMİR	*1st*	0	3.606.326
2	MANİSA	*2nd*	36	924.267
3	BALIKESİR	*2nd*	173	694.926
4	DENİZLİ	*2nd*	224	641.093
5	BURSA	*3rd*	322	2.308.574
6	İSTANBUL	*3rd*	565	13.120.596
7	ANKARA	*3rd*	580	4.641.256
8	KAYSERİ	*4th*	867	1.064.164
9	MERSİN	*4th*	889	1.281.048
10	ADANA	*4th*	896	1.836.432
11	GAZİANTEP	*5th*	1105	1.501.566
12	ŞANLIURFA	*5th*	1242	922.539
13	DİYARBAKIR	*5th*	1422	1.090.172

Table 6: Densely populated provinces

Based on the data in Table 6, transportation costs are calculated and given in Table 7. Distance based unit costs are provided by Ceva Logistics Company, which is located in Izmir. Truck capacity used in the analysis is 80 m^3.

k	**Total Transportation Cost (Tax added) TL**	**Calculated Transportation Cost (Tax added) –Including Truck Capacity Constraint (per m3)**
1	0	0
2	413.00	5.1625
3	649.00	8.1125
4	885.00	11.0625
5	944.00	11.8000
6	1,298.00	16.2250
7	1,534.00	19.1750
8	2,065.00	25.8125
9	2,360.00	29.5000
10	2,360.00	29.5000
11	2,832.00	35.4000
12	3,186.00	39.8250
13	3,186.00	39.8250

Table 7: Transportation Costs Based on Distances

We also calculated the volumes of each final product. In calculation we accept 1lt=0.001 m3. Volumes of each product and corresponding transportation cost per unit are given in Table 8.

Unit transportation costs of final products to each province are given in Appendix 8. As mentioned in this Chapter, production percentages are given on the monthly basis in Appendices 3, 4, 5 and 6 are based on the assumption that the capacity of the manufacturing plant is 45.000 lt./month and the plant works at full-capacity. Since the company only provided only the production percentages, we calculated *"average production volumes of each product per year"* using the total capacity and the production percentages. We assume that all these products are consumed in 13 representative provinces *(k).* Therefore, we calculated the total population of the representative provinces. By dividing total production volume to the total population, we found *"available product volume per person"*. Then, we multiplied *"product volume per person"* by the *"population of each province"* and found *"available production volume for each province"* and accept it as the *"representative demand of the*

province according to the product". Table 9, Table 10 and Table 11 present the related data.

i	**Volume of the final product (m3)**	**Transportation Cost Per Unit (TL)**
1	0,001	0,0051625
2	0,0015	0,0121688
3	0,002	0,0221250
4	0,003	0,0354000
5	0,005	0,0811250
6	0,018	0,3451500
7	0,00025	0,0064531
8	0,0005	0,0147500
9	0,00075	0,0221250
10	0,001	0,0354000

Table 8: Transportation Costs for Final Product Type

i	**Average Production Volume (yearly)**
1	59.483
2	98.246

3	103.370
4	51.878
5	137.371
6	6.837
7	9.901
8	20.757
9	35.680
10	16.226

Table 9: Average Production Volume

i	**Calculated Product Volume *(per person)***
1	0,00218
2	0,00240
3	0,00190
4	0,00063
5	0,00101
6	0,00001
7	0,00145
8	0,00152
9	0,00098
10	0,00060

Table 10: Calculated Product Volume

Demand *(i/k)*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	7.872	2.017	1.517	1.399	5.039	28.639	10.131	2.323	2.796	4.008	3.278	2.014	2.380
2	8.668	2.221	1.670	1.541	5.549	31.535	11.155	2.558	3.079	4.414	3.609	2.217	2.620
3	6.840	1.753	1.318	1.216	4.378	24.884	8.803	2.018	2.430	3.483	2.848	1.750	2.068
4	2.288	586	441	407	1.465	8.326	2.945	675	813	1.165	953	585	692
5	3.636	932	701	646	2.327	13.228	4.679	1.073	1.292	1.851	1.514	930	1.099
6	50	13	10	9	32	183	65	15	18	26	21	13	15
7	5.241	1.343	1.010	932	3.355	19.068	6.745	1.547	1.862	2.669	2.182	1.341	1.584
8	5.494	1.408	1.059	977	3.517	19.987	7.070	1.621	1.952	2.798	2.287	1.405	1.661
9	3.541	908	682	630	2.267	12.884	4.558	1.045	1.258	1.803	1.475	906	1.071
10	2.147	550	414	382	1.37	7.812	2.764	634	763	1.09	894	549	649

					5					3				

Table 11: Volume of Demand

5.2. SOLUTION AND RESULTS

We conducted the computational experiments on an HP Laptop with AMD Triple Core Processor 1.80 GHz, 4GB RAM and Windows 7 Professional. We solved the mathematical models using GAMS 22.5 and the solver CPLEX 11.2. Mixed Integer Programming Method is used for the analysis and the solution.

