

DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

**AN ANALYSIS OF OUTBOUND LOGISTICS
PROCESSES FROM LEAN MANUFACTURING
SYSTEMS PERSPECTIVE: A VALUE STREAM
MAPPING APPROACH**

by
Yiğit Halim BULUT

December, 2019
İZMİR

AN ANALYSIS OF OUTBOUND LOGISTICS PROCESSES FROM LEAN MANUFACTURING SYSTEMS PERSPECTIVE: A VALUE STREAM MAPPING APPROACH

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in Logistics Engineering**

**by
Yiğit Halim BULUT**

December, 2019

İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled “AN ANALYSIS OF OUTBOUND LOGISTICS PROCESSES FROM LEAN MANUFACTURING SYSTEMS PERSPECTIVE: A VALUE STREAM MAPPING APPROACH” completed by YİĞİT HALİM BULUT under supervision of ASSOC. PROF. DR. GÜL DENKTAŞ ŞAKAR and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

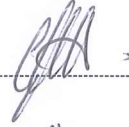


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Yiğit Halim BULUT

AN ANALYSIS OF OUTBOUND LOGISTICS PROCESSES FROM LEAN MANUFACTURING SYSTEMS PERSPECTIVE: A VALUE STREAM MAPPING APPROACH

ABSTRACT

Value stream mapping had its origin in the lean manufacturing, material and information flow diagrams developed originally by Ohno (1988) in Toyota and called it Toyota Production System. Firstly, it was used to identify the source of wastes in the manufacturing area and eliminate them. This has already been extended to help in the design of improvement programs oriented to eliminate waste in logistics and service operations. Then it was adapted to support efficiency improvement programs in the transport operations environment. A new value stream map and an efficiency measure for transport operations were proposed by Villarreal (2012) and it was referred to as Transportation Value Stream Mapping (TVSM). TVSM is a value stream mapping approach for distribution operations for identifying availability, performance and quality wastes. VSM was used to find bottlenecks and the source of wastes. It serves as an applied case study to reveal the current logistics process map (via TVSM) and detailed transportation processes from a large food packaging manufacturer to its European customers through its logistics partners. The study aims to examine the transportation processes of the case study firm from origin to destination and find a solution to optimize routes. The Beresford time cost distance model was used after TVSM analyzes as a method to find optimal route in terms of transportation costs, transit times and distance. One company for each country (Germany, Belgium, and the Netherlands) was identified and all possible shipping routes were examined in this research in terms of advantages and disadvantages.

Keywords: Beresford time cost distance model, lean manufacturing, transportation, transportation value stream mapping, value stream mapping

FİZİKSEL DAĞITIM SÜREÇLERİNİN YALIN ÜRETİM SİSTEMLERİ AÇISINDAN İNCELENMESİ: DEĞER AKIŞ HARİTALAMA YAKLAŞIMI

ÖZ

Değer akış haritalama ilk olarak Toyota’da yalın üretim, malzeme ve bilgi akış şemalarında Ohno (1988) tarafından geliştirilmiş ve Toyota’da geliştirildiği için bu yönteme Toyota Üretim Sistemi denilmiştir. İlk olarak üretim alanındaki israfların kaynağını belirlemek ve bu israfları ortadan kaldırmak için kullanılmıştır. Değer akış haritalama yöntemi sadece üretim alanında kullanılmakla kalmayıp aynı zamanda, lojistik ve hizmet operasyonlarındaki israfı ortadan kaldırmaya yönelik iyileştirme programlarının tasarlanmasına yardımcı olmak içinde kullanılmıştır. Ardından ulaştırma operasyonlarındaki verimlilik, iyileştirme programlarını desteklemek üzere uyarlanmıştır. 2012 yılında Villarreal (2012) tarafından yeni bir değer akış haritası ve ulaşım operasyonları için bir verimlilik ölçüsü önerilmiş ve Ulaştırma Değer Akışı Haritalaması olarak adlandırılmıştır. Ulaştırma değer akış haritalama yöntemi, uygulanabilirlik, performans ve kalite israflarını belirlemek için dağıtım süreçlerinde kullanılan bir değer akış haritalama yaklaşımıdır. Değer akış haritalama tekniği, darboğazları ve israfların kaynağını bulmak için kullanılmıştır. Türkiye’deki büyük bir gıda ambalajlama üreticisinden Avrupa’da ki müşterilerine lojistik partnerleri aracılığıyla yapılan mevcut lojistik süreçleri ve detaylı nakliye süreçlerini ortaya koyan uygulamalı bir vaka çalışması olarak hizmet vermektedir. Bu çalışma, vaka çalışması firmasının nakliye sürecini merkezden varış noktasına kadar incelemeyi ve rotaları optimize etmek için bir çözüm bulmayı amaçlamaktadır. Ulaştırma değer akışı haritalama analizlerinden sonra Beresford zaman maliyeti mesafe modeli, ulaşım maliyetleri, transit süreleri ve mesafeleri açısından en uygun rotayı bulma yöntemi olarak kullanılmıştır. Her ülke için bir şirket (Almanya, Belçika ve Hollanda) belirlenmiş ve bu çalışmada olası tüm nakliye yolları avantaj ve dezavantajları açısından incelenmiştir.

Anahtar Kelimeler: Beresford zaman maliyet mesafe modeli, yalın üretim, ulaştırma, ulaştırma değer akış haritalama, değer akış haritalama

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CHAPTER ONE

INTRODUCTION

In the global world, competitiveness is in high level around the world. Most of the global enterprises make investments to their research and development (R&D) departments to minimize the expenses and wastes. Since companies are constantly in competition, they attach great importance to lean manufacturing activities and constantly develop and improve themselves. So, lean manufacturing techniques are used by companies to find bottlenecks and wastes in the process to eliminate all wastes and useless processes. The value stream mapping (VSM) as one of the lean manufacturing techniques, is a tool to identify the waste of sources. When the source of wastes was found, it is much easier to make progress to improve the current situation. This research uses one of the lean-manufacturing techniques “value stream mapping” to investigate the current situation of transportation systems of the food packaging manufacturing firm. The current situation of the firm was analyzed to find non-value-added processes in the transportation system. In this research, the transportation value stream mapping method developed by Villarreal (2012) was used to investigate the process of transportation systems. Transportation value stream mapping (TVSM) was adapted by Villarreal (2012) to measure the total operational vehicle effectiveness (TOVE) and overall vehicle effectiveness (OVE) index.

At first, TVSM was applied to the food packaging manufacturer firm to achieve this goal and solve the problem. The necessary steps were determined to make progress and examine the current state but detailed freight prices were not known by the case study firm. Only cumulative freight prices were taken by the case study firm from its forwarders for each transportation operation since the case study firm makes business with freight forwarders to transport the goods to its customers. While transportation systems were examined, detailed information about freight rates was taken from different freight forwarders since freight forwarders of the investigated firm did not share freight rates in detail. The case study firm needs alternative routes to minimize transportation costs, find the fastest way to transport the goods to its customers and find the optimal solution to compete with other companies. The case study firm has to

provide the best service to its customers while optimizing its transportation systems. In this case study, Beresford time cost distance model was selected to examine the components of transportation systems such as routes, alternative routes, transit times, costs, distances, detailed transportation costs for each stage like custom fee, port fee, port handling fee, etc.

1.1 Objective

This research uses lean-manufacturing tool (VSM) to find bottlenecks, the source of wastes and it serves as an applied case study to reveal the current logistics process map (via transportation value stream mapping) and detailed transportation processes of a large food packaging manufacturer firm to its European customers by logistics partners. The study aims to examine the current transportation system of the food packaging manufacturer firm by using lean manufacturing techniques. The main goal of the study is to analyze the outbound transportation system with the value stream mapping method which is called transportation value stream mapping (TVSM) and find bottlenecks, source of wastes and value-added and non-value-added activities. This study is focused on eliminating those wastes to improve all transportation process. By doing that Beresford time cost distance model was integrated into the TVSM approach to improve the transportation processes and find alternative solutions. This research has the value of being the first research that is investigating the non-value-added process of TVSM with the Beresford time cost distance model. Beresford's time cost distance model was never integrated with lean manufacturing approaches before.

1.2 Purpose of the Study

In this case, the main focus is to optimize the outbound transportation system of the food packaging manufacturer firm. By doing that, it is also targeted to give valuable information about transportation inputs to the food packaging manufacturer firm in detail. The company works with forwarders. Only cumulative prices are given from forwarders to the food packaging manufacturer firm for transporting the goods to the customers of the food packaging manufacturer firm. So, this research is focused on

improving and finding alternative transportation routes and alternative solutions to optimize the current transportation process. It is also aimed to minimize lead-time, transportation costs and find alternative transportation routes to make the transportation processes better. This research analyzes the transportation routes in terms of transportation costs, transit time and distance. Beresford (1999) developed a model that determines the most appropriate mode of transport in terms of cost and time variables in freight transport and highlighted the factors that affecting the choice of transportation mode or combination of the transportation. Beresford time cost distance model, which is one of the applications of The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) where detailed time, cost and distance analysis of intermodal routes determined by the purpose and conceptual model of the research, can be performed as a method.

1.3 Motivation

The author's graduation from Industrial Engineering, work in the field of productivity in business life and the author's interest in lean manufacturing, productivity and efficiency led to work in this project to help and guide manufacturers in Turkey to find optimal routes for transportation options to Europe. The study was planned on the idea to examine the transportation routes for a more convenient way between Turkey to Germany, Turkey to Belgium and Turkey to the Netherlands and helps other manufacturers in Turkey to choose the best transportation route alternatives. There are no studies in Turkey about TVSM. There are also no studies which investigated transportation mode selection integrated with TVSM in the related literature. Those are the main motives for the author and also it will provide room for further studies in the field.

1.4 Scope

The scope of this study consists of a food packaging manufacturer's (since the original company name cannot be shared because of confidentiality reasons, the case study firm will be mentioned as ABC Co) exports logistics activities from Turkey to Europe (Germany, Belgium, the Netherlands). ABC Co has a remarkable export activity to Europe averagely 483 pallets/week and these transportations are partial transportation. Because of partial transportation, transportation costs are high. ABC Co wants to decrease these transportation costs with alternative solutions by the result of this research. In this case, the study focused on full truckload to minimize transportation costs. ABC Co has not preferred all-water transportation (container transportation by sea or ocean) mode for its transportation, despite its high export levels. Global companies generally choose container transportation for large-scale transportation options for low-cost reasons. Instead of choosing all-water transportation, alternative ways of transportation such as all road options, road combined with RO-LA option and road combined with RO-RO ship options were chosen by ABC Co for transportation options until now. The company does not use the advantages of the container shipment for the large-scale transports. All logistics activities are outsourced and costs are high since ABC Co does not have a fleet.

The study includes custom fees, highway fees, toll fees, bridge fees, etc. and also, driver rest and breaks, port handling time, time at borders and ports, etc. for the transit time. This research did not investigate TVSM approaches with TOVE and OVE indexes. The first step of TVSM which is selecting route was examined in this research. Not in transit (NIT) and in transit (IT) percentages could not have been investigated since the case firm did not own its transportation fleet. Because of that, the author aimed at route optimization in this case study to optimize the transportation problems of ABC Co.

CHAPTER TWO

LITERATURE REVIEW

2.1 Lean Manufacturing

Lean manufacturing concept was introduced to the world for the first in Japan, 1988. Toyota was the first company, which used lean practices. These lean practices were used by Taiichi Ohno (1988) on Toyota Production System for the first time. That's why the lean manufacturing system is known as the Toyota production system as well. Lean principles and main concepts come under the lean philosophy. According to Womack & Jones (1996) lean is defined as a process that includes five steps. These steps are listed below as:

- 1- Defining customer
- 2- Defining the value stream
- 3- Making it flow
- 4- Establish pull
- 5- Striving excellence.

These steps have to be followed by the order to make a company lean. First, customers and need of customers have to be defined, then the value stream has to be defined as the second stage, then value stream mapping has to be made to see the big picture, then create better flow in work process, and then use the pull-based system to limit the inventory and work in process. It will allow for just in time (JIT) delivery which is the goal of lean manufacturing. Then as a last step continuous improvement culture must be developed. It is the most important stage among all steps. It makes lean thinking and continuous improvement a part of the organizational culture. Back in the 1980s changing plant to lean production from mass production was considered to be very difficult. Workers did not want to take responsibility for quality improvement in the production line because mass production was easy. Workers only responded when management actually, truly valued the workers' skills. They started responding when they knew management rewording them and care about the workers.

The motto was “do it right the first time” it’s like a well-known “Just in time” motto, which means “do it right on time”. Womack et al. (1990) explained how the movement of automobile manufacturing took place from craft production to mass production and then to lean production from mass production.

According to Bhasin & Burcher (2006), lean is a philosophy, lean is a lifestyle, lean is more than strategy. Lean manufacturing must be considered as a continuous improvement process from the past to the future for better results. It’s important to know the meaning of waste and the term waste. There are two types of wastes at the systems. The first one is obvious waste and it results from over-production, waiting, inappropriate processing, excessive inventory (over-stock), excess motion and defects and waiting. The second is a less obvious waste, which is the result of variability. According to Dhamija et al. (2011), lean organizations utilize less material to create their work and get the jobs done. Lean organizations need fewer human efforts to perform the work, need less time to design and develop less energy and space. For instance, Toyota produced automobiles with lesser inventory, human effort, investment, and defects and introduced a greater and ever-growing variety of products. Lean organizations produce high-quality products and services in the most effective, economical and lean way. Rose et al. (2011) proposed 17 lean practices, which are considered to be the best feasible and relevant to small and medium scale characteristics. They suggested that the implementation of lean practices should be done consistently. Inconsistency in the efforts may not lead any organization to avail full benefits from lean practices.

The main purpose of lean manufacturing is to be highly responsive to customer demand by reducing waste. Lean manufacturing aims at producing products and services at the lowest cost and as fast as required by the customer. Lean manufacturing uses several tools and techniques such as value stream mapping (VSM), plan-do-check-act (PDCA), the five whys, continuous flow (aka one-piece flow), cellular manufacturing, 5S, kaizen, total quality management (TQM), Kanban, total productive maintenance (TPM), takt time, standardized work, mistake proofing, leveling the workload, poka-yoke, etc. to identify and eliminate the waste from any procedures

(Shah & Ward, 2003, 2007; Singh & Sharma, 2009). In this case study, the lean manufacturing tool VSM is chosen to analyze the transportation system and to find bottlenecks and wastes to improve or eliminate them.

2.2 Value Stream Mapping

Value stream mapping is a lean manufacturing tool for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer with reduced lean wastes as compared to the current map (Rother & Shook, 1999). It is defined as: *“The value stream mapping process, in short, can be defined as the representation of all the activities transpiring within the value stream of a product or group of products”* (Womack & Jones, 1996, p. 353). A more specific explanation of value stream mapping would describe it as the simple process of straight inspecting the movements of information and materials as they currently occur, compiling them visually and then envisioning a future state with much better enforcement (Jones & Womack, 2000). The primary objective of the VSM is to identify all kinds of waste in the value stream to take action to eliminate these waste (Rother & Shook, 2009). VSM had its provenience in the material and information flow diagrams initially in Toyota. VSM was used by Toyota to specify the source of wastes and remove them. VSM was sophisticated by Rother & Shook (1999) into what is called value stream maps now. Additionally, one of the main purposes of VSM is to define non-adding activities in the manufacturing process and remove them to greater the efficiency of the factory (Rother & Shook, 2003).

In the first place, this tool was designed to be used in the manufacturing area to eliminate seven wastes (Muda) in the Toyota Production System (TPS) and develop its performance concerning cost, quality and service by Ohno (1988) while he worked at Toyota. These seven wastes were listed below as:

1. Transport: Waste in transportation includes any unnecessary movement like the movement of tools, people, inventory, materials, products, selecting the wrong route for transportation. Extravagant movement of products can cause

damage and defects to products. Furthermore, over the movement of people, double handling can lead to damage and disruptions.

2. Inventory: Unnecessary inventory tends to greater lead-time in the production process. It leads to having problems like disruption of products or damage materials, ineffectual allocation of capital and problems hidden away in the inventory.
3. Motion: Waste in motion includes excessive movement of people where operators have to walk, stretch, reach, pick up and bend for finish the task. This kind of wastes is tiring for the employers and its likely to decrease productivity and often cause quality problems. This includes walking, lifting, reaching, bending, stretching and moving. Unergonomic production lines where operators over walking, reaching, bending, stretching and moving because of these results.
4. Waiting: Whenever goods are not being processed or not moving, the waste of waiting occurs. It results in spending time waiting for goods and it affects workers because workers wait for goods to be processed. Waste is the time when workers wait for goods to be processed without doing anything.
5. Over Processing: Many organizations use expensive, high-precision equipment where simple tools are sufficient. This often results in poor plant placement because previous or subsequent operations are distant from each other. Additionally, they encourage the use of high assets (overproduction with minimum changes) to recover the high cost of this equipment. Toyota is renowned for the use of low-cost automation and is often equipped with clean maintenance on older machines. If possible, building production cells and combining steps, investing in smaller, more flexible equipment will greatly reduce improper process waste.

6. Over Production: Overproduction is to produce an item before it is actually needed. Overproduction is highly costly to a manufacturing plant. It prohibits the smooth flow of materials and actually decreases quality and productivity. Overproduction manufacturing creates greater lead times, as a result of this, it costs high storage costs, and makes it difficult to determine defects. Additionally, overproduction cause unnecessary work-in-progress stocks, which results in misallocating of the operations because of frequently weak communication.
7. Defects: As a result, quality defects that have a direct impact on reprocessing or scrap are a tremendous cost for organizations. Related costs include quarantining inventory, reviewing, re-planning, and capacity loss. In many organizations, the total error cost is usually a significant percentage of the total production cost. Thanks to employee involvement and Continuous Process Improvement (CPI), there is a great opportunity to reduce errors in many facilities.

VSM is used to make improvements in lead times and identify opportunities in lean conditions. VSM is often correlated with manufacturing but also it is practiced in planning, logistics, supply chains, and service-related industries including health care, software, and product development (Rutledge et al., 2010). VSM is widely used in lean environments to identify opportunities for improvement in lead times.

According to value stream mapping characteristics, classifying each step for gaining economic outlook is an appropriate method and these two characteristics were listed below;

- Value adding (VA)
- Non-value adding (NVA)

Value-added activities are processing and helping in converting raw materials into semi-finished and finally finished products in the least optimal way and time, at

optimal costs. These activities are those, which add value to the process or product for which customers willing to pay. It aims at helping the business to deliver or service while fully conforming to customer requirements or specifications.

The non-value-adding activities do not add any value to the product or service and service but are a significant part of the process and for which customer is not willing to pay for. These activities are mentioned as pure Muda and prove to be a burden on the organization and affect its efficiency. These are unnecessary activities and therefore should be removed entirely. These unnecessary activities are like waiting times, stacking intermediate products or double handling (Maximilian et al., 2011). Generally, VSM is practiced to develop or resolve unique, particular problems in order of use cases (Lian & Van Landeghem, 2007; Yang & Lu, 2011). Moreover, VSM is utilized as a rationalization approach in numerous publications. It is also used by managements to adopt lean thinking as a standard to continuous lean developments such as systematic productivity development. (Bhamu et al., 2013; Roosen & Pons, 2013). Besides, a lot of publications present how VSM is used in several fields to identify improvements. These papers provide evidence for accomplished lead-time reduction, productivity enhancement and reduction of inventory (Singh & Sharma, 2009; Chen et al., 2010; Green et al., 2010; Seyedhosseini et al., 2013) in production, logistics, trade, textile industry and medical services (Saleeshya & Raghuram, 2012; Villarreal, 2012; Xie & Peng, 2012). Schultetus (2001) especially refers that existing methodologies have to be evolved based on new scientific studies, new scientific innovation to integrate, to standardize, to develop continuous improvement culture, implement lean thinking and to utilize them in a commonly affirmed way (Sunk et al., 2017).

VSM is a lean approach, which is used to improve systems therefore, the value stream mapping tool can also be used in different fields. There are some examples of the value stream mapping approach in different fields in Table 2.1 below.

Table 2.1 Value stream mapping studies in literature (1997-2018)

Field	Author	Year	Title of the research
VSM	Peter Hines & Nick Rich	1997	The seven value stream mapping tools
VSM	Peter Hines, Nick Rich & Ann Esain	1999	Value Stream Mapping
Product Development	Hugh L. McManus & Richard L. Millard	2002	Value Stream Analysis and Mapping for Product Development
Simulation in Lean Manufacturing	Yang-Hua Lian & Hendrik Van Landeghem	2002	An Application of Simulation and Value Stream Mapping in Lean Manufacturing
Motor Company	Dinesh Seth & Vaibhav Gupta	2005	Application of value stream mapping for lean operations and cycle time reduction: an Indian case study
Physician's Clinic	Rhonda R. Lummus, Robert J. Vokurka & Brad Rodeghiero	2007	Improving Quality through Value Stream Mapping: A Case Study of a Physician's Clinic
Steel Mill	Fawaz A. Abdulmalek & Jayant Rajgopal	2007	Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study
Manufacturing	Ibon Serrano, Carlos Ochoa & Rodolfo De Castro	2008	Evaluation of value stream mapping in manufacturing system redesign
Roasted and Ground Coffee Industry	Parthana Parthanadee & Jirachai Buddhakulsomsiri	2010	Production efficiency improvement in batch production system using value stream mapping and simulation: a case study of the roasted and ground coffee industry
Emergency Department Care	David Cookson, Colin Read, Pro Mukherjee & Matthew Cooke	2011	Improving the quality of Emergency Department care by removing waste using Lean Value Stream mapping
Refrigerator production process	M. Braglia, G. Carmignani & F. Zammori	2011	A new value stream mapping approach for complex production systems
Steel Company (Indian Industry)	Bhim Singh, Suresh K. Garg & Surrender K. Sharma	2011	Value stream mapping: literature review and implications for Indian industry
Automotive	R. M. Belokar, Vikas Kumar & Sandeep Singh Kharb	2012	An Application of Value Stream Mapping in Automotive Industry: A Case Study
Transportation	Bernardo Villarreal	2012	The Transportation Value Stream Map (TVSM)
Machining Process	K. Venkataramana, B. Vijaya Ramnathb, V. Muthu Kumar & C. Elanchezhian	2014	Application of Value Stream Mapping for Reduction of Cycle Time in a Machining Process
Manufacturing	Adam Brown, Joseph Amundson & Fazleena Badurdeen	2014	Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies
Order Production System	D. T. Matt	2014	Adaptation of the value stream mapping approach to the design of lean engineer-to-order production systems
Quality of Manufacturing	Benjamin Haefner, Alexandra Kraemer, Torsten Stauss & Gisela Lanza	2014	Quality Value Stream Mapping

Table 2.1 continues

Field	Author	Year	Title of the research
Gas Turbine Product	Satish Tyagi, Alok Choudhary, Xianming Cai & Kai Yang	2015	Value stream mapping to reduce the lead-time of a product development process
Production	Amir Azizi & Thulasi Manoharan	2015	Designing a Future Value Stream Mapping to Reduce Lead Time using SMED-A Case Study
Gear Shaft Manufacturing	S. Nallusamy	2016	Lean Manufacturing Implementation in a Gear Shaft Manufacturing Company Using Value Stream Mapping
Production	Tobias Meudt, Joachim Metternich & Eberhard Abele	2017	Value stream mapping 4.0: Holistic examination of value stream and information logistics in production
Transportation	Bernardo Villarreal, Jose Arturo Garza-Reyes, Priscila Ocanas & Fernanda Martinez	2017	A Lean Transportation Approach for Reducing Distribution Cost: A Case Study
Transportation	Mihaela Cornelia Popescu	2018	Eliminating transportation waste using the transportation value stream map

These studies as shown in Table 2.1 show the importance of lean manufacturing, lean thinking and lean management and their contributions to literature and companies. Through the VSM method, which is one of the lean manufacturing tools, can be examined by looking at how much the productivity of companies increases and how it has a positive impact on companies listed above.

2.3 Transportation Value Stream Mapping

Globalization, a continuous international exchange, high-level use of computer technology programs and low manufacturing costs from overseas made big changes in the last 20 decades in the manufacturing industry. 20-30% of the supply chain costs originate from the transportation and distribution industry. Accordingly, the performance of the companies is affected by the efficiency of transportation and distribution solutions. It has a massive impact on the industry (Benavides-Pena et al., 2017). A lean integrated solution requires a lot of planning and control in the process of managing different transportation modes like air, road, rail, sea, and barge. It also requires developing large brokerage contracts, coordinating drivers and sending and executing paperwork. Companies have to choose the right planning tools and the most beneficial route. Also, companies have to choose those tools to be successful, make the most profit, be efficient and be lean. Companies need the knowledge to choose right shippers, forwarders and make the right process to avoid wastes and manage tight

delivery schedules (Popescu, 2018). Villarreal (2012) has a specific publication called “The Transportation Value Stream Map” within limited research undertaken in the field of Transportation Value Stream Map (TVSM). It is the first source regarding transportation in value stream mapping. Villarreal (2012) claimed that the supply chain is a process to transport the goods closer to the purchasers can be mentioned as value-adding actions. Supply chain can be viewed as a process. Non-value and value-adding actions in any sort of transportation and it could be measured and exposed waste eliminated. According to Monden (1993), all freight transport can be considered as non-value adding activity or as a waste. For instance, the most effective scenario to minimize transit time, transit distance and the costs of the transportation system would be locating the manufacturing field next to the customers or retailers but in reality, this is usually not possible. Therefore, it is necessary to improve transportation routes or find alternative transportation routes to make efficient progress.

Transportation value stream mapping is an adapted version of VSM, which is used to identify waste of sources of any carrier and freight forwarder during transport and logistics operations. Usage of TVSM tool is suggested to improve transportation systems and identify a specific type of wastes to eliminate them. The tool was developed based on the "overall vehicle effectiveness" measure. Simons et al. (2004) studied to provide a general operational measure of road transport efficiency. The authors designed the importance of the road freight sector's measure to reflect on the “Sustainable development strategy of UK and increase the profitability of transport providers” (p. 119). This was achieved by changing the principles of the "overall equipment efficiency" measure to measure the effective use of a vehicle in the freight transport industry. This research led to the explanation of the five transport wastes:

- Driver breaks
- Excess load time
- Fill loss
- Speed loss
- Quality delay

The five wastes of transportation system determined and identified by Simons et al. (2004) and these wastes were used to determine non-value adding activities on the value stream map. These wastes were adapted from the seven manufacturing wastes of Taiichi Ohno which were designed for the Toyota production system (Ohno, 1988, p. 129). These wastes are mentioned as:

- Overproduction
- Waiting
- Transporting
- Over Processing
- Inventory
- Motion
- Defects

If seven wastes (Muda) of Ohno compared with transportation wastes then wrong route selection can be defined as transporting wastes because with wrong route selection the cost of goods will increase, efficiency of transportation line will decrease and the transit time will be excessive. It will lead to unable to compete with other companies in the competitive business world.

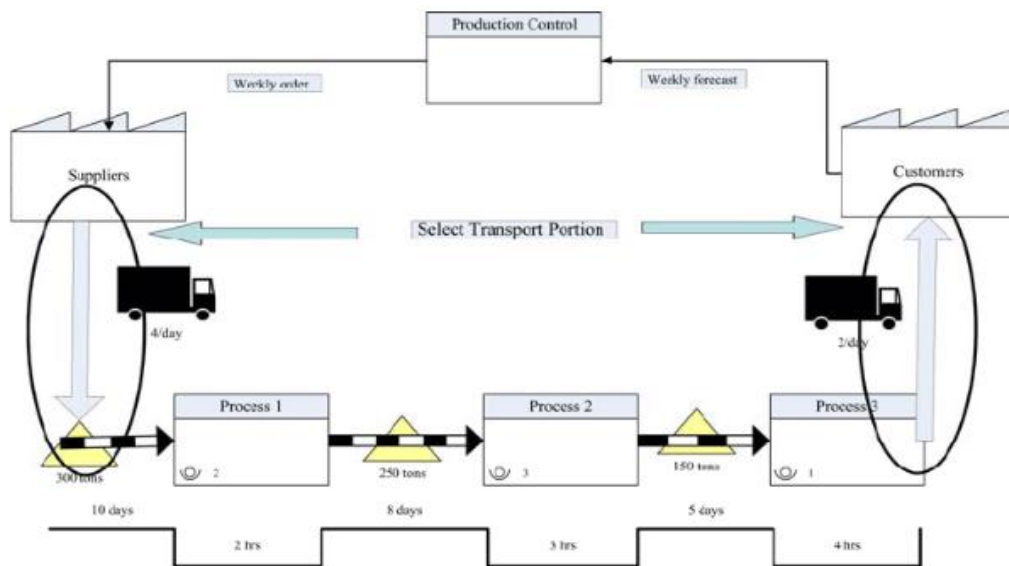


Figure 2. 1 Transport portions of supply chain (Villarreal, 2012)

Following on, to reflect the efficiency of a route, Guan et al. (2003) modified overall vehicle effectiveness (OVE) by dividing the performance factor into two components: route and time efficiencies. Finally, Villarreal (2012) proposed a modified version of the OVE measure called transportation overall vehicle effectiveness (TOVE) while he studied lean manufacturing tool TVSM in Mexican company. Unlike OVE, TOVE considers total calendar time instead of loading time. This is because waste identification and elimination are related to the selection of the best transportation route. Since vehicles represent a high investment, it is important to select the optimal route for the last destination to work efficiently. Waste identification is supported by the elaboration of a TVSM. As pointed out in Section 3.1 of his study, the focus of this map will be on identifying and reducing waste-related factors to the flow of the vehicles. As shown in Figure 2.1 in this research, *“the first step would be to select the transportation route of interest for performance improvement”* (Villarreal, 2012, p. 223).

The field of route and transport mode selection by the help of Beresford time cost distance model integrated with TVSM was not investigated before and this study aims to fill the gap in this specific field.

2.4 Transport Cost Models

Competitiveness is at a high level with globalism and companies try to find logistics strategies to reduce transportation costs because globalization led to a competitive world than before for business trading internationally. Reducing costs is important to compete with other companies in this competitive world. Companies try to obtain higher service standards while reducing costs and improving the quality of their services. Controlling transportation costs has become important like keeping down other production costs. The emergence of reliable and competitive door-to-door multimodal transport services can contribute and foster new trading opportunities as well as increased competitiveness (UNCTAD, 1994).

Transportation costs are seen as one of the largest outgoings in logistics activity. The selection of the route and transportation modes can directly affect transit time, transportation costs and distance between two destinations. In particular, multimodal transport route selection is salient in international trade to minimize cost, risk and provide on-time service (Beresford et al., 2011). The choice of transport mode or combination of transport modes has a direct impact on the efficiency of a multimodal transport system. According to Liberatore & Miller, (1995), based on the chosen mode logistic activities, efficiency of the transportation progress, transit time and costs will be affected. In general, the overall performance of the whole transportation system will be affected. *“Simple cost-distance models of road versus rail are commonly found (Fowkes et al., 1989; Hayuth, 1992; Marlow & Boerne, 1992) for national movements or sea versus air (Hayuth, 1985; Jung & Beresford, 1994) over longer, intercontinental routes. As the multimodal choice is of vital importance to the success of international trade, various models have also been created (Beresford & Dubey, 1990; Beresford, 1999; Minh, 1991; Barnhart & Ratliff, 1993; Yan et al., 1995) to aid transport decision-makers in choosing the most effective transport mode or combination of transport modes that not only minimizes cost and risk, but also satisfies various on-time service requirements”* (as cited in Banomyong, 2004, p. 63)

In recent years, *“the evolution of transport logistics has had a tremendous impact on trade in logistics services. The container has become a tool for revenue control of freight in transit from origin to destination (door-to-door). The financial liquidity offered to international multimodal transport operators by advance payments on containerized door-to-door transport contracts, has provided these operators with key financial leverage and with the possibility of subcontracting, at competitive rates, shipping, railway, and truck capacity while controlling subcontractor’s payment schedules (usually after services have been rendered). In some developing countries (and particularly LDCs), the shortage of knowhow and network capacities on the part of the domestic freight forwarding industries, has helped to divert the financial flows associated with door-to-door freight-forwarding from domestic operators to their better organized counterparts in industrialized countries. Moreover, with the growing volumes of container trade, and with greater demand for speed and tight scheduling,*

it has become necessary for the water, road, and rail transport systems to be physically and operationally closely linked” (UNCTAD, 2006).

“Reducing waiting times in seaports for ships and their cargo has a direct bearing on trade costs. First, from the shippers’ perspective, it implies lower costs associated with the holding of inventory en route to the final destination. It has been estimated that each additional day cargo spends in transit is equivalent to an ad valorem tariff of 0.6 to 2.1 per cent” (Hummels & Schaur, 2013, as cited in UNCTAD, 2014, p. 49).

“International transport costs are a key component of trade costs and economic development. Recent research in Asia and the Pacific suggests that tariffs account for only 0-10 percent of bilateral comprehensive trade costs, while other policy-related trade costs (that is, of a non-tariff nature) account for 60–90 percent of bilateral trade costs. Put differently, issues such as transport costs, maritime connectivity, and procedures have a stronger bearing on trade costs than customs duties” (UNCTAD, 2015, p. 53).

According to the analysis of UNCTAD data on transport costs, developing countries pay more for the international transport of their imports than developed countries. The main reason is trade imbalances, pending port and trade facilitation reforms, as well as lower trade quantities and transportation connectivity. There is a potential for policymakers to partly remedy the situation through investments and reforms, especially in the regions’ seaports, transit systems, and customs administrations. There are also some alternatives exist to decrease expenses by upgrading port infrastructure and improving efficiency in the logistic part of the supply chain, including through trade and transport facilitation, and more effective port operations, or to become more engaging as a port of call, which would require more port investments, and maritime transport service liberalization, as well as economic reformations, to strengthen industry and trade relationships (UNCTAD, 2015).

