MURAT SAKA

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A DRY PORT MODEL FOR KOCAELI CONTAINER TERMINALS

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DEDICATION

I dedicate this thesis to my beloved wife Işın,
who has always provided me with the infinite support,
and to my beloved son Orkan,
who has always made me proud of.

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TEXT OF OATH

I declare and honestly confirm that my study, titled “A Dry Port Model for Kocaeli Container Terminals” and presented as a Ph.D. Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Murat Saka

January 03, 2020

ABSTRACT

A DRY PORT MODEL FOR KOCAELI CONTAINER TERMINALS

The increase in maritime transport continues due to the increase in global trade. The containerized trade has recently been the fastest-growing segment among all types of maritime transport. The container, which provides great convenience through inland transport after the sea phase, has also triggered the development of intermodal transport.

This situation is prominently observed in Kocaeli ports, which perform as an important gate for Turkish foreign trade. These ports almost have very limited opportunities to increase the stacking capacity by expanding their land areas, since they are surrounded by urban settlements. Considering the increase in container traffic, it was calculated that the total available capacity of Kocaeli container terminals would be insufficient to meet the expected demand in 2035. It is considered that the dry port implementation could be an appropriate method to create additional capacity that would be needed. It would also relieve congestion in ports and port cities to a certain extent. In this way, it is foreseen that a port which is about to be constrained due to the capacity problem may increase its transaction volume and revenue.

This thesis aims to solve such problems that Kocaeli container terminals may face in the future. Quantitative method was applied in this thesis. First of all, taking into account the possible container traffic in 2035, the capabilities that a dry port should have to be able to support the Kocaeli ports have been examined. In the following stage, the most suitable location for the dry port that would have the required capabilities was determined by an AHP model. The weights of the AHP criteria were determined by a survey method to which 94 experts took part from 11 sectors.

In the last stage, an optimization model has been developed to help the sea port authority in the decision-making process for the incoming cargo when the seaport is about to be constrained due to the lack of the space if it is collaborating with a dry port. This optimization model aims to maximize the productivity and the income of the seaport depending on the container transactions. To this end, if the amount of cargo that would arrive for the coming periods is known, the solution of the model reveals how much cargo should be stacked in the terminal and how much should be sent to the dry port. This model was tested with a case study that could be encountered in the 2030s. It is seen that the transportation capacity to be provided between sea port and dry port is an extremely important factor. Besides, it has been determined that dry port implementation will provide additional benefits for dry port and railway operator as well as sea port. On the other hand, it is considered that as a result of transferring the cargo to the railroad which is an environmentally friendly type of transport instead of truck, the traffic disturbance in the port city and the associated harmful gas emission would be reduced to a certain extent.

ÖZET

KOCAELİ KONTEYNER TERMİNALLERİ İÇİN BİR KURU LİMAN MODELİ

Deniz yolu taşımacılığındaki artış, küresel ticaretteki artışa bağlı olarak devam etmektedir. Deniz yolu taşımacılığı türleri arasında son yıllarda en hızlı artış gösteren taşıma türü ise konteyner taşımacılığı olmuştur. Deniz aşamasından sonra iç taşımada da büyük kolaylık sağlayan konteyner, intermodal taşımacılığın da gelişmesini tetiklemiştir.

Artan dış ticaret hacmi, limanlar üzerindeki yükü de artırmaktadır. Türkiye'nin dış ticareti açısından önemli bir kapısı durumunda olan, ancak kentsel alanlar ile çevrelenmiş olmaları nedeniyle genişleme imkânları son derece kısıtlı olan Kocaeli limanları, bu yükü oldukça ciddi boyutta hissetmektedirler. Konteyner trafiğindeki artış dikkate alındığında, Kocaeli konteyner terminallerinin toplam mevcut kapasitesinin, 2035 yılında oluşması beklenen talebi karşılamada yetersiz kalacağı hesaplanmıştır. Kuru liman uygulamasının, ihtiyaç duyulacak ilave kapasitenin yaratılması, ayrıca limanlarda ve liman şehirlerinde oluşacak tıkanıklığı belli bir oranda rahatlatabilmek için uygun bir çözüm yöntemi olacağı düşünülmektedir. Bu şekilde, kapasite sorunu nedeniyle sorun yaşamak üzere olan bir limanın işlem hacmini ve gelirini artırabileceği öngörülmektedir.

Bu tez çalışması, Kocaeli konteyner terminallerinin gelecekte yaşayabileceği bu tür problemlere bir çözüm üretmeyi hedeflemektedir. Tezde sayısal yöntem kullanılmıştır. Öncelikle, 2035 yılında gerçekleşmesi muhtemel konteyner trafiği dikkate alınarak, Kocaeli limanlarını bu açıdan destekleyecek bir kuru limanın sahip olması gereken yetenekler ortaya konmuştur. Müteakip aşamada ise bu yeteneklere sahip olacak kuru liman için en uygun lokasyon bir AHP modeli ile belirlenmiştir. AHP modelinde kullanılan kriterlerin ağırlıkları, konu ile ilgili 11 sektörden toplam 94 uzmanın katıldığı bir anket ile belirlenmiştir.