We selected CPLEX solver, since it is one of the most commonly used solvers for these types of problems. GAMS code is provided in Appendix 9. Another solver software, "Baron", widely used by experts, is also used to check and verify the results. The results were exactly same.

Based on the GAMS solution production volumes for each product type proposed by the results are different than the real production volumes. In Table 12, the "optimal column" shows production volumes provided by GAMS model. The "real column" shows the real production data of the company.

i	**Optimal**	**Real**	**Relative Gap**
1	73.413	59.483	0,23
2	80.836	98.246	-0,18
3	63.789	103.370	-0,38
4	21.341	51.878	-0,59
5	14.219	137.371	-0,90
6	0	6.837	-1,00
7	48.879	9.901	3,94
8	51.236	20.757	1,47
9	33.028	35.680	-0,07
10	20.026	16.226	0,23

Table 12: ComparisonTable for GAMS Solution and the Real Data

According to the Table 9, there is a gap between the real production data and the proposed solution. Direction of the relative gap represents the need for increase or decrease in the real production volume to reach the optimal values. Size of the relative gap represents need for percentage change in the real production volume.

Results show that, production of olive oil in 18 litre tin can (*i*=6) is not optimal. Also, optimal production level is for 5 litre tin can (*i*=5) is low although the real production is high. Therefore, there is high (negative) relative gap. On the other hand, according to the results, the production of 250 ml of glass bottle (*i*=7), has to be increased, since the relative gap is positive and has highest value. A lower, but still positive relative gap is found for 500 ml of glass bottle (*i*=8).

Since the price of glass bottled olive oils are higher than the tin cans, it is logical to increase the production volumes of both 250 ml of glass bottle and 500 ml of glass bottle. Also, there is improving customer awareness on healthy foods and packaging. Therefore, it can be said that the demand on glass bottled foods would increase.

i/k	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	7872	2017	1517	1399	5039	28639	10131	2323	2796	4008	3278	2014	2380
2	8668	2221	1670	1541	5549	31535	11155	2558	3079	4414	3609	2217	2620
3	6840	1753	1318	1216	4378	24884	8803	2018	2430	3483	2848	1750	2068
4	2288	586	441	407	1465	8326	2945	675	813	1165	953	585	692
5	3636	932	701	646	2327	5977	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	524	134	101	932	335	1906	6745	154	186	266	218	134	158

	1	3	0		5	8		7	2	9	2	1	4
8	5494	1408	1059	977	3517	19987	7070	1621	1952	2798	2287	1405	1661
9	3541	908	682	630	2267	12884	4558	1045	1258	1803	1475	906	1071
10	2147	550	414	382	1375	7812	2764	634	763	1093	894	549	649

Table 13: Distribution of Optimal Quantities to Provinces

According to the results, distribution of optimal quantities of each product to each province is given in Table 13.

Results show that, distribution of olive oil in 18 litre tin can (i=6) to any of the provinces is not optimal. It is logical since it is also not optimal to market the olive oil in 18 litre of tin cans. Also, distribution of 5 litre tin cans (i=5) to the provinces in; Ankara, Kayseri, Mersin, Adana, Gaziantep, Şanlıurfa and Diyarbakır is not optimal according to the results. These provinces are mainly located mainly in the 4th and 5th regions which are relatively far away from the production facility.

i/k	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	7872	2017	1517	1399	5039	28639	10131	2323	2796	4008	3278	2014	2380
2	8668	2221	1670	1541	5549	31535	11155	2558	3079	4414	3609	2217	2620
3	6840	1753	1318	1216	4378	24884	8803	2018	2430	3483	2848	1750	2068
4	2288	586	441	407	1465	8326	2945	675	813	1165	953	585	692
5	3636	932	701	646	2327	5977	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	5241	1343	1010	932	3355	19068	6745	1547	1862	2669	2182	1341	1584
8	5494	1408	1059	977	3517	19987	7070	1621	1952	2798	2287	1405	1661
9	3541	908	682	630	2267	12884	4558	1045	1258	1803	1475	906	1071
10	2147	550	414	382	1375	7812	2764	634	763	1093	894	549	649

Table 14: Distribution of Optimal Quantities to Provinces

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

In this thesis, we formulated a generic model for a food supply chain. Then, we proposed a distribution network model for an olive oil supply chain of a company which operates in Turkey. For the analysis, we proposed a mathematical programming model. The proposed model aims to optimize distribution and production system of Tariş by minimizing cost and maximizing profit. We modeled the problem using integer programming model and solved the problem exactly using Cplex solver on GAMS Software.