2.4.1 Transport Costs

Transport costs are generally known as the expenses incurred in moving products, goods, or assets to a different place, which are often transferred to consumers. Lambert et al. (1998) stated that *“transportation costs can be divided into two groups: product-related factors and market-related factors. The product-related factors are influenced by the characteristics of the product being transported, such as: density, stowability, difficulty in handling and accountability”* (as cited in Inmuang, 2010, p. 5).

Density is a ratio of the product, which is found by a division of weight to volume. If the weight of the cargo is high density it means it is heavier than size. In other situations, such as cargoes with low density tend to be more expensive to transport on a one-kilo basis because it occupies more space than the one with high diversity. *“The second factor is stowability, which is the ability that a product can fill the available space in a vehicle”* (Inmuang, 2010, p. 5). Products are carried in twenty-foot, forty-foot or forty-five-foot container transport units. The third one is the difficulty of handling. Products cost less if it is easy to handle them. This leads to lower overall transport costs and lower overall transit time cause if it's easy to handle it, it means it is faster to fill the space in a vehicle. The last one is liability which is known as accountability as well. It represents assumable risk that carrier or transport operator takes. Cargoes with high liability, with high value, will be charged with an extra fee or higher insurance costs (Inmuang, 2010).

The second transportation cost group is as known as market-related factors. These factors are influenced by the following transport market conditions: the degree of intermodal and intramodal competition; location of markets; transport distance; the nature and scope of state transport regulations; balance or unbalance of freight traffic; seasonality of product movements; and types of transport, i.e. domestic or international.

2.4.2 Transport Mode Selection

Trucks, automobiles, planes, ships, trains and most of the vehicles are designed to carry freights or passengers but most of them carry them both. As these vehicles designed for this purpose, transport modes are designed with the same purpose such as carrying freight or passengers in a routine, decreasing transportation costs and giving fast service to the customers. According to that most modes designed to carry the combination of both. For instance, a truck can carry freight, an automobile can carry freight and passengers while an airplane the one only carries passengers (passenger plane) has a belly hold that is used for luggage and cargo. Technical, operational and commercial characteristic of each mode is characterized (Rodrigue, 2017).

Logistic and operational decisions are affected by each transportation, and the performance of modes is influenced by variables such as distance, capacity, loading, procedure and duration, fuel consumption, customer needs, and topography. Considering such factors, the decision makers make decisions regarding transport modes. There are various studies concentrating on transport mode selection and costing of transport modes.

Jeffs & Hills (1990) conducted a survey to investigate the determinants of mode selection of freight transport in the United Kingdom. At the microeconomic level, the results show that mode options are subject to group decisions, customer requirements, price and budget constraints, urgent deliveries, transport infrastructure, company policy, and production level. Group decisions are decisions made by transport companies to determine the modes of transport to be used. To a large extent, customer requirements also play an important role because customers prefer or request for one or more mode options according to product characteristics such as time accuracy and urgency as they can determine. Transport infrastructure means the availability and quality of existing infrastructure, such as the presence, ease, and accessibility of railways for transport companies themselves. Jeffs & Hills (1990) determined that the most important determinants for mode selection were transport reliability, checking

shipment, checking delivery time, avoidance of damaging the product during transport, product safety during transport, transport time and availability when required.

Matear & Gray (1993) summarized the factors such as demand level, transport time, characteristics of transported goods, special offers, transport speed (transport time), damage of shipment, reliability of carrier, transport mode's characteristics, characteristics of the transport decision-maker, route (frequency, capacity, convenience, versatility and flexibility), costs (freight rate and other related costs) and service factors (delays, reliability and urgency, avoidance of damage, theft, fast reply for any problems, cooperation between the shipper and the carrier, documentation and tracing capability) (Inmuang, 2010). On mode option, in modal competition between Rotterdam and Duisburg route is investigated in a research, there are two major factors which are transit time and costs, influencing the choices between three modes of transport such as road (freeways), water (River Rhine), and rail (Betuwe Line) were concluded by Ribbink et al. (2005). Ribbink et al. (2005) suggested that the decision on transport mode selection affected due to market failure because the total cost of using road transport does not include external pollution costs such as light pollution, air pollution, and accidents.

The literature shows that to determine the winner in the intermodal competition, it is critical to consider transport cost and transit time of the modes. Transport costs, urgency and transit time can influence the user's decision on mode selection. To show the competition between modes of transport, there is a study about how transport costs affect users' decisions on mode selection. That study provided by Ribbink et al. (2005) is a good example to show how transit time and transportation costs vital to decide mode between modes.

2.5 Beresford Time Cost Distance Model for Multimodal Transport

In 1990, the multimodal transport cost model originally proposed by Beresford and Dubey (1990). Since multimodal selection is vital to the success of international trade, several models have been found as well (Minh, 1991; Barnhart & Ratliff, 1993; Yan

et al., 1995 and Beresford, 1999). In 2001, Banomyong and Beresford developed the model further with the case study which is focused on Indo-China Multimodal selection. According to Banomyong & Beresford (2001), it was really important to assist decision makers of the transport system to choose the most efficient mode of transport or to select a transportation mode combination that not only minimizes costs and risks but also meets a variety of timely service requirements. The cost model, which is investigated in this study, has both transport methods (road, rail, and sea) and intermodal transfer (ports, rail freight) like cost components and this model has been developed by (Beresford & Dubey, 1990) and improved by Beresford in 1999. The model is investigated in four developmental stages from its basic shape as shown in Figure 2.2 (Figure (a) through two intermediate stages Figure (b) and Figure (c) to its final combined shape Figure (d)).

The main assumptions of the Beresford time cost distance model are based on the premise that unit costs of transport vary between modes and the steepness of the cost curves highlight that for volume movements, sea transport should be the cheapest per ton-km, road transport should normally be the most expensive (at least over a certain distance), and waterway and rail costs should be intermediate. As seen from Figure 2.3, a freight handling charge is levied at ports and inland terminals, without any progress being made along the overall chain and each vertical step in the cost curve represents the costs incurred (Beresford, 1999).

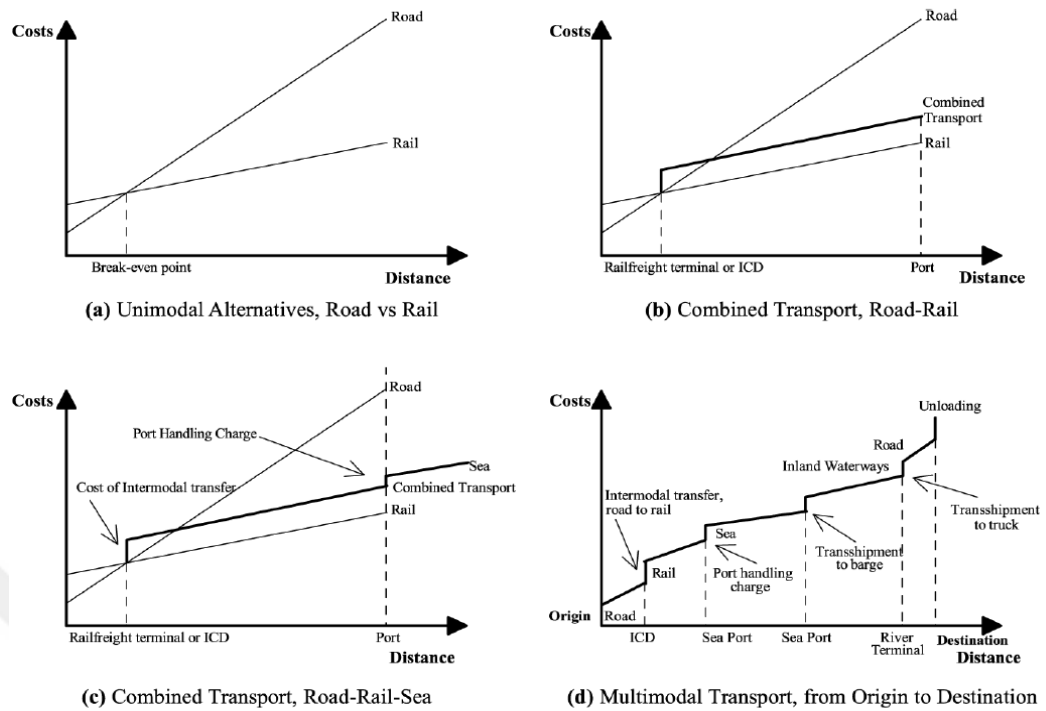


Figure 2.2 Structure of Beresford time cost distance model (Beresford, 1999)

Beresford (1999) tested this developed model on the UK-Greece transport corridor. The Beresford time cost distance model showed the given movements according to transport modes or combination or route decisions. The model could assist in the logistics trade-offs like speed and costs.

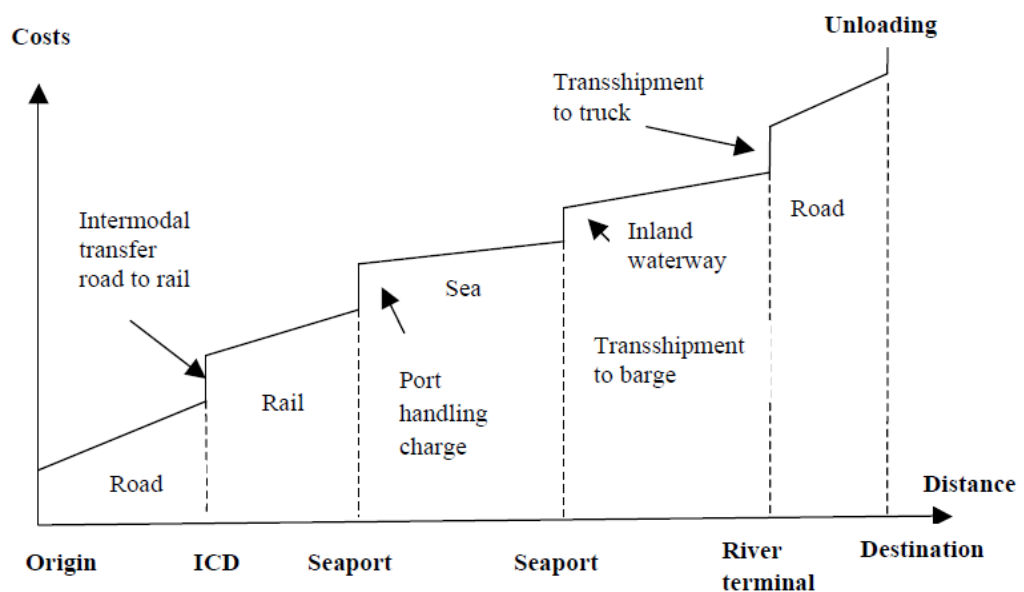


Figure 2.3 Cost model for multimodal transport (Beresford, 1999)

Since its development, its validity has been tested against actual data over a number of alternative routes between origins and destinations and some contributions to the model itself such as confidence index, decomposition of terminal charges into various cost components were noted. No method or model is without its limitations and this model does not take into account some variables which are also very important for mode choice decisions such as the nature of freight, cargo-value density, marketing policy, risk of damage and pilferage, packing requirement, security, etc. (Banomyong & Beresford, 2001).

The Beresford time cost distance model was adopted by UNESCAP in 2003 to two forms. Cost versus distance and cost versus time. In the study, several routing alternatives in the central Asia region, much of which is landlocked were studied. UNESCAP also concluded that the model can be useful to policymakers in focusing their policy approaches on the most critical issues. It can help to evaluate the competitiveness and effectiveness of their supply chain in specific export/import industries. In the last decade, the Beresford cost time distance model has been applied to various routes and products to examine the relationship between the type of cargo and the structure of supply chain. These studies are listed in Table 2.1 as seen below.

In 2012 UNESCAP “*updated the model to straighten the transport line and decrease the time/cost angle. This updated model provides graphical representation of cost and time data associated with transport processes, can help identify inefficiencies and isolate bottlenecks along a particular route by looking at the cost and time characteristics of every section along a transport route, it includes detailed breakdown of cost and time spent, enables policymakers to compare the changes of cost and/or time required for transportation on a certain route over a period of time and helps evaluate competing modes of transport operating on the same route and assess alternative transport routes*” (UNESCAP, 2012).

Table 2. 2 Studies on International Multimodal Transport using the Beresford Cost Model

Origin and Destinations	Product	Source
UK-Greece	Whiskey	Beresford 1999
Lao PDR-EU	Garments	Banomyong, Beresford (2001)
Vietnam-Singapore	Container-based products	Banomyong (2001)
Australia-China	Iron ore	Beresford, Lui ve Petit (2006)
Turkey-UK	Textile	Denktaş Şakar (2010)
Turkey-Russia	Natural Stones	Abdullayev (2013)
Turkey-Germany	Cable	İnak (2015)

The Beresford time cost distance model was used to optimize transportation routes by many researchers. The areas in which the Beresford time cost distance model was used to analyze and optimize the transportation route operation were shown in Table 2.1 above.

In this case study, The Beresford time cost distance model was used to optimize transportation route of ABC Co. At the next chapter there will be some information about methodology of the study, how the model was integrated to TVSM tool.

CHAPTER THREE

METHODOLOGY

3.1 Problem Definition and Purpose of the Research

Since the product value in the packaging sector and thus the revenues obtained is low, it is very important to reduce logistics costs and especially transportation costs in order to be competitive in the global world.

ABC Co is a food packaging manufacturer firm in Izmir, Turkey. ABC Co has a remarkable export activity to Europe (averagely 483 pallets/week) and these transportations are partial transportation. ABC Co makes partial transportation to its customers in Germany, Belgium, and the Netherlands. In general, the manufacturers do not know which expenses they paid for. The manufacturers have only received cumulative freight prices. Just like other manufacturers, ABC Co has only received the cumulative freight prices and has not received transportation freight prices in detail by its forwarders. ABC Co looks for a way to minimize transportation costs and optimize the transit time. ABC Co has a certain cost and transit time for the mode and route of transport used for shipments to European customers. In order to provide more competitive solutions to its customers, it has been determined that ABC Co should find optimum solutions especially in transportation costs and evaluate alternative route options.

In the current situation, the advantages of economies of scale and CO₂ emission cannot be utilized and thus economic gains cannot be achieved because of the usage of highway and partial transportation between Izmir-Germany, Izmir-Belgium, and Izmir-Netherlands. Because of having a transit crossing limit due to bilateral agreements of governments and waiting periods in customs (border crossings) alternative routes needed to be examined due to improving delivery times, minimizing costs and ensure competition with other companies.

ABC Co's transportation routes and modes used for shipments to its customers in Europe have a certain cost and transit time. ABC Co has to provide competitive solutions for its customers especially to find optimal transportation costs, transit time and alternative route options. In this context, it is of great importance for ABC Co to lower logistics costs and reduce the export transit times. In this process, interviews have been made with several businesses to collect data and find different modes than used ones.

This case study aims to help ABC Co to negotiate with the transportation companies, suppliers or freight forwarders and help ABC Co to see transportation costs in detail. It will give them alternative solutions for their needs such as transporting goods in minimal time and minimal costs, responding customers JIT. ABC Co will see the optimal way to transport its goods to its customers after this case study. In this part, The Beresford time cost distance model was used to optimize transportation routes as it used before by many researchers.

3.2 Methods Employed in the Study

TVSM and Beresford time cost distance models are the methods, which are studied in this research. Detailed information is given about these methods in section 3.5 (Application of TVSM) and 3.6 (Beresford Time Cost Distance Model).

3.3 Data Collection

The data collection part consists of two stages. At the first stage, data was collected to use the TVSM tool to analyze the transportation system of ABC Co. The dates of the collection of data are shown below with the contents of the meetings. In the second stage, data was collected from several businesses to make Beresford time cost distance model analyzes and these are showed below in Table 3.1 at the data collection part. During the process of analysis, meetings were held at regular intervals between the participants to define the problems in detail and determine the data-sharing requirements. During the meetings held with the participation of the case firm (ABC

Co), freight forwarder firm and academic staff and students of Dokuz Eylül University Maritime Faculty Logistics Management Department on the dates which are specified below, analysis methods and data requirements were examined. The contents of the meetings held are as follows:

08.04.2019: Informing about the project, bringing together the related participants,

17.04.2019: Examination of packaging operations, determination of needs,

02.05.2019: Determining the purpose and objectives of the project and determining which locations should be given priority,

10.05.2019: Inspection of how ABC Co customers' orders are determined, shipment processes of products produced, storage requirements, order management system and preparation of products for shipment,

16.05.2019: Implementation of TVSM study within the frame of all destinations of ABC Co,

29.05.2019: Evaluating the routes used by ABC Co and making determinations for customer groups to be analyzed,

21.06.2019: Identification of Germany, Belgium, and the Netherlands as destinations for the evaluation of the main customer groups and analysis of the Beresford Cost-Time Model,

10.07.2019: Sharing the findings of the Beresford cost time distance model and identifying missing data,

24.07.2019: Review of the results.

In parallel with the meetings held, it was decided to implement two main methods to consider the objectives of the project. These are the transport value stream mapping (TVSM) and the Beresford time cost distance model method. When TVSM methods were implemented to the ABC Co, the results showed that current routes needed more detailed examinations. Then it was decided to examine the current and alternative routes with the Beresford time cost distance model. For the research, the Beresford time cost distance model was used to shorten the transit time, find alternative routes to optimize transit time and transit costs of transportation routes and to analyze each transportation mode and routes for destination points.

The analysis was conducted in two stages. In the first part, all ABC Co processes were analyzed with the TVSM tool in this research. Then the transportation routes were examined with the Beresford time cost distance model and the optimal routes were shown in order to minimize transit time, optimize transit costs and distance parameters. In the second part, current routes and alternative routes of the transportation routes of ABC Co were examined with the Beresford time cost distance model and current routes were compared with alternative routes.

A need to collect data related to freight, transit time and distance has emerged primarily depending on the characteristics of each route to carry out the analysis. The interviews have been made with five forwarder companies during the data collection process. There is detailed information about the companies which are interviewed and the title of the interviewees, the date and form of the interview were given in Table 3.1 below.

Table 3.1 Data collection for case study

Company	Interviewee Title	Interview Date	Interview Type	Information about Sea, Road and Railway Transportation
Road Transport Company	Manager	02/07/2019	Face to face	Freight, locals and transit times
Freight Forwarder	Region Manager	28/06/2019	Face to face	Freight, locals and transit times
Road and Sea Transportation Company	Region Manager	14/06/2019	Face to face	Freight, locals and transit times
Shipowner Operation	Expert	09/07/2019	E-mail	Freight, locals and transit times
Freight Forwarder	International Supply Chain Manager	During Project	Face to face at the meetings	Freight, locals and transit times

Furthermore, the necessary support has been received about road tolls fees, highway fees, freight costs and transit times and data in this case study from project partners and the other companies which are shown in Table 3.1. Besides, the data was presented to the case study firm and project partners and it was confirmed by them. The companies as shown in Table 3.1, gave their full support for the research and shared the necessary data obtained by them.

3.4 Information about Customers of ABC Co.

ABC Co is a large food packaging manufacturer company in Turkey. The customers of ABC Co are selected for the case study in terms of volume and importance for ABC Co. As shown in Table 3.2, there is some information about transportation volumes of companies and the last destinations of transportation routes for the customers of ABC Co. There are figures for each company based in each country below. Overall 7,685,159 kg goods transferred to the following countries such as the Netherlands, Belgium, and Germany from Turkey between 04/01/2018 to 31/05/2019 by ABC Co. 23.61% of it is transported to Bosch. The main base of Bosch is in Germany and it is shown at Figure 3.1. 21.37% of it is transported to Roger & Roger. The base of it is in Belgium and it is shown in Figure 3.2. The last one is The Flexible Packaging Combination BV and 0.02% of all transportations is transferred to The Flexible Packaging Combination BV. The Flexible Packaging Combination BV was selected for the case study because it is the largest customer among all ABC Co customers in the Netherlands. These 3 companies cover 45% of all transport within these 3 countries.

Table 3.2 Information about companies that analyzed in the study

Country	Company	Quantity	Post Code
Germany	BOSCH TIERNÄHRUNG GMBH&CO.KG	1,815,137	74572
Belgium	ROGER & ROGER	1,642,752	7700
Netherlands	FLEXIBLE PACKAGING COMBINATION BV	155,617	8253

The last destination points for ABC Co to carry the goods to its customers are shown in Figure 3.1, Figure 3.2 and Figure 3.3 below. the. Detailed analyzes will be made based on those points in this chapter.

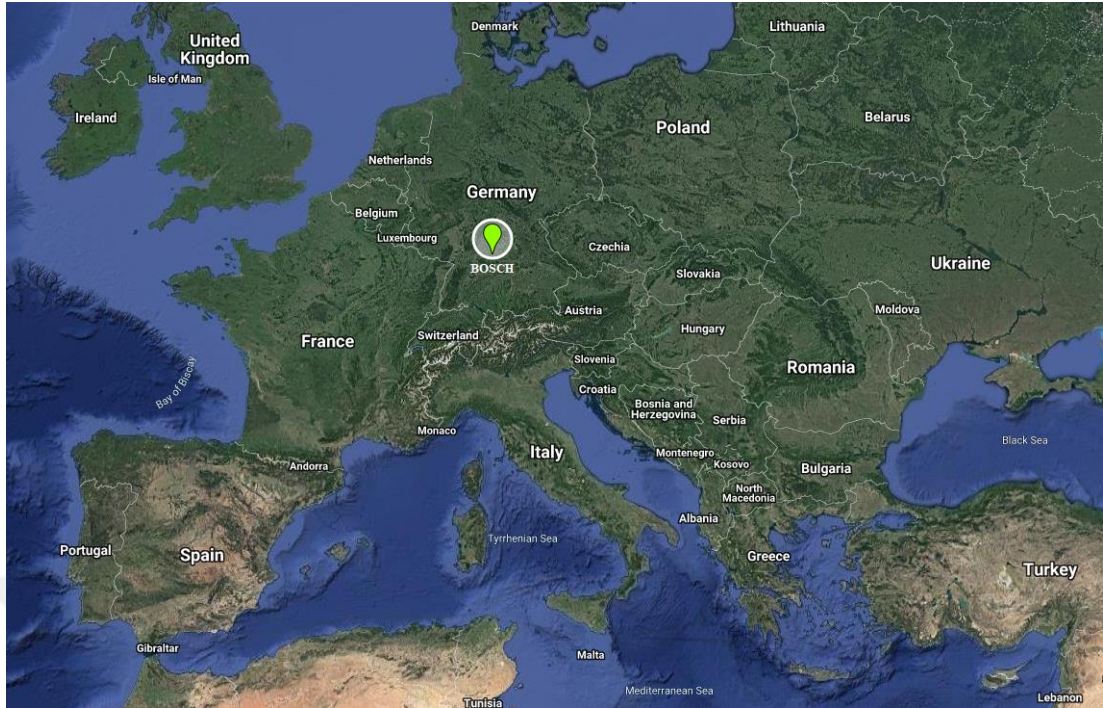


Figure 3.1 Bosch Tiernahrung GmbH&Co.Kg, 74572 Blaufelden (adapted from Google Earth, 2019)



Figure 3.2 Roger & Roger, 7700, Belgium (adapted from Google Earth, 2019)



Figure 3.3 Flexible Packaging Combination Bv, 8253, Netherlands (adapted from Google Earth, 2019)

There is a base of The Flexible Packaging Combination BV shown in Figure 3.3 above. There are 783,768 kg food packages transport to the Netherlands for 18 months and 19.85% of it is for The Flexible Packaging Combination BV. Because of that The Flexible Packaging selected to examine for this case study in the Netherlands.

3.5 Application of TVSM

As a result of the meetings with ABC Co, it is thought that the company should make improvements in the transit times and transportation costs to compete with the other food packaging manufacturers in the world. To improve transportation times and transportation costs, the current situation needs to be analyzed in detail. In this study, the TVSM method was preferred as the best analysis of the current situation. Also, according to Villarreal (2012), the first step of making value stream mapping is selecting the transportation route of interest for performance improvement. In this part, it is assumed that products are ready for delivery in the trucks to begin the journey to the last destinations.

First of all, ABC Co transports its products to its customers through logistics companies or freight forwarders. ABC Co has not owned a fleet for transportation. In this study, all shipments to its customers were investigated and the largest countries and the largest companies in those countries in terms of volume were selected.

According to the data which is given by ABC Co, there are three route options used by ABC Co to deliver the goods to its customers in time. The first option is all road option. In this option, all vehicles start their journey from Izmir towards to Bulgaria border. It takes approximately two days to cross the Bulgaria border. Then it takes one day to cross Bulgarian territory, one day to cross Serbian territory, one day to cross Croatian territory, one day to cross Slovenian territory and one day to cross Austrian territory. Then vehicles wait at the Austria-German border crossing for one day for German customs work. After crossing the German border, it takes one day to arrive at customers in Germany and two days to arrive at customers in the Netherlands and Belgium. In total, the trucks arrive to its customers in Germany in 9 days and the trucks arrive to its customers in Belgium and the Netherlands in 10 days.

The second one is the road- RO-RO- road option. At first, fully loaded trucks carry the goods to the port of Cesme in Turkey. Then trucks with the goods inside are loaded to RO-RO ships and trucks are carried by RO-RO ships until the port of Trieste in Italy. The sea part of the journey takes three days. Once ships arrived at Trieste port, controlling and checking processes start immediately at customs in Trieste port and it takes two days. After that trucks start the land part of their journey and trucks reach Austria-German border in one day. Then trucks wait at the Austria-German border crossing for one day for German customs work. After crossing the German border, it takes one day to arrive at the customers in Germany and it takes two days to arrive at the customers in the Netherlands and Belgium. In total, the trucks arrive at the customers in Germany in 8 days and it takes nine days to arrive at the customers in Belgium and the Netherlands. Additionally, the RO-RO ship line expedition (Cesme to Trieste) can only be used three times a week.

road option is chosen as a way to transport the goods to the customers of ABC Co, it takes 8 days to arrive customers in Germany, and it takes 9 days to arrive customers in Belgium and the Netherlands. If the road- RO-RO- RO-LA- road option is chosen as a way to transport the goods to the customers of ABC Co, it takes 8.5 days to arrive customers in Germany, Belgium, and the Netherlands. The Beresford time cost distance model will be used to investigate the details of transportation routes and alternative transportation routes in the next section. There are many applications in the literature for optimizing transportation routes such as deterministic optimization model, normalized normal constraint method, dynamic model, bi-objective mixed integer linear programming model, ant colony algorithm, fuzzy programming (fuzzy chance-constrained programming and the mixed integer nonlinear programming), etc. The Beresford time cost distance model is selected to be used to optimize transportation routes in this research because of the usage of multimodal transportation, the limited data taken from the company and its co-forwarders and time limitation.

3.6 Application of Beresford Time Cost Distance Model

The Beresford time cost distance model, which was developed by Beresford (1999) to determine the consistency weights of both qualitative and quantitative decision criteria, shows comparative graphical curves of quantitative factors such as cost, time and distance.

In this section, first of all, the shipments of the produced products by ABC Co from Izmir to customers in Germany, Belgium, and the Netherlands were examined according to the Beresford time cost distance model. In this context, 5 main modes and 20 main routes were examined based on FTL (Full Truck Load) and 40' DC containers. It was assumed that containers and trucks were fully loaded. A total of thirty-six different route alternatives were investigated due to differences in destinations.

The project aims to analyze the shipments of products by ABC Co to its most important customers (the highest volume of customers in terms of shipment quantity)

in three main destinations (Germany, Belgium, Netherlands) and analyze the shipments on the existing and possible alternative routes to make recommendations. In this content, the Beresford time cost distance model was used to determine the most suitable route in terms of transportation cost, transit time and distance.

3.6.1 Main Transportation Routes between Turkey and Germany, Turkey and Belgium and Turkey and the Netherlands

In this case study, there are three main transportation routes from ABC Co to its customers. Only main destination points are listed below and the main destination points of transportation routes are shown in Table 3.3, Table 3.4 and Table 3.5. The transportation route of ABC Co is shown in Table 3.3 below for the shipments to Germany. The list of the main destination points for the shipments to Belgium is shown in Table 3.4 and the list of the main destination points for the shipments to the Netherlands is shown in Table 3.5.

Table 3.3 Mode and route alternatives for freight between Turkey and Germany (Bosch)

Route 1	All road option	Izmir-Stuttgart via Bulgaria, Romania, Hungary, Austria, Germany or Greece, Macedonia, Serbia, Croatia, Slovenia, Austria, Germany
Route 2	All road with RO-LA train option	Izmir-Stuttgart via Bulgaria, Serbia, Croatia, Slovenia (Maribor)-Austria (Wels) (RO-LA), Germany
Route 3	Road- RO-RO- Road option	Izmir-Stuttgart via Cesme-Trieste (RO-RO), Trieste-Germany (Road)
Route 4	RO-RO and RO-LA option	Izmir-Stuttgart via Cesme-Trieste (RO-RO), Trieste- (Wels, Bettembourg, Salzburg or Genk) (RO-LA), Germany
Route 5	All water option	Izmir-Stuttgart via Aliaga port and port of Antwerp, Rotterdam or Hamburg

Table 3.4 Mode and route alternatives for freight between Turkey and Belgium (Roger & Roger)

Route 1	All road option	Izmir-Mouscron via Bulgaria, Romania, Hungary, Austria, Germany or Greece, Macedonia, Serbia, Croatia, Slovenia, Austria, Germany, Belgium
Route 2	All road with RO-LA train option	Izmir-Mouscron via Bulgaria, Serbia, Croatia, Slovenia (Maribor)-Austria (Wels) (RO-LA), Germany, Belgium
Route 3	Road- RO-RO- Road option	Izmir-Mouscron via Cesme-Trieste (RO-RO), Trieste-Belgium (Road)
Route 4	RO-RO and RO-LA option	Izmir-Mouscron via Cesme-Trieste (RO-RO), Trieste- (Wels, Bettembourg, Salzburg or Genk) (RO-LA), Germany, Belgium
Route 5	All water option	Izmir-Mouscron via Aliaga port and port of Antwerp, Rotterdam or Hamburg

Table 3.5 Mode and route alternatives for freight between Turkey and Netherlands (Flexible Packaging Combination BV)

Route 1	All road option	Izmir-Amersfoort via Bulgaria, Romania, Hungary, Austria, Germany or Greece, Macedonia, Serbia, Croatia, Slovenia, Austria, Germany, Netherlands
Route 2	All road with RO-LA train option	Izmir-Amersfoort via Bulgaria, Serbia, Croatia, Slovenia (Maribor)-Austria (Wels) (RO-LA), Germany, Netherlands
Route 3	Road- RO-RO- Road option	Izmir-Amersfoort via Cesme-Trieste (RO-RO), Trieste-Netherlands (Road)
Route 4	RO-RO and RO-LA option	Izmir-Amersfoort via Cesme-Trieste (RO-RO), Trieste-(Wels, Bettembourg, Salzburg or Genk) (RO-LA), Germany, Netherlands
Route 5	All water option	Izmir-Amersfoort via Aliaga port and port of Antwerp, Rotterdam or Hamburg

As listed in Table 3.3, Table 3.4, Table 3.5, the routing options diversify from the all-road option to the all-water option. Besides these, different combinations, different routes, different interchange points, and different multimodal transfer options can be used. For instance, instead of Trieste terminal, Genoa (Italy) or Venice (Italy) terminal can be used for RO-RO or instead of loading trucks to RO-RO ships, goods can load to containers from Aliaga port and transport to Genoa port, Trieste port or Venice port with container ships. These are the alternative options for the port of Trieste when RO-RO ships are needed to use. In Table 3.3, Table 3.4 and Table 3.5 show the main route options within this project. Also, the shuttle train option (RO-LA train alternative) between Trieste and Duisburg (Germany) can be considered as an alternative transportation option. Trieste-Duisburg RO-LA shuttle train has been serving since 2014 and it has round trips four times a week. They have active services for all crane trucks and all containers. This lane is not using often by Turkish companies in logistics operations when the goods are carried to the EU countries but it should be considered as a good alternative transportation option.

Table 3.6 Detailed mode and route alternatives for freight between Turkey and Germany

Route	Exit Point	Mode	Leg	Mode	Leg	Mode	Leg	Mode	Leg	Mode	Final Destination
1	Izmir	Road									Germany
2	Izmir	Road	Maribor	Rail	Wels	Road					Germany
3	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Road					Germany
4	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			Wels	Road	Germany
5	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			B.bourg	Road	Germany
6	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			Genk	Road	Germany
7	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Road	Fernetti	Rail	Salzburg	Road	Germany
8	Izmir	Road	Aliaga	Sea (Cont.)	Antwerp					Road	Germany
9	Izmir	Road	Aliaga	Sea (Cont.)	Rotterdam					Road	Germany
10	Izmir	Road	Aliaga	Sea (Cont.)	Hamburg					Road	Germany

Table 3.7 Detailed mode and route alternatives for freight between Turkey and Belgium

Route	Exit Point	Mode	Leg	Mode	Leg	Mode	Leg	Mode	Leg	Mode	Final Destination
1	Izmir	Road									Belgium
2	Izmir	Road	Maribor	Rail	Wels	Road					Belgium
3	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Road					Belgium
4	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			Wels	Road	Belgium
5	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			B.bourg	Road	Belgium
6	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			Genk	Road	Belgium
7	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Road	Fernetti	Rail	Salzburg	Road	Belgium
8	Izmir	Road	Aliaga	Sea (Cont.)	Antwerp					Road	Belgium
9	Izmir	Road	Aliaga	Sea (Cont.)	Rotterdam					Road	Belgium
10	Izmir	Road	Aliaga	Sea (Cont.)	Hamburg					Road	Belgium

Table 3.8 Detailed mode and route alternatives for freight between Turkey and Netherlands

Route	Exit Point	Mode	Leg	Mode	Leg	Mode	Leg	Mode	Leg	Mode	Final Destination
1	Izmir	Road									Netherlands
2	Izmir	Road	Maribor	Rail	Wels	Road					Netherlands
3	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Road					Netherlands
4	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			Wels	Road	Netherlands
5	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			B.bourg	Road	Netherlands
6	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Rail			Genk	Road	Netherlands
7	Izmir	Road	Cesme	Sea (RO-RO)	Trieste	Road	Fernetti	Rail	Salzburg	Road	Netherlands
8	Izmir	Road	Aliaga	Sea (Cont.)	Antwerp					Road	Netherlands
9	Izmir	Road	Aliaga	Sea (Cont.)	Rotterdam					Road	Netherlands
10	Izmir	Road	Aliaga	Sea (Cont.)	Hamburg					Road	Netherlands

In this case study, Route 1 is the one when only the all-road option is used in logistics operation by forwarders. Only the road option is used while the goods are carried to the EU countries by trucks. TIRs go through Europe on two different border gates (as shown in Table 3.3, Table 3.4, Table 3.5) one from Bulgaria and it is called

as Kapi Kule border gate, and the other one is from Greece and it is called as Ipsala border gate. 6 alternative routes are investigated in this part of the study for the all-road option.