Son aşamada ise bir kuru liman ile koordineli çalışacak olan deniz limanı otoritesinin, beklenen yük durumu karşısında işlem hacmini ve gelirini azami seviyeye çıkarabilmesi maksadıyla gelen yükü ne oranda istiflemesi ve hangi oranda kuru limana göndermesi gerektiğini ortaya koyan bir optimizasyon modeli geliştirilmiştir. Bu model 2030'lu yıllara uygun bir vaka çalışması ile test edilmiştir. Modelin çalıştırılması neticesinde deniz limanı ile kuru liman arasında sağlanacak ulaştırma kapasitesinin son derece önemli bir faktör olduğu; uygulamanın, deniz limanının yanı sıra kuru liman ve demiryolu operatörü açısından da ilave faydalar sağlayacağı tespit edilmiştir. Ayrıca, yükün kamyon taşımacılığı yerine çevre dostu bir taşıma türüne transferi neticesinde, liman şehri üzerindeki zararlı gaz emisyonunun da belli bir oranda azaltılabileceği, diğer bir ifadeyle çevresel açıdan da fayda temin edilebileceği değerlendirilmektedir.

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LIST OF SYMBOLS

$\sum$	Summation
$\forall$	For all
$\in$	Element of, belongs to
{ }	Set
$\|A\|$	The number of elements of set A
λ_{max}	Maximum eigen value

LIST OF ABBREVIATIONS

AFY	Afyonkarahisar
AHP	Analytic Hierarchy Process
AIZ	Asım Kibar Industrial Zone
ANK	Ankara
BAL	Balıkesir
BAR	Bartın
BIL	Bilecik
BLC	Bozüyük Logistics Center
BNSF	Burlington Northern Santa Fe Railway
BOL	Bolu
BUR	Bursa
CAGR	Compound Annual Growth Rate
CAN	Çanakkale
CEN	Centrality in the transport network
CFS	Container freight station
CI	Consistency index
CNR	Compagnie Nationale du Rhône
COS	Cost of investment
CR	Consistency Ratio
DIZ	Dilovası Industrial Zone
DT	Average container dwell time
DUZ	Düzce
ELECTRE	Elimination Et Choice Translating Reality
ENV	Environmental effect on urban areas
ESCAP	Economic and Social Commission for Asia and the Pacific
ESK	Eskişehir
EST	Process of establishing a dry port
ha	Hectare
HLC	Hasanbey Logistics Center
ICD	Inland Clearance Depot
IND	Proximity to the industry

IST	İstanbul
ITF	International Transport Forum
IZ	Industrial Zone
KLC	Köseköy Logistics Center
km	Kilometer
KOC	Kocaeli
KON	Konya
KUT	Kütahya
LA	Los Angeles
LC	Logistics Center
LLI	Lloyd's List Intelligence
LP	Linear Programming
MADM	Multi-attribute decision making
MARKA	East Marmara Development Agency
MTI	Ministry of Transportation and Infrastructure
N/A	Not available
NAU	Not available to unload
OECD	Organization for Economic Co-operation and Development
OIZ	Organized Industrial Zone
OR	Operations Research
OSBÜK	Organized Industrial Zones Supreme Organization
POR	Proximity to the port
PORT	Kocaeli Ports
PPP	Public Private Partnership
RI	Random Consistency Index
RMG	Rail Mounted Gantry
RTG	Rubber Tyred Gantry
SAK	Sakarya
STS	Ship-to-Shore
TCDD	Turkish Republic State Railways
TEM	Transit European Motorway
TEU	Twenty-foot equivalent unit
THC	Terminal Handling Cost

TMZ	Zaragoza Maritime Terminal
TRA	Convenience for transportation within the hinterland
TUDEMSAŞ	Turkey Railway Machines Industry Inc.
TURKLİM	Port Operators Association of Turkey
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UN ECE	United Nations Economic Commission for Europe
UN ESCAP	UN Economic and Social Commission for Asia and the Pacific
USA	Uşak
YAL	Yalova
ZON	Zonguldak

1. INTRODUCTION

Maritime transportation plays a crucial role in global trade. Shipment of more than 80% of global trade by volume is being provided by maritime transportation. From another perspective, approximately 70% of the traded goods in value are being carried by merchant ships (UNCTAD, 2017). The port sector represents another crucial actor in global trade. The above-mentioned amount is handled at sea ports worldwide. Due to their fundamental roles, the seaports can be regarded as the gates of the countries to foreign trade. The demand for maritime transport services depends on the performance of the world economy. Economic growth in the world will lead to the growth of maritime transport and other related sectors.