When we compare the results of solution and the real data, we realized that the production volumes for each product type proposed by the results are different than the real production volumes. Based on the optimal results proposed by the solution, required changes on the production volumes are given. Similarly, distribution of optimal quantities of each product to each province is different than the real data.

The production and distribution systems of Tariş have to be redesigned. Based on the comparisons between optimal results and real data, production and distribution network decisions for 18 lt. and 5 lt. tin cans have to be reconsidered.

As reference to further research, problems of other companies operating in the same sector can be further investigated. The solution may also be done by using real demand data. Other potential members of supply chain can be included to the model and the problem can be tested again. Same problem could be applied for the other product categories.

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APPENDICES

Appendix 1: Net Production and Consumption of Olive Oil

	00/01	01/02	02/03	03/04	04/05	05/06
Area (hectare)	600.000	600.000	620.000	625.000	644.000	660.000
Total Trees Number (1000)	97.770	99.000	101.600	102.750	107.100	109.000
Total Grain Production (ton)	1.800.000	600.000	1.800.000	850.000	1.600.000	880.000
Output (kg/hectare)	3.000	1.000	2.903	1.360	2.484	1.333
Grain for Olive Oil Production (1000 ton)	1.310.000	425.500	1.350.000	500.000	1.290.000	600.000
SUPPLY (ton)	1000	1000	1000	1000	1000	1000
Beginning Stock (October,1st)	14,5	25	7	21	10	8
Production	175	65	140	83	145	155
Import	0	0	0	0	0	0
Total Supply	189,5	90	147	104	155	123
USAGE (ton)	1000	1000	1000	1000	1000	1000
Consumption	72,5	55	52	48	55	50
Export	92	28	74	46	92	73
Final Stock (September, 30th)	25	7	21	10	8	0
Total Usage	189,5	90	147	104	155	123
Stock/Usage Rate (%)	13,19	7,78	14,29	9,62	5,16	0,00

Appendix 2: Figures of Olive and Olive Oil Production in Turkey [2]

Years	**Number of trees (fruitful)**	**Number of trees (no fruitful) (1000)**	**Olive Production (ton)**	**Olives for Culinary (ton)**	**Olives for Olive Oil (ton)**	**Olive Oil Production (ton)**
1989-1990	79.460	6.250	500.000	162.000	338.000	35.000
1990-1991	79.600	5.960	1.100.000	337.0000	763.000	80.000
1991-1992	81.520	6.185	640.000	181.000	459.000	60.000
1992-1993	81.260	5.828	750.000	213.000	519.000	56.000
1993-1994	81.703	5.460	550.000	200.000	350.000	48.000

1994-1995	82.192	5.955	1.400.000	350.000	1.050.000	160.000
1995-1996	82.192	6.144	515.000	206.000	309.000	40.000
1996-1997	83.200	6.540	1.800.000	435.000	1.365.000	200.000
1997-1998	85.700	10.000	510.000	200.000	310.000	40.000
1998-1999	85.850	7.600	1.650.000	430.000	1.220.000	170.000
1999-2000	87.130	8.370	600.000	240.000	360.000	70.000
2000-2001	89.200	8.570	1.800.000	490.000	1.310.000	190.000

Appendix 3: Production Volumes of Natural Extra Virgin Olive Oil in 2008 (January-June)

2008	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
Standard Products in Domestic Market	**Rate %**					
1 lt tin box	15,62	8,38	5,73	5,88	9,97	11,78
1.5 lt tin box	32,17	11,70	11,60	26,647	24,82	32,28
2 lt tin box	41,40	23,69	6,79	23,090	11,49	22,51
3 lt tin box	0,68	9,91	7,81	0,227	0,04	0,05
5 lt tin box	9,01	35,83	60,21	27,839	25,34	18,69
18 lt tin box	0,00	0,00	1,68	0,068	2,27	3,30
250 ml glass bottle	0,00	1,49	0,60	0,944	3,94	0,21
500 ml glass bottle	0,00	3,07	1,75	6,433	9,82	2,53
750 ml glass bottle	0,00	4,37	2,77	6,699	9,67	6,62
1000 ml glass bottle	0,00	1,56	1,06	2,176	2,64	2,03