Route 2 is the all-road with the RO-LA option. Two main roads are used in this route and these are via Greece and Bulgaria (as shown in Table 3.3, Table 3.4, Table 3.5). TIRs go through until Maribor after each border gate and TIRs are loaded to train line for usage of Maribor-Wells ROLA line at Maribor train station. Six route alternatives are investigated in this part of the study for the all-road with RO-RO option.

Route 3 is the road- RO-RO- road option. TIRs are loaded to RO-RO ships at Cesme port in Turkey and carry by RO-RO ships until Trieste port in Italy. Then TIRs pass through Villach-Salzburg way to go to the last destinations. Three route alternatives are examined for this part of the study for the road- RO-RO- road option.

Route 4 is the road- RO-RO- RO-LA- road option. In logistics operations, road transportation is only used between ABC Co to Cesme port and from the exiting point of the train station to the last customer by forwarders for this route. Goods are carried by RO-RO ships until Trieste port from Cesme port. After that in terms of benefit and availability, one of the RO-LA providers is selected (Trieste-Wels, Trieste-Bettembourg, Trieste- Salzburg or Trieste- Genk). There is no direct RO-LA train line between Trieste and Salzburg that's why TIRs go to Ferneti train station which is a small town in Trieste just 18 km away from the port and Ferneti train station is used for RO-LA service. Twelve route alternatives are examined for this part of the study for the road- RO-RO- RO-LA- road option.

Route 5 is the all-water option. The road is only used while the containers are carried to the Aliaga port from the warehouse of ABC Co and Antwerp, Hamburg or Rotterdam ports to the customers by forwarders. Nine route alternatives are examined for this part of the study for the all water option. Crossed countries and legs are shown in Table 3.6, Table 3.7, Table 3.8 to go to the last destination.

After brief information about possible routes, the following section will provide detailed analyses about the routes listed in Table 3.3, Table 3.4 and Table 3.5 above and compare the routes to each other to find a feasible route for ABC Co transportation operations. Alternative routes will be examined to minimize the transportation costs and optimize the transit time to help ABC Co to compete with other companies.

3.6.1.1 All Road Option (Route 1)

Firstly, the all-road option (as shown in Figure 3.5) between these three countries which is used widely by transportation service providers of ABC Co was investigated. Turkey is a country in which investments in the transportation system concentrated on road transport infrastructure and vehicles currently have one of the largest road transports fleets in Europe (ACEA, 2018). Transportation routes (as seen in Table 3.9, Table 3.10 and Table 3.11) were examined in terms of transit time, transportation cost and distance parameters.

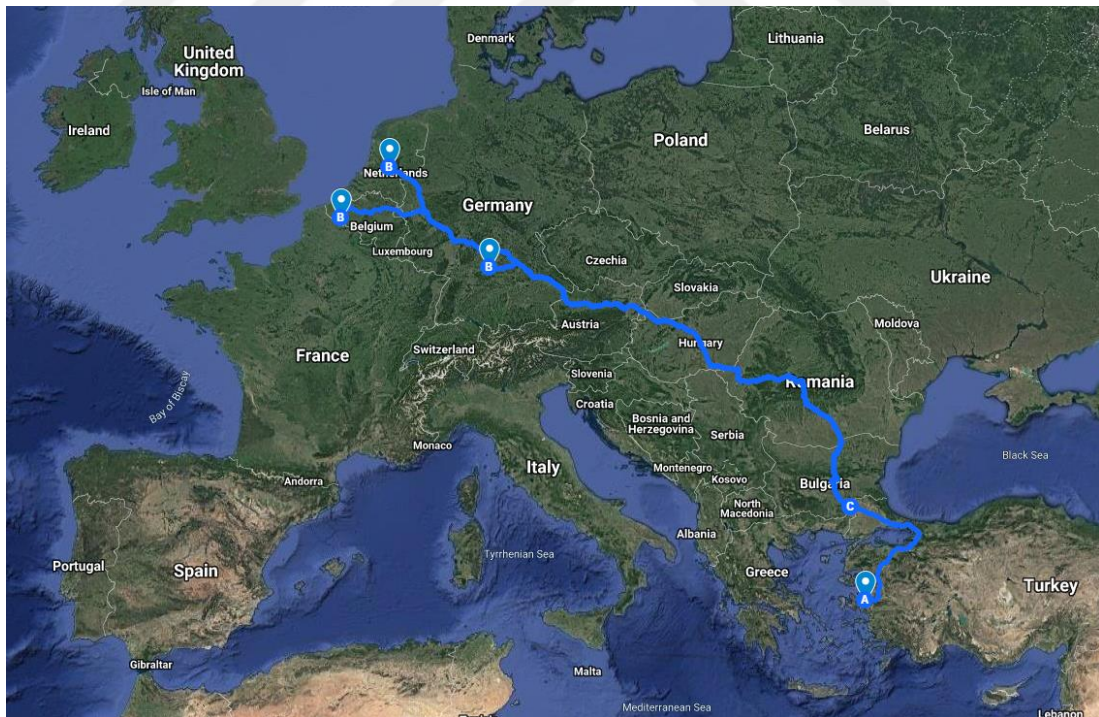


Figure 3.5 Map of all road option via Bulgaria (Route 1) (adapted from Google Earth, 2019)

Trucks start the journey from Izmir at the base of ABC Co and arrive at Bulgarian border which is Kapi Kule and this journey approximately takes 32 hours 47 min including time spent at custom. Then TIRs pass through Ruscuk which is the Romanian border, then Sziget (Hungarian border), then Nickelsdorf (Austrian border), then Suben (German border), and then it arrives at Blaufelden 74572, Stuttgart to the main warehouse of the customer. This journey (all transportation operation, door-to-door) takes 92 hours 59 min including customs. The traveled distance is 2590 km and the cost of the transportation routes is 2602.8 Euro which is known as freight by transportation companies. This is the best route option within all-road options for Germany. The rest of the tables and comparisons between routes are in the Appendices section (detailed information about all road option is shown in Table A.1, Table A.2 and Table A.3).

In general, the overall transit time for the all-road option is four days for transportation to Germany and the cost of it is 2602.8 Euro. It takes five days to arrive at the customers in Belgium and the optimal transportation cost of the journey of the all-road option is 2914.7 Euro. It takes five days to arrive at the customers in the Netherlands and the transportation cost of the journey is 2883.75 Euro. It is assumed that one driver used in the overall route and drivers' daily rests and breaks calculated according to the AETR convention. The speed of the trucks assumed as 70 km per hour and calculations made in terms of full truckload (FTL) transportation, not less than truckload shipping (LTL). In urgent situations like limited transit time, etc., the option of two drivers may also be used and this will decrease the overall duration by 1 or 2 days. According to the AETR convention, in normal circumstances, TIR drivers can drive 9 hours maximum in a single day and they must take a break at least 1 hour after 4 hours of drive. This an hour rest included 9 hours maximum driving duration. The drivers have to rest 9 hours if they drive 9 hours a single day. Sometimes drivers drive 11 hours per day when the final destination closer than 2 hours after drive of 9 hours. At that times drivers have to rest 11 hours per day. If drivers accompany a vehicle being moved by ferry or train, time spent at the train or ferry can be considered as a part of their daily rest and break requirements (UNECE, 2006). The time calculations were made based on these assumptions. The daily rest and break times of

the drivers, detailed information of the legs as transit time, distance and transportation costs are shown in Table A.1, Table A.2 and Table A.3 and general information of legs is shown in Table 3.9, Table 3.10 and Table 3.11. (Denktaş Şakar, 2010). As shown in Figure 3.5, there are many inevitable stops through the route between the legs. These stops effectuate 60.22% of the overall transit time related to the route (3 days 20 hours 50 min) and those breaks have seen in Figure 3.5. *“When the main assumptions of the study are considered, it should be mentioned that a standard TIR (length:13.60 m, width:2.42 m, height:2.40 m, volume:79 m³, 26 euro pallet) was used in the road leg of the routes with an average speed of 70 km/h. Beresford et al. (2007) mentioned that truck speed limits vary across the EU such as 90 km/h in France, 80 km/h in Germany and Netherlands which makes it difficult to calculate actual truck speed. When the differences in transport infrastructure in the countries where the trucks pass through and the local traffic are considered, an average speed of 70 km/h was assumed”* (Denktaş Şakar, 2010, p.210). It was assumed that TIRs leave anytime it is loaded and there are no time boundaries for that and driver bans neglected which is happening because of the relationships between two governments.

Table 3.9 All road Izmir to Germany via Bulgaria

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Bulgaria (Kapi Kule)	Road	32 hours 47 min	545	506.05
2	Bulgaria (Kapi Kule)-Romania (Ruscuk)	Road	5 hours 25 min	310	270.5
2-3	Romania (Ruscuk) – Hungary (Szeget)	Road	20 hours 20 min	724	382.4
3	Hungary (Szeget)-Austria (Nickelsdorf)	Road	13 hours 55 min	344	290.4
3-4	Austria (Nickelsdorf) – Germany (Suben)	Road	14 hours 50 min	338	758.3
3-4	Germany – Bosch 74572 Blaufelden	Road	5 hours 42 min	329	395.15
3-4	Overall		92 hours 59 min	2590	2602.8

Table 3.10 All road Izmir to Belgium via Bulgaria

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Bulgaria (Kapi Kule)	Road	32 hours 47 min	545	506.05
2	Bulgaria (Kapi Kule)-Romania (Ruscuk)	Road	5 hours 25 min	310	270.5
2-3	Romania (Ruscuk) – Hungary (Szeget)	Road	20 hours 20 min	724	382.4
3	Hungary (Szeget)-Austria (Nickelsdorf)	Road	13 hours 55 min	344	290.4
3-4	Austria (Nickelsdorf) – Germany (Suben)	Road	14 hours 50 min	338	758.3
4-5	Germany – Germany (Aachen)	Road	20 hours 11 min	713	529.55
4-5	Germany – Roger & Roger 7700	Road	4 hours 34 min	250	187.5
4-5	Overall		112 hours 2 min	3224	2924.7

Table 3.11 All road Izmir to Netherlands via Bulgaria

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Bulgaria (Kapi Kule)	Road	32 hours 47 min	545	506.05
2	Bulgaria (Kapi Kule)-Romania (Rusçuk)	Road	5 hours 25 min	310	270.5
2-3	Romania (Rusçuk) – Hungary (Szeget)	Road	20 hours 20 min	724	382.4
3	Hungary (Szeget)-Austria (Nickelsdorf)	Road	13 hours 55 min	344	290.4
3-4	Austria (Nickelsdorf) – Germany (Suben)	Road	14 hours 50 min	338	758.3
4-5	Germany – The Flexible Packaging Company Amersfoort	Road	23 hours 5 min	846	676.1
4-5	Overall		110 hours 22 min	3107	2883.75

All costs are shown in Table 3.9, Table 3.10 and Table 3.11 such as the bridge fee, health document fee (it is necessary for the company because of the food packaging business), ferry fee, running costs, TIR carnet, fuel, CMR insurance, transit document fee, custom fee, highway fee, toll fee, etc.. Time versus distance and cost versus distance calculations are shown in Figure 3.6 and Figure 3.7 below. The cost of the route as shown in Table 3.9 calculated as 1.005 Euro per km. The rate of the trucking is 1.005 €/km for Germany. The trucking rate is 0.91 €/km for Belgium and it is 0.93 €/km for the Netherlands. There is a comparison of routes as shown in Table 3.15 below. As seen in Table 3.15 the transportation route via Bulgaria has benefits for route 1. Via Bulgaria mode for route 1 is faster and less expensive than via Greece mode. That's why transportation route 1 via Bulgaria is the best choice between other routes in all road option (Route 1).

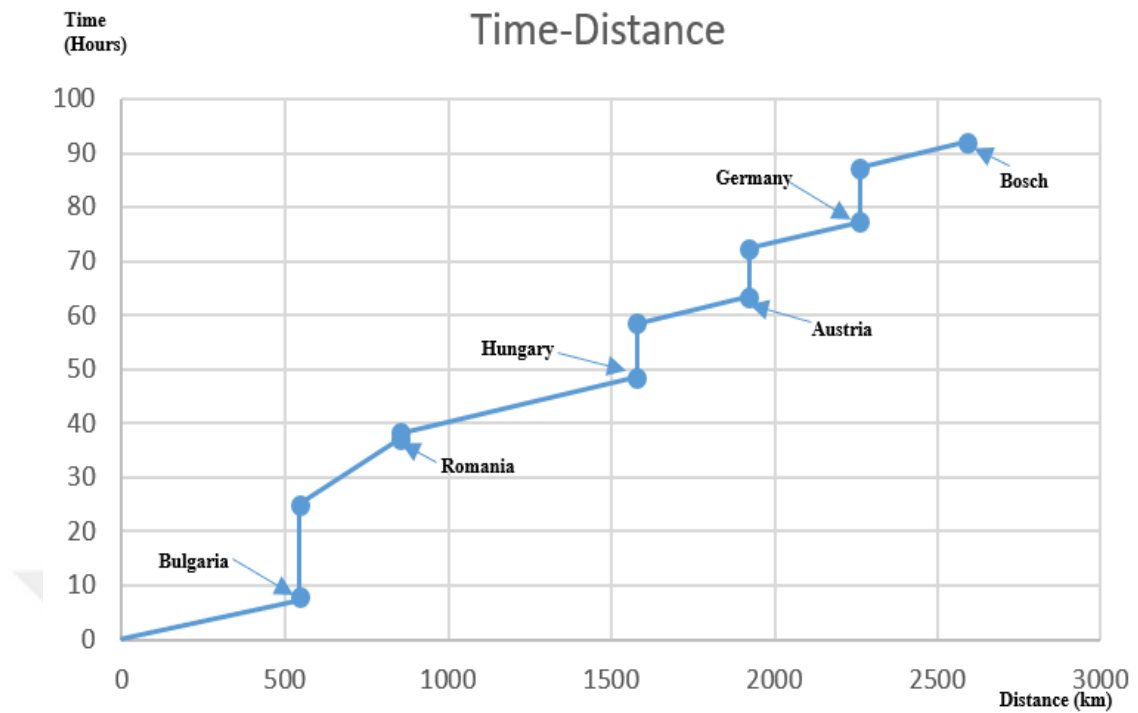


Figure 3.6 Time-distance for all road option for Germany via Bulgaria (Route 1)

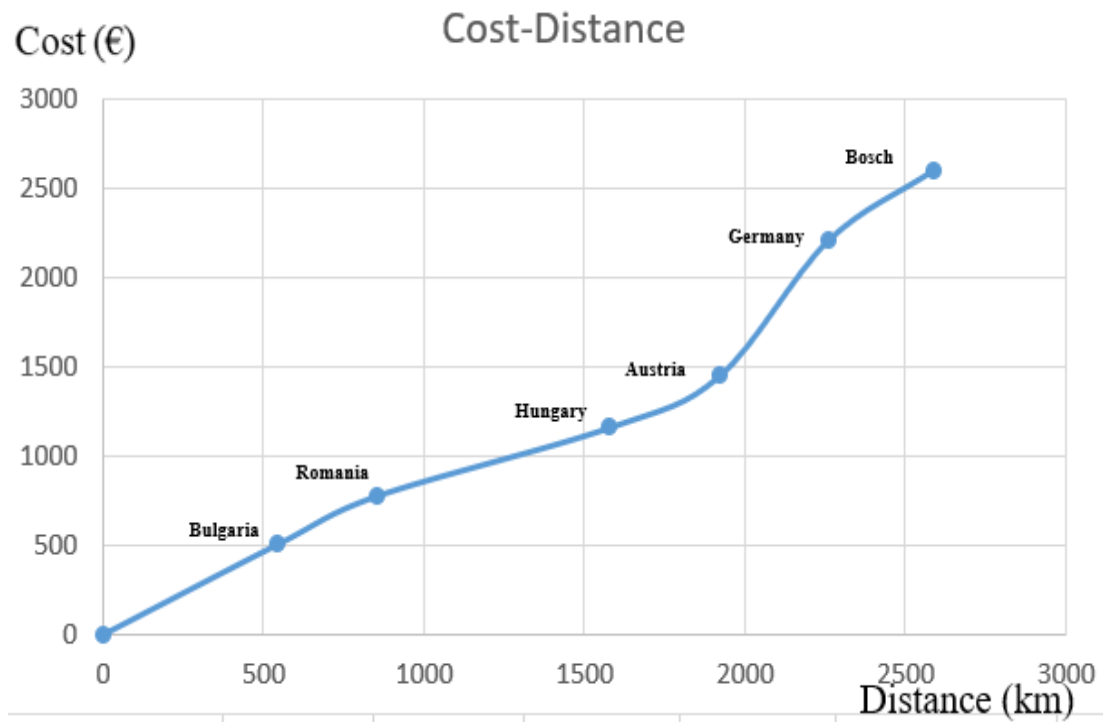


Figure 3.7 Cost-distance for all road option for Germany via Bulgaria (Route 1)

3.6.1.2 All Road with RO-LA Train Option (Route 2)

The second alternative route is called as all-road with RO-LA train supported option. The starting point of this route is Izmir, the main base of ABC Co just like the all-road transportation route option. Goods are carried out to Europe via Bulgaria or Greece as seen in Table 3.3, Table 3.4, Table 3.5. TIRs pass the border of Bulgaria or Greece and then TIRs directly go to Maribor train station and are loaded on the shuttle train the Maribor-Wels RO-LA line to go to Wels. Then the rest of the destination continues with road transportation until the final destination point. The first alternative of this route follows the route of Izmir to Bulgaria, Bulgaria to Serbia, Serbia to Croatia, Croatia to Slovenia, Slovenia to Austria (by RO-LA train) and then TIRs go to Germany, Belgium or the Netherlands based on the last destination after Austrian border is passed. As seen in Figure 3.8, the second alternative of route 2 follows the route of Izmir to Greece, Greece to Macedonia, Macedonia to Serbia, Serbia to Croatia, Croatia to Slovenia, Slovenia to Austria (by RO-LA train) and then TIRs go to Germany, Belgium or the Netherlands based on the last destination after Austrian border is passed.

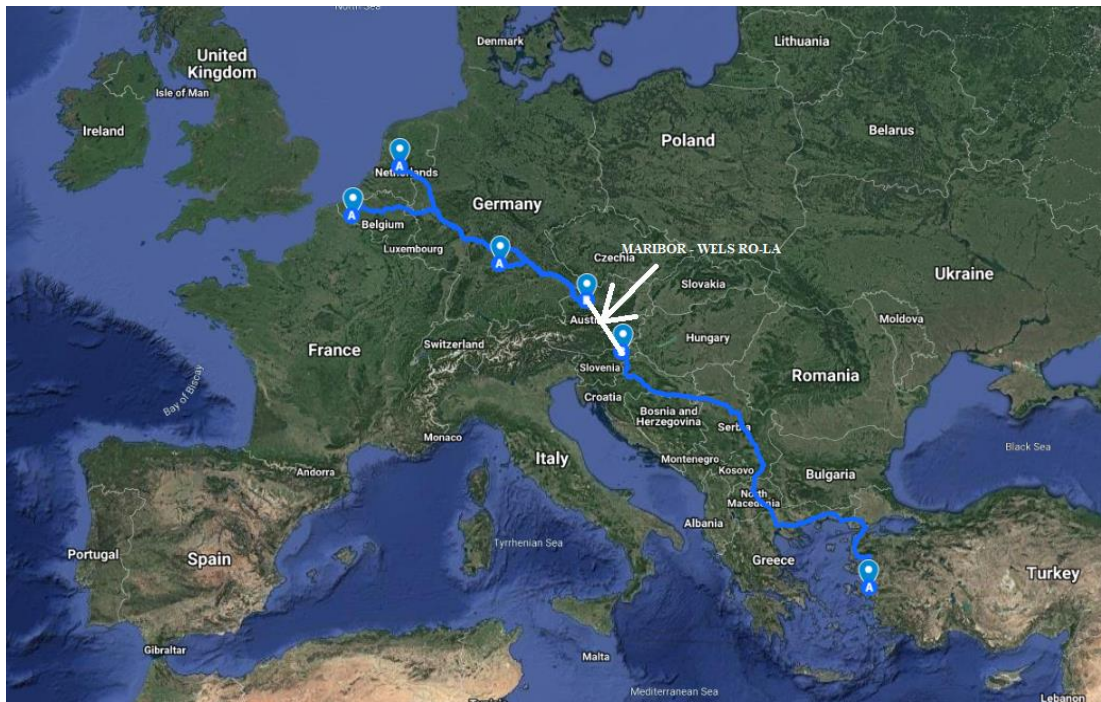


Figure 3.8 Map of all road with RO-LA train option via Greece (Route 2) (adapted from Google Earth, 2019)

Although this route which is shown in Figure 3.8, is predominantly referred to as road transport, it was supported by using the RO-LA train transportation method on the Maribor-Wels line as well. Transportation routes are shown in Table 3.12, Table 3.13 and Table 3.14 were examined in terms of transit time, cost and distance parameters.

“As a result of the main disadvantages of road transport such as air pollution, possible delays due to traffic jam at highways, decreases in the service quality in the overall performance of the transport system, RO-LA system emerged as a new alternative to the users of that route” (Denktas Sakar, 2010, p. 223). The main advantages of the usage of the RO-LA train are mentioned to be possible decreases in personal costs as well as fuel, tires, repair, and maintenance and also, avoids the toll fee, highway fee, dozvola (border crossing certificate) fee, customs fee. The truck drivers travel in wagon with beds so they can have a rest during the travel time. According to the industry sources, although the maximum permissible running speed is around 100 km/h, the average speed varies according to the conditions such as mountains, tunnels, etc. for RO-LA trains so that average speed is assumed as 51.7 km/h. Table 3.12, Table 3.13 and Table 3.14 shows the main figures related to that and to represent time versus distance and cost versus distance graphs for route 2 in Figure 3.9 and Figure 3.10. Transit time is lower compared to route 1 but the overall cost is more (2602.8 € for Germany at route 1 and it is 3363.7 € for Germany at Route 2). Comparisons are shown in Table 3.15 between two routes and two modes (First route and second route). The overall cost for the optimal solution of route 2 for Belgium is 3685.6 € and it is 3644.65 € for Netherlands. The time has been traveled to transport the goods from Izmir to Germany is 78 hours 8 min. Route 2 is the fastest route to transport the goods to Germany within all alternative transportation options and it is also 97 hours 11 min for Belgium and 95 hours 31 min for the Netherlands.

When route 2 is examined in detail, TIRs are departed from Izmir to go to Greece (Ipsala border gate) and TIRs pass Greece border in 10 hours 30 min, custom time and driver breaks are included. After crossing the Ipsala border gate, TIRs go through the road and arrive at Maribor train station. TIRs are loaded to the railway at the Maribor

RO-LA train terminal. It takes 4 hours to load the trucks to the RO-LA train and 2 hours to unload the truck from the RO-LA train line. It takes 6 hours to load and unload the trucks to the RO-LA train line. These unloading and loading part is counted as waiting time. 40 hours are spent for rests, breaks and wait for loading and unloading TIRs to the RO-LA train to transport the goods from Turkey to Germany as shown in Table 3.12. This means stops effectuate 52.2% of the overall transit time related to the route of Germany. The railway constitutes 13% and road transportation constitutes 87% of the total transit time of the route. In terms of cost, the railway constitutes 23.5% and the highway constitutes 76.5% of the total route.

Table 3.12 All road with RO-LA option Izmir to Germany via Greece (Route 2)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Greece (Ipsala)	Road	10 hours 30 min	455	474.55
1-2	Greece (Ipsala) –Macedonia (Evzonoi)	Road	15 hours 45 min	403	316.05
1-2	Macedonia (Evzonoi)– Serbia (Lipovac)	Road	14 hours	350	152.5
2-3	Serbia (Lipovac) – Batrovci (Croatia)	Road	5 hours 52 min	411	303.85
2-3	Croatia (Batrovci) – Croatia (Zagreb)	Road	13 hours 3 min	284	179.4
2-3	Croatia (Zagreb) – Slovenia (Maribor)	Road	1 hours 52 min	131	45.85
3-4	Slovenia (Maribor)-Austria (Wels)	Rail	10 hours 16 min	215	860
3-4	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	511.35
3-4	Germany (Suben)– Bosch 74572 Blaufelden	Road	5 hours 42 min	329	520.15
	Overall		78 hours 8 min	2657	3363.7

Table 3.13 All road with RO-LA option Izmir to Belgium via Greece (Route 2)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
0-1	Izmir – Greece (Ipsala)	Road	10 hours 30 min	455	474.55
1-2	Greece (Ipsala) –Macedonia (Evzonoi)	Road	15 hours 45 min	403	316.05
1-2	Macedonia (Evzonoi)– Serbia (Lipovac)	Road	14 hours	350	152.5
1-2	Serbia (Lipovac) – Batrovci (Croatia)	Road	5 hours 52 min	411	303.85
2-3	Croatia (Batrovci) – Croatia (Zagreb)	Road	13 hours 3 min	284	179.4
2-3	Croatia (Zagreb) – Slovenia (Maribor)	Road	1 hours 52 min	131	45.85
2-3	Slovenia (Maribor)-Austria (Wels)	Rail	10 hours 16 min	215	860
3-4	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	511.35
3-4	Germany – Germany (Aachen)	Road	20 hours 11 min	713	654.55
4-5	Germany – Roger & Roger 7700	Road	4 hours 34 min	250	187.5
4-5	Overall		97 hours 11 min	3291	3685.6

50 hours are spent for rests, breaks and wait for loading TIRs to the RO-LA train to the purpose of transporting the goods from main base of ABC Co to Belgium as shown in Table 3.13. This means stops effectuate 51.4% of the overall transit time related to the route of Belgium. The railway constitutes 10.5% and road transportation

constitutes 89.5% of the total transit time of the route. In terms of cost, the railway constitutes 23.33% and the highway constitutes 76.67% of the total route.

Table 3.14 All road with RO-LA option Izmir to Netherlands via Greece (Route 2)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
0-1	Izmir – Greece (Ipsala)	Road	10 hours 30 min	455	474.55
1-2	Greece (Ipsala) –Macedonia (Evzonoi)	Road	15 hours 45 min	403	316.05
1-2	Macedonia (Evzonoi)– Serbia (Lipovac)	Road	14 hours	350	152.5
1-2	Serbia (Lipovac) – Batrovci (Croatia)	Road	5 hours 52 min	411	303.85
2-3	Croatia (Batrovci) – Croatia (Zagreb)	Road	13 hours 3 min	284	179.4
2-3	Croatia (Zagreb) – Slovenia (Maribor)	Road	1 hours 52 min	131	45.85
2-3	Slovenia (Maribor)-Austria (Wels)	Rail	10 hours 16 min	215	860
3-4	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	511.35
3-4	Germany (Suben) – The Flexible Packaging Company Amersfoort	Road	23 hours 5 min	846	801.1
3-4	Overall		95 hours 31 min	3174	3644.65

As shown in Table 3.14, 50 hours are spent for rests, breaks and wait for loading TIRs to the RO-LA train o the purpose of transporting the goods from Turkey to the Netherlands. This means stops effectuate 52.35% of the overall transit time related to the route of the Netherlands. The railway constitutes 10.7% and road transportation constitutes 89.3% of the total transit time of the route. In terms of cost, the railway constitutes 23.6% and the highway constitutes 76.4% of the total route.

Besides, route 2 has advantages about transit time and transportation costs against via Bulgaria route as shown in Table A.7, Table A.8, Table A.9 in detailed. When you compare two modes of route 2 with each other, as shown in Table 3.15, the difference between transit times and transportation cost is significant difference to choose one within two routes for logistics operations. Route 2 via Greece is faster and cheaper than route 2 via Bulgaria mode. Route 2 via Greece mode is 55.75 Euro cheaper and it is 9 hours 37 min faster than route 2 via Bulgaria mode. Route 2 via Greece mode has to be chosen based on these data and benefits of it. A comparison of overall results is shown in Table 3.15 below for route 1 and route 2. Because of that transportation route 2 via Greece is the best choice between other modes in the all-road with RO-LA option (Route 2). Detailed information about route 1 and route 2 are shown in tables

in Appendices section (Table A.1, Table A.2, Table A.3, Table A.4, Table A.5, Table A.6, Table A.7, Table A.8, Table A.9, Table A.10, Table A.11, Table A.12).

Table 3.15 Comparison of Route 1 and Route 2 for shipments to Germany, Belgium and Netherlands

		Route 1			Route 2		
		via Greece	via Bulgaria	Difference	via Greece	via Bulgaria	Difference
Germany	Transit Time	96 hours 16 min	92 hours 59 min	3 hours 17 min	78 hours 8 min	87 hours 45 min	9 hours 37 min
	Distance	2753	2590	163	2657	2422	235
	Cost	2852.55	2602.8	249.75	3363.7	3419.45	-55.75
Belgium	Transit Time	116 hours 16 min	112 hours 2 min	4 hours 14 min	97 hours 11 min	106 hours 48 min	9 hours 37 min
	Distance	3387	3224	163	3291	3056	235
	Cost	3174.45	2924.7	249.75	3685.6	3741.35	-55.75
Netherlands	Transit Time	113 hours 39 min	110 hours 22 min	3 hours 17 min	95 hours 31 min	105 hours 8 min	9 hours 37 min
	Distance	3270	3107	163	3174	2939	235
	Cost	3133.5	2883.75	249.75	3644.65	3700.4	-55.75

In addition, it is necessary to consider the availability of the RO-LA line, the eligibility of expedition days when using the RO-LA lines. In some cases, the lines are maintained and inspected to the purpose of better service. The line cannot be used even though the reservation has been made. Sometimes the line cannot be booked during peak periods. A review of these situations is important to choose the best route.

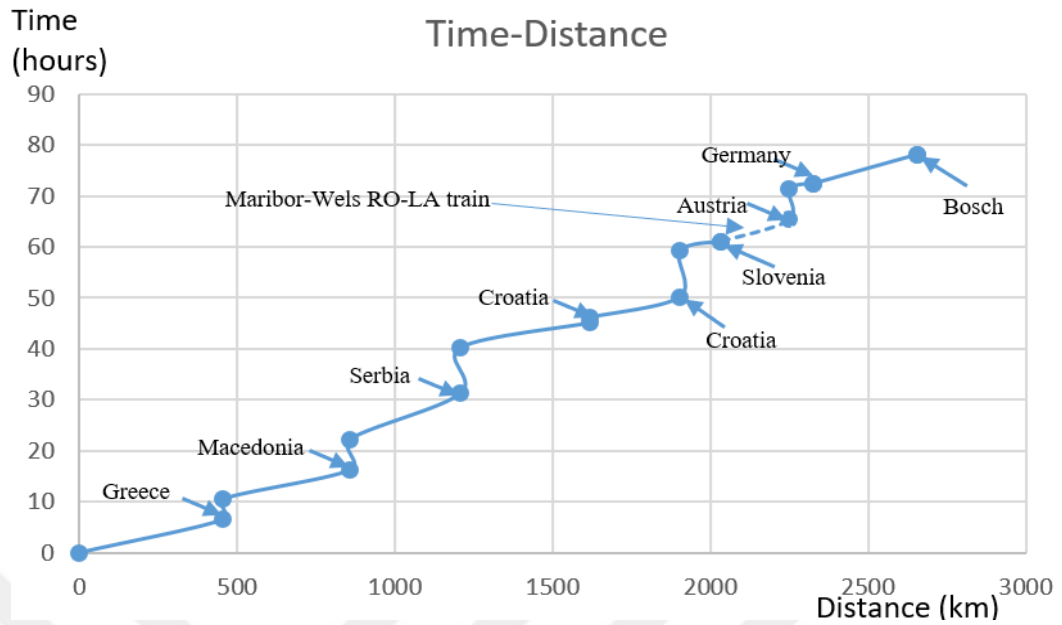


Figure 3.9 Time-distance for all road with RO-LA option for Germany via Greece (Route 2)

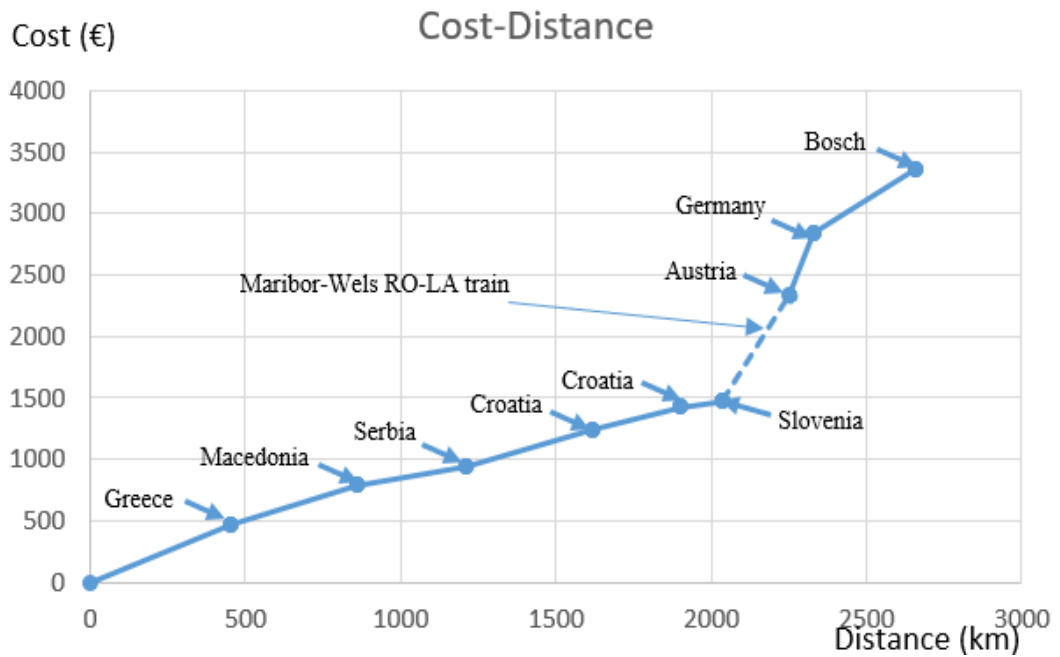


Figure 3.10 Cost-distance for all road with RO-LA option for Germany via Greece (Route 2)

3.6.1.3 Road- RO-RO- Road Option (Route 3)

Route 3 which is included in the study, examines the use of the seas (RO-RO shipment) with road transportation method. These routes offer an alternative routing options for transportation between Turkey and Germany, Turkey and Belgium and

Turkey and the Netherlands destinations. In this route, the RO-RO maritime voyage is used from Izmir (Cesme port) to Trieste port in Italy. This route includes road transport from Trieste to Germany, Trieste to Belgium, Trieste to Netherlands after RO-RO ships arrived Trieste port.