The maritime transport and port sectors have been transformed into environments of keen competition over time. The seaport authorities invested to modernize their ports to become more competitive. Most of them obtained technological equipment to handle the goods faster, renovated the docks to welcome larger and deeper vessels, expanded the yard areas to stack more goods than they could before, collaborated with other related sectors to increase the accessibility of their ports within the inland transportation networks. While the ports with a central location once had advantages, the ports, which nowadays provide easier access to the hinterland for transporting the goods, have reached more advantageous positions compared to the former ones in terms of attracting customers. It has been observed that the number of port authorities investing in railway transportation and cooperating with the dry ports is on the rise.

Within the maritime transportation sector the most quickly developing type of transportation among all types has been of course the container transportation. The container, whose dimensions have been adopted by ISO (International Organization for Standardization) to be the standard in the 1960s, has nowadays become an indispensable part of logistics and caused a competitive environment among the ports. Container transportation has increased from 102 million tons in 1980 to 1.834 million tons at the end of 2017, grown almost 18 times in the last 36 years period. World containerized trade volumes expanded by 6.4% in 2017 (UNCTAD, 2018). In general Turkey and especially the Kocaeli Ports showed a much better performance in 2017 compared to the world average (Saka and Çetin, 2019a).

The container, which took its place in the transportation sector, also contributed to the development of intermodal transportation. The invention of container helped carriers in transporting many kinds of goods in the same box although the carrying units of those goods might have changed throughout the journey. Many intermodal nodes have been constructed worldwide in parallel with this development. It is clear that the cooperation between the intermodal stations and the seaports have improved by now. Having a railway connection and the intermodal property have become advantageous specialties for seaports in the time. Such property enabled the carriers to transport the goods to inland destinations more quickly and more economically.

Countries have recognized the importance of trade with other countries in order to increase their prosperity level and therefore the global trade has steadily increased. Meanwhile, the growing population of countries has led to the growth of the cities. The encirclement and containment of ports during the growth of the cities have limited the possibility of the expansion of some ports. Today, most of the seaports in Turkey are having difficulty to expand their facilities and to increase their stacking capacities (Saka and Çetin, 2017) because of such urbanization.

Container transportation is expected to grow with a rate between 4,6% and 6% until 2026 (UNCTAD, 2018). This increase is expected to lead to an increased volume of transactions in the ports. Esmer and Oral (2008) predicted that the total transaction volume of Turkey's container terminals could reach 17 million TEU in 2025 related to an average forecast, and to 26.5 million TEU in the same year with an optimistic forecast. Considering the contribution of Kocaeli and the surrounding cities to foreign trade, Kocaeli ports are expected to have an important share in this total transaction volume. In this regard, Erdoğan (2011) estimated that the total volume handled in Kocaeli container terminals could reach four million TEU in 2023. In a recent study, Saka and Çetin (2019b) estimated that the throughput values of Turkey's ports in total could reach 34 million TEUs and that of Kocaeli ports to eight million TEUs in 2035 with an optimistic forecast. On the other side, the current throughput capacity of Kocaeli ports in total is calculated as 5,4 million TEUs (Saka and Çetin, 2019b). It is assessed that the current total capacity of Kocaeli container terminals will fall short of meeting the demand in 2035.

The majority of ports in Turkey are having difficulty to fulfill the functions other than loading and unloading due to insufficient land (Esmer, 2008). The lack of space restricts the ports to expand their yard and increase stacking capacity. Another problem is the poor transportation network and the deficiency of railway transportation although the Kocaeli ports are located next to the railways. Taking into account the amount of cargo carried between ports and cities, it is observed that 97.6% of the cargo is transported by road and only 2.4% by rail (MTI, 2015). However, it is promising for the future that increasing the share of railway transportation of goods to 20% is indicated as Turkey's 2035 targets in its logistics vision (MTI, 2018).

1.1. Definition of the Problem

The problem issues that constitute the basis of the thesis research can be listed as follows:

(1) It is expected that the increase in container transportation will continue. Taking into account the prediction of UNCTAD and the recent development in the transaction volumes of Kocaeli ports, it is projected that the container load of Kocaeli ports could reach eight million TEUs in 2035 with an optimistic approach. In the current situation, the total throughput capacity of the Kocaeli container terminal is about 5,4 million TEUs. Unless some necessary measure is taken until 2035, it is obvious that the current capacity will not be able to meet the demand at that time.

(2) The seaports throughout the coast of the Kocaeli Gulf have been encircled by the urban areas. The containment of the ports limits the possibility of expansion. The limited land area restricts the ports to increase their stacking capacity.