Appendix 4: Production Volumes of Natural Extra Virgin Olive Oil in 2008 (July-December)

2008	**JULY**	**AUGUST**	**SEPT.**	**OCT.**	**NOV.**	**DEC.**
Standard Products in Domestic Market	**Rate %**					
1 lt tin box	9,05	12,88	13,44	8,24	16,37	10,34
1.5 lt tin box	15,92	18,68	15,97	16,62	23,99	25,93
2 lt tin box	14,89	18,61	15,19	29,90	9,50	14,01
3 lt tin box	35,81	11,31	0,05	0,00	0,00	20,81
5 lt tin box	0,11	20,39	34,11	14,73	37,56	15,35
18 lt tin box	2,41	0,00	1,93	0,00	2,00	0,00
250 ml glass bottle	5,27	2,65	3,76	2,77	0,61	0,44
500 ml glass bottle	1,03	1,45	2,39	10,54	2,60	2,88
750 ml glass bottle	4,59	9,52	9,51	8,96	7,09	9,36
1000 ml glass bottle	10,93	4,50	3,66	8,23	0,29	0,89

Appendix 5: Production Volumes of Natural Extra Virgin Olive Oil in 2007 (January-June)

2007	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
Standard Products in Domestic Market	**Rate %**					
1 lt tin box	30,64	6,29	6,07	9,31	4,14	18,03
1.5 lt tin box	0,00	0,00	15,16	17,16	22,46	6,21
2 lt tin box	27,99	31,46	24,12	7,06	6,97	36,40
3 lt tin box	8,86	19,47	12,36	26,61	13,22	0,15
5 lt tin box	28,21	28,17	31,39	16,04	20,63	25,68
18 lt tin box	0,00	0,02	0,02	3,62	0,00	2,81
250 ml glass bottle	0,31	2,07	1,06	1,17	4,92	0,20
500 ml glass bottle	1,17	4,27	3,07	8,00	12,27	2,38
750 ml glass bottle	1,63	6,08	4,87	8,33	12,08	6,23
1000 ml glass bottle	1,20	2,17	1,86	2,70	3,30	1,91

Appendix 6: Production Volumes of Natural Extra Virgin Olive Oil in 2007 (July-December)

2007	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.
Standard Products in Domestic Market	**Rate %**					
1 lt tin box	10,64	4,59	8,59	13,70	15,89	8,80
1.5 lt tin box	18,63	18,92	18,69	20,31	23,55	19,23
2 lt tin box	10,76	43,09	18,81	7,29	8,45	5,95
3 lt tin box	5,92	12,41	9,63	16,32	18,92	0,00
5 lt tin box	38,81	4,80	26,64	20,23	23,46	47,31
18 lt tin box	0,00	2,25	2,93	0,02	0,03	5,03
250 ml glass bottle	3,68	2,04	2,86	2,01	0,56	0,44
500 ml glass bottle	0,72	1,12	1,82	7,65	2,38	2,91
750 ml glass bottle	3,20	7,32	7,24	6,50	6,50	9,44
1000 ml glass bottle	7,63	3,46	2,79	5,97	0,26	0,90

Appendix 7: Distance and Population Table

PROVINCE	DISTANCE FROM IZMIR	POPULATION
İZMİR	0	3.606.326
MANİSA	36	924,267
AYDIN	130	588,552
BALIKESİR	173	694,926
UŞAK	211	225,57
DENİZLİ	224	641,093
MUĞLA	231	350,05
ÇANAKKALE	319	269,035