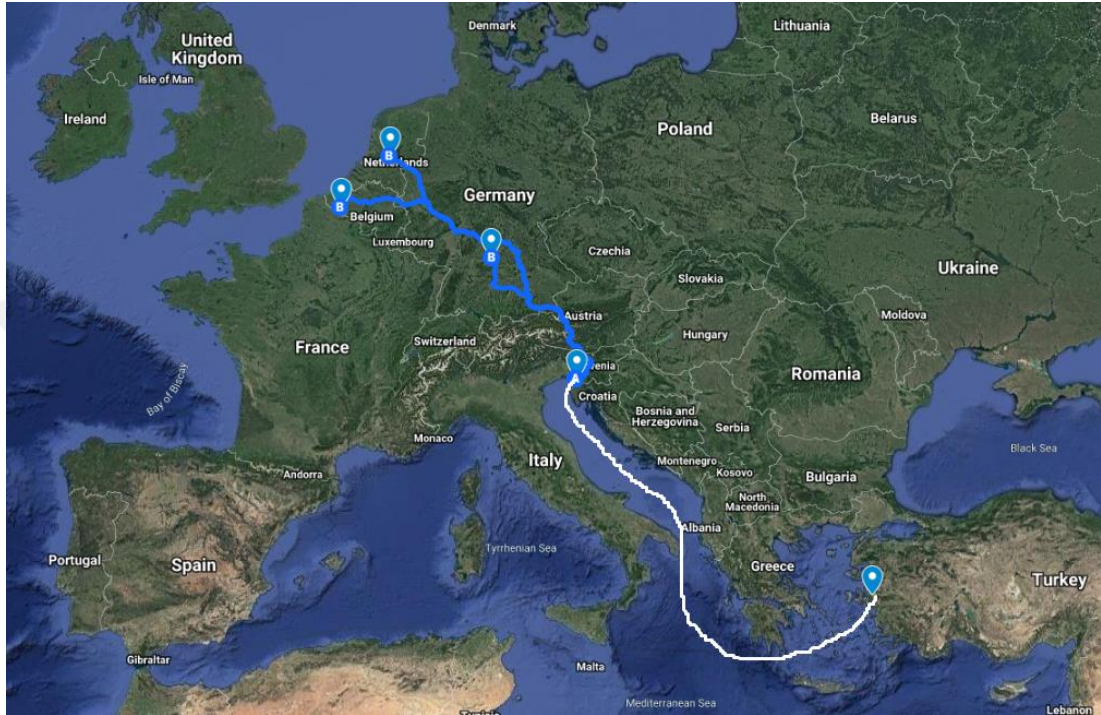


Figure 3.11 Map of Road- RO-RO- Road option via Villach-Salzburg (Route 3) (adapted from Google Earth, 2019)

As seen in Figure 3.11, at the first stage of the transportation route, water transportation option use to carry the goods from Izmir to Trieste by ABC Co. Once RO-RO ships arrive at the port of Trieste, trucks are unloaded from RO-RO ships to carry the goods to the Austria-Germany border. After that trucks pass Austria-Germany border and go through road based on last destinations which are Germany, Belgium or the Netherlands.

Table 3.16 Road- RO-RO- Road option Izmir to Germany via Villach-Salzburg (Route 3)

Day	Rota	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir - Cesme	Road	25 hours 49 min	127	329.42
3-4	Çesme -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
4-5	Trieste (Italy)-Villach (Austria)	Road	2 hours 48 min	197	98.15
4-5	Villach (Austria) – Salzburg (Austria)	Road	3 hours 43 min	191	646.85
4-5	Germany – Bosch 74572 Blaufelden	Road	14 hours 48 min	406	422.1
4-5	Overall		115 hours 40 min	2580	3156.52

When this route is examined in terms of transit time, 59.2% of it is composed of RO-RO maritime transport and 40.8% of it is composed of road transport. In terms of cost, RO-RO constitutes 52.5% and road transportation constitutes 47.5%. If the first three routes are compared to each other. Route 3 can be used as an alternative route for shipments to Germany from Turkey when route 1 is not available and 20 hours delay in transit time is not important. As shown in Table 3.16, the sea leg constitutes the longest part of the route and route 3 has the longest transit time within the first three routes for the shipments to Germany. In terms of distance, the sea leg constitutes 64.3% of this route (1659 km). The total distance for this route becomes 921 km when this part of the transportation is disregarded.

Table 3.17 Road- RO-RO- Road option Izmir to Belgium via Villach-Salzburg (Route 3)

Day	Rota	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Çesme	Road	25 hours 49 min	127	329.42
3-4	Çesme -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
4-5	Trieste (Italy)-Villach (Austria)	Road	2 hours 48 min	197	98.15
4-5	Villach (Austria) – Salzburg (Austria)	Road	3 hours 43 min	191	646.85
5-6	Germany – Germany (Aachen)	Road	21 hours 18 min	792	557.2
5-6	Germany – Roger & Roger 7700	Road	13 hours 34 min	250	187.5
5-6	Overall		135 hours 44 min	3216	3479.12

When this route is examined in terms of transit time, 50.46% of it is composed of RO-RO maritime transport and 49.54% of it is composed of road transport. In terms of cost, RO-RO constitutes 47.7% and road transportation constitutes 52.3%. If the first three routes are compared to each other. Route 3 can be used as an alternative

route for shipments to Belgium from Turkey when route 1 is not available and a 23 hours 42 min delay in transit time is not important. As shown in Table 3.17, the sea leg constitutes the longest part of the route and route 3 has the longest transit time within the first three routes for the shipments to Belgium. In terms of distance, the sea leg constitutes 51.6% of this route (1659 km). The total distance for this route becomes 1557 km when this part of the transportation is disregarded.

Table 3.18 Road- RO-RO- Road option Izmir to Netherlands via Villach-Salzburg (Route 3)

Day	Rota	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Çesme	Road	25 hours 49 min	127	329.42
3-4	Çesme -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
4-5	Trieste (Italy)-Villach (Austria)	Road	2 hours 48 min	197	98.15
4-5	Villach (Austria) – Salzburg (Austria)	Road	3 hours 43 min	191	646.85
5-6	Germany – The Flexible Packaging Company Amersfoort	Road	23 hours 11 min	923	703.05
5-6	Overall		124 hours 3 min	3097	3437.47

When route 3 is examined in terms of transit time, 55.24% of it is composed of RO-RO maritime transport and 44.76% of it is composed of road transport. In terms of cost, RO-RO constitutes 48.3% and road transportation constitutes 51.7%. If the first three routes are compared to each other. Route 3 can be used as an alternative route for shipments to the Netherlands from Turkey when route 1 is not available and a 13 hours 4 min delay in transit time is not important. As shown in Table 3.18, the sea leg constitutes the longest part of route 3 and this route has the longest transit time within the first three routes for shipments to the Netherlands. In terms of distance, the sea leg constitutes 53.6% of this route (1659 km). The total distance of this route becomes 1438 km when the sea leg of the transportation is disregarded.

One of the motivating factors to start-up to the RO-RO line is related to the problem of the nature of the roads itself. The usage of RO-RO ships comes with advantages. For instance, the usage of RO-RO ships prevents consisting of custom standby wastes during road transport between Turkey and Europe. The usage of RO-RO ships ensures that there are no problems at the border gates and no waiting due to truck failure. With RO-RO transportation, the fees paid during road crossings such as customs, fuel,

highway, transportation and carbon dioxide emission can be prevented (Bulgaria, Greece, Serbia, Hungary, Romania, Croatia), driver rest and breaks can be reduced. In route 3, transit times and transit costs higher than route 1 for all destinations (as seen in Table 3.16, Table 3.17, Table 3.18). That reduction at the total distance is the main reason for the customers to choose the RO-RO train line because it will be possible to avoid possible problems and delays.

Despite the main advantages of the usage of RO-RO transport, it is seen that RO-RO transportation is not advantageous for transports to Belgium and the Netherlands. In this research, it can be considered as an alternative option for transportations to Germany when RO-RO is available and it can only be feasible to main destination points such as Germany, Italy, Austria, Hungary, France, Croatia, Slovenia. However, the possibility of delay less likely compared to the all-road with RO-RO option.

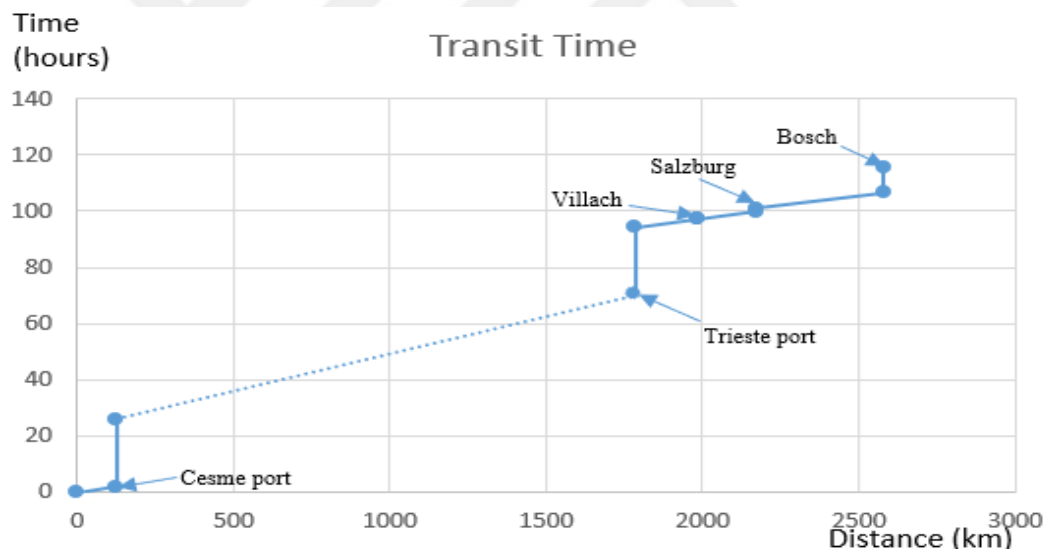


Figure 3.12 Time-distance for Road- RO-RO- Road option for Germany via Villach-Salzburg (Route 3)

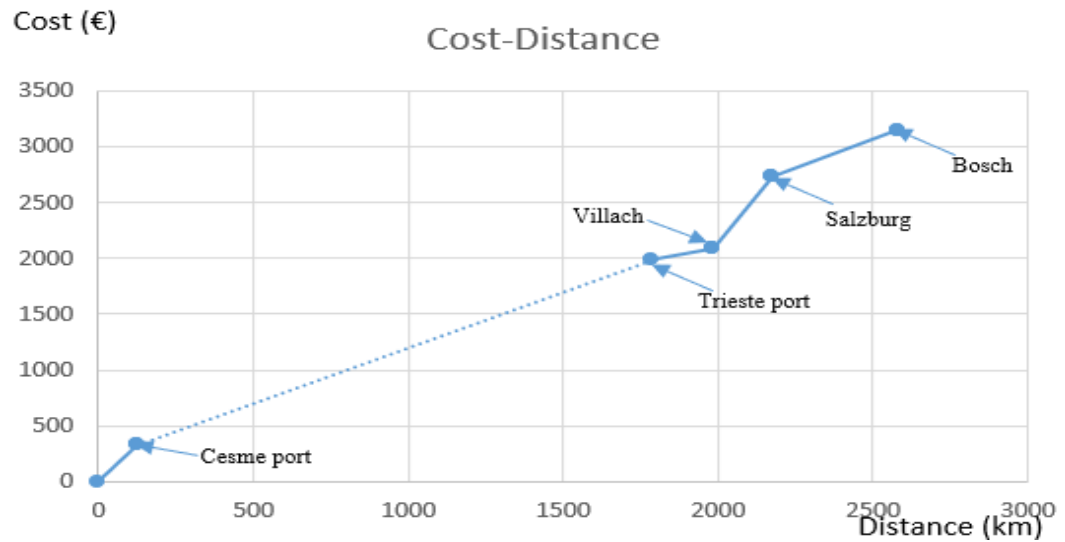


Figure 3.13 Cost-distance for Road- RO-RO- Road option for Germany via Villach-Salzburg (Route 3)

3.6.1.4 RO-RO and RO-LA Option (Route 4)

Despite the name of this section, road transportation is used in this route too. The road transportation is used to carry the goods between manufacturer to the ports and between train station to customers in this route. There are maps of each single route alternative below (as shown in Figure 3.14, Figure 3.15, Figure 3.16, Figure 3.17)

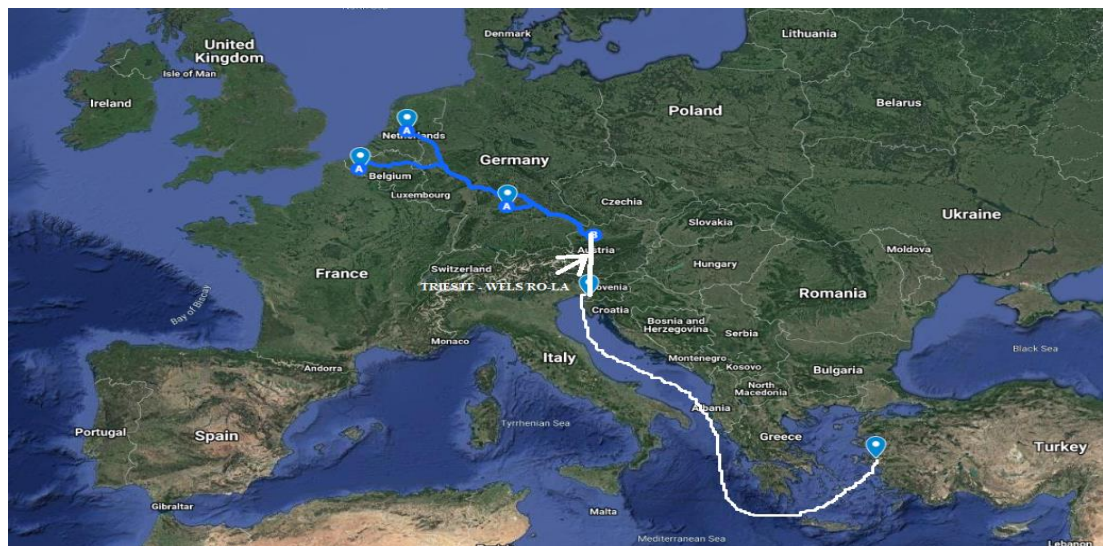


Figure 3.14 Map of RO-RO and RO-LA option via Trieste-Wels RO-LA line (Route 4) (adapted from Google Earth, 2019)

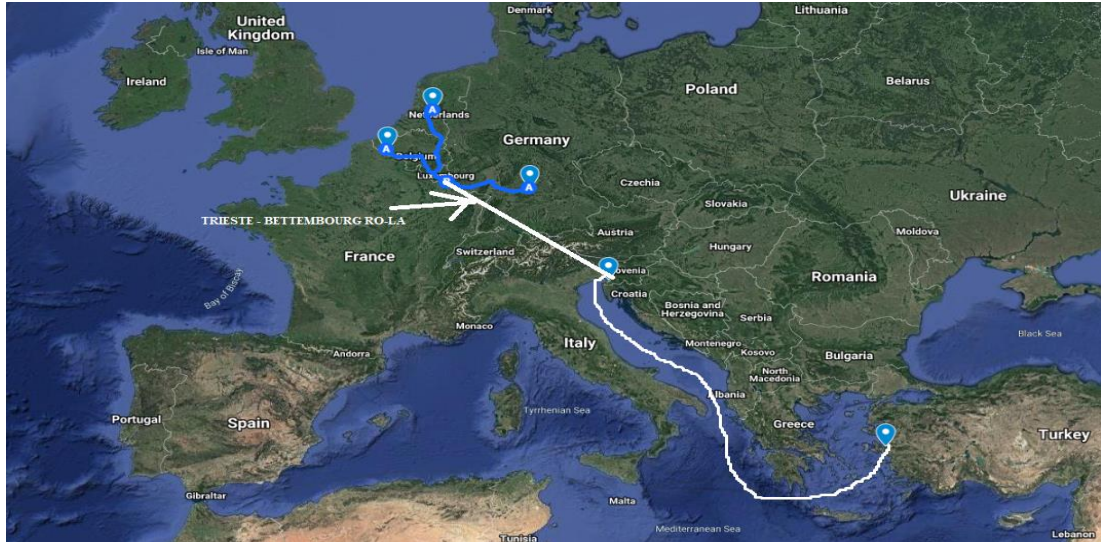


Figure 3.15 Map of RO-RO and RO-LA option via Trieste-Bettembourg line (Route 4) (adapted from Google Earth, 2019)

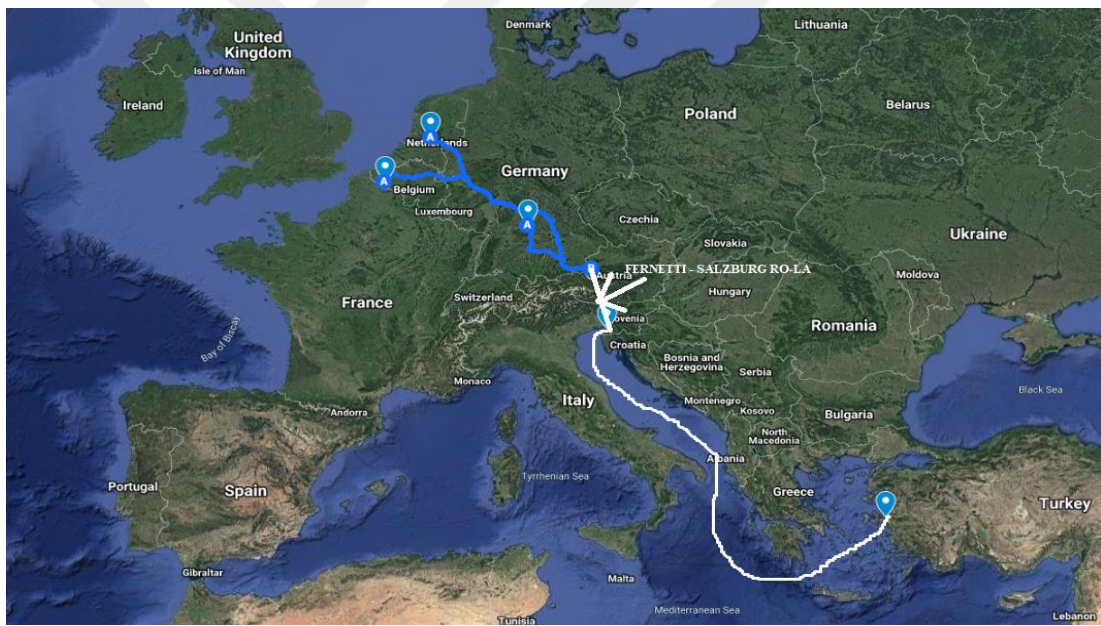


Figure 3.16 Map of RO-RO and RO-LA option via Ferneti-Salzburg RO-LA line (Route 4) (adapted from Google Earth, 2019)

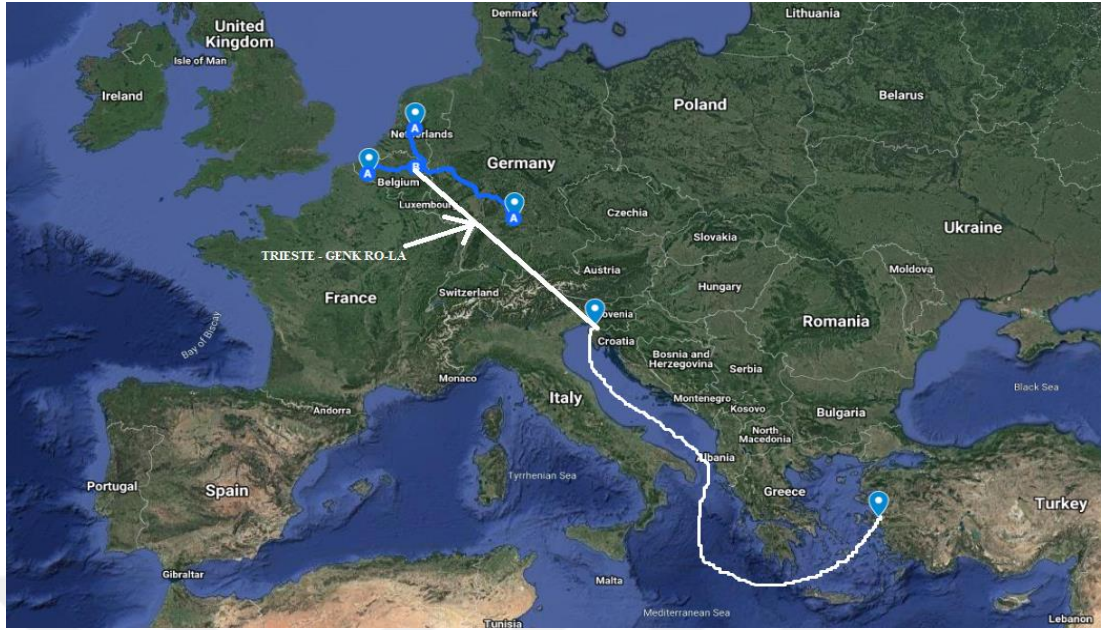


Figure 3.17 Map of RO-RO and RO-LA option via Trieste-Genk RO-LA line (Route 4) (adapted from Google Earth, 2019)

Route 4 is a different version of Route 3. RO-LA option is the only different thing between these two routes. Route 4 can be considered as completely multimodal transport concept because it includes many transport forms together. As seen in Figure 3.14, Figure 3.15, Figure 3.16 and Figure 3.17 the goods are carried by forwarders until Trieste port by RO-RO ships and the goods with TIRs are loaded to the RO-LA trains after arriving Trieste port and TIRs are carried by RO-LA trains until the last destination of the terminals. Then TIRs are unloaded from train terminals at last destination of RO-LA terminals and then the goods are carried by trucks on road until last destinations from the RO-LA terminals. In this route, there are four different options to carry the goods to the last destination from Izmir, Turkey. These route options were compared to each other and the optimal route is selected and analyzed below. Detailed information about the other options and comparison and differences between modes of route 4 is shown at Table A.16, Table A.17, Table A.18, Table A.19, Table A.20, Table A.21, Table A.22, Table A.23, Table A.24, Table A.25, Table A.26, Table A.27. Trieste-Wels RO-LA line (as shown Figure 3.14) is the first option after the goods are carried by forwarder to Trieste port, second option is Trieste-Bettembourg RO-LA line (as shown Figure 3.15), third option is Ferneti-Salzburg RO-LA line (as shown Figure 3.16) and the last investigated option is Trieste-Genk

RO-LA line (as shown Figure 3.17) option to carry the goods to its customers. Route 4 involves many transport operations. Firstly, the goods are transported to Cesme port by road transport then it is followed by RO-RO shipment to Trieste Port from Cesme Port. When vehicles disembark from the ships at Trieste Port, trucks are loaded to trains and trains are carrying the vehicles depart from the RO-LA terminal at Trieste to Bettembourg, Trieste to Genk, Trieste to Salzburg or Trieste to Wels in terms of the last destinations. The main information related to route 4 is shown in Table 3.19, Table 3.20, Table 3.21, Table 3.22 and Table 3.23. These routes are the best options compared to other transportation options in route 4.

Table 3.19 RO-RO and RO-LA option Izmir to Germany via Ferneti-Salzburg RO-LA line (Route 4)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Cesme (Turkey)	Road	25 hours 49 min	127	329.42
3-4	Cesme (Turkey) -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
3-4	Trieste (Italy)-Ferneti (Italy)	Road	15 min	18.1	66.33
4-5	Ferneti – Salzburg (Austria)	Rail	10 hours 41 min	242	500
4-5	Salzburg – Bosch 74572 Blaufelden	Road	6 hours 42 min	399	419.65
4-5	Overall		111 hours 59 min	2445.1	2975.4

When this route is examined in terms of transit time, 61.16% of it is composed of RO-RO maritime transport, 9.51% of it is composed of RO-LA rail transport and 29.33% of it is composed of road transport. In terms of cost, RO-RO ships constitutes 55.79%, RO-LA train constitutes 16.8%, and road transportation constitutes 27.41% of it. In this route, the longest part of the route constitutes by sea leg. In terms of distance, the sea leg constitutes 67.84% of this route (1659 km). The total distance of this route becomes 786.1 km when the sea leg part of the transportation is disregarded.

Table 3.20 RO-RO and RO-LA option Izmir to Belgium via Trieste-Bettembourg RO-LA line (Route 4)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Cesme (Turkey)	Road	25 hours 49 min	127	329.42
3-4	Cesme (Turkey) -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
4-5	Trieste (Italy)–Bettembourg (Lux)	Rail	19 hours 52 min	717	930
4-5	Luxembourg – Roger & Roger 7700	Road	5 hours 22 min	306	267.1
4-5	Overall		119 hours 35 min	2809	3186.52

Table 3.21 RO-RO and RO-LA option Izmir to Belgium via Trieste-Genk RO-LA line (Route 4)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Cesme (Turkey)	Road	25 hours 49 min	127	329.42
3-4	Cesme (Turkey) -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
4-5	Trieste (Italy)-Genk (Belgium)	Rail	22 hours 28 min	851	875
4-5	Genk – Roger & Roger 7700	Road	2 hours 50 min	199	154.65
4-5	Overall		119 hours 39 min	2836	3019.07

This route (the route at Table 3.21) is the best solution within route 4 options for shipments to Belgium from Turkey. When this route is examined (the one shown in Table 3.21) in terms of transit time, 57.25% of it is composed of RO-RO maritime transport, 18.8% of it is composed of RO-LA rail transport and 23.95% of it is composed of road transport. In terms of transportation costs, RO-RO maritime transportation constitutes 54.98%, RO-LA rail transportation constitutes 28.98% and road transportation constitutes 16.04% of it. In this route, the longest part of the route constitutes by sea leg. In terms of distance, the sea leg constitutes 58.50% of this route (1659 km). The total distance of this route becomes 1177 km when the sea leg part of the transportation is disregarded.

Table 3.22 RO-RO and RO-LA option Izmir to Netherlands via Trieste-Bettembourg RO-LA line (Route 4)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Cesme (Turkey)	Road	25 hours 49 min	127	329.42
3-4	Cesme (Turkey) -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
4-5	Trieste (Italy)–Bettembourg (Lux)	Rail	19 hours 52 min	717	930
5-6	Luxembourg – The Flexible Packaging Company Amersfoort	Road	6 hours 49 min	407	402.45
5-6	Overall		121 hours 2 min	2910	3321.87

Table 3.23 RO-RO and RO-LA option Izmir to Netherlands via Trieste-Genk RO-LA line (Route 4)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir – Cesme (Turkey)	Road	25 hours 49 min	127	329.42
3-4	Cesme (Turkey) -Trieste (Italy)	Sea	68 hours 32 min	1659	1660
4-5	Trieste (Italy)-Genk (Belgium)	Rail	22 hours 28 min	851	875
4-5	Genk – The Flexible Packaging Company Amersfoort	Road	2 hours 32 min	178	172.3
4-5	Overall		119 hours 21 min	2815	3036.72

This route (the route at Table 3.23) is the best solution within route 4 options for shipments to the Netherlands. When this route is examined (the one shown in Table 3.23) in terms of transit time, 57.4% of it is composed of RO-RO maritime transport, 18.86% of it is composed of RO-LA rail transport and 23.74% of it is composed of road transport. In terms of transportation costs, RO-RO maritime transportation constitutes 54.66%, RO-LA rail transportation constitutes 28.81% and road transportation constitutes 16.53% of it. In this route, the longest part of the route constitutes by sea leg. In terms of distance, the sea leg constitutes 58.93% of this route (1659 km). The total distance of this route becomes 1156 km when the sea leg part of the transportation is disregarded.

The optimal route is the route when Ferneti-Salzburg RO-LA train line is used for shipments to Germany from Turkey. On the other hand, the optimal route for shipments to Belgium and the Netherlands from Turkey occur when Trieste-Genk RO-LA train line is used. As shown in Table 3.20, when the Trieste-Bettembourg RO-LA train line is used by ABC Co to transport the goods to Belgium instead of the Trieste-Genk RO-LA train line (as shown Table 3.21), the transportation costs increase 167.45 Euro more for shipments to Belgium even though transit time 5 min less. On the other hand, there is a same result for shipments to the Netherlands. When the Trieste-Bettembourg RO-LA train line is used by ABC Co to transport the goods to the Netherlands instead of the Trieste-Genk RO-LA train line, the transportation costs increase 285.15 Euro more even though transit time 1 hour 41 min shorter. By the information received from ABC Co, ABC Co usually using the Trieste-Bettembourg line for their operations, for shipments to Belgium, Netherlands and sometimes Germany instead of Trieste-Genk RO-LA train line. This research shows that usage of the Trieste-Genk RO-LA train line has more benefits than the usage of the Trieste-Bettembourg RO-LA train line and if it is available it must be used instead of Trieste-Bettembourg RO-LA train line for shipments to Belgium and the Netherlands.

Also, route 4 offers the second-lowest-cost within the first 4 route options. Route 4 can be really good alternative to the all-road option (route 1) when the disadvantages of the all-road option are considered such as border crossing, driver rests and breaks,

illegal refugee problems, etc. and also, the advantages of usage of RO-LA train lines are considered such as no extra daily rest and break time is added to the transit time calculation since truck drivers not driving vehicles when RO-LA train lines are used until Salzburg RO-LA terminal or Genk RO-LA terminal or other last points of RO-LA terminals. Permitted drivers rest and break times are used during RO-RO ships and RO-LA train journeys. Time-distance and cost-distance graphs are presented in Figure 3.18 and Figure 3.19 for shipments to Germany (Bosch), Figure 3.20 and Figure 3.21 for shipments to Belgium (Roger & Roger) and Figure 3.22 and Figure 3.23 for shipments to the Netherlands (The Flexible Packaging Company Amersfoort).