(3) While the highest traffic density on the Turkish highway network is at the Marmara region, one of the most intense axes on the region is the Istanbul-Kocaeli-Sakarya axis. There is a large flow of products and traffic between Istanbul and Anatolia on the basis of raw materials and final products. It is inescapable to pass through Kocaeli for those flows. Kocaeli is in a strategic position to connect Istanbul and Anatolia. The transportation between the port and its hinterland is mostly dependent on highways due to the very limited railway capacity besides the situation that the majority of the ports do not have railway connection. Some of the Kocaeli ports are located in front of the Organized Industrial Zone (OIZ) of Dilovası and some are located throughout the shore of D-100 highway. The total of the freight movements originating in the OIZ and the seaports cause congestion on the roads. Especially the congestion on D-100 affects the city traffic adversely.

1.2. Motivation to Study on Dry Port Concept

A dry port application may be an effective measure to deal with capacity problems for the container terminals and to reduce the associated congestion and harmful gas emissions, especially in port cities (Roso, V. and Lumsden, K., 2009; Notteboom, T. and Rodrigue, J.P., 2009). There are a great number of dry port examples in the world. These logistics facilities mainly aim at supporting the seaports through various functions that are normally implemented at seaports. In other words, a well-established dry port may have all the abilities that a seaport can fulfill. It may be either close to the seaport or far away. The more important issue for such a facility is its accessibility from the seaport. It should have a well-established transportation network preferably through railway and additionally other means.

The dry port concept is quite new for Turkey. The Turkish Republic State Railways (TCDD), knowing the importance of port and railway connections related to this concept, is leading the way in this regard. Currently, there are nine logistics centers that have been put into operation by TCDD (TCDD, 2018). It is predicted that these logistics centers could serve in accordance with the dry port concept in the future provided that necessary investments in infrastructure and superstructure are realized.

The seaports located in the Marmara region have a significant role in foreign trade since the majority of the Turkish foreign trade is processed within this region. But unfortunately, most of the ports in this region have limited land capacity and poor accessibility for the transportation network. Especially the ports located along with Istanbul and Kocaeli have no possibility to expand their boundaries. For the seaports with limited stacking capacity like the ones located along with Kocaeli Gulf, the dry port concept seems a very logical solution in coping with capacity problems. A direct railway connection with a dry port might accelerate the container traffic from the seaport which will result in more handling volumes in that seaport. Since all the procedures that should be done in a seaport will also be able to be managed in a well-established dry port, the sole issue will be transferring the boxes/goods from the seaport directly to the dry port. This kind of implementation would relieve the seaport in managing its other activities.

In Turkey, the seaports having railway connections are few in number. When considering the ports at the northern shore of the Kocaeli Gulf, it's very surprising to see that most of them have no connection with the railways although it is just passing very close to those ports. This is a serious deficiency that should have been dealt with by now. The logistics vision also deems it as a deficiency by announcing its target to increase the share of railway freight transportation to 20% from today's poor rate (MTI, 2018).

The deficiency of a well-established freight transportation system for the seaports and the prevailing circumstance that the dry port concept is yet at its infancy provides the motivation for this research. Maritime transportation acts a very important role in global trade, so does a seaport. A seaport may be a competitive and favored one by enhancing its capability in terms of throughput values and its accessibility to main transportation networks. A well-established railway connection to a well-established dry port might boost the productivity and efficiency of the connected seaport. It is intended to put forward the benefits of such a collaboration which could attract the relevant actors in taking necessary measures.

1.3. Research Objective

As stated in the previous subsection, the objective of this thesis is to put forward the benefits of a collaboration between a seaport and a dry port. Not only these two actors but also other actors such as the railway operator and the transportation providers may also gain benefits due to a dry port application.

This thesis aims to create a dry port model that can support the cargo transportation to be carried out through the Kocaeli container terminals. To specify the required capabilities and general specialties of this dry port constitutes the first step. The second step involves the process of the determination the location of this dry port. And finally, to put forward the benefits of a collaboration of this dry port with a Kocaeli container terminal which is about to suffer from the lack of space constitutes the third step. The research objectives and the work plan to obtain these objectives are explained below:

1.3.1. Research Objective-I: Determination of the Required Capabilities of a Dry Port that could Support Container Transportation through Kocaeli Ports

Before determining the location of the intended dry port it is necessary to designate the minimum required capabilities of this dry port. At first, the future demand related to the container transaction volumes should be evaluated. The projections for future demand will help to estimate the minimum requirements. In this way, it will be possible to determine the minimum size of the dry port to be able to embrace the additional cargo and also to specify the required capacity to transport the freight through the railways

1.3.2. Research Objective-II: Determination of the Dry Port Location to Support the Kocaeli Container Terminals

Determination of the location of a logistics facility is a delicate process. This process should take into account the results of the first research objective which aims to determine the required capabilities of the intended dry port. There might be a number of alternatives to constitute a dry port, and a number of criteria to take into account during the determination process. The most appropriate dry port location will be determined by applying an “Analytic Hierarchy Process (AHP)” based on the determined alternatives and the criteria.