BURSA	322	2.308.574
AFYON	323	365,421
KÜTAHYA	334	383,572
BURDUR	374	159,508
ISPARTA	382	311,064
YALOVA	391	139,388
ESKİŞEHİR	412	681,854
BİLECİK	416	173,389
ANTALYA	445	1.392.974
KOCAELİ	454	1.459.772
SAKARYA	480	646,899
TEKİRDAĞ	505	545,481
EDİRNE	534	261,92
KONYA	546	1.486.653
DÜZCE	549	194,128
KIRKLARELİ	551	219,333
İSTANBUL	565	13.120.596
ANKARA	580	4.641.256
BOLU	594	169,962
KIRIKKALE	657	233,073
KARAMAN	659	159,834
ZONGULDAK	663	287,321
AKSARAY	688	228,06
ÇANKIRI	711	110,222
KARABÜK	728	177,189
BARTIN	752	63,984
KIRŞEHİR	755	156,731
NEVŞEHİR	763	154,103
NİĞDE	795	163,237
YOZGAT	799	268,349
ÇORUM	824	355,015
KASTAMONU	825	195,059
KAYSERİ	867	1.064.164
MERSİN	889	1.281.048
ADANA	896	1.836.432
AMASYA	916	219,541
TOKAT	979	363,944
OSMANİYE	983	346,707
SAMSUN	999	816,576
SİNOP	1019	107,275
SİVAS	1023	433,932

Apppendix 7: Distance and Population Table (Cont'd)

PROVINCE	DISTANCE FROM IZMIR	POPULATION
KAHRAMANMARAŞ	1084	636,828
HATAY	1088	743,439
GAZİANTEP	1105	1.501.566
KİLİS	1142	85,923
ORDU	1164	404,39
GİRESUN	1208	245,381
MALATYA	1208	480,144
ADIYAMAN	1229	347,236
ŞANLIURFA	1242	922,539

ERZİNCAN	1269	134,028
ELAZIĞ	1309	400,675
TRABZON	1345	415,652
GÜMÜŞHANE	1368	61,162
BAYBURT	1377	37,537
TUNCELİ	1399	47,531
RİZE	1420	197,52
DİYARBAKIR	1422	1.090.172
MARDİN	1429	428,899
BİNGÖL	1453	138,069
ERZURUM	1457	489,486
BATMAN	1517	373,388
MUŞ	1563	143,624
ARTVİN	1579	89,96
SİİRT	1604	181,41
ŞIRNAK	1608	269,494
BİTLİS	1632	168,787
AĞRI	1638	275,785
KARS	1658	123,452
ARDAHAN	1685	33,701
IĞDIR	1749	95,55
VAN	1786	539,619
HAKKARİ	1959	136,05

Appendix 8: Unit Transportation Costs of Final Products to Provinces

i/k	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0,003	0,005	0,008	0,011	0,012	0,016	0,019	0,026	0,030	0,030	0,035	0,040	0,040
2	0,004	0,008	0,012	0,017	0,018	0,024	0,029	0,039	0,044	0,044	0,053	0,060	0,060
3	0,005	0,010	0,016	0,022	0,024	0,032	0,038	0,052	0,059	0,059	0,071	0,080	0,080
4	0,008	0,015	0,024	0,033	0,035	0,049	0,058	0,077	0,089	0,089	0,106	0,119	0,119
5	0,013	0,026	0,041	0,055	0,059	0,081	0,096	0,129	0,148	0,148	0,177	0,199	0,199
6	0,046	0,093	0,146	0,199	0,212	0,292	0,345	0,465	0,531	0,531	0,637	0,717	0,717
7	0,001	0,001	0,002	0,003	0,003	0,004	0,005	0,006	0,007	0,007	0,009	0,010	0,010
8	0,001	0,003	0,004	0,006	0,006	0,008	0,010	0,013	0,015	0,015	0,018	0,020	0,020
9	0,002	0,004	0,006	0,008	0,009	0,012	0,014	0,019	0,022	0,022	0,027	0,030	0,030
10	0,003	0,005	0,008	0,011	0,012	0,016	0,019	0,026	0,030	0,030	0,035	0,040	0,040

Appendix 9: GAMS Code

Sets

i product types /1*10/

k customer regions /1*13/

;

Parameter p(i)   sales price of product i

/1 26.90, 2 40.50, 3 51.90, 4 65.50, 5 82.50, 6 260, 7 12.90, 8 18.50, 9 22.00, 10 24.50/;

Parameter oil(i) amount of oil required to produce product i

/1 1, 2 1.5, 3 2, 4 3, 5 5, 6 18, 7 0.25, 8 0.5, 9 0.75, 10 1/;

Scalar oc   unit(liter) cost of oil /3/;

Scalar t   unit(liter) transportation cost of oil from Kuzey Ege(Balikesir) to the factory / 0.0175/;

Scalar toil total amount of oil available for production /540000/;

Parameter pc(i)   packaging cost of product i

/1 0.1, 2 0.2, 3 0.3, 4 0.4, 5 0.5, 6 1, 7 1, 8 1.5, 9 2, 10 2.5/;