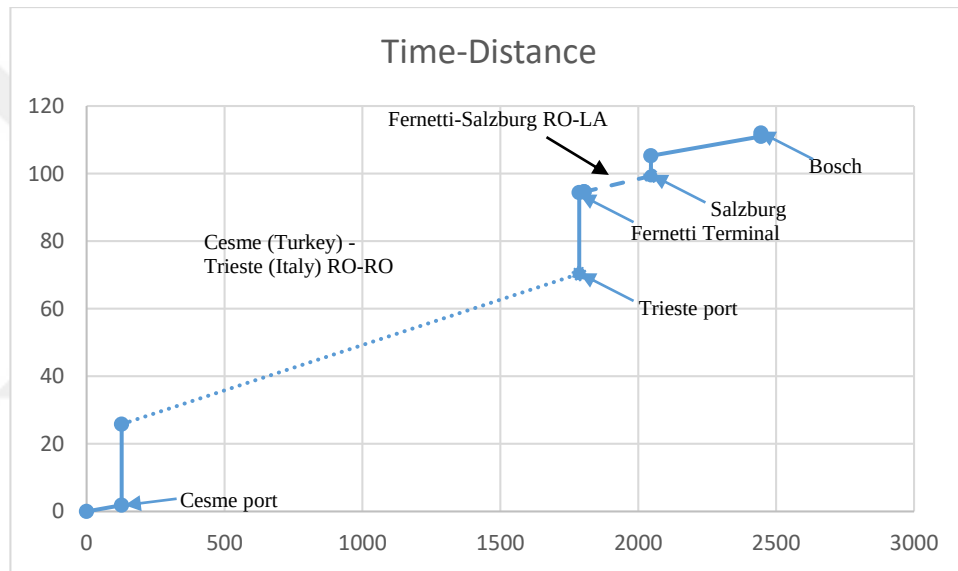


Figure 3.18 Time-distance graph of transportation of ABC Co to Bosch (Germany)

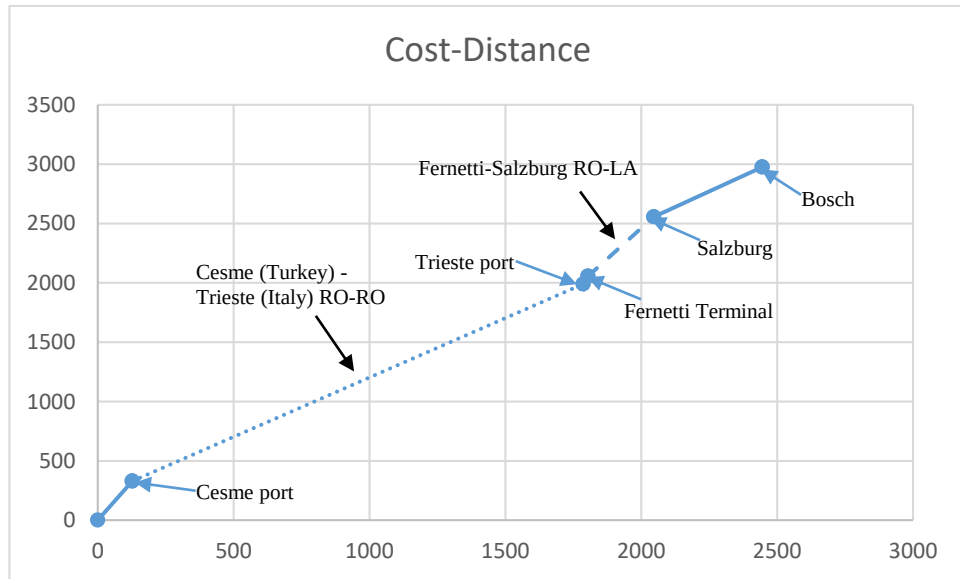


Figure 3.19 Cost-distance graph of transportation of ABC Co to Bosch (Germany)

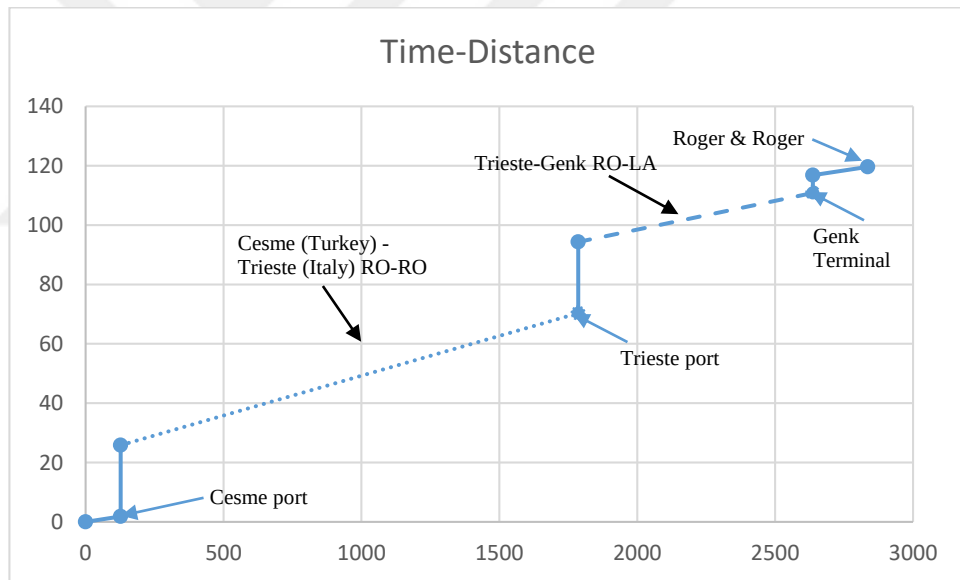


Figure 3.20 Time-distance graph of transportation of ABC Co to Roger & Roger (Belgium)

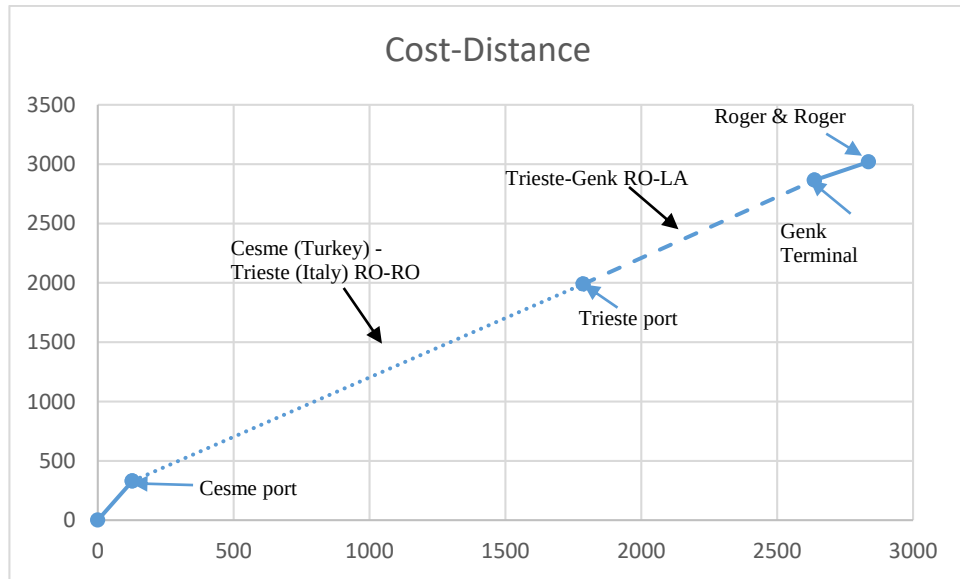


Figure 3.21 Cost-distance graph of transportation of ABC Co to Roger & Roger (Belgium)

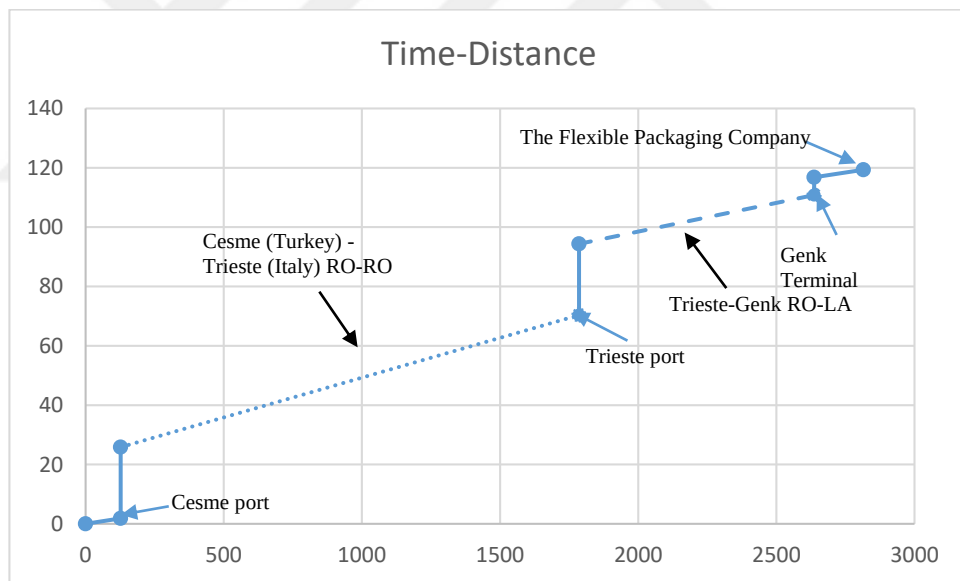


Figure 3.22 Time-distance graph of transportation of ABC Co to The Flexible Packaging Company (Netherlands)

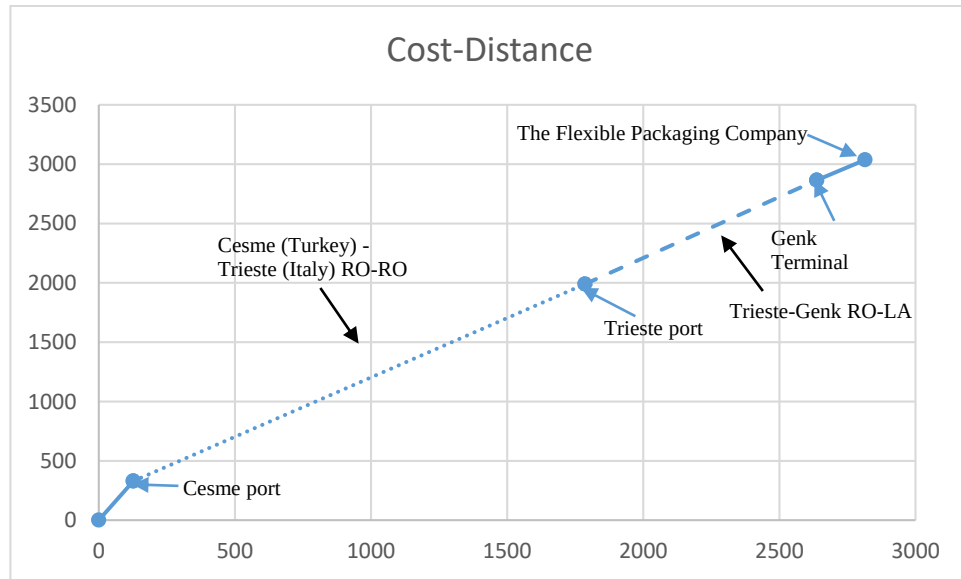


Figure 3.23 Cost-distance graph of transportation of ABC Co to The Flexible Packaging Company (Netherlands)

3.6.1.5 All Water Option (Route 5)

Under this title, as seen in Figure 3.24, Figure 3.25 and Figure 3.26, Antwerp, Rotterdam and Hamburg ports are examined in the outbound transportation system of ABC Co to serve its customers. Ports are examined in detail below.

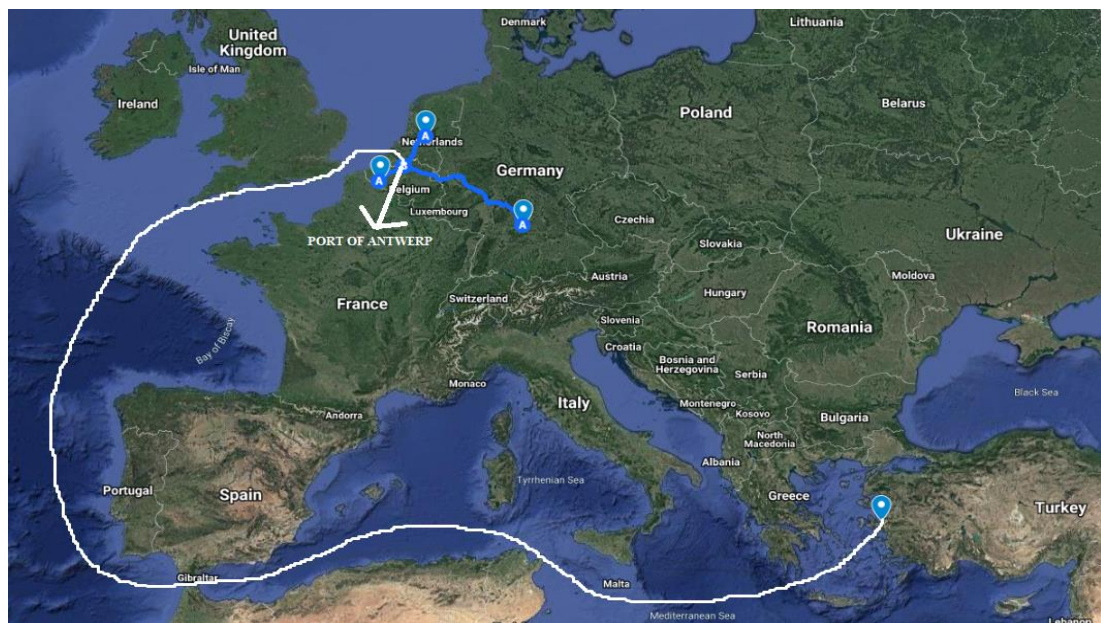


Figure 3.24 Map of all water option via Antwerp Port (Route 5) (adapted from Google Earth, 2019)

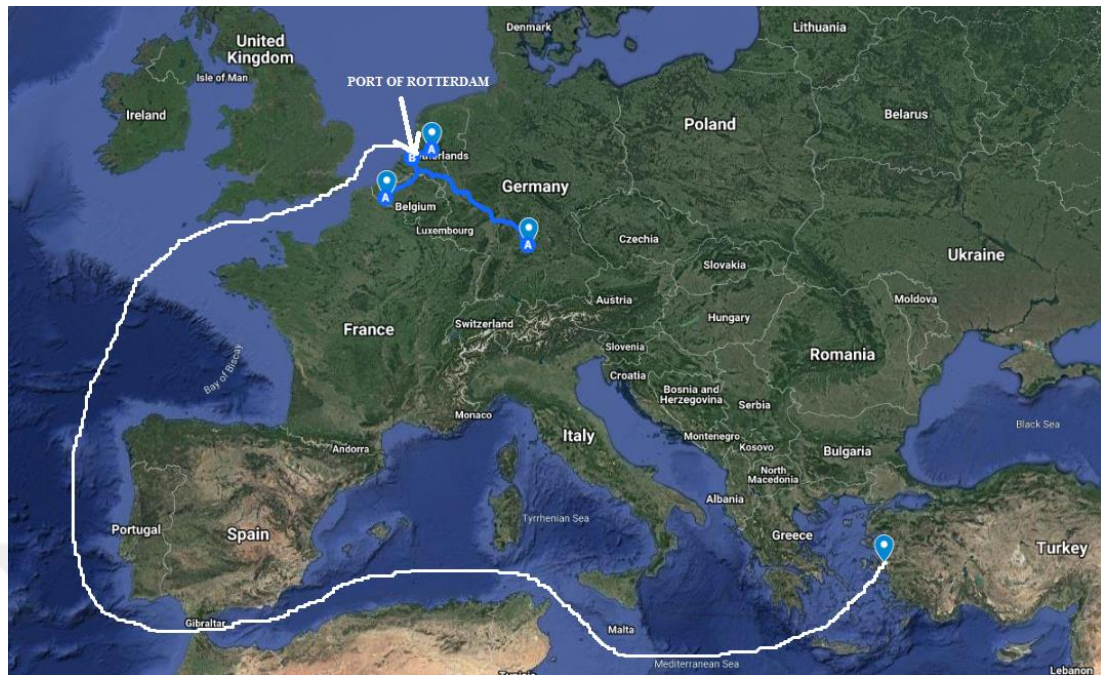


Figure 3.25 Map of all water option via Rotterdam Port (Route 5) (adapted from Google Earth, 2019)

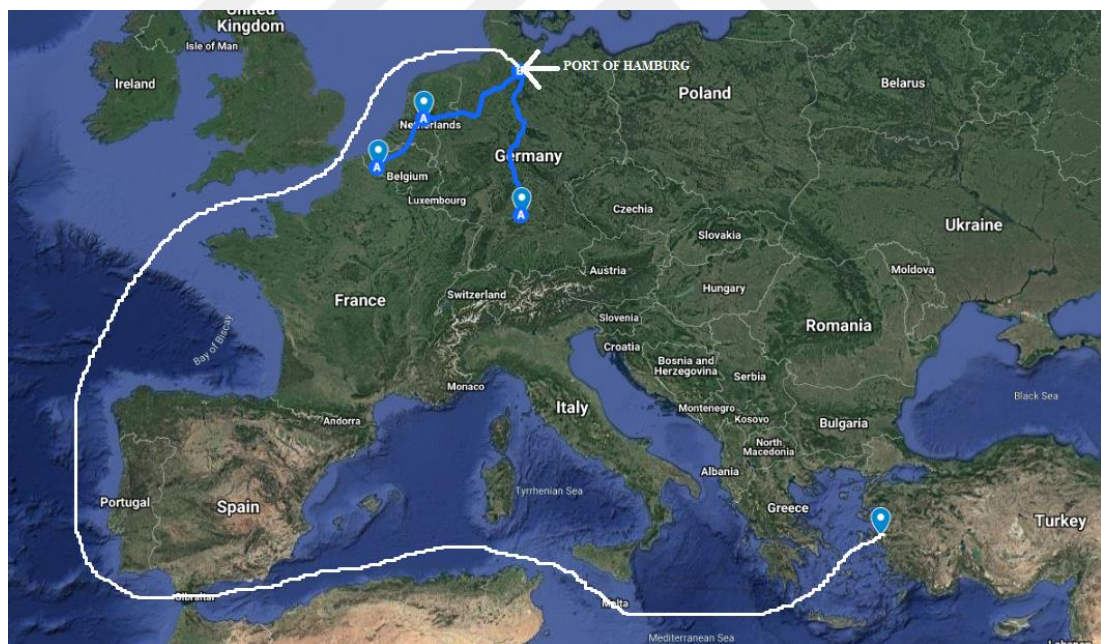


Figure 3.26 Map of all water option via Hamburg Port (Route 5) (adapted from Google Earth, 2019)

In this part of the section, the sea leg is dominant for the all-water route in these three maps above. Road transport is only utilized for pick-up and delivery legs of the journey in route 5. Pick-up part of the journey contains picking the goods up from company (ABC Co) and carry them until Aliaga port then pick them up again at

Antwerp, Rotterdam or Hamburg ports then delivery them to the customers which are Bosch in Germany, Roger & Roger in Belgium and The Flexible Packaging Company Amersfoort in the Netherlands. The goods are carried in 40-foot containers in this route from Izmir (ABC Co) to Aliaga port by road and then the sea leg begin and sea transport is followed in this journey from Aliaga port to Antwerp, Rotterdam or Hamburg ports. The last part of the transportation is the delivery part of this route. The goods are carried from the selected port to the last destinations. Ports are selected in terms of low costs and less transit time. All-water route is known as a traditional transportation for many freight forwarders and cargo groups.

Table 3.24 Busiest cargo ports in Europe

Rank	Port	Country	Total Cargo Volume (Tons)
1	Rotterdam	Netherlands	466,363
2	Antwerp	Belgium	208,423
3	Hamburg	Germany	137,824

The Turkey-Belgium trade is served by many shipping lines like Arkas, Maersk, MSC, Evergreen, Turkon, Hamburg Sud. According to this study, the Aliaga port is assumed as the departure port from Turkey for the examination of the all-water option and it is situated in Izmir. Antwerp port is selected as an arrival port in Belgium. Antwerp port is considered as the largest container port and a major hub in Belgium. Port of Antwerp is the second-largest port in Europe after Rotterdam port and 17th largest port in the world. Besides, intercontinental shipments are made from Antwerp port. Turkey-Netherlands trade is served by many shipping lines like Arkas, Maersk, MSC, Evergreen, Turkon, Hamburg Sud. Rotterdam port is selected as an arrival port in the Netherlands. Rotterdam port is considered as the largest container port and a major hub in the Netherlands. The port of Rotterdam in the Netherlands is the largest port in Europe and the 4th largest in the world. Besides, intercontinental shipments are made from Rotterdam port as well. Turkey-Germany trade is served by many shipping lines like Arkas, Maersk, MSC, Evergreen, Turkon, Hamburg Sud. Hamburg port is selected as an arrival port in Germany. Hamburg port is considered as the largest container port and a major hub in Germany. The port of Hamburg is the 3rd largest port in Europe (World Atlas, 2018). List of these ports and the yearly volumes of shipments of these ports listed above in Table 3.24.

Table 3.25 All water option via Aliaga-Hamburg to Bosch in Germany (Route 5)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir - Aliaga	Road	24 hours 39 min	45.3	460.85
11-12	Aliaga-Hamburg	Sea	242 hours 35 min	5276	750
11-12	Hamburg – Bosch 74572 Blaufelden	Road	9 hours 14 min	577	577
11-12	Overall		276 hours 28 min	5898.3	1787.85

*40' foot container

The main transit time, distance and cost data for route 5 is shown in Table 3.25 for shipments to Germany from Turkey. Ship speed assumed as 15knot besides emergency calls. It is assumed that there are no emergency calls during shipments. The sea leg has a huge part of this route. The overall transit time of the all-water option is 276 hours 28 min. The transit time for the sea leg is 242 hours 35 min for shipments to Bosch, Germany. Which means 87.7% of overall transit time for the all-water option. The overall distance of the all-water option is 5898.3 km. The distance for the sea leg is 5276 km. 89.5% of the overall distance consists of a sea leg for shipments to Bosch, Germany. The total cost of shipments to Bosch, Germany is 1787.85 Euro. Less than 50% of the costs consist of the sea leg. That analyzes have already shown the cost-efficiency of all water option. The cost of the sea leg is 750 Euro. 42% of the overall costs consists of the sea leg for the shipments to Bosch, Germany. On the other hand, when the road transportation part is examined in terms of transit time, distance and transportation costs for Bosch, Germany. The road transportation part of transit time consists of 12.3% of overall transit time for the all-water option as 33 hours 53 min. 10.5% of the distance of overall transportation consists of road transportation and it is 622.3 km. 58% of the cost of overall transportation consists of road transportation and it is 1037.85 Euro. The sea transport is the main leg of this route. It takes 9 days to arrive at the port of Hamburg and overall transit time is 12 days for this route. This is the longest route within all routes. All information about analysis is shown in Table 3.24 above and detailed information about transportation costs, transit times, rest and breaks are shown in Table A.28, Table A.31, Table A.34.

Table 3.26 All water option via Aliaga-Antwerp to Roger & Roger in Belgium (Route 5)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir - Aliaga	Road	24 hours 39 min	45.3	460.85
10-11	Aliaga-Antwerp	Sea	224 hours 31 min	4841	720
10-11	Antwerp – Roger & Roger 7700	Road	1 hour 43 min	120	310
10-11	Overall		250 hours 53 min	5006.3	1490.85

*40' foot container

The main transit time, distance and transportation costs data for route 5 is shown in Table 3.26 for shipments to Belgium from Turkey. Ship speed assumed as 15knot besides emergency calls. It is assumed that there are no emergency calls during transportation. The sea leg has a huge part of this route. The overall transit time of the all-water option is 250 hours 53 min. The transit time for the sea leg is 224 hours 31 min for shipments to Roger & Roger, Belgium. Which means 89.5% of overall transit time for the all-water option. The overall distance of the all-water option is 5006.3 km. The distance for the sea leg is 4841 km. 96.7% of the overall distance consists of the sea leg for shipments to Roger & Roger, Belgium. The total cost of shipments to Roger & Roger, Belgium is 1490.85 Euro. Less than 50% of it consists of the sea leg. That analyzes have already shown the cost-efficiency of the all-water option. The cost of the sea leg is 720 Euro. 48.3% of the overall cost consists of the sea leg for the shipments to Roger & Roger, Belgium. On the other hand, when the road transportation part is examined in terms of transit time, distance and transportation costs for Roger & Roger, Belgium. The road transportation part of transit time consists of 10.5% of overall transit time for the all-water option as 26 hours 22 min. 3.3% of the distance of overall transportation consists of road transportation and it is 165.3 km. 51.7% of the cost of overall transportation consists of road transportation and it is 770.85 Euro. The sea transport is the main leg of this route. It takes 8 days to arrive at the port of Antwerp and overall transit time is 11 days for this route. All information about analysis is shown in Table 3.26 above and detailed information about costs, transit times, rest and breaks are shown in Table A.29, Table A.32, Table A.35.

Table 3.27 All water option via Aliaga-Rotterdam to The Flexible Packaging Company Amersfoort in Netherlands (Route 5)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
1-2	Izmir - Aliaga	Road	24 hours 39 min	45.3	460.85
10-11	Aliaga-Rotterdam	Sea	224 hours 41 min	4843	698.2
10-11	Rotterdam – The Flexible Packaging Company Amersfoort	Road	1 hour 38 min	115	310
10-11	Overall		250 hours 58 min	5003.3	1469.05

*40' foot container

The main transit time, distance and transportation costs data for route 5 is shown in Table 3.27 for shipments to the Netherlands from Turkey. Ship speed assumed as 15knot besides emergency calls. It is assumed that there are no emergency calls during shipments. The sea leg has a huge part of this route. The overall transit time of the all-water option is 250 hours 58 min. The transit time for the sea leg is 224 hours 41 min for shipments to The Flexible Packaging Company Amersfoort, Netherlands. Which means 89.5% of overall transit time for the all-water option. The overall distance of the all-water option is 5000.3 km. The distance for the sea leg is 4843 km. 96.8% of the overall distance consists of the sea leg for shipments to The Flexible Packaging Company Amersfoort, Netherlands. The total cost of shipments to The Flexible Packaging Company Amersfoort, Netherlands is 1787.85 Euro. Less than 50% of it consists of the sea leg. That analyzes have already shown the cost-efficiency of the all-water option. The cost of the sea leg is 698.2 Euro. 47.5% of the overall cost consists of the sea leg for the shipments to The Flexible Packaging Company Amersfoort, Netherlands. On the other hand, when the road transportation part is examined in terms of transit time, distance and transportation costs for The Flexible Packaging Company Amersfoort, Netherlands. The road transportation part of transit time consists of 10.5% of overall transit time for the all-water option as 26 hours 17 min. 3.2% of the distance of overall transportation consists of road transportation and it is 160.3 km. 51.7% of the cost of overall transportation consists of road transportation and it is 770.85 Euro. The sea transport is the main leg of this route. It takes 8 days to arrive at the port of Rotterdam and overall transit time is 11 days for this route. All information about analysis is shown in Table 3.27 above and detailed information about costs, transit times, rest and breaks are shown in Table A.30, Table A.33, Table A.36.

Table 3.28 Comparison of sea leg of all water option

Table	Transit Time	Distance	Cost
Table 3.25	87.7%	89.5%	42%
Table 3.26	89.5%	96.7%	48.3%
Table 3.27	89.5%	96.8%	47.5%

As seen in Table 3.28, the sea leg is dominant for this route. The sea leg consists of more than 85% in terms of transit time, more than 89% in terms of distance and less than 50% in terms of transportation cost. It may be longer but cost-effective way to transport. Time-distance and cost-distance graphs are presented in Figure 3.27 and Figure 3.28 for shipments from Turkey to Germany, Figure 3.29 and Figure 3.30 for shipments from Turkey to Belgium and Figure 3.31 and Figure 3.32 for shipment from Turkey to the Netherlands.

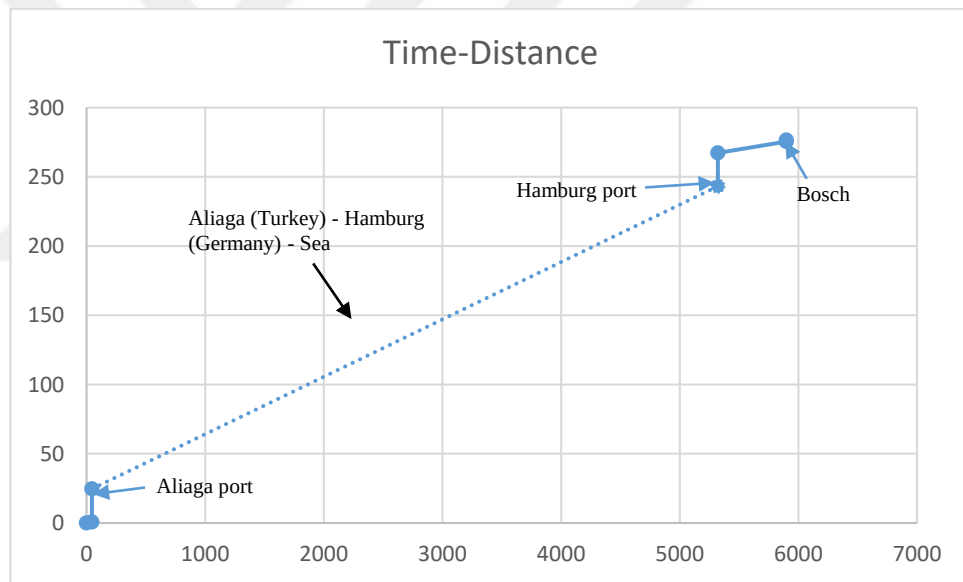


Figure 3.27 Time-distance graph of transportation of ABC Co to Bosch (Germany)

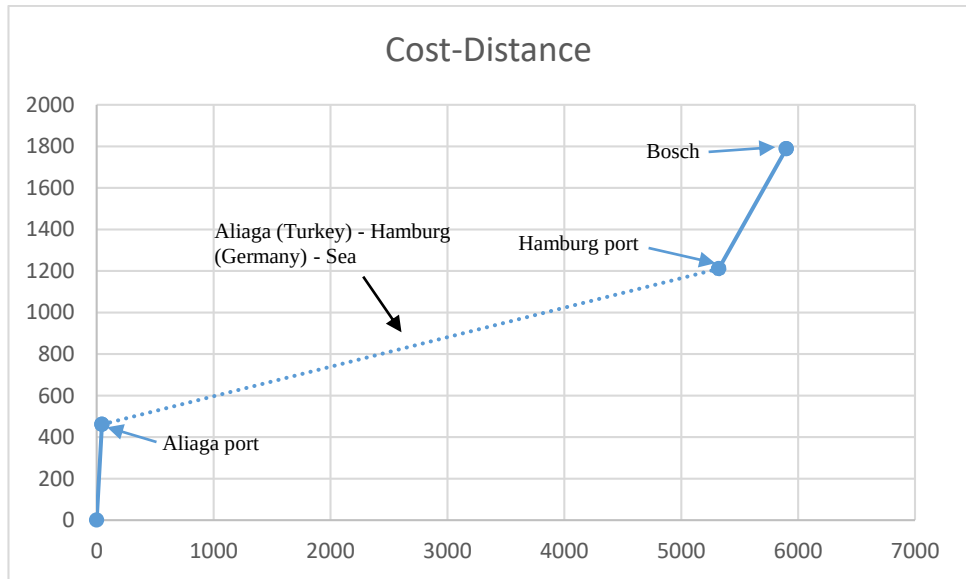


Figure 3.28 Cost-distance graph of transportation of ABC Co to Bosch (Germany)

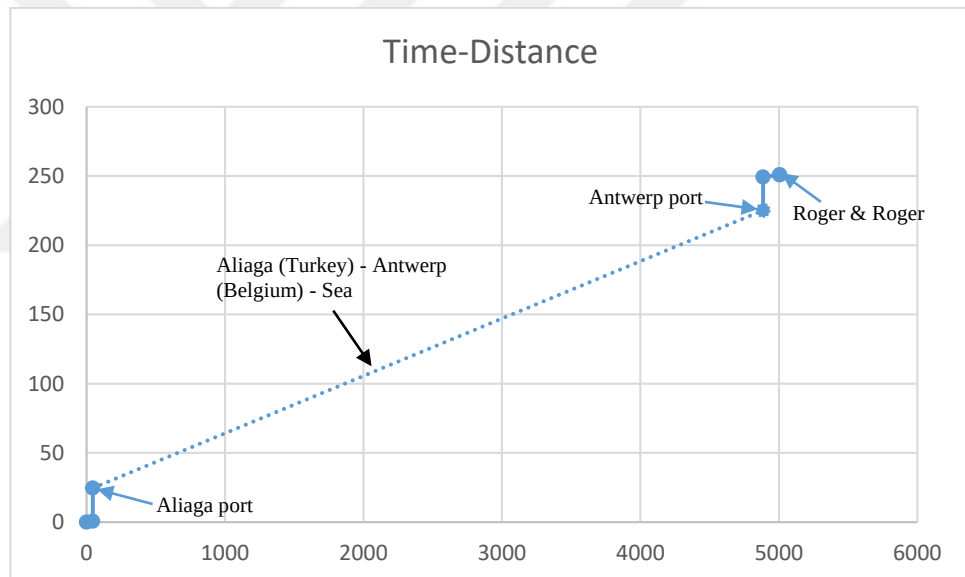


Figure 3.29 Time-distance graph of transportation of ABC Co to Roger & Roger (Belgium)

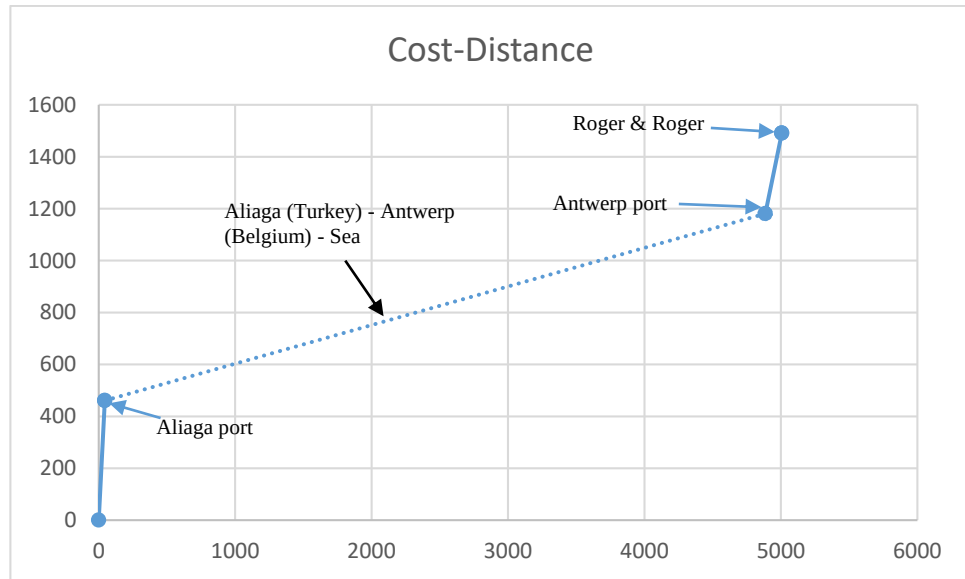


Figure 3.30 Cost-distance graph of transportation of ABC Co to Roger & Roger (Belgium)

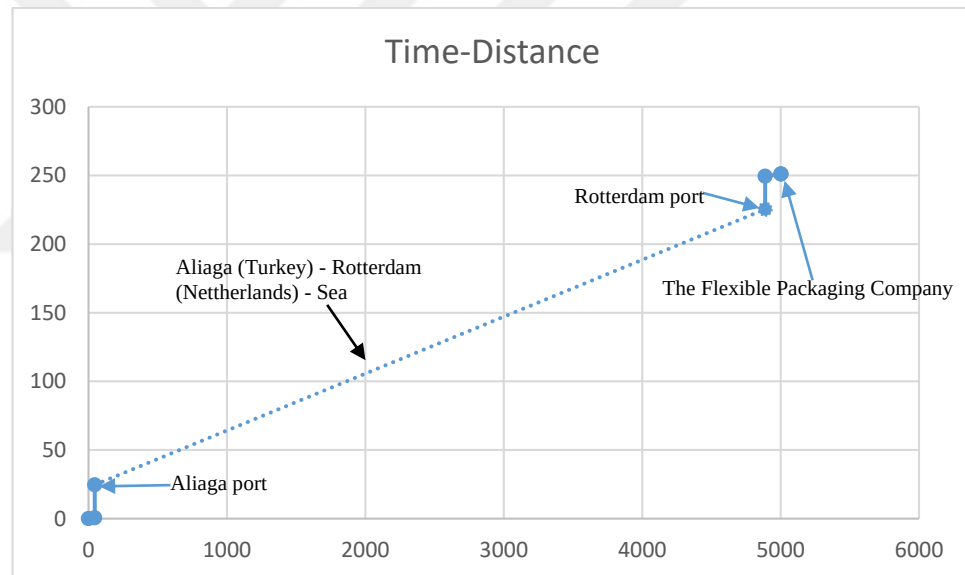


Figure 3.31 Time-distance graph of transportation of ABC Co to The Flexible Packaging Company (Netherlands)

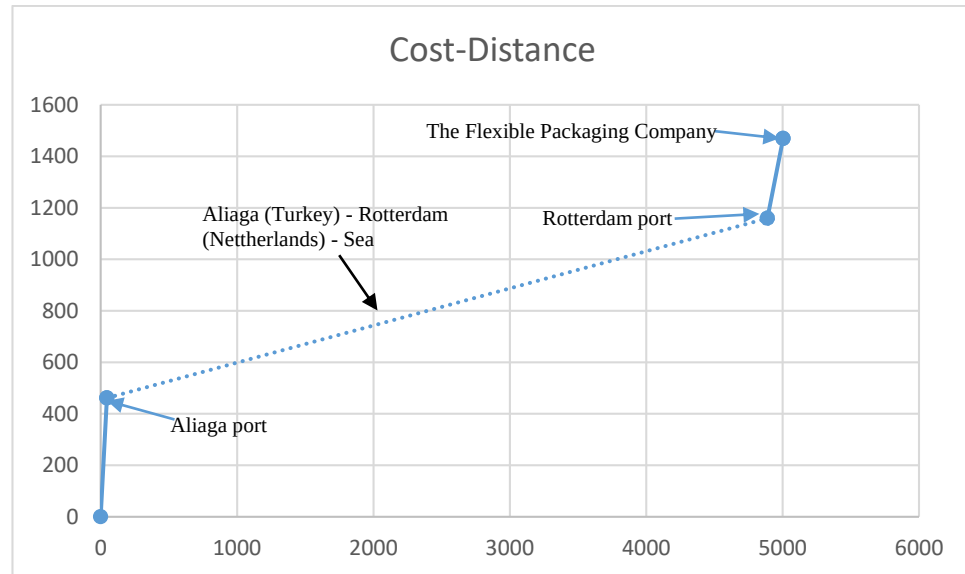


Figure 3.32 Cost-distance graph of transportation of ABC Co to The Flexible Packaging Company (Netherlands)

3.7 Analysis of the Outbound Logistics System of ABC Co

The result of TVSM and the Beresford time cost distance model analyses are examined under this title. As a result of TVSM analysis, ABC Co does not have its fleet to deliver the goods to its customers promptly, so it receives external services from Freight Forwarders. The time spent at border crossings and port customs are fixed and it is seen that improvement of those processes is not in the hands of the company. As a result of the researches and analyzes, it has been seen that the improvements that the company will make in the transportation processes will allow it to compete with other companies. During this process, data were collected from the company, the countries with the highest volume of shipment were identified and the companies with the highest volume of shipment were selected within these countries. ABC Co cooperates with companies in European countries such as Lithuania, Slovakia, Poland, Austria, Germany, Romania, Hungary, Bulgaria, United Kingdom, Denmark, Ireland, Switzerland, France, Belgium, and the Netherlands. ABC Co sends its produced packaging to these countries. It makes these shipments day by day in order to not to exceed transit times and to manage the whole process at the most appropriate cost. Among these countries, the three companies with the highest volume in Germany, Belgium and the Netherlands were selected and examined in this research. This

analysis can be used for other customers of ABC Co from different countries in Europe. After a detailed examination of ABC Co's deliveries to these 3 countries, it is seen that the transportation methods to the customs points were the same and that different transportation options could be preferred after customs. It is decided to integrate the Beresford time cost distance model used in the literature to this stage of TVSM to find and examine these different transportation routes in detail. The purpose of adding the Beresford time cost distance model is to find alternative routes, to take down lead times, and also to evaluate these routes at optimal costs. In this way, the first stage of the TVSM which is the simplification of the route will be improved by the Beresford time cost distance model method.