1.3.3. Research Objective-III: Development of an Optimization Model to Help the Decision-Makers of the Seaport to Maximize the Productivity and the Income

When taking into account the operations for import containers within a transportation process, unloading the containers from the ships and keeping them on the yard/warehouse are the main "Income-generating" operations for a container terminal. A seaport authority would desire to take in as many containers as maximum to increase its throughput and income. But a container terminal with limited capacity may be in a jam especially at the peak periods of container traffic. A container may increase its productivity by collaborating with a dry port. Sending some of the containers directly to a dry port could relieve the seaport especially when it is about to suffer due to the capacity constraints If the seaport authority has absolute right in determining the amounts to be transferred directly to the dry port and the amount to be stacked in its terminal, it may have the chance to maximize its productivity. Consequently, the seaport may handle more than its stacking capacity provides.

Developing an optimization model to help the decision-maker of the seaport to arrange its recourses to gain the maximum income will constitute the third research objective. For this model, a selected Kocaeli container terminal will be assumed to commence collaboration with the dry port which is determined according to the second research objective. A case study between these actors (selected seaport and the determined dry port as samples) will be created considering the possible values that might be encountered in the 2030s and the developed optimization model will be run to find the optimal solutions based upon the possible circumstances of the future.

1.4. Outline of the Thesis

The thesis study has been carried out in eight chapters including the introduction.

A market survey takes place in the second chapter to give some dry port examples from different regions in the world. Since a dry port application is considered as a relieving factor for Kocaeli container terminals in the future it is deemed necessary to investigate well-developed samples to take lessons from. This chapter investigates a total of six dry ports located on the continents of Europa, Asia, and America.

A literature review related to the thesis subject is included in the third chapter. The review has been executed in two main categories as "Reviewing the concepts and theories" and "Reviewing the previous research findings". "Dry Port Concept" has taken a significant place within the literature review. Keywords such as “dry port”, “inland terminal”, “inland port”, “container”, “container terminal”, “terminal planning”, “container transportation”, “intermodal”, “intermodal transportation”, “maritime logistics”, “inland transportation”, “railway transportation”, “road transportation”, “optimization model”, “liner programming”, “public-private partnership”, “AHP”, and “sensitivity analysis” have been searched in academic databases, journals and scholarly search engines for the literature review. Articles related to the thesis topic were selected according to the result of these searches. Additionally, the references to the articles were verified to find other resources related to the thesis topic. Sector reports and online news websites such as “United Nations Conference on Trade and Development (UNCTAD)”, “Ministry of Trade of Turkish Republic”, “Ministry of Transportation and Infrastructure of Turkish Republic”, “Istanbul and Marmara, Aegean, Mediterranean", and "Black Sea Regions Chamber of Shipping” were also used for data collection related to some topics in literature review. Furthermore, the books that stand out in terms of maritime transportation, maritime logistics, intermodal transportation, and operational research were referred to as important resources as well.

As a result of the literature review, it’s been seen that the related subjects and especially the subject of “dry port” have been tackled from many aspects. These aspects can be stated as “concept and theory”, “implementation of the concept”, “case studies”, “models to determine the location for a dry port” and so on. Among them, the “application in Turkey” has a very limited share. The subject of "Developing optimization models to test the benefits of a dry port application in Turkey for the cooperating seaports and other actors" was detected as a literature gap. This literature gap was especially taken into account during the field studies.

The fourth chapter explains the research methodology of the thesis study. The phases of the whole thesis studies, the definition of the research problem, the hypothesis of the thesis, and the process throughout the studies are explained in this chapter.

The fifth chapter mentions the field studies carried out related to the thesis subject. Kocaeli container terminals were visited to study about their capabilities, and to detect the current and possible problems in regards to container transportation. Köseköy Logistics Center, as being the closest logistics center to the Kocaeli ports was visited for similar purposes and to acquire some idea to be able to imagine the design of a dry port. This chapter puts forward the predictions for the future of Turkey and Kocaeli ports taking into account the statistics. In line with these forecasts, a dry port is being designed to meet the needs that may arise in 2035.

An AHP (Analytic Hierarchy Process) is developed in the sixth chapter to determine the best alternative location to construct a dry port to support container transportation through Kocaeli ports. Working group meetings were held in two different public institutions to designate alternative locations to rank through the developed AHP model. The criteria of the AHP model were weighted through a survey to which a total of 94 participators from 11 different sectors answered the questionnaire.

The seventh chapter explains the optimization model which was developed to help decision-makers of the seaports to maximize the port's productivity. This model was run according to a case study which was created taking into account the future demands.

The conclusions and proposals of the thesis study are explained in the last chapter.

2. MARKET SURVEY

There are a large number of dry ports all over the world. It is observed that the dry port concept is more common especially in the developed countries, but it is also in a rise in the developing countries.

A total of six dry ports were determined and investigated for sampling: three of them from Europe, two from China and the last one from the United States of America. The results of the examination are described in the following section.