Parameter tc(i) unit transportation cost of packaging material for product i from suppliers to the factory

/1 0.013275, 2 0.0199125, 3 0.02655, 4 0.039825, 5 0.066375, 6 0.23895, 7 0.00405625, 8 0.0081125, 9 0.01216875, 10 0.016225/;

Table c(i,k) cost of transportation for product i from factory to sales region k

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0025813	0.0051625	0.0081125	0.0110625	0.0118000	0.0162250	0.0191750	0.0258125	0.0295000	0.0295000	0.0354000	0.0398250	0.0398250

2	0.0038719	0.0077438	0.0121688	0.0165938	0.0177000	0.0243375	0.0287625	0.0387188	0.0442500	0.0442500	0.0531000	0.0597375	0.0597375	
3	0.0051625	0.0103250	0.0162250	0.0221250	0.0236000	0.0324500	0.0383500	0.0516250	0.0590000	0.0590000	0.0708000	0.0796500	0.0796500	
4	0.0077438	0.0154875	0.0243375	0.0331875	0.0354000	0.0486750	0.0575250	0.0774375	0.0885000	0.0885000	0.1062000	0.1194750	0.1194750	
5	0.0129063	0.0258125	0.0405625	0.0553125	0.0590000	0.0811250	0.0958750	0.1290625	0.1475000	0.1475000	0.1770000	0.1991250	0.1991250	
6	0.0464625	0.0929250	0.1460250	0.1991250	0.2124000	0.2920500	0.3451500	0.4646250	0.5310000	0.5310000	0.6372000	0.7168500	0.7168500	
7	0.0006453	0.0012906	0.0020281	0.0027656	0.0029500	0.0040563	0.0047938	0.0064531	0.0073750	0.0073750	0.0088500	0.0099563	0.0099563	
8	0.0012906	0.0025813	0.0040563	0.0055313	0.0059000	0.0081125	0.0095875	0.0129063	0.0147500	0.0147500	0.0177000	0.0199125	0.0199125	
9	0.0019359	0.0038719	0.0060844	0.0082969	0.0088500	0.0121688	0.0143813	0.0193594	0.0221250	0.0221250	0.0265500	0.0298688	0.0298688	

10 0.0025813 0.0051625 0.0081125 0.0110625 0.0118000

0.0162250 0.0191750 0.0258125 0.0295000 0.0295000 0.0354000

0.0398250 0.0398250

;

Table d(i,k) demand of sales region k for product i

1 2 3 4 5 6 7 8 9 10 11

12 13

1 7872 2017 1517 1399 5039 28639 10131 2323 2796

4008 3278 2014 2380

2 8668 2221 1670 1541 5549 31535 11155 2558 3079

4414 3609 2217 2620

3 6840 1753 1318 1216 4378 24884 8803 2018 2430

3483 2848 1750 2068

4 2288 586 441 407 1465 8326 2945 675 813

1165 953 585 692

5 3636 932 701 646 2327 13228 4679 1073 1292

1851 1514 930 1099

6 50 13 10 9 32 183 65 15 18 26

21 13 15

7 5241 1343 1010 932 3355 19068 6745 1547 1862

2669 2182 1341 1584

8 5494 1408 1059 977 3517 19987 7070 1621 1952

2798 2287 1405 1661

9 3541 908 682 630 2267 12884 4558 1045 1258

1803 1475 906 1071

10 2147 550 414 382 1375 7812 2764 634 763

1093 894 549 649

;

Positive Variable

x number of product i produced

y number of product i shipped to sales region k

;

Variable

z objective function

;

Equations

obj maximize profit

c1 the amount of product i shipped cannot be more than produced

c2 the total amount of all products produced should be less than or equal to total oil available

c3 the amount of product i shipped to region k cannot be more than the demand of region k for product i

c4

*c5

*c6

;

```
obj..    z=E= sum((i,k), (p(i)- c(i,k))*y(i,k)) - sum((i),   (oc*oil(i)- pc(i)-tc(i))*x(i))  ;


c1(i)    .. x(i)=G=sum(k, y(i,k));

c2       .. sum(i, oil(i)*x(i))=L=toil;

c3(i,k)  .. y(i,k)=L=d(i,k);

c4(i)    .. sum(k, y(i,k)) =L= x(i);


*c5;

*c6


Model taris /all/;

Solve taris using MIP maximizing z;

Display x.L, y.L, z.L;
```


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