Comprehensive analysis of the routes and mode combinations between Turkey and Germany, Turkey and Belgium and Turkey and the Netherlands were provided in previous sections. This section is given valuable information about the comparison of the routes according to advantages and disadvantages. Evaluations are made by the data obtained by the researcher. The variables used in this evaluation were mostly taken from companies in the transportation/shipment field and these variables were supported with the variables from the literature related to the route or mode selection and organizational purchasing. Brief of the routes concerning transit time, distance and transit costs are shown below in Table 3.31 for Germany, Table 3.34 for Belgium and Table 3.37 for the Netherlands before evaluation of the routes. All advantages and disadvantages of the transportation routes are given according to transit time, distance and cost for every single route and what circumstances the routes should select by ABC Co. These analyses are made for each last destination in the sections below.

3.7.1 Bosch, Germany

As seen in Table 3.31 all routes have specific advantages and disadvantages from each other. For instance, the all-road with RO-LA train option has a shorter transit time than other routes and it is 78 hours 8 min. Besides that, the all-road with RO-LA train option has higher costs than the other routes and longer distance than the other routes for shipments to Bosch, Germany except the all-water option. As seen in Table 3.15,

two modes are examined for the all-road with the RO-LA option route and the best transportation route is selected as the main mode and shown in Table 3.31. There is a comparison of two modes of the all-road with the RO-LA train option route. The first transportation mode examines route 2 via the Bulgaria route for shipments and the second transportation mode examines route 2 via Greece route for shipments. Route 2 via Greece route has 9 hours 37 min shorter transit time than route 2 via Bulgaria route. It is 235 km longer but 55.75 Euro less expensive. Considering all these evaluations, shipments via Greece to Germany are reasonable to choose for the ABC Co than shipment via Bulgaria for the all-road with the RO-LA train option route.

On the other hand, route 1 via Bulgaria route is chosen for shipments to Germany for the all-road option route because route 1 via Bulgaria route has 3 hours 17 min shorter transit time, 163 km shorter distance and 249.75 Euro less expensive than route 1 via Greece route for shipment to Germany.

As seen in Table 3.29, it is clear that the route with the Ferneti-Salzburg RO-LA train is the most beneficial transportation route than the other transportation route alternatives of route 4. It has less transit time and less distance and it is less expensive than the other routes of the RO-RO and RO-LA route option. The overall transit time is 111 hours 59 min. The route with the Ferneti-Salzburg RO-LA train has 36 min shorter transit time than the route with Trieste-Wels RO-LA train. The route with the Ferneti-Salzburg RO-LA train has 8 hours 21 min less transit time than the route with Trieste-Bettembourg RO-LA train and 12 hours 38 min shorter transit time than the route with Trieste-Genk RO-LA train for the shipments to Bosch, Germany in route 4. In terms of distance, the route with the Ferneti-Salzburg RO-LA is the shortest route within all modes for route 4. It is 28.9 km less than the route with Trieste-Wels RO-LA train, 416.9 km less than the route with Trieste-Bettembourg RO-LA train and 667.9 km less than the route with Trieste-Genk RO-LA train for shipments to Bosch, Germany for route 4. In terms of cost comparison, the route with the Ferneti-Salzburg RO-LA train is the least expensive one within all modes for route 4. It is 490.55 Euro cheaper than the route with Trieste-Wels RO-LA train, 409.67 Euro cheaper than the

route with Trieste-Bettembourg RO-LA train and 420.62 Euro cheaper than the route with Trieste-Genk RO-LA train for shipments to Bosch, Germany for route 4.

As seen in Table 3.30, most of the mode of route 5 has similar transit time and distance. In this situation, the cost is a step away to choose which mode is the optimal transportation route. In terms of cost comparison of the all-water option, shipments between the port of Aliaga to the port of Hamburg is the cheapest one. The mode of shipments via the port of Aliaga to the port of Hamburg is 243 Euro cheaper than shipments via the port of Aliaga to the port of Antwerp and it is 251.2 Euro cheaper than shipments via the port of Aliaga to the port of Rotterdam for transportation to Bosch, Germany for the all-water option. Because of that shipments via the port of Aliaga to the port of Hamburg is to be examined in this research to the shipments to Bosch, Germany for the all-water option.

Route 3 is the simplest route within all routes in this research. There are only one direction and one mode are used according to the information given by forwarders and road transportation companies for this route. The overall information about it is shown in Table 3.31 and detailed information about the road- RO-RO- road option is given in Table A.13.

In terms of transit time, the all-road with RO-LA train option is the best transportation option for ABC Co and for its customers, when all routes are compared to each other for shipments to Bosch, Germany. Route 2 must be considered as the first option for transporting the goods to Bosch, Germany, when urgent shipments needed, but it comes with high expenses as 3363.7 Euro which is the highest cost within all routes and it comes with risks such as refugee problem, border crossing, availability of RO-LA terminals, truck accidents and waiting. It is assumed that there is no refugee, border crossing, availability of RO-LA terminals, accident and waiting problem in this case study. Border crossings are assumed as 24 hours. RO-LA train terminals are assumed as always available and there is no delay because of accidents, etc. In terms of cost, the all-water option is the best transportation option within all routes as seen in Table 3.31 and also it is the cheapest route within all routes. When

both transit time and transportation costs are important, route 1 seems like the selectable one within all routes but risks of road transportation are still valid. Route 3 and Route 4 can be considered as an alternative transportation route to route 1 and route 2. When both route 1 and route 2 cannot be used as a transportation route, route 3 and route 4 can be used for the shipments to Bosch, Germany because of the transportation costs of route 3 and route 4. Transportation costs of these routes are cheaper than route 2 but transit times are more than route 1 and route 2. If there is a warehouse between Germany, Belgium, and the Netherlands in Europe then route 5 must be thinking as a first option because of cost-efficiency. Route 5 is the cheapest option within all routes and shipping at almost half the cost of the nearest comparison but transit times are higher.

Table 3.29 Comparison of modes to shipments to Bosch, Germany for Route 4

Route 4 (RO-LA)	Transit Time	Distance (km)	Cost (€)
Via Trieste-Wels	112 hours 35 min	2474	3465.95
Via Trieste-Bettembourg	120 hours 20 min	2862	3385.07
Via Ferneti-Salzburg	111 hours 59 min	2445.1	2975.4
Via Trieste-Genk	124 hours 37 min	3113	3396.02

Table 3.30 Comparison of modes to shipments to Bosch, Germany for Route 5

Route 5 (Sea Leg)	Transit Time	Distance (km)	Cost (€)
Via Aliaga-Antwerp	258 hours 18 min	5456.3	2030.85
Via Aliaga-Rotterdam	259 hours 29 min	5529.3	2039.05
Via Aliaga-Hamburg	276 hours 28 min	5898.3	1787.85

Table 3.31 Comparison of routes in the study for Germany

Routes	Transit Time	Distance (km)	Cost (€)
Route 1: All road option	92 hours 59 min	2590	2602.8
Route 2: All road with RO-LA train option	78 hours 8 min	2657	3363.7
Route 3: Road- RO-RO- Road option	115 hours 40 min	2580	3156.52
Route 4: RO-RO and RO-LA option	111 hours 59 min	2445.1	2975.4
Route 5: All water option	276 hours 28 min	5898.3	1787.85

3.7.2 Roger & Roger, Belgium

As seen in Table 3.34, all routes have specific advantages and disadvantages from each other just like the previous section. For example, the all-road with RO-LA train option has a shorter transit time than other routes and transit time of it is 97 hours 11

min. Besides that, the all-road with RO-LA train option has higher costs than the other routes and longer distance than the other routes for shipments to Roger & Roger, Belgium except the all-water option. As seen in Table 3.15, two modes are examined for the all-road with the RO-LA train option route and the best one is selected as the main mode and shown in Table 3.34. There is a comparison of two modes of the all-road with the RO-LA train option route. The first transportation mode examines route 2 via the Bulgaria route for shipments and the second transportation mode examines route 2 via Greece route for shipments to Roger & Roger, Belgium from Turkey. Route 2 via Greece route has 9 hours 37 min shorter transit time than route 2 via Bulgaria route. It is 235 km longer and but it is 55.75 Euro less expensive. Considering all these evaluations, shipments via Greece to Belgium are reasonable to choose for the ABC Co than shipment via Bulgaria for the all-road with the RO-LA train option route.

On the other hand, route 1 via Bulgaria route is chosen for shipments to Germany for the all-road option route because route 1 via Bulgaria route has 4 hours 14 min shorter transit time, 163 km shorter distance and it is 249.75 Euro less expensive than route 1 via Greece route for shipment to Germany.

As seen in Table 3.32, it is clear that the route with Trieste-Genk RO-LA train is the most beneficial transportation route than the other transportation route alternatives of route 4. It has less transit time and less distance and it is less expensive than the other transportation routes for RO-RO and RO-LA route option except the route with Trieste-Bettembourg RO-LA train. The route with the Trieste-Bettembourg RO-LA train for shipment to Belgium is almost similar for distance and transit time variables but expensive than the route with Trieste-Genk RO-LA train. The overall transit time of the route with the Trieste-Genk RO-LA train is 119 hours 39 min. It has 11 hours 59 min shorter transit time than the route with Trieste-Wels RO-LA train. It has 4 min more transit time than the route with the Trieste-Bettembourg RO-LA train and 11 hours 32 min shorter transit time than the route with the Ferneti-Salzburg RO-LA train for shipment to Roger & Roger, Belgium. In terms of distance, the route with the Trieste-Genk RO-LA train is the 2nd shortest one within all modes for route 4 and it is 2836 km. It is 272 km less than the route with the Trieste-Wels RO-LA train, 25 km

more than the route with the Trieste-Bettembourg RO-LA train and 254.1 km less than the route with the Ferneti-Salzburg RO-LA train for shipments to Roger & Roger, Belgium for route 4. In terms of cost comparison, the route with the Trieste-Genk RO-LA train is the least expensive one within all transportation routes for route 4 and it is 3019.07 Euro. It is 768.78 Euro cheaper than the route with the Trieste-Wels RO-LA train, 167.43 Euro cheaper than the route with the Trieste-Bettembourg RO-LA train and 282.08 Euro cheaper than the route with the Ferneti-Salzburg RO-LA train for shipments to Roger & Roger, Belgium for route 4.

As seen in Table 3.33, most of the mode of route 5 has similar transit time and distance but transportation costs are different and it is a determinant one to choose an optimal transportation route. In terms of the cost comparison of the all-water option, shipments between the port of Aliaga to the port of Antwerp is the cheapest one. The mode of shipments via the port of Aliaga to the port of Antwerp is 70.2 Euro cheaper than shipments via the port of Aliaga to the port of Rotterdam and it is 386 Euro cheaper than shipments via the port of Aliaga to the port of Hamburg for transportation to Roger & Roger, Belgium for all water option. Because of that shipments via the port of Aliaga to port of Antwerp is chosen to be examined in this research to the shipments to Roger & Roger, Belgium for all water option.

Route 3 is the simplest route within all routes in this research. There is only one direction and one mode are used according to the information given by forwarders and road transportation companies for this route. The overall information about it is shown in Table 3.34 and detailed information about the road- RO-RO- road option is given in Table A.14.

In terms of transit time, the all-road with RO-LA train option is the best transportation option for ABC Co when all routes are compared to each other for shipments to Roger & Roger, Belgium, and its customers, and it is 97 hours 11 min. Route 2 must be considered as the first option for transport the goods to Roger & Roger, Belgium, when urgent shipments needed, but it comes with high expenses as 3685.6 Euro which is the highest cost within all routes and also, it comes with risks

such as refugee problem, border crossing, availability of RO-LA terminals, accident and waiting. It is assumed that there is no refugee, border crossing, availability of RO-LA terminals, truck accidents and waiting problems in this case study. Border crossings are assumed as 24 hours. RO-LA train terminals are assumed as always available and there is no delay because of accidents, etc. In terms of cost, the all-water option is the best option within all routes as seen Table 3.34 and it is the cheapest route within all routes. When both transit time and transportation costs are important, route 1 seems like the selectable one within all routes but risks of road transportation are still valid. Route 3 and Route 4 can be considered as an alternative transportation route to route 1 and route 2. When both route 1 and route 2 cannot be used as a transportation route, route 3 and route 4 can be used for the shipments to Bosch, Germany because of the transportation costs of route 3 and route 4 are cheaper than route 2 but transit times are more than route 1 and route 2. If there is a warehouse between Belgium, the Netherlands, and Germany in Europe then route 5 must be thinking as a first option because of cost-efficiency. It is the cheapest option within all routes and shipping at almost half the cost of the nearest comparison but transit times are higher.

Table 3.32 Comparison of modes to shipments to Roger & Roger, Belgium for Route 4

Route 4 (RO-LA)	Transit Time	Distance (km)	Cost (€)
Via Trieste-Wels	131 hours 38 min	3108	3787.85
Via Trieste-Bettembourg	119 hours 35 min	2809	3186.52
Via Ferneti-Salzburg	131 hours 11 min	3090.1	3301.15
Via Trieste-Genk	119 hours 39 min	2836	3019.07

Table 3.33 Comparison of modes to shipments to Roger & Roger, Belgium for Route 5

Route 5 (Sea Leg)	Transit Time	Distance (km)	Cost (€)
Via Aliaga-Antwerp	250 hours 53 min	5006.3	1490.85
Via Aliaga-Rotterdam	252 hours 39 min	5120.3	1561.05
Via Aliaga-Hamburg	277 hours 45 min	5987.3	1876.85

Table 3.34 Comparison of routes in the study for Belgium

Routes	Transit Time	Distance (km)	Cost (€)
Route 1: All road option	112 hours 2 min	3224	2924.7
Route 2: All road with RO-LA train option	97 hours 11 min	3291	3685.6
Route 3: Road- RO-RO- Road option	135 hours 44 min	3216	3479.12
Route 4: RO-RO and RO-LA option	119 hours 39 min	2836	3019.07
Route 5: All water option	250 hours 53 min	5006.3	1490.85

3.7.3 The Flexible Packaging Company Amersfoort, Netherlands

As seen in Table 3.37 all routes have specific advantages and disadvantages from each other. For example, the all-road with RO-LA train option has a shorter transit time than other routes. Besides that, the all-road with RO-LA train option has higher costs than the other transportation routes and longer distance than the other transportation routes for shipments to The Flexible Packaging Company Amersfoort, Netherlands. As seen in Table 3.15, two modes are examined for the all-road with the RO-LA train option route and the best transportation route is selected as the main mode and shown in Table 3.37. There is a comparison of two modes of the all-road with the RO-LA train option route. The first transportation mode examines route 2 via the Bulgaria route for shipments and the second transportation mode examines route 2 via Greece route for shipments to The Flexible Packaging Company Amersfoort, Netherlands. Route 2 via Greece route has 9 hours 37 min shorter transit time than route 2 via Bulgaria route. It is 235 km longer and 55.75 Euro less expensive. Considering all these evaluations, shipments via Greece to the Netherlands are reasonable to choose for the ABC Co than shipment via Bulgaria for the all-road with the RO-LA train option route.

On the other hand, route 1 via Bulgaria route is chosen for shipments to the Netherlands for the all-road option route because route 1 via Bulgaria route has 3 hours 17 min shorter transit time, 163 km shorter distance and it is 249.75 Euro less expensive than route 1 via Greece route for shipment to the Netherlands.

As seen in Table 3.35, it is clear that the route with Trieste-Genk RO-LA train is the most beneficial transportation route than the other transportation modes for route 4. It has less transit time and less distance and it is less expensive than the other transportation routes for the RO-RO and RO-LA route option. The overall transit time is 119 hours 21 min for this mode. It has 10 hours 37 min shorter transit time than the route with the Trieste-Wels RO-LA train. 1 hour 41 min less transit time than the route with the Trieste-Bettembourg RO-LA train and 10 hours 10 min shorter transit time than the route with the Ferneti-Salzburg RO-LA train for shipment to The Flexible

Packaging Company, Netherlands. In terms of distance, RO-LA train between Trieste-Genk is the shortest one within all transportation modes for route 4 and it is 2815 km. It is 176 km less than the route with the Trieste-Wels RO-LA train, 95 km less than the route with the Trieste-Bettembourg RO-LA train and 158.1 km less than the route with the Ferneti-Salzburg RO-LA train for shipments to The Flexible Packaging Company, Netherlands for route 4. In terms of cost comparison, RO-LA train between Trieste-Genk is the least expensive one within all modes for route 4 and it costs 3036.72 Euro. It is 620.18 Euro cheaper than the route with the Trieste-Wels RO-LA train, 285.15 Euro cheaper than the route with the Trieste-Bettembourg RO-LA train and 223.48 Euro cheaper than the route with Ferneti-Salzburg RO-LA train for shipments to The Flexible Packaging Company Amersfoort, Netherlands for route 4.

As seen in Table 3.36, most of the mode of route 5 has similar transit time and distance. In this situation, the cost is a step away to choose which mode is the optimal one. In terms of the cost comparison of the all-water option, shipments between the port of Aliaga to the port of Rotterdam is the cheapest one. The mode of shipments via the port of Aliaga to the port of Rotterdam is 51.8 Euro cheaper than shipments via the port of Aliaga to the port of Antwerp and it is 151.8 Euro cheaper than shipments via the port of Aliaga to the port of Hamburg for transportation to The Flexible Packaging Company, Netherlands for the all-water option. Because of that shipments via the port of Aliaga to the port of Rotterdam is chosen to be examined in detail in this research to the shipments to The Flexible Packaging Company, the Netherlands for the all-water option.

Route 3 is the simplest route within all routes in this research. There is only one direction and one mode are used according to the information given by forwarders and road transportation companies for this route. The overall information about it is shown in Table 3.37 and detailed information about the road- RO-RO- road option is given in Table A.15.

In terms of transit time, the all-road with RO-LA train option is the best transportation route option for ABC Co and for its customers, when all routes are

compared to each other for the shipments to The Flexible Packaging Company, Netherlands. Overall transit time for the all-road with RO-LA train option is 95 hours 31 min. Route 2 must be considered as the first option for transporting the goods to The Flexible Packaging Company, Netherlands, when urgent shipments are needed, but it comes with high expenses as 3644.65 Euro which is the highest cost within all routes and it comes with risks such as refugee problem, border crossing, availability of RO-LA terminals, accident and waiting. It is assumed that there is no refugee, border crossing, availability of RO-LA terminals, accident and waiting problem in this case study. Border crossings are assumed as 24 hours. RO-LA train terminals are assumed as always available and there is no delay because of accidents, etc. In terms of cost, the all-water option is the best transportation option within all routes as seen Table 3.37 and it is the cheapest route within all routes. When both transit time and transportation costs are important, the all-road option seems like reasonable one within all routes but risks of road transportation are still valid. Route 3 and Route 4 can be considered as an alternative transportation route option to the route 1 and route 2. When both route 1 and route 2 cannot be used as a transportation route, route 3 and route 4 can be used for the shipments to The Flexible Packaging Company, Netherlands because of the costs of route 3 and route 4 are cheaper than route 2 but transit times of route 3 and route 4 are more than route 1 and route 2. If there is warehouse between Belgium, Germany and the Netherlands in Europe then route 5 must be considered as a first option because of cost-efficiency. It is the cheapest option within all routes and shipping at almost half the cost of the nearest comparison but transit times are higher.

Table 3.35 Comparison of modes to shipments to The Flexible Packaging Company, Netherlands for Route 4

Route 4 (RO-LA)	Transit Time	Distance (km)	Cost (€)
Via Trieste-Wels	129 hours 58 min	2991	3656.9
Via Trieste-Bettembourg	121 hours 2 min	2910	3321.87
Via Ferneti-Salzburg	129 hours 31 min	2973.1	3260.2
Via Trieste-Genk	119 hours 21 min	2815	3036.72

Table 3.36 Comparison of modes to shipments to The Flexible Packaging Company, Netherlands for Route 5

Route 5 (Sea Leg)	Transit Time	Distance (km)	Cost (€)
Via Aliaga-Antwerp	251 hours 11 min	5028.3	1520.85
Via Aliaga-Rotterdam	250 hours 58 min	5003.3	1469.05
Via Aliaga-Hamburg	274 hours 5 min	5731.3	1620.85

Table 3.37 Comparison of routes in the study for Netherlands

Routes	Transit Time	Distance (km)	Cost (€)
Route 1: All road option	110 hours 22 min	3107	2883.75
Route 2: All road with RO-LA train option	95 hours 31 min	3174	3644.65
Route 3: Road- RO-RO- Road option	124 hours 3 min	3097	3437.47
Route 4: RO-RO and RO-LA option	119 hours 21 min	2815	3036.72
Route 5: All water option	250 hours 58 min	5003.3	1469.05

Table 3.38 The current transportation conditions of ABC Co

Routes	Bosch		Roger & Roger		The F.P.C	
	Transit Time	Cost (€)	Transit Time	Cost (€)	Transit Time	Cost (€)
Route 1	10 days	3500	11 days	3500	11 days	3500
Route 3	9 days	3300	10 days	3000	10 days	3100
Route 4	8.5 days	3500	8.5 day	3500	8.5 days	3500

As seen in Table 3.38, ABC Co is not using the all-road with RO-LA train option (Route 2) and the all-water option (Route 5) as a transportation option during its transportation process. Current transit time and transportation costs are high than examined routes. This shows the importance of owning a fleet, because transit time in the examined routes for route 1 is 3 days 21 hours while the current transportation condition was 10 days for shipments to Bosch. In terms of transportation cost, it is 2602.8 Euro for the shipments to Germany in the examined transportation route and it is 3500 Euro in the current transportation condition. Transit time is 4 days and 16 hours while the current transportation condition of ABC Co is 11 days for Roger & Roger and the examined transit cost is 2924.7 Euro while the current transit cost is 3500 Euro. It is 4 days and 14 hours while the current transportation condition of ABC Co is 11 days for The Flexible Packaging Company BV and the examined transit cost is 2883.75 Euro while the current transit cost is 3500 Euro.

Transit time in the examined routes for route 3 is 4 days and 19 hours while the current transportation condition for route 3 is 9 days and the examined transportation cost is 3156.52 Euro while current transportation cost is 3300 Euro for the shipments

to Bosch. Transit time of the examined route 3 is 5 days 15 hours while current transportation condition of ABC Co is 10 days and transportation cost of the examined route is 3479.12 Euro while transportation cost of the current condition is 3000 Euro for the shipments to Roger & Roger. Transit time of the examined route 3 for the shipments to The Flexible Packaging Company is 5 days and 4 hours while the current transit time is 10 days and transportation cost of the examined route is 3437 Euro while current transportation cost is 3100 Euro.

Transit time in the examined routes for route 4 is 4 days 16 hours while it is 8.5 days in current condition. Transportation cost in the examined route 4 is 2975.4 Euro for the shipment to Bosch while it is 3500 Euro. Examined transit time of Roger & Roger is 5 days while it is 8.5 days in current condition and examined transportation cost is 3019.07 Euro while it is 3500 Euro in current condition. Examined transit time of The Flexible Packaging Company is 5 days while it is 8.5 days and transportation cost of examined route 4 is 3036.72 Euro while it is 3500 Euro in current condition.

CHAPTER FOUR

CONCLUSIONS AND FURTHER RESEARCH

In this section, findings are discussed and direction for future studies are explained. First of all, ABC Co gets the best possible services and freight prices from freight forwarders and solution partners it can. Therefore, to decrease freight costs, achieve further improvements and compete with other packaging manufacturer firms, it is necessary to decreased transportation costs with fewer transit times. ABC Co receives the cumulative shipping costs from transportation companies to carry the goods from its center to its customers. As a result of this research, ABC Co is expected to understand the detailed transportation costs and the company will be able to negotiate detailed freight rates with its service providers. Alternative transportation routes will be considered by ABC Co to carry the goods to its customers and ABC Co will understand the benefits of every single route and will be able to decide which one of them should be used as a feasible transportation option. These options are listed in detail as transit time, transportation costs and distance parameters. According to these parameters and customer needs, ABC Co will be able to choose which transportation route is the best transportation option for the company.

4.1 Conclusion

VSM has proven to be a very useful tool to identify wastes in the manufacturing and service process including logistics operations. This study describes the application of the efficiency improvement approach to the distribution operations of one of the leading food packaging manufacturer Turkish conglomerates. The company is facing a significant level of transportation costs originated by wrong transportation route selection or unused transportation route options. TVSM is the new version of VSM for analyzing transportation operations efficiency such as mode selection. Transportation value stream mapping tool is used in the main purpose of increasing the efficiency of the transportation system and reducing the distribution costs by changing the mode of transport in this case study. This research identifies the pin-points of mode selection and gives important feedback about owning a warehouse or changing transportation

routes to eliminate the wastes and increase transportation efficiency to reduce transportation costs and increase customer satisfaction. The Beresford time cost distance model is chosen to analyze these pin-points of mode selection to find alternative routes to improve the efficiency of the outbound transportation system and compare it with the current outbound transportation system to show the advantages and disadvantages of the current routes/alternative routes.

4.2 Summary of Research Findings

4.2.1 Bosch, Germany

According to data given by ABC Co, it takes 9 days by road- RO-RO- road option, 10 days by the all-road option and 8.5 days by the RO-RO and RO-LA option via Trieste-Bettembourg to carry the goods to customers of ABC Co in Germany. In terms of cost, the all-road option (route 1) and the RO-RO and RO-LA option via Trieste-Bettembourg RO-LA train (route 4) cost 3500 Euro for each route individually. Also, it is 3300 Euro for road- RO-RO- road option (route 3).

According to study, it takes 115 hours 40 min (4-5 days) by the road- RO-RO- road option, 92 hours 59 min (3-4 days) by the all-road option and 111 hours 59 min (4-5 days) by the RO-RO and RO-LA option to carry the goods to the customers of ABC Co in Germany. Route 2 (All road with RO-LA train option) and route 5 (all-water option) were not considered by ABC Co as a transportation option before. In this case study, according to examined data, the all-road with RO-LA train option has the shortest transit time within all routes and it is 78 hours 8 min. The all-road with the RO-LA train option must be used by ABC Co when there are urgent needs of its customers. On the other hand, the all-water option has the cheapest costs within all examined routes and it is 1787.85 Euro. It is almost half of the size of its nearest comparison. In the research, in terms of cost comparison between the current state and future state of ABC Co, transportation cost of the all-road (route 1) option is 2602.8 Euro and it is less than the current transportation cost of ABC Co (current transportation costs are shown in Table 3.38). Transportation cost of the RO-RO and

RO-LA option via Trieste-Bettembourg (route 4) is 3385.07 Euro but there is a cost-efficient RO-LA train line instead of Trieste-Bettembourg RO-LA train line and it is called Ferretti-Salzburg RO-LA train line and the cost of it is 2975.4 Euro. Also, it is 3437.47 Euro for road- RO-RO- road option (route 3).

If ABC Co considers to make an investment for a warehouse in Europe between Germany, Belgium, and the Netherlands, the all-water option (route 5) must be considered as number one transportation option within transportation routes because container transportation by sea has the lowest costs within all transportation systems but it comes with higher transit times. Because of that, route 5 should be considered as an option when transit time is not an obligation or there is a warehouse between the Netherlands, Belgium, and Germany in Europe. If the food packaging manufacturer firm can make an investment for a warehouse in Europe, transportation costs will be less with the usage of the all-water option and transit time will be shorter because deliveries will be able to send from the warehouse to its customers.

As a result of that, customer satisfaction will increase and the optimal solution will be the all-water options within all 5 routes which is container transportation by sea. Besides investing in a warehouse in Europe. In current circumstances, the all-road option looks selectable transportation option within examined routes with the 92 hours 59 min transit time and 2602.8 Euro transit cost. It is the 2nd route in terms of transportation costs and transit time.

4.2.2 Roger & Roger, Belgium

According to data given by ABC Co, it takes 10 days by the road- RO-RO- road option, 11 days by the all-road option and 8.5 days by the RO-RO and RO-LA train option via Trieste-Bettembourg RO-LA train line to carry the goods to customers of ABC Co in Belgium. In terms of cost, the all-road option (route 1) and the RO-RO and RO-LA train option via Trieste-Bettembourg RO-LA train (route 4) cost 3500 Euro for each route individually. Also, it is 3000 Euro for the road- RO-RO- road option (route 3).

According to study, it takes 135 hours 44 min (5-6 days) by the road- RO-RO- road option, 112 hours 2 min (4-5 days) by the all-road option and 119 hours 39 min (5 days) by the RO-RO and RO-LA train option to carry the goods to customers of ABC Co in Belgium. Route 2 (All road with RO-LA train option) and route 5 (all water option) alternative routes were not considered by ABC Co as a transportation option before. In this case study, according to examined data, the all-road with RO-LA train option has the shortest transit time within all routes and it is 97 hours 11 min. The all-road with the RO-LA train option must be used by ABC Co when there are urgent needs of ABC Co's customers. On the other hand, the all-water option has the cheapest costs within all investigated routes and it is 1490.85 Euro. It is half of the cost of its nearest comparison. In the research, in terms of cost comparison between the current state and examined state of ABC Co, transportation cost of the all-road (route 1) option is 2924.7 Euro and it is less than the current transportation cost of ABC Co (current transportation costs are shown in Table 3.38). Transportation cost of the RO-RO and RO-LA train option via Trieste-Bettembourg (route 4) is 3186.52 Euro but there is another cost-efficient RO-LA train line instead of Trieste-Bettembourg RO-LA train line and it is called Trieste-Genk RO-LA train line. The cost of it is 3019.07 Euro. Also, the transit cost of the road- RO-RO- Road option (route 3) is 3437.47 Euro.