2.1. Lyon Terminal

Lyon Terminal is an official partnership between the port of Marseille and the river port Edouard Herriot in Lyon, which is 310 km inland. This partnership is based on relations between private and public stakeholders respectively involved in port, river and rail operations (Rodrigue et al., 2010). It was established in 1993 by the "Compagnie Nationale du Rhône (CNR)", which is an independent electricity producer and marketing its energy since 2001. CNR is a stakeholder with 64,08%. The first river service was started in 1994, and the rail shuttle was launched in 1997. It includes two terminals, each having 10 hectares of surface. Terminal-I has a linear rail of 1.200 meters and one gantry with a capacity of 250 tons. Terminal-II has a dock with a 200-meter dimension, 2 km railway, and one mobile crane. Regular waterway and rail services are carried out from the terminals.

The throughput values of Lyon Terminal in 2017 are 72,763 TEUs through the river, 61,393 TEUs through railways and 134,362 TEUs through the roadway, with a total volume of 268,518 TEUs. It is seen that the total volumes of environmentally friendly modes are equal to the volume of classical transport mode of roadway (Lyon, 2019).

2.2. Zaragoza Maritime Terminal

Spain's leading dry port, Zaragoza Maritime Terminal (TMZ) has a railway terminal specialized in container handling. Having a direct connection to the main Spanish ports, TMZ opened its doors in 2001 with the intention of boosting import/export possibilities for companies. It has handled about 15,000 trains since 2008. Rail transport has led to the decongestion of the entrance to the ports. TMZ has 10 tracks of railway lines with over 6,000 meters, which is located on an operating area of over 100,000 m^2 which is available for further expansion. Within this area, 65,000 m^2 is dedicated to the container depot, with a storage capacity of over 4,000 containers. Activities of TMZ are mainly oriented towards three aims which are contributing to the economic development, fostering the freight development especially through the railway mode which brings about low energy consumption, and being a potent generator of wealth in the region boosting employment and targeting social balance (TMZ, 2019).

TMZ is a strategic initiative of the Port of Barcelona, a strategy aiming at the promotion of inland freight distribution and expanding the port hinterland. The Port of Barcelona participated mainly in the funding of a new rail terminal in partnership with the national rail infrastructure manager (RENFE) (Rodrigue et al., 2010). TMZ was born as an initiative of public-private collaboration, in which Mercazaragoza is the greatest stakeholder with 56,7% share. Other stakeholders are Authority of Barcelona Port (21,5%), Governance of Aragon (20,5%), and a combined group involving Samca Group, Eurozasa, APM terminals and Hutchison Ports (1,3%). The greatest stakeholder Mercazaragoza is a compound organization involving the City Council of Zaragoza and Mercasa National Company. Mercasa is a state-owned company responsible for the support, promotion, and modernization of commercial infrastructures in Spain, with two shareholders, Ministry of Agriculture and Ministry of Finance.

2.3. Eskilstuna Logistics Park

Eskilstuna is a city with strong industrial traditions combined with the development of knowledge-intensive companies. Another area under strong expansion is logistics. Eskilstuna's excellent geographical location combined with well-developed infrastructure and an expansive intermodal terminal makes Eskilstuna very attractive to freight carriers, warehouse and distribution operations, and service logistics. Eskilstuna has an optimal geographic location in the rapidly growing Stockholm-Malarregion. It has a strategic location in the middle of the transport flow to and from Stockholm-Malarregion. It is approximately 110 km. West of Stockholm and 370 km. North-East of Götenborg.

Eskilstuna Logistics Park ties together three transport systems: railway, motorway, and airports. The 300-acre area for warehouses and industrial terminals includes rail connections and lies adjacent to the E20 motorway as well as Eskilstuna Airport. The terminal has a capacity of 300 000 TEUs. The terminal has two connections to the national railway for quick freight transport. The entire terminal has power as well as four full-length tracks for reloading containers and trailers. Additional terminals provide efficient handling of all containers, trailers and bulk commodities. The cross-docking station with its own customs simplifies and cuts the costs of joint transport and goods import/export. This fully electrified intermodal terminal was awarded “Transport Solution of the Year 2013”.

The area of the terminal is 83.000 m^2. The capacity of the terminal is 300.000 TEU/year. There are four tracks to use for the handling purposes and two rail switches within the terminal. The Eskilstuna Logistics Park has a cooperation agreement with the Port of Gothenburg and is a part of the Railport Scandinavia concept. This means that the intermodal terminal is one of the terminals in Sweden selected to administrate the handling of customs, warehousing, documentation and other services. Owing to this cooperation, the goods can be shipped quickly and easily from port to dry-port by means of Railport Scandinavia. Railport Scandinavia provides direct access to the Port of Gothenburg and Scandinavia’s largest selection of maritime shipping lines for the customers of Eskilstuna Logistics Park. As mentioned above, the terminal has a connection to the airport in addition to the connections for railway and motorway. This gives an additional advantage to Eskilstuna Logistics Park. Together with Stockholm Business Alliance, it establishes relationships with international companies that can contribute to developing the logistics region as a hub for Northern Europe. It is obvious that the terminal has benefited from having relationships with the related companies in logistics works. The Port of Gothenburg and Stockholm Business Alliance are examples of two vital partners.