The same propositions like Bosch, Germany from the previous section apply to companies in Belgium too. If ABC Co consider to investing in a warehouse in Europe between Germany, Belgium, and the Netherlands, the all-water option (route 5) must be considered as number one option within transportation routes because container transportation by the sea has the lowest costs within all transportation systems but it comes with higher transit times always. Because of that route 5 should be considered as an option when transit time is not an obligation or there is a warehouse between the Netherlands, Belgium, and Germany in Europe. If there is a warehouse in Europe, transportation costs will be less with the usage of the all-water option and transit time will be shorter because deliveries will be able to send from the warehouse to its customers.

As a result of that, customer satisfaction will increase and the optimal solution within all 5 routes will be the all-water option which is container transportation by sea. Besides investing in warehouse in Europe. In current circumstances, RO-RO and RO-LA option (route 4) looks selectable option within all examined routes with 119 hours 39 min transit time and 3019.07 Euro transit cost. It is the 3rd route in terms of cost. All road option should not consider as an option prior from RO-RO and RO-LA option when costs and transit times this close because of *“restricted number of permits granted to Turkish road haulers along the transport corridors to Western Europe (particularly in Hungary, Austria, Italy, and Slovenia) creates difficulties for international transport”* (Denktaş Şakar, 2010, p. 228).

4.2.3 The Flexible Packaging Company, Netherlands

According to data given by ABC Co, it takes 10 days by the road- RO-RO- road option, 11 days by the all-road option and 8.5 days by the RO-RO and RO-LA train option via Trieste-Bettembourg RO-LA train to carry the goods to customers of ABC Co in the Netherlands. In terms of cost, the all-road option (route 1) and the RO-RO and RO-LA train option via Trieste-Bettembourg RO-LA train line (route 4) costs 3500 Euro for each route individually. Also, it is 3100 Euro for the road- RO-RO- road option (route 3).

According to study, it takes 124 hours 3 min (5-6 days) by the road- RO-RO- road option, 110 hours 22 min (4-5 days) by the all-road option and 119 hours 21 min (5 days) by the RO-RO and RO-LA train option to carry the goods to customers of ABC Co in the Netherlands. Route 2 (All road with RO-LA train option) and route 5 (all water option) alternative routes were not considered by ABC Co as a transportation option. In this case study, according to examined data, the all-road with RO-LA train option has the shortest transit time within all routes and it is 95 hours 31 min. The all-road with RO-LA train option must be used by ABC Co when there are urgent needs of ABC Co's customers. On the other hand, the all-water option has the cheapest costs within all examined routes and it is 1469.05 Euro. It is half of the cost of its nearest comparison. In the research, in terms of cost comparison between the current state and

examined state of ABC Co, transportation cost of the all-road (route 1) option is 2883.75 Euro and it is less than the current transportation cost of ABC Co. Transportation cost of the RO-RO and RO-LA train option via Trieste-Bettembourg RO-LA train (route 4) is 3321.87 Euro but there is another cost-efficient RO-LA line instead of Trieste-Bettembourg RO-LA train line and it is called Trieste-Genk RO-LA train line and the cost of it is 3036.72 Euro. Also, it is 3437.47 Euro for road- RO-RO-road option (route 3).

The same propositions like Bosch, Germany and Roger & Roger, Belgium from previous sections apply to companies in the Netherlands too. If ABC Co consider to making an investment for a warehouse in Europe between Germany, Belgium, and the Netherlands the all-water option (route 5) must be considered as number one option within transportation routes because container transportation by sea has the lowest costs within all transportation systems but it comes with higher transit times. Because of that, route 5 should be considered as an option when transit time is not an obligation or there is a warehouse between the Netherlands, Belgium, and Germany in Europe. If there is a warehouse in Europe, costs will be less than other routes and transit time will be shorter because deliveries will be able to send from the warehouse to its customers.

As a result of that, customer satisfaction will increase and the optimal solution within all 5 routes will be the all-water option. Besides investing in a warehouse in Europe. In current circumstances, the RO-RO and RO-LA option (route 4) looks selectable option within all examined routes with 119 hours 39 min transit time and 3036.72 Euro transit cost. It is the 3rd route in terms of cost and transit time. The all-road option should not consider as an option before the RO-RO and RO-LA option when costs and transit times this close.

4.2.4 Future TVSM

As mentioned at the previous sections, applications that help to choose an optimal transportation route would have positive impact on the improvement of the first step of the TVSM. This route optimization is projected to increase from 10 days to 3 days

21 hours due to improved transit time for the shipments to Bosch, Germany. 11 days to 4 days 16 hours for the shipments to Roger & Roger, Belgium and 11 days to 4 days 14 hours for the shipments to The Flexible Packaging Company, the Netherlands. This projected TVSM is for the usage of the all-road option. On the other hand, transportation costs increased from 3500 Euro to 2602 Euro for Germany, it is 3500 Euro to 2924 Euro for Belgium and 3500 Euro to 2883 Euro for shipments to the Netherlands. Also, if the all-water option is chosen as a transportation option and if there is a warehouse in Europe, transit times would be 2 days max. Transportation costs would be half of the current costs. It will be 1787 Euro for Germany, 1490 Euro for Belgium and 1469 Euro for the shipments to the Netherlands.

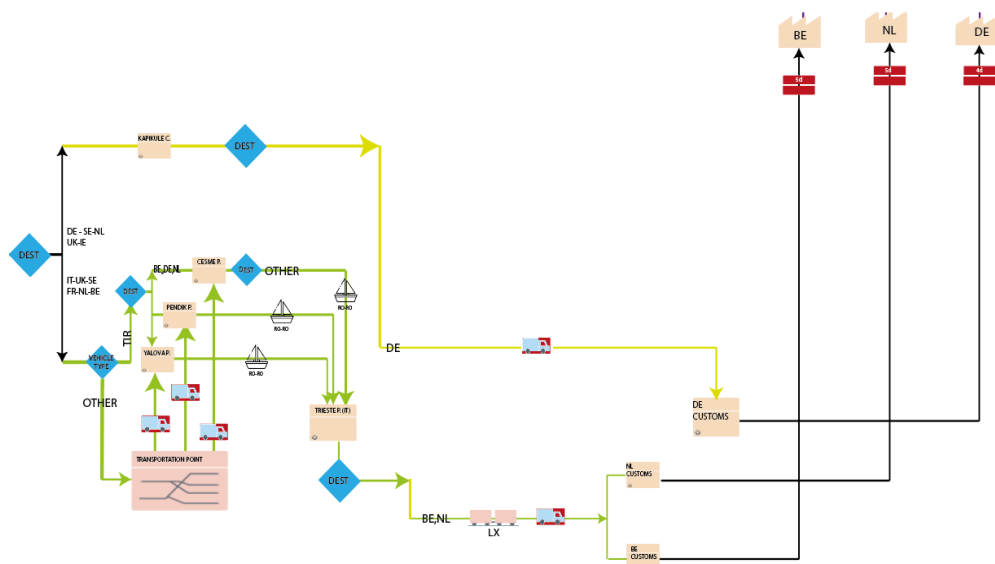


Figure 4.1 TVSM Routes

As seen in Figure 4.1 above, when the all-water route is used as a transportation option, ABC Co will not deal with customs, border crossings, driver rests and breaks, accidents, etc. The goods will carry port to port and from port to a warehouse. Once there is a goods inside of the warehouse, it would be easy to respond to the needs of the customers. The needs of the customers will be responded in 2 days and that will help to compete with other food packaging manufacturers in Europe. With this projected TVSM, the needs of the ABC Co and its customers would be satisfied.

Table 4.1 Current costs of the transportation routes

Routes	Bosch		Roger & Roger		The F.P.C	
	Transit Time	Cost (€)	Transit Time	Cost (€)	Transit Time	Cost (€)
Route 1	10 days	3500	11 days	3500	11 days	3500
Route 3	9 days	3300	10 days	3000	10 days	3100
Route 4	8.5 days	3500	8.5 day	3500	8.5 days	3500

Table 4.2 The costs of the suggested transportation routes

Routes	Bosch		Roger & Roger		The F.P.C	
	Transit Time	Cost (€)	Transit Time	Cost (€)	Transit Time	Cost (€)
Route 5	11.5 days	1787.85	10.5 days	1490.85	11.5 days	1469.05
From Warehouse	2 days	1787.85 + Holding Cost	1 day	1490.85 + Holding Cost	1 day	1469.05 + Holding Cost

As seen in Table 4.1, transit times and costs of the transportation routes are more than the ones at Table 4.2. The route from warehouse uses route 5 but holding the goods at the warehouse and transporting those to the last destinations. That's why transit times are 2 or 1 days and cost comes with the additional holding cost charge. According to data taken from co-forwarder of ABC, holding costs assumes as 10% of the total cost. Holding costs may vary according to bilateral agreements.

As a result of the analyzes, if examined routes applied the transit time of the transportation system will 66.7% decrease for the shipments to Bosch, 50% for the shipments to Roger & Roger and 50% for the shipments to The Flexible Packaging Company with the usage of current transportation methods such as all-road transportation. As previously mentioned, if there is a warehouse in Europe, transit time will be 2 days max for the shipments to these countries. In some cases, the goods can be transported in 1 day. This means 77.8% decrease in transit time for the shipments to Bosch, 80% decrease in transit time for the shipments to Roger & Roger and The Flexible Packaging Company with the usage of the all-water transportation option.

4.3 Research Limitations

The study is limited with the downstream players of ABC Co's Global Supply Chain Logistics activities. It was hard to get information about transportation process by ABC Co's co-forwarders in detail, so needed information was taken from other

global forwarders and the Beresford time cost distance model analyzes made according to that. It is assumed that there is no accident, driver break and no problem to find a place to rest for the TIR drivers. It is also assumed that TIRs are loaded to RO-LA trains and RO-RO ships once they arrived immediately, there is no time wasted while waiting for loading and unloading. The increase in inventory level was ignored. Company's considered internal operations are order management and logistics arrangements rather than the production process, since it is very complex in packaging industry and creates risk for depth of the research and time was another limitation of the study.

4.4 Contribution of the Research

This study contributes to the field of the global supply chain in terms of utilizing TVSM integrated the Beresford time cost distance model for finding the optimal transportation route for a non-carrier firm's logistics process mapping. Exploring the necessary function of TVSM integrated optimal transportation route selection solutions that are expected to benefit manufacturer companies and freight forwarders. It will help them to analyze the benefits of an investment about having their fleet or having a warehouse.

According to the findings of the study, new investments can be made in terms of warehouses in Europe. Container transportation would be a perfect solution when the optimal warehouse locations find in Europe however this can lead to new needs such as warehouse management. The benefits of that warehouse can be analyzed by the Beresford time cost distance model. Integrating the Beresford time cost distance model to optimal warehouse location assignments would be a new approach to reduce transportation time and it has a direct impact on TVSM and lean manufacturing literature when it is considered as reducing transportation times. Finding an optimal transportation route is a lean approach because it involves eliminating wastes, analysis of the process, making all processes lean and calculate all data involves to the transportation route. Integrating Beresford time cost distance model to the TVSM will open new approaches. There is no study about TVSM integrated the Beresford time

cost distance mode to find optimal transportation routes and analyze the current outbound transportation system to reduce transit time and transportation costs. This study shows how transportation mode selection important for the TVSM tool and important to eliminate wastes to improve the efficiency of all transportation systems. All TVSM process begins with transportation mode selection. According to Villarreal (2012) transportation route selection is the first step of TVSM. When the best route is selected by the help of the Beresford time cost distance model and efficiency of transportation mode selection is improved by this chose, improvements can be considered in other stages of the transportation system. Other stages of the transportation system can be examined with the lean manufacturing perspective to improve efficiency of it after this research.

4.4.1 Academic Contribution

This study is the first study to investigate route optimization in TVSM operations with the Beresford time cost distance model. The Beresford time cost distance model was used for route optimization before, but it wasn't used as a TVSM, lean manufacturing tool before. TVSM is also new approach in lean manufacturing field and this research is the first research in Turkey about it.

The future work for this study is suggested as optimal warehouse location assignments to reveal the optimal conditions and direct benefits of proposed solutions. Route optimization with the Beresford time cost distance model can be used as a tool of TVSM in Lean manufacturing field for route optimization. It is also can be used for optimal warehouse location assignments to see which warehouse location has the best transportation option in terms of transit time, transportation costs and distance to optimize the cost and increase the efficiency of the transportation system to carry the goods from retails to consumers.

As mentioned before, integrating the Beresford time cost distance model to optimal warehouse location assignments would be a new approach to reduce transportation time and it has a direct impact on TVSM and lean manufacturing literature when it is

considered as reducing transportation times. Finding an optimal transportation route is a lean approach because it involves eliminating wastes, analysis of the processes, making all processes lean and calculate all data involves to the transportation route. Integrating Beresford time cost distance model to the TVSM will open new approaches. There is no study about TVSM integrated the Beresford time cost distance model to find optimal transportation routes and analyze the current outbound transportation system to reduce transit time and transportation costs. This study shows how transportation mode selection important for the TVSM tool and important to eliminate wastes to improve the efficiency of all transportation systems.

4.4.2 Practical Contribution

One of the practical contributions of this research is the detailed information about transportation process provided by TVSM tool to show the first of the area that needs improvement most which is outbound transportation system. According to that the Beresford time cost distance model is integrated to TVSM tool to optimize the transportation routes. This implies that with the effective analyzes it is possible to find bottlenecks in the process and remove them and find an effective and profitable way to transport the goods to the customers and it is possible to increase customer satisfaction in the same time.

This research also reveals that ABC Co professionals and managers need to make investment and search the alternative transportation methods/ways to continuous improvement to compete and be a market lead. Otherwise it will lose the customers they currently have and the current position in the market.

As a result of the research, ABC Co should have a warehouse or rent a warehouse at a strategic location in Europe between Germany, Belgium and the Netherlands. The result of having a warehouse at a strategic point in Europe, the all-water transportation option can be used as a first transportation option to decrease the transportation costs. This will lead to decrease transportation costs more than 50% and as a result of having a warehouse, ABC Co will be able to deliver the goods to its customers in a day.

4.5 Suggestions for Future Research

As a result of this study, ABC Co can invest to have its fleet or to have a warehouse at a convenient point in Europe. Owning a fleet can be seen as a huge investment but in return, it can result in a decrease in transportation costs with optimal route selection in long term (detailed analyzes needed). If ABC Co will have a warehouse between Germany, Belgium or the Netherlands, route 5 which is the all-water option (container carriage) will be the best option to lessen the transportation costs and respond to the customer needs with short transit time. Transportation value stream mapping of it is shown in Figure 4.2. According to this statement, the goods will be stocked at warehouse to satisfy the needs of customers. Customer needs will be held in one or two day with lesser costs from warehouse in Europe instead of 5 or more days with higher costs from Turkey.

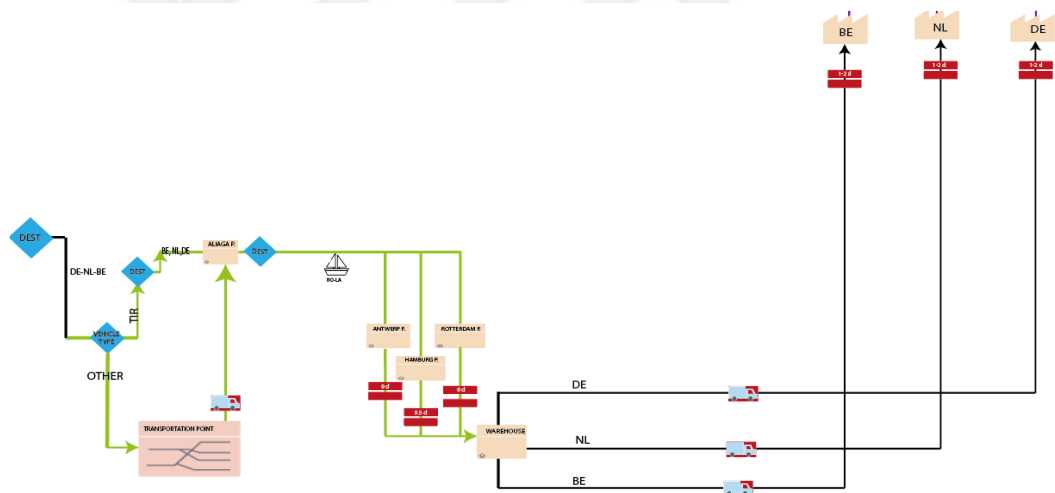


Figure 4.2 TVSM via all-water option

According to the result of this study, if these recommendations are applied, production companies will be provided with major improvements, transit times and transportation costs will be reduced and customer satisfaction will be increased because customer needs met just in time.

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APPENDICES

APPENDIX-1 Beresford Time Cost Distance Model Routes

All-Road Option (Route 1)

Table A.1 All-road option via Bulgaria (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Bulgaria (Kapi Kule)	Road	7 hours 47 min	545	
	Bridge fee				
	Health document fee				16.3
	Ferryboat fee				22
	Running cost *				
	Fuel				190.75
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		24 hours		100
	Driver daily rest and break		1 hour		
	Total		32 hours 47 min		506.05
	Bulgaria (Kapi Kule)-Romania (Rusçuk)	Road	4 hours 25 min	310	
	Highway fee				75
	Running cost *				50
	Fuel				108.5
	Bridge fee				
	Toll fee				37
	Other expenses				
	Driver daily rest and break		1 hour		
	Total		5 hours 25 min		270.5
	Romania (Rusçuk) – Hungary (Szeget)	Road	10 hours 20 min	724	
	Ro-Vignette				52
	Running cost *				30
	Fuel				253.4
	Toll fee				47
	Other expenses				
	Driver daily rest and break		9 hours + 1 hour		
	Total		20 hours 20 min		382.4
	Hungary (Szeget)-Austria (Nickelsdorf)	Road	4 hours 55 min	344	
	Highway fee				120
	Running cost *				50
	Fuel				120.4
	Toll fee				
	Driver daily rest and break		9 hours		
	Total		13 hours 55 min		290.4
	Austria (Nickelsdorf) – Germany (Suben)	Road	4 hours 50 min	338	
	Highway fee				180
	Running cost *				400
	Fuel				118.3
	Schengen visa fee				60
	Driver daily rest and break		1 hour + 9 hours		
	Total		14 hours 50 min		758.3
	Germany – Bosch 74572 Blaufelden	Road	4 hours 42 min	329	
	Highway fee				260
	Running cost *				20
	Fuel				115.15
	Driver daily rest and break		1 hour		
	Total		5 hours 42 min		395.15
	Overall		92 hours 59 min	2590	2602.8

*Driver allowances, administration, repair and maintenance, depreciation

Table A.2 All-road option via Bulgaria (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Bulgaria (Kapi Kule)	Road	7 hours 47 min	545	
	Bridge fee				
	Health document fee				16.3
	Ferryboat fee				22
	Running cost *				
	Fuel				190.75
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		24 hours		100
	Driver daily rest and break		1 hour		
	Total		32 hours 47 min		506.05
	Bulgaria (Kapi Kule)-Romania (Rusçuk)	Road	4 hours 25 min	310	
	Highway fee				75
	Running cost *				50
	Fuel				108.5
	Bridge fee				
	Toll fee				37
	Other expenses				
	Driver daily rest and break		1 hour		
	Total		5 hours 25 min		270.5
	Romania (Rusçuk) – Hungary (Szeget)	Road	10 hours 20 min	724	
	Ro-Vignette				52
	Running cost *				30
	Fuel				253.4
	Toll fee				47
	Other expenses				
	Driver daily rest and break		9 hours + 1 hour		
	Total		20 hours 20 min		382.4
	Hungary (Szeget)-Austria (Nickelsdorf)	Road	4 hours 55 min	344	
	Highway fee				120
	Running cost *				50
	Fuel				120.4
	Toll fee				
	Driver daily rest and break		9 hours		
	Total		13 hours 55 min		290.4
	Austria (Nickelsdorf) – Germany (Suben)	Road	4 hours 50 min	338	
	Highway fee				180
	Running cost *				400
	Fuel				118.3
	Schengen visa fee				60
	Driver daily rest and break		1 hour + 9 hours		
	Total		14 hours 50 min		758.3
	Germany – Germany (Aachen)	Road	10 hours 11 min	713	
	Highway fee				260
	Running cost *				20
	Fuel				249.55
	Driver daily rest and break		1 hour + 9 hours		
	Total		20 hours 11 min		529.55
	Germany – Roger & Roger 7700	Road	3 hours 34 min	250	
	Highway fee				75
	Running cost *				25
	Fuel				87.5
	Driver daily rest and break		1 hour		
	Total		4 hours 34 min		187.5
	Overall		112 hours 2 min	3224	2924.7

*Driver allowances, administration, repair and maintenance, depreciation

Table A.3 All-road option via Bulgaria (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Bulgaria (Kapi Kule)	Road	7 hours 47 min	545	
	Bridge fee				
	Health document fee				16.3
	Ferryboat fee				22
	Running cost *				
	Fuel				190.75
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		24 hours		100
	Driver daily rest and break		1 hour		
	Total		32 hours 47 min		506.05
	Bulgaria (Kapi Kule)-Romania (Rusçuk)	Road	4 hours 25 min	310	
	Highway fee				75
	Running cost *				50
	Fuel				108.5
	Bridge fee				
	Toll fee				37
	Other expenses				
	Driver daily rest and break		1 hour		
	Total		5 hours 25 min		270.5
	Romania (Rusçuk) – Hungary (Szeget)	Road	10 hours 20 min	724	
	Ro-Vignette				52
	Running cost *				30
	Fuel				253.4
	Toll fee				47
	Other expenses				
	Driver daily rest and break		9 hours + 1 hour		
	Total		20 hours 20 min		382.4
	Hungary (Szeget)-Austria (Nickelsdorf)	Road	4 hours 55 min	344	
	Highway fee				120
	Running cost *				50
	Fuel				120.4
	Toll fee				
	Driver daily rest and break		9 hours		
	Total		13 hours 55 min		290.4
	Austria (Nickelsdorf) – Germany (Suben)	Road	4 hours 50 min	338	
	Highway fee				180
	Running cost *				400
	Fuel				118.3
	Schengen visa fee				60
	Driver daily rest and break		1 hour + 9 hours		
	Total		14 hours 50 min		758.3
	Germany – The Flexible Packaging Company Amersfoort	Road	12 hours 5 min	846	
	Highway fee				335
	Running cost *				45
	Fuel				296.1
	Driver daily rest and break		1 hour + 9 hours + 1 hour		
	Total		23 hours 5 min		676.1
	Overall		110 hours 22 min	3107	2883.75

*Driver allowances, administration, repair and maintenance, depreciation

Table A.4 All-road option via Greece (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Greece (Ipsala)	Road	6 hours 30 min	455	
	Bridge fee				
	Ferryboat fee				22
	Running cost *				
	Fuel				159.25
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		3 hours		100
	Driver daily rest and break		1 hour		
	Total		10 hours 30 min		458.25
	Greece (Ipsala) – Macedonia (Evzono)	Road	5 hours 45 min	403	
	Highway (Selanik)				75
	Running cost *				100
	Fuel				141.05
	Bridge fee				
	Toll fee				
	Other expenses				
	Driver daily rest and break		9 hours + 1 hours		
	Total		15 hours 45 min		316.05
	Macedonia (Evzono) – Serbia (Lipovac)	Road	5 hours	350	
	Petrovec-Veles				30
	Running cost *				
	Fuel				122.5
	Bridge fee				
	Other expenses				
	Driver daily rest and break		9 hours		
	Total		14 hours		152.5
	Serbia (Lipovac) – Croatia (Batrovci)	Road	4 hours 50 min	339	
	Highway fee				150
	Running cost *				10
	Fuel				118.65
	Driver daily rest and break		1 hours		
	Total		5 hours 50 min		278.65
	Croatia (Batrovci) – Croatia (Zagreb)	Road	4 hours 3 min	284	
	Highway fee				60
	Running cost *				20
	Fuel				99.4
	Driver daily rest and break		9 hours		
	Total		13 hours 3 min		179.4
	Croatia (Zagreb) – Slovenia (Ljubljana)	Road	4 hours	140	
	Highway fee				
	Running cost *				
	Fuel				49
	Driver daily rest and break		1 hours		
	Total		5 hours		49
	Slovenia (Ljubljana) – Austria (Spielfeld)	Road	4 hours 4 min	147	
	Highway fee				40
	Running cost *				
	Fuel				51.45
	Driver daily rest and break		9 hours		
	Schengen visa fee				60
	Total		13 hours 4 min		151.45
	Austria (Spielfeld) – Germany (Suben)	Road	4 hours 22 min	306	
	Highway fee				340
	Running cost *				400
	Fuel				107.1
	Driver daily rest and break		1 hour		
	Total		5 hours 22 min		847.1
	Germany (Suben) – Bosch 74572 Blaufelden	Road	4 hours 42 min	329	
	Highway fee				285
	Running cost *				20
	Fuel				115.15
	Driver daily rest and break		9 hours		
	Total		13 hours 42 min		420.15
	Overall		96 hours 16 min	2753	2852.55

*Driver allowances, administration, repair and maintenance, depreciation

Table A.5 All-road option via Greece (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Greece (Ipsala)	Road	6 hours 30 min	455	
	Bridge fee				
	Ferryboat fee				22
	Running cost *				
	Fuel				159.25
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		3 hours		100
	Driver daily rest and break		1 hour		
	Total		10 hours 30 min		458.25
	Greece (Ipsala) – Macedonia (Evzono)	Road	5 hours 45 min	403	
	Highway (Selanik)				75
	Running cost *				100
	Fuel				141.05
	Bridge fee				
	Toll fee				
	Other expenses				
	Driver daily rest and break		9 hours + 1 hours		
	Total		15 hours 45 min		316.05
	Macedonia (Evzono) – Serbia (Lipovac)	Road	5 hours	350	
	Petrovec-Veles				30
	Running cost *				
	Fuel				122.5
	Bridge fee				
	Other expenses				
	Driver daily rest and break		9 hours		
	Total		14 hours		152.5
	Serbia (Lipovac) – Croatia (Batrovci)	Road	4 hours 50 min	339	
	Highway fee				150
	Running cost *				10
	Fuel				118.65
	Driver daily rest and break		1 hours		
	Total		5 hours 50 min		278.65
	Croatia (Batrovci) – Croatia (Zagreb)	Road	4 hours 3 min	284	
	Highway fee				60
	Running cost *				20
	Fuel				99.4
	Driver daily rest and break		9 hours		
	Total		13 hours 3 min		179.4
	Croatia (Zagreb) – Slovenia (Ljubliana)	Road	4 hours	140	
	Highway fee				
	Running cost *				
	Fuel				49
	Driver daily rest and break		1 hours		
	Total		5 hours		49
	Slovenia (Ljubliana) – Austria (Spielfeld)	Road	4 hours 4 min	147	
	Highway fee				40
	Running cost *				
	Fuel				51.45
	Driver daily rest and break		9 hours		
	Schengen visa fee				60
	Total		13 hours 4 min		151.45
	Austria (Spielfeld) – Germany (Suben)	Road	4 hours 22 min	306	
	Highway fee				340
	Running cost *				400
	Fuel				107.1
	Driver daily rest and break		1 hour		
	Total		5 hours 22 min		847.1
	Germany – Germany (Aachen)	Road	10 hours 11 min	713	
	Highway fee				285
	Running cost *				20
	Fuel				249.55
	Driver daily rest and break		9 hours + 1 hour + 9 hours		
	Total		29 hours 11 min		554.55
	Germany – Roger & Roger 7700	Road	3 hours 34 min	250	
	Highway fee				75
	Running cost *				25
	Fuel				87.5
	Driver daily rest and break		1 hour		
	Total		4 hours 34 min		187.5
	Overall		116 hours 19 min	3387	3174.45

*Driver allowances, administration, repair and maintenance, depreciation

Table A.6 All-road option via Greece (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Greece (Ipsala)	Road	6 hours 30 min	455	
	Bridge fee				
	Ferryboat fee				22
	Running cost *				
	Fuel				159.25
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		3 hours		100
	Driver daily rest and break		1 hour		
	Total		10 hours 30 min		458.25
	Greece (Ipsala) – Macedonia (Evzanoi)	Road	5 hours 45 min	403	
	Highway (Selanik)				75
	Running cost *				100
	Fuel				141.05
	Bridge fee				
	Toll fee				
	Other expenses				
	Driver daily rest and break		9 hours + 1 hours		
	Total		15 hours 45 min		316.05
	Macedonia (Evzanoi) – Serbia (Lipovac)	Road	5 hours	350	
	Petrovec-Veles				30
	Running cost *				
	Fuel				122.5
	Bridge fee				
	Other expenses				
	Driver daily rest and break		9 hours		
	Total		14 hours		152.5
	Serbia (Lipovac) – Croatia (Batrovci)	Road	4 hours 50 min	339	
	Highway fee				150
	Running cost *				10
	Fuel				118.65
	Driver daily rest and break		1 hours		
	Total		5 hours 50 min		278.65
	Croatia (Batrovci) – Croatia (Zagreb)	Road	4 hours 3 min	284	
	Highway fee				60
	Running cost *				20
	Fuel				99.4
	Driver daily rest and break		9 hours		
	Total		13 hours 3 min		179.4
	Croatia (Zagreb) – Slovenia (Ljubliana)	Road	4 hours	140	
	Highway fee				
	Running cost *				
	Fuel				49
	Driver daily rest and break		1 hours		
	Total		5 hours		49
	Slovenia (Ljubliana) – Austria (Spielfeld)	Road	4 hours 4 min	147	
	Highway fee				40
	Running cost *				
	Fuel				51.45
	Driver daily rest and break		9 hours		
	Schengen visa fee				60
	Total		13 hours 4 min		151.45
	Austria (Spielfeld) – Germany (Suben)	Road	4 hours 22 min	306	
	Highway fee				340
	Running cost *				400
	Fuel				107.1
	Driver daily rest and break		1 hour		
	Total		5 hours 22 min		847.1
	Germany – The Flexible Packaging Company Amersfoort	Road	12 hours 5 min	846	
	Highway fee				360
	Running cost *				45
	Fuel				296.1
	Driver daily rest and break		9 hours +1 hour + 9 hours		
	Total		31 hours 5 min		701.1
	Overall		113 hours 39 min	3270	3133.5

*Driver allowances, administration, repair and maintenance, depreciation

All-Road with RO-LA Train Option (Route 2)

Table A.7 All-road with RO-LA train option via Bulgaria (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir- Bulgaria (Kapi Kule)	Road	7 hours 47 min	545	
	Health document fee				16.3
	Ferryboat fee				22
	Running cost *				
	Fuel				190.75
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		24 hours		100
	Driver daily rest and break		1 hour		
	Total		32 hours 47 min		506.05
	Bulgaria-Serbia (Dimitrovgrad)	Road	5 hours 8 min	360	
	Toll fee (Bulgaria)				37
	Highway (Vignette)				75
	Running cost *				50
	Fuel				126
	Driver Daily rest and break		1 hour		
	Total		6 hours 8 min		288
	Serbia (Dimitrovgrad)-Croatia (Batrovci)	Road	6 hours 35 min	461	
	Toll fee				
	Visa fee				
	Highway fee				170
	Parking fee				
	Other expenses				
	Running cost *				10
	Fuel				161.35
	Driver daily rest and break		9 hours		
	Total		15 hours 35 min		341.35
	Croatia (Batrovci) – Zagreb (Croatia)	Road	4 hours 17 min	302	
	Toll fee				
	Highway fee				175
	Other expenses				
	Running cost *				20
	Fuel				105.7
	Driver daily rest and break		1 hour + 9 hours		
	Total		14 hours 17 min		300.7
	Croatia – Slovenia (Maribor)	Road	1 hours 52 min	131	
	Highway fee				46
	Running cost *				
	Fuel				45.85
	Total		1 hours 52 min		91.85
	Maribor (Slovenia)-Wels (Austria)	Rail	4 hours 16 min	215	
	Maribor-Wels rail transport (ROLA)		6 hours		860
	Running cost *				
	Total		10 hours 16 min		860
	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 8 min		511.35
	Germany – Bosch 74572 Blaufelden	Road	4 hours 42 min	329	
	Highway fee				385
	Running cost *				20
	Fuel				115.15
	Driver daily rest and break		1 hour		
	Total		5 hours 42 min		520.15
	Overall		87 hours 45 min	2422	3419.45

*Driver allowances, administration, repair and maintenance, depreciation

Table A.8 All-road with RO-LA train option via Bulgaria (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir- Bulgaria (Kapi Kule)	Road	7 hours 47 min	545	
	Health document fee				16.3
	Ferryboat fee				22
	Running cost *				
	Fuel				190.75
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		24 hours		100
	Driver daily rest and break		1 hour		
	Total		32 hours 47 min		506.05
	Bulgaria-Serbia (Dimitrovgrad)	Road	5 hours 8 min	360	
	Toll fee (Bulgaria)				37
	Highway (Vignette)				75
	Running cost *				50
	Fuel				126
	Driver Daily rest and break		1 hour		
	Total		6 hours 8 min		288
	Serbia (Dimitrovgrad)-Croatia (Batrovci)	Road	6 hours 35 min	461	
	Toll fee				
	Visa fee				
	Highway fee				170
	Parking fee				
	Other expenses				
	Running cost *				10
	Fuel				161.35
	Driver daily rest and break		9 hours		
	Total		15 hours 35 min		341.35
	Croatia (Batrovci) – Zagreb (Croatia)	Road	4 hours 17 min	302	
	Toll fee				
	Highway fee				175
	Other expenses				
	Running cost *				20
	Fuel				105.7
	Driver daily rest and break		1 hour + 9 hours		
	Total		14 hours 17 min		300.7
	Croatia – Slovenia (Maribor)	Road	1 hours 52 min	131	
	Highway fee				46
	Running cost *				
	Fuel				45.85
	Total		1 hours 52 min		91.85
	Maribor (Slovenia)-Wels (Austria)	Rail	4 hours 16 min	215	
	Maribor-Wels rail transport (ROLA)		6 hours		860
	Running cost *				
	Total		10 hours 16 min		860
	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 8 min		511.35
	Germany – Germany (Aachen)	Road	10 hours 11 min	713	
	Highway fee				385
	Running cost *				20
	Fuel				249.55
	Driver daily rest and break		1 hour + 9 hours		
	Total		20 hours 11 min		654.55
	Germany – Roger & Roger 7700	Road	3 hours 34 min	250	
	Highway fee				75
	Running cost *				25
	Fuel				87.5
	Driver daily rest and break		1 hour		
	Total		4 hours 34 min		187.5
	Overall		106 hours 48 min	3056	3741.35

*Driver allowances, administration, repair and maintenance, depreciation

Table A.9 All-road with RO-LA train option via Bulgaria (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir- Bulgaria (Kapi Kule)	Road	7 hours 47 min	545	
	Health document fee				16.3
	Ferryboat fee				22
	Running cost *				
	Fuel				190.75
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		24 hours		100
	Driver daily rest and break		1 hour		
	Total		32 hours 47 min		506.05
	Bulgaria-Serbia (Dimitrovgrad)	Road	5 hours 8 min	360	
	Toll fee (Bulgaria)				37
	Highway (Vignette)				75
	Running cost *				50
	Fuel				126
	Driver Daily rest and break		1 hour		
	Total		6 hours 8 min		288
	Serbia (Dimitrovgrad)-Croatia (Batrovci)	Road	6 hours 35 min	461	
	Toll fee				
	Visa fee				
	Highway fee				170
	Parking fee				
	Other expenses				
	Running cost *				10
	Fuel				161.35
	Driver daily rest and break		9 hours		
	Total		15 hours 35 min		341.35
	Croatia (Batrovci) – Zagreb (Croatia)	Road	4 hours 17 min	302	
	Toll fee				
	Highway fee				175
	Other expenses				
	Running cost *				20
	Fuel				105.7
	Driver daily rest and break		1 hour + 9 hours		
	Total		14 hours 17 min		300.7
	Croatia – Slovenia (Maribor)	Road	1 hours 52 min	131	
	Highway fee				46
	Running cost *				
	Fuel				45.85
	Total		1 hours 52 min		91.85
	Maribor (Slovenia)-Wels (Austria)	Rail	4 hours 16 min	215	
	Maribor-Wels rail transport (ROLA)		6 hours		860
	Running cost *				
	Total		10 hours 16 min		860
	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 8 min		511.35
	Germany – The Flexible Packaging Company Amersfoort	Road	12 hours 5 min	846	
	Highway fee				460
	Running cost *				45
	Fuel				296.1
	Driver daily rest and break		1 hour + 9 hours + 1 hour		
	Total		23 hours 5 min		801.1
	Overall		105 hours 8 min	2939	3700.4

*Driver allowances, administration, repair and maintenance, depreciation

Table A.10 All-road with RO-LA train option via Greece (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Greece (Ipsala)	Road	6 hours 30 min	455	
	Health document fee				16.3
	Highway and ferry fee				22
	Running cost *				
	Fuel				159.25
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		3 hours		100
	Driver daily rest and break		1 hour		
	Total		10 hours 30 min		474.55
	Greece (Ipsala) –Macedonia (Evzono)	Road	5 hours 45 min	403	
	Highway (Vignette)				75
	Running cost *				100
	Fuel				141.05
	Bridge fee				
	Driver daily rest and break		9 hours +1 hour		
	Other expenses				
	Total		15 hours 45 min		316.05
	Macedonia (Evzono)– Serbia (Lipovac)	Road	5 hours	350	
	Ro-Vignette				30
	Running cost *				
	Fuel				122.5
	Bridge fee				
	Other expenses				
	Driver daily rest and break		9 hours		
	Total		14 hours		152.5
	Serbia (Lipovac) – Batrovci (Croatia)	Road	4 hours 52 min	411	
	Highway fee				150
	Running cost *				10
	Fuel				143.85
	Parking fee				
	Toll fee				
	Driver daily rest and break		1 hour		
	Total		5 hours 52 min		303.85
	Croatia (Batrovci) – Croatia (Zagreb)	Road	4 hours 3 min	284	
	Toll fee				60
	Running cost *				20
	Fuel				99.4
	Driver daily rest and break		9 hours		
	Total		13 hours 3 min		179.4
	Croatia (Zagreb) – Slovenia (Maribor)	Road	1 hours 52 min	131	
	Toll fee				
	Running cost *				
	Fuel				45.85
	Total		1 hour 52 min		45.85
	Slovenia (Maribor)-Austria (Wels)	Rail	4 hours 16 min	215	
	Maribor-Wels rail transport (ROLA)		6 hours		860
	Running cost *				
	Total		10 hours 16 min		860
	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 8 min		511.35
	Germany (Suben)– Bosch 74572 Blafelden	Road	4 hours 42 min	329	
	Highway fee				385
	Running cost *				20
	Fuel				115.15
	Driver daily rest and break		1 hour		
	Total		5 hours 42 min		520.15
	Overall		78 hours 8 min	2657	3363.7

*Driver allowances, administration, repair and maintenance, depreciation

Table A.11 All-road with RO-LA train option via Greece (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Greece (Ipsala)	Road	6 hours 30 min	455	
	Health document fee				16.3
	Highway and ferry fee				22
	Running cost *				
	Fuel				159.25
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		3 hours		100
	Driver daily rest and break		1 hour		
	Total		10 hours 30 min		474.55
	Greece (Ipsala) –Macedonia (Evzonoï)	Road	5 hours 45 min	403	
	Highway (Vignette)				75
	Running cost *				100
	Fuel				141.05
	Bridge fee				
	Driver daily rest and break		9 hours +1 hour		
	Other expenses				
	Total		15 hours 45 min		316.05
	Macedonia (Evzonoï)– Serbia (Lipovac)	Road	5 hours	350	
	Ro-Vignette				30
	Running cost *				
	Fuel				122.5
	Bridge fee				
	Other expenses				
	Driver daily rest and break		9 hours		
	Total		14 hours		152.5
	Serbia (Lipovac) – Batrovci (Croatia)	Road	4 hours 52 min	411	
	Highway fee				150
	Running cost *				10
	Fuel				143.85
	Parking fee				
	Toll fee				
	Driver daily rest and break		1 hour		
	Total		5 hours 52 min		303.85
	Croatia (Batrovci) – Croatia (Zagreb)	Road	4 hours 3 min	284	
	Toll fee				60
	Running cost *				20
	Fuel				99.4
	Driver daily rest and break		9 hours		
	Total		13 hours 3 min		179.4
	Croatia (Zagreb) – Slovenia (Maribor)	Road	1 hours 52 min	131	
	Toll fee				
	Running cost *				
	Fuel				45.85
	Total		1 hour 52 min		45.85
	Slovenia (Maribor)-Austria (Wels)	Rail	4 hours 16 min	215	
	Maribor-Wels rail transport (ROLA)		6 hours		860
	Running cost *				
	Total		10 hours 16 min		860
	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 8 min		511.35
	Germany – Germany (Aachen)	Road	10 hours 11 min	713	
	Highway fee				385
	Running cost *				20
	Fuel				249.55
	Driver daily rest and break		1 hour + 9 hours		
	Total		20 hours 11 min		654.55
	Germany – Roger & Roger 7700	Road	3 hours 34 min	250	
	Highway fee				75
	Running cost *				25
	Fuel				87.5
	Driver daily rest and break		1 hour		
	Total		4 hours 34 min		187.5
	Overall		97 hours 11 min	3291	3685.6

*Driver allowances, administration, repair and maintenance, depreciation

Table A.12 All-road with RO-LA train option via Greece (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Greece (Ipsala)	Road	6 hours 30 min	455	
	Health document fee				16.3
	Highway and ferry fee				22
	Running cost *				
	Fuel				159.25
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Custom fee		3 hours		100
	Driver daily rest and break		1 hour		
	Total		10 hours 30 min		474.55
	Greece (Ipsala) –Macedonia (Evzono)	Road	5 hours 45 min	403	
	Highway (Vignette)				75
	Running cost *				100
	Fuel				141.05
	Bridge fee				
	Driver daily rest and break		9 hours +1 hour		
	Other expenses				
	Total		15 hours 45 min		316.05
	Macedonia (Evzono)– Serbia (Lipovac)	Road	5 hours	350	
	Ro-Vignette				30
	Running cost *				
	Fuel				122.5
	Bridge fee				
	Other expenses				
	Driver daily rest and break		9 hours		
	Total		14 hours		152.5
	Serbia (Lipovac) – Batrovci (Croatia)	Road	4 hours 52 min	411	
	Highway fee				150
	Running cost *				10
	Fuel				143.85
	Parking fee				
	Toll fee				
	Driver daily rest and break		1 hour		
	Total		5 hours 52 min		303.85
	Croatia (Batrovci) – Croatia (Zagreb)	Road	4 hours 3 min	284	
	Toll fee				60
	Running cost *				20
	Fuel				99.4
	Driver daily rest and break		9 hours		
	Total		13 hours 3 min		179.4
	Croatia (Zagreb) – Slovenia (Maribor)	Road	1 hours 52 min	131	
	Toll fee				
	Running cost *				
	Fuel				45.85
	Total		1 hour 52 min		45.85
	Slovenia (Maribor)-Austria (Wels)	Rail	4 hours 16 min	215	
	Maribor-Wels rail transport (ROLA)		6 hours		860
	Running cost *				
	Total		10 hours 16 min		860
	Wels (Austria)-Germany (Suben)	Road	1 hour 8 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 8 min		511.35
	Germany – The Flexible Packaging Company Amersfoort	Road	12 hours 5 min	846	
	Highway fee				460
	Running cost *				45
	Fuel				296.1
	Driver daily rest and break		1 hour + 9 hours + 1 hour		
	Total		23 hours 5 min		801.1
	Overall		95 hours 31 min	3174	3644.65

*Driver allowances, administration, repair and maintenance, depreciation

RO-RO with Road Option (Route 3)

Table A.13 RO-RO with Road option (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Villach (Austria)	Road	2 hours 48 min	197	
	Highway toll fee				29.20
	Running cost *				
	Fuel				68.95
	Total		2 hours 48 min		98.15
	Villach (Austria) – Salzburg (Austria)	Road	2 hours 43 min	191	
	Highway				180
	Running cost *				400
	Fuel				66.85
	Driver daily rest and break		1 hour		
	Total		3 hours 43 min		646.85
	Germany – Bosch 74572 Blaufelden	Road	5 hours 48 min	406	
	Highway fee				260
	Running cost *				20
	Fuel				142.1
	Driver daily rest and break		9 hours		
	Total		14 hours 48 min		422.1
	Overall		115 hours 40 min	2580	3156.52

*Driver allowances, administration, repair and maintenance, depreciation

Table A.14 RO-RO with Road option (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Villach (Austria)	Road	2 hours 48 min	197	
	Highway toll fee				29.20
	Running cost *				
	Fuel				68.95
	Total		2 hours 48 min		98.15
	Villach (Austria) – Salzburg (Austria)	Road	2 hours 43 min	191	
	Highway				180
	Running cost *				400
	Fuel				66.85
	Driver daily rest and break		1 hour		
	Total		3 hours 43 min		646.85
	Germany – Germany (Aachen)	Road	11 hours 18 min	792	
	Highway fee				260
	Running cost *				20
	Fuel				277.2
	Driver daily rest and break		9 hours + 1 hours		
	Total		21 hours 18 min		557.2
	Germany – Roger & Roger 7700	Road	3 hours 34 min	250	
	Highway fee				75
	Running cost *				25
	Fuel				87.5
	Driver daily rest and break		9 hours		
	Total		13 hours 34 min		187.5
	Overall		135 hours 44 min	3216	3479.12

*Driver allowances, administration, repair and maintenance, depreciation

Table A.15 RO-RO with Road option (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Villach (Austria)	Road	2 hours 48 min	197	
	Highway toll fee				29.20
	Running cost *				
	Fuel				68.95
	Total		2 hours 48 min		98.15
	Villach (Austria) – Salzburg (Austria)	Road	2 hours 43 min	191	
	Highway				180
	Running cost *				400
	Fuel				66.85
	Driver daily rest and break		1 hour		
	Total		3 hours 43 min		646.85
	Germany – The Flexible Packaging Amersfoort	Road	13 hours 11 min	923	
	Highway fee				335
	Running cost *				45
	Fuel				323.05
	Driver daily rest and break		9 hours +1 hour		
	Total		23 hours 11 min		703.05
	Overall		124 hours 3 min	3097	3437.47

*Driver allowances, administration, repair and maintenance, depreciation

RO-RO and RO-LA Option (Route 4)

Table A.16 RO-RO and RO-LA option via Trieste-Wels RO-LA (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Wels (Austria)	Rail	5 hours 25 min	280	
	RO-LA fee				570
	Running cost *		6 hours		
	Total		11 hours 25 min		570
	Wels (Austria) - Germany (Suben)	Road	1 hour 7 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 7 min		511.35
	Germany (Suben) – Bosch 74572 Blaufelden	Road	4 hours 42 min	329	
	Highway fee				260
	Running cost *				20
	Fuel				115.15
	Driver daily rest and break		1 hour		
	Total		5 hours 42 min		395.15
	Overall		112 hours 35 min	2474	3465.95

*Driver allowances, administration, repair and maintenance, depreciation

Table A.17 RO-RO and RO-LA option via Trieste-Wels RO-LA (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Wels (Austria)	Rail	5 hours 25 min	280	
	RO-LA fee				570
	Running cost *		6 hours		
	Total		11 hours 25 min		570
	Wels (Austria) - Germany (Suben)	Road	1 hour 7 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 7 min		511.35
	Germany – Germany (Aachen)	Road	10 hours 11 min	713	
	Highway fee				260
	Running cost *				20
	Fuel				249.55
	Driver daily rest and break		1 hour + 9 hours		
	Total		20 hours 11 min		529.55
	Germany – Roger & Roger 7700	Road	3 hours 34 min	250	
	Highway fee				75
	Running cost *				25
	Fuel				87.5
	Driver daily rest and break		1 hour		
	Total		4 hours 34 min		187.5
	Overall		131 hours 38 min	3108	3787.85

*Driver allowances, administration, repair and maintenance, depreciation

Table A.18 RO-RO and RO-LA option via Trieste-Wels RO-LA (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Wels (Austria)	Rail	5 hours 25 min	280	
	RO-LA fee				570
	Running cost *		6 hours		
	Total		11 hours 25 min		570
	Wels (Austria) - Germany (Suben)	Road	1 hour 7 min	79	
	Highway fee				23.7
	Running cost *				400
	Fuel				27.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		1 hour 7 min		511.35
	Germany – The Flexible Packaging Company Amersfoort	Road	12 hours 5 min	846	
	Highway fee				335
	Running cost *				45
	Fuel				296.1
	Driver daily rest and break		1 hour + 9 hours + 1 hours		
	Total		23 hours 5 min		586.1
	Overall		129 hours 58 min	2991	3656.9

*Driver allowances, administration, repair and maintenance, depreciation

Table A.19 RO-RO and RO-LA option via Trieste-Bettembourg RO-LA (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)–Bettembourg (Lux)	Rail	13 hours 52 min	717	
	RO-LA fee				930
	Running cost *		6 hours		
	Total		19 hours 52 min		930
	Luxembourg – Bosch 74572 Blaufelden	Road	5 hours 7 min	359	
	Highway fee				260
	Running cost *				20
	Fuel				125.65
	Schengen visa fee				60
	Driver daily rest and break		1 hour		
	Total		6 hours 7 min		465.65
	Overall		120 hours 20 min	2862	3385.07

*Driver allowances, administration, repair and maintenance, depreciation

Table A.20 RO-RO and RO-LA option via Trieste-Wels RO-LA (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)–Bettembourg (Lux)	Rail	13 hours 52 min	717	
	RO-LA fee				930
	Running cost *		6 hours		
	Total		19 hours 52 min		930
	Luxembourg – Roger & Roger 7700	Road	4 hours 22 min	306	
	Highway fee				75
	Running cost *				25
	Fuel				107.1
	Schengen visa fee				60
	Driver daily rest and break		1 hour		
	Total		5 hours 22 min		267.1
	Overall		119 hours 35 min	2809	3186.52

*Driver allowances, administration, repair and maintenance, depreciation

Table A.21 RO-RO and RO-LA option via Trieste-Bettembourg RO-LA (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)–Bettembourg (Lux)	Rail	13 hours 52 min	717	
	RO-LA fee				930
	Running cost *		6 hours		
	Total		19 hours 52 min		930
	Luxembourg – The Flexible Packaging Company Amersfoort	Road	5 hours 49 min	407	
	Highway fee				150
	Running cost *				50
	Fuel				142.45
	Schengen visa fee				60
	Driver daily rest and break		1 hour		
	Total		6 hours 49 min		402.45
	Overall		121 hours 2 min	2910	3321.87

*Driver allowances, administration, repair and maintenance, depreciation

Table A.22 RO-RO and RO-LA option via Ferneti-Salzburg RO-LA (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Ferneti (Italy)	Road	15 min	18.1	
	Highway fee				
	Running cost *				
	Fuel				6.33
	Schengen visa fee				60
	Driver daily rest and break				
	Total		15 min		66.33
	Ferneti – Salzburg (Austria)	Rail	4 hours 41 min	242	
	RO-LA fee				500
	Running cost *		6 hours		
	Total		10 hours 41 min		500
	Salzburg – Bosch 74572 Blaufelden	Road	5 hours 42 min	399	
	Highway fee				260
	Running cost *				20
	Fuel				139.65
	Driver daily rest and break		1 hour		
	Total		6 hours 42 min		419.65
	Overall		111 hours 59 min	2445.1	2975.4

*Driver allowances, administration, repair and maintenance, depreciation

Table A.23 RO-RO and RO-LA option via Ferneti-Salzburg RO-LA (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Ferneti (Italy)	Road	15 min	18.1	
	Highway fee				
	Running cost *				
	Fuel				6.33
	Schengen visa fee				60
	Driver daily rest and break				
	Total		15 min		66.33
	Ferneti – Salzburg (Austria)	Rail	4 hours 41 min	242	
	RO-LA fee				500
	Running cost *		6 hours		
	Total		10 hours 41 min		500
	Germany – Germany (Aachen)	Road	11 hours 20 min	794	
	Highway fee				260
	Running cost *				20
	Fuel				277.9
	Driver daily rest and break		1 hour + 9 hours		
	Total		21 hours 20 min		557.9
	Germany – Roger & Roger 7700	Road	3 hours 34 min	250	
	Highway fee				75
	Running cost *				25
	Fuel				87.5
	Driver daily rest and break		1 hour		
	Total		4 hours 34 min		187.5
	Overall		131 hours 11 min	3090.1	3301.15

*Driver allowances, administration, repair and maintenance, depreciation

Table A.24 RO-RO and RO-LA option via Ferneti-Salzburg RO-LA (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Ferneti (Italy)	Road	15 min	18.1	
	Highway fee				
	Running cost *				
	Fuel				6.33
	Schengen visa fee				60
	Driver daily rest and break				
	Total		15 min		66.33
	Ferneti – Salzburg (Austria)	Rail	4 hours 41 min	242	
	RO-LA fee				500
	Running cost *		6 hours		
	Total		10 hours 41 min		500
	Germany – The Flexible Packaging Company Amersfoort	Road	13 hours 14 min	927	
	Highway fee				335
	Running cost *				45
	Fuel				324.45
	Driver daily rest and break		1 hour + 9 hours + 1 hours		
	Total		24 hours 14 min		704.45
	Overall		129 hours 31 min	2973.1	3260.2

*Driver allowances, administration, repair and maintenance, depreciation

Table A.25 RO-RO and RO-LA option via Trieste-Genk RO-LA (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Genk (Belgium)	Rail	16 hours 28 min	851	
	RO-LA fee				875
	Running cost *		6 hours		
	Total		22 hours 28 min		875
	Genk – Bosch 74572 Blaufelden	Road	6 hours 48 min	476	
	Highway fee				260
	Running cost *				45
	Fuel				166.6
	Schengen visa fee				60
	Driver daily rest and break		1 hour		
	Total		7 hours 48 min		531.6
	Overall		124 hours 37 min	3113	3396.02

*Driver allowances, administration, repair and maintenance, depreciation

Table A.26 RO-RO and RO-LA option via Trieste-Genk RO-LA (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Genk (Belgium)	Rail	16 hours 28 min	851	
	RO-LA fee				875
	Running cost *		6 hours		
	Total		22 hours 28 min		875
	Genk – Roger & Roger 7700	Road	2 hours 50 min	199	
	Highway fee				
	Running cost *				25
	Fuel				69.65
	Schengen visa fee				60
	Driver daily rest and break				
	Total		2 hours 50 min		154.65
	Overall		119 hours 39 min	2836	3019.07

*Driver allowances, administration, repair and maintenance, depreciation

Table A.27 RO-RO and RO-LA option via Trieste-Genk RO-LA (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir – Cesme (Turkey)	Road	1 hour 49 min	127	
	Highway fee				1.67
	TIR carnet				87
	CMR insurance				50
	Transit document fee				40
	Running cost *				
	Fuel				44.45
	Cesme Port				
	Health document fee				16.3
	Port expenses				90
	Custom expenses				
	Time at port		24 hours		
	Total		25 hours 49 min		329.42
	Cesme (Turkey) -Trieste (Italy)	Sea	44 hours 32 min	1659	
	Ro-Ro fee				1570
	Running cost *				
	Total				1570
	Trieste port:				
	Port expenses				90
	Time at port		24 hours		
	Total		68 hours 32 min		1660
	Trieste (Italy)-Genk (Belgium)	Rail	16 hours 28 min	851	
	RO-LA fee				875
	Running cost *		6 hours		
	Total		22 hours 28 min		875
	Genk – The Flexible Packaging Company Amersfoort	Road	2 hours 32 min	178	
	Highway fee				
	Running cost *				50
	Fuel				62.3
	Schengen visa fee				60
	Driver daily rest and break				
	Total		2 hours 32 min		172.3
	Overall		119 hours 21 min	2815	3036.72

*Driver allowances, administration, repair and maintenance, depreciation

All-Water Option (Route 5)

Table A.28 All-water option via Antwerp (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Antwerp	Sea	200 hours 31 min	4841	
	Freight*				280
	Antwerp port handling				195
	Custom expenses				75
	Other expenses				170
	Time at port		24 hours		
	Total		224 hours 31 min		720
	Antwerp – Bosch 74572 Blaufelden	Road	8 hours 8 min	570	
	Antwerp to Bosch 74572 Blaufelden				850
	Driver daily rest and break		1 hour		
	Total		9 hours 8 min		
	Overall		258 hours 18 min	5456.3	2030.85

*40' foot container

Table A.29 All-water option via Antwerp (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Antwerp	Sea	200 hours 31 min	4841	
	Freight*				280
	Antwerp port handling				195
	Custom expenses				75
	Other expenses				170
	Time at port		24 hours		
	Total		224 hours 31 min		720
	Antwerp – Roger & Roger 7700	Road	1 hour 43 min	120	
	Antwerp to Roger & Roger 7700				310
	Total		1 hour 43 min		310
	Overall		250 hours 53 min	5006.3	1490.85

*40' foot container

Table A.30 All-water option via Antwerp (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Antwerp	Sea	200 hours 31 min	4841	
	Freight*				280
	Antwerp port handling				195
	Custom expenses				75
	Other expenses				170
	Time at port		24 hours		
	Total		224 hours 31 min		720
	Antwerp – The Flexible Packaging Company Amersfoort	Road	2 hours 1 min	142	
	Antwerp to The Flexible Packaging Company Amersfoort				340
	Total		2 hours 1 min	142	340
	Overall		251 hours 11 min	5028.3	1520.85

*40' foot container

Table A.31 All-water option via Rotterdam (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Rotterdam	Sea	200 hours 41 min	4843	
	Freight*				250
	Rotterdam port handling				209
	Custom expenses				70
	Other expenses				169.2
	Time at port		24 hours		
	Total		224 hours 41 min		698.2
	Rotterdam – Bosch 74572 Blaufelden	Road	9 hours 9 min	641	
	Rotterdam to Bosch 74572 Blaufelden				880
	Driver daily rest and break		1 hour		
	Total		10 hours 9 min	641	880
	Overall		259 hours 29 min	5529.3	2039.05

*40' foot container

Table A.32 All-water option via Rotterdam (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Rotterdam	Sea	200 hours 41 min	4843	
	Freight*				250
	Rotterdam port handling				209
	Custom expenses				70
	Other expenses				169.2
	Time at port		24 hours		
	Total		224 hours 41 min		698.2
	Rotterdam – Roger & Roger 7700	Road	3 hours 19 min	232	
	Rotterdam to Roger & Roger 7700				402
	Total		3 hours 19 min	232	402
	Overall		252 hours 39 min	5120.3	1561.05

*40' foot container

Table A.33 All-water option via Rotterdam (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Rotterdam	Sea	200 hours 41 min	4843	
	Freight*				250
	Rotterdam port handling				209
	Custom expenses				70
	Other expenses				169.2
	Time at port		24 hours		
	Total		224 hours 41 min		698.2
	Rotterdam – The Flexible Packaging Company Amersfoort	Road	1 hour 38 min	115	
	Rotterdam to The Flexible Packaging Company Amersfoort				310
	Total		1 hour 38 min	115	310
	Overall		250 hours 58 min	5003.3	1469.05

*40' foot container

Table A.34 All-water option via Hamburg (Izmir-Bosch)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Hamburg	Sea	218 hours 35 min	5276	
	Freight*				270
	Hamburg port handling				250
	Custom expenses				75
	Other expenses				155
	Time at port		24 hours		
	Total		242 hours 35 min		750
	Hamburg – Bosch 74572 Blaufelden	Road	8 hours 14 min	577	
	Hamburg to Bosch 74572 Blaufelden				577
	Driver daily rest and break		1 hour		
	Total		9 hours 14 min	577	577
	Overall		276 hours 28 min	5898.3	1787.85

*40' foot container

Table A.35 All-water option via Hamburg (Izmir-Roger&Roger)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Hamburg	Sea	218 hours 35 min	5276	
	Freight*				270
	Hamburg port handling				250
	Custom expenses				75
	Other expenses				155
	Time at port		24 hours		
	Total		242 hours 35 min		750
	Hamburg – Roger & Roger 7700	Road	9 hours 31 min	666	
	Hamburg to Roger & Roger 7700				666
	Driver daily rest and break		1 hour		
	Total		10 hours 31 min	666	666
	Overall		277 hours 45 min	5987.3	1876.85

*40' foot container

Table A.36 All-water option via Hamburg (Izmir-The Flexible Packaging Company)

Day	Leg	Mode	Transit Time	Distance (km)	Cost (Euro)
	Izmir - Aliaga	Road	39 min	45.3	
	Izmir - Aliaga road transport				15.85
	Highway				
	Aliaga port handling				270
	Custom expenses				
	B/L charge				22.25
	Time at port		24 hours		
	Other expenses				152.75
	Total		24 hours 39 min		460.85
	Aliaga-Hamburg	Sea	218 hours 35 min	5276	
	Freight*				270
	Hamburg port handling				250
	Custom expenses				75
	Other expenses				155
	Time at port		24 hours		
	Total		242 hours 35 min		750
	Hamburg – The Flexible Packaging Company Amersfoort	Road	5 hours 51 min	410	
	Hamburg to The Flexible Packaging Company Amersfoort				410
	Driver daily rest and break		1 hour		
	Total		6 hours 51 min	410	410
	Overall		274 hours 5 min	5731.3	1620.85

*40' foot container

APPENDIX-2 TVSM Workshop Photographs

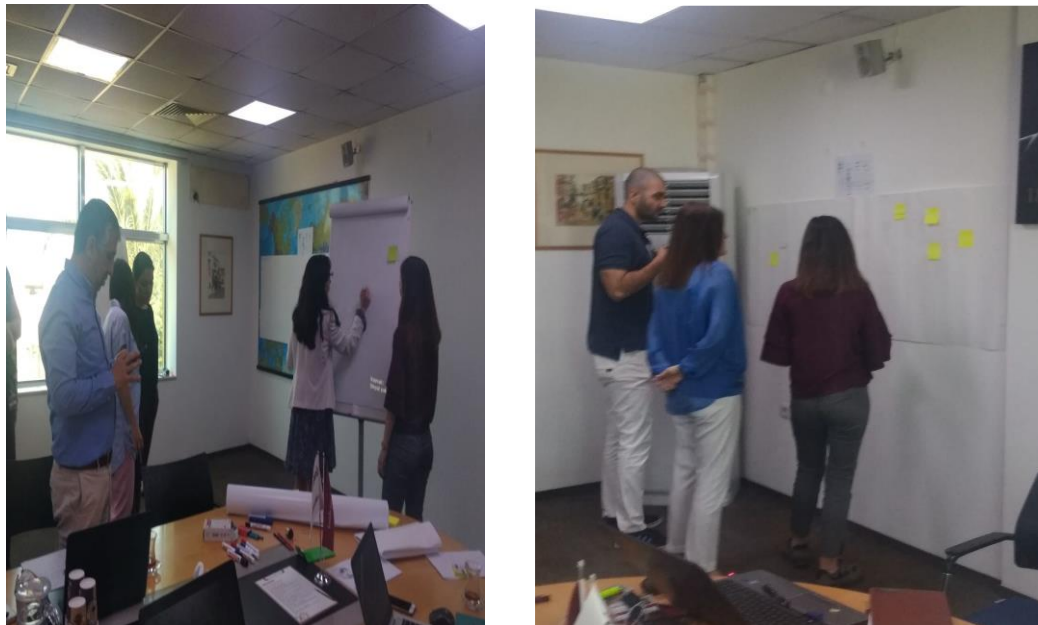


Figure A.1 TVSM workshop photographs (Personal archive, 2019)

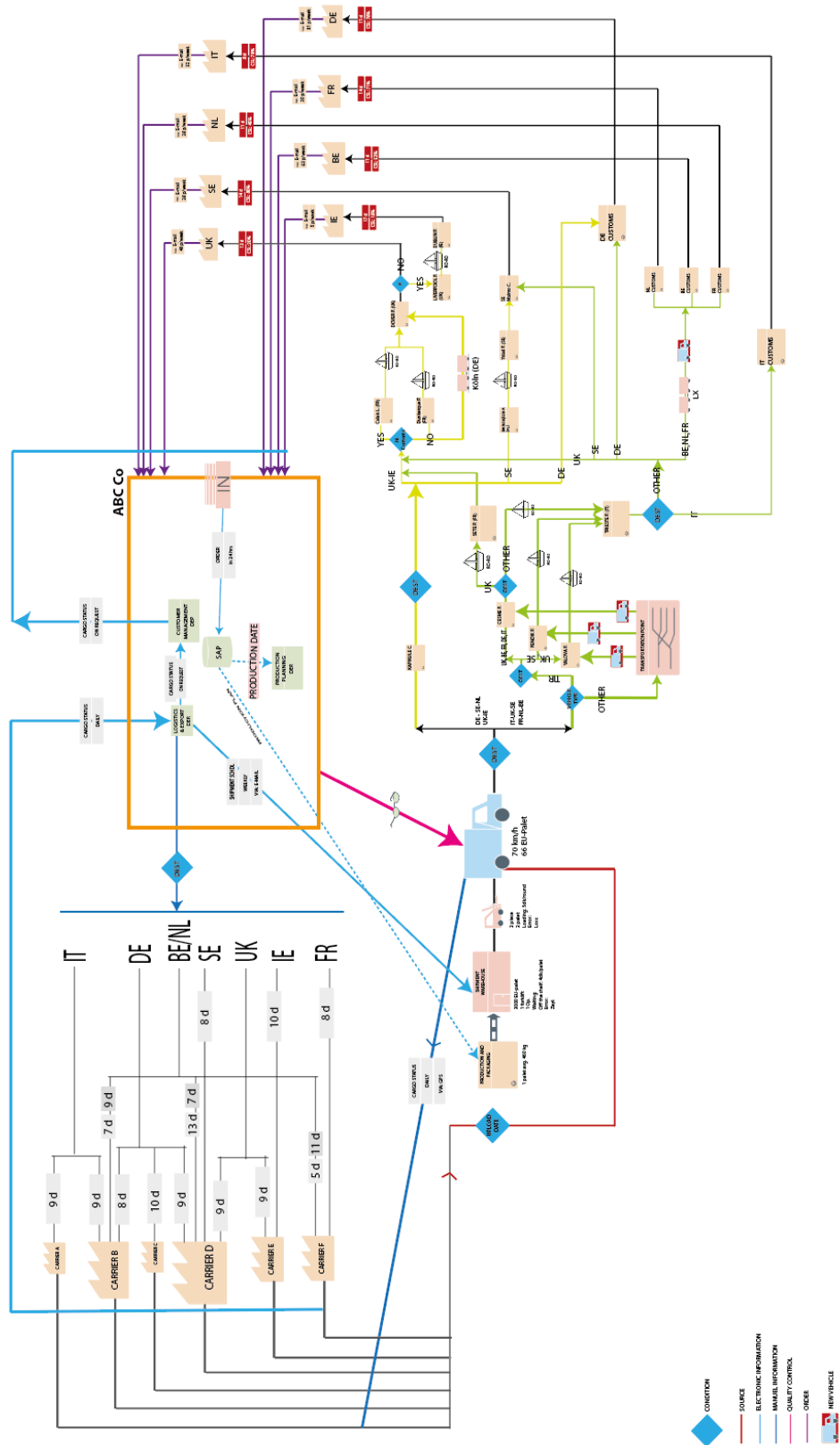


Figure A.2 Current Transportation Value Stream Map of ABC Co's EU export operations

APPENDIX-3 Abbreviations

ACEA	European Automobile Manufacturers Association
FTL	Full Truck Load
IT	In Transit
JIT	Just in Time
NVA	Non-Value Adding
NIT	Not in Transit
OVE	Overall Vehicle Effectiveness
PDCA	Plan-Do-Check-Act
R&D	Research and Development
TOVE	Total Operational Vehicle Effectiveness
TPM	Total Productive Maintenance
TPS	Toyota Production System
TQM	Total Quality Management
TVSM	Transportation Value Stream Mapping
UNCTAD	United Nations Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe
UNESCAP	The United Nations Economic and Social Commission for Asia and the Pacific
VA	Value Adding
VSM	Value Stream Mapping