The terminal was realized through cooperation between Eskilstuna Municipality and its public utility organization Eskilstuna Energi & Miljö, the rail operators ICS and Green Cargo. Eskilstuna Energi & Miljö is the owner while a local hauler Sörmlast AB runs the terminal today, although Green Cargo was in charge of the terminal operations at the beginning. The idea for the implementation of the terminal came in autumn 2002 when Eskilstuna municipality promised to build a terminal to attract H&M (the famous Swedish Fashion Company) to the area (Eskilstuna Logistics, 2019).

2.4. Shijiazhuang Dry Port

The Shijiazhuang dry port, with a design capacity of 205,000 TEU per year, is one of the largest dry ports in China. This dry port has both rail and road access. Customs, inspection, and quarantine are available here. This dry port has direct links with Tianjin seaport and mainly serves as a feeder for that port (Hanaoka and Regmi, 2011). The distance between Shijiazhuang dry port and Tianjin seaport is around 400 kilometers.

Shijiazhuang dry port project is an initiative of the Tianjin Port Authority and a PPP constitution with the central, provincial and municipal governments. The facility has a land area of 26.2 ha. This project has succeeded in attracting more export volumes from a major industrial province in the region. Strong support is being given by both the provincial and municipal governments. Support from the local government helps the dry port resolve the problems of land and financial issues. (Beresford et al., 2012).

2.5. Xi'an Dry Port

Xi’an dry port is located in Shaanxi province (Kurtulus, 2018), taking part in Xi’an International Trade and Logistics Park (XITLP), with status as a leading logistics hub in Central China. The dry port is purely state-owned in nature. The municipal government has directly invested in land, infrastructure, basic facilities and superstructure (Beresford et al., 2012). Xi'an dry port has managed to act as a bridge between East Asia and Europa through the railways. It is also cooperating with coastal ports in Shanghai, Qingdao, Ningbo, and Tianjin to develop combined maritime-rail freight routes (Morgan, 2017).

Although the Xi'an dry port is governed by the Municipal Government and four state-owned companies, the government tries to attract private investments. The main objectives of this logistics park are strengthening transport capacity by introducing more private and foreign logistics partners, extending the seaport's hinterland, and attract more goods by encouraging the development of a mature logistics cluster. (Beresford et al., 2012).

2.6. BNSF Logistics Park Chicago

BNSF Logistics Park Chicago is the largest intermodal rail terminal built by BNSF[1]. Operating one of the largest railroad networks in North America, BNSF spent almost one billion for pioneering this private initiative. It is located on an area of 638 acres with a capacity of 3 million TEU per year (Kurtulus, 2018), having approximately 24 kilometers rail track within the dry port, parking area for 6,000 wheeled vehicle and 34 overhead cranes. With this project, a co-located logistics zone fulfills a wide range of functions built upon an area of 2200 acres (Rodrigue et al., 2010). It functions as an extended gate of the seaports of the West Coast (Kurtulus, 2018).

BNSF Logistics Park Chicago leverages the interests of several private actors in transportation and freight distribution. The users of this park benefit from more reliable rail services as well as better rates linked to economies of scale and short transfer distances; the rail terminal becomes part of the inventory management systems of the co-located customers (Rodrigue et al., 2010).

[1] The Acronym BNSF stands for Burlington Northern Santa Fe Railway.

2.7. Summary of the Survey Related to Sample Dry Ports

The intermodality, having a large area, direct connection with at least one seaport, transporting the goods through high capacity corridors, and expanding the hinterland of the seaports are detected as the common features of the six dry ports that are investigated in this section. The distance from the seaports are some hundred kilometers, and for BNSF Logistics Park Chicago it might be more than thousand kilometers. Although the distance may be so huge between them, the main concept is to support the freight transportation through high capacity corridor, to enlarge the hinterland, to boost import and export operations, and to provide extra storage possibilities.

The samples mostly have partnership models in terms of governing. The ports authorities, railway operators, municipalities and some other entrepreneurs are observed as the partners in the governing bodies of these dry ports.

3. LITERATURE REVIEW

Due to the large scope of the thesis study, the literature review is explained in two main sections. In the first section, the subjects related to the problems to be dealt with in the thesis study were examined. In this context, maritime transportation, containerization, container terminals, dry ports, intermodal transportation, hinterland, and similar issues were covered within the first section. The methods used in the solution of the problems were discussed in the second section. In this context, the Analytic Hierarchy Process (AHP), which is a subsection in multi-criteria decision-making methods, and the optimization technique, which is a subsection in operations research methods, are discussed in the second section.

3.1. Literature Review over the Subjects Related to the Problems to be Dealt with

This section was grouped under two subsections. The first subsection covers the subjects of maritime transportation, containerization and container terminals whereas the following subsection covering the subjects of dry port, intermodal transportation, and other related subjects.

3.1.1. Maritime Transportation, Sea Ports and Inland Transportation

Maritime transportation plays a crucial role in global trade. Shipment of more than 80% of global trade by volume is being provided by maritime transportation. From another perspective, approximately 70% of the traded goods in value are being carried by merchant ships (UNCTAD, 2017). Demand for maritime transport services is mostly influenced by the performance of the world economy (Jugović et al., 2015). Economic growth in the world leads to the growth of maritime transport and other related sectors (UNCTAD, 2017).

Maritime transportation has functioned as a facilitator of global trade making the lands and countries more proximate to each other through the marine networks (Hall and

Jacobs, 2010; Ng, 2012). As being a cheap and efficient transportation system, maritime transportation has an immense impact on the ports (ICS, 2007). The port sector represents another crucial actor in global trade (Meersman et al., 2012). The traded goods transported by merchant ships are handled at the seaports worldwide.

Due to their fundamental roles, the seaports can be regarded as the gates of the countries to foreign trade (ICS, 2007). The role of the port can be explained as "A place handling ships and cargo within an economic hierarchy framework" (Robinson, 2002). A port provides interchange services (Talley, 2012). Song and Panayides (2008) define the ports as bi-directional logistics systems since they act as a bridge between the marine and inland transportation lines. The port is considered as part of a cluster in which various transport and logistics operators take place in bringing value to the final consumers (Panayides and Song, 2012).

The idea of transporting the goods in a box revolutionized maritime transportation. The idea was put forward by Malcolm P. McLean, who at first considered transport the loaded carriers on vessels around the 1930s (Solmaz and Saygılı, 2017). This idea soon led to the transport of loads in standard containers. Containerization, since its first launch in 1956, has boosted the maritime transportation and the globalization within a few decades (Ham and Rijsenbrij, 2012). The invention of the container at first was targeting take place in maritime transportation, but in time it also took place in inland transportation (Notteboom and Rodrigue, 2008). In addition to the possibility of storing the goods to be carried, containerization provided great flexibility to the logistics system (Hesse and Rodrigue, 2004), making it feasible to integrate the maritime and inland transportation (Panayides, 2002).

Fremont (2007) explains the success of containerization with two factors. First, it enables Cargo handling in the seaports, which is a rapid process increasing productivity. Second, the container transportation network attracting major lines has improved gradually. By enabling a quicker freight distribution system the container shipping has opened new global markets (Notteboom and Rodrigue, 2008).

The time spent by ships at the ports has been reduced due to transporting the goods in the boxes (containers). Container transportation brought in a new concept, “Door – to – door” service, making the transportation providers consider the transportation and distribution processes as a whole. The need to manage this new concept has further stimulated the development of intermodal transportation (Fan et al., 2012).

The term “Intermodal transportation” is defined as “The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes” (UNECE (United Nations Economic Commission for Europe), 2001). By extension, the term intermodality has been used to describe a system of transport whereby two or more modes of transport are used to transport the same loading unit or truck in an integrated manner, without loading or unloading, in a [door to door] transport chain.

Containerization and intermodal transportation have advanced simultaneously after that milestone relying on technologic developments (Rodrigue and Slack, 2017). Intermodal transportation generally refers to the transportation of freight in an intermodal container or vehicle, using two or more modes of transportation (Fan et al., 2012).

The use of intermodal transportation has increased in parallel with the growth of global trade (Agamez-Arias and Moyano-Fuentes, 2017). Intermodality has had a global impact through increases in transport volumes, reduction of logistics costs and greater accessibility to markets (Simina et al. 2012). Managing safe and efficient freight transportation requires an extensive and well-established network as well as well-equipped terminals (Hesse and Rodrigue, 2004). Intermodal transportation requires the development of proper infrastructure within the transportation network such as roads, railways, and terminals (Vasiliauskas, 2002). It also has been deemed as a solution for congestion on roads, environmental concerns and traffic safety (Caris et al., 2008).

Developments on intermodal transportation and the inland transportation networks have made the container ports, which are located in the same region, substitutes of each other and pushed them into a stiff competition (OECD/ITF, 2008). Competition among container ports is expected to intensify due to the continuous growth of container volumes (Berg and Langen, 2011) and based on the construction of new ports and the investments to upgrade the older facilities (Hoshino, 2010).

Container ports serve as important nodes in facilitating the efficient flow of containerized cargoes (Notteboom and Yap, 2012). Containerization has extended the hinterland reach of seaports (Berg and Langen, 2011) escalating the inter-port competition (Hayuth, 1981). Such extension over hinterlands has transformed captive hinterlands to shared or contestable hinterlands which also has placed the hinterland connections to a key area for the competition among the seaports (Notteboom, 2008).

The dramatically increased freight movements are stressing ports and the transportation systems within their hinterlands (Zhang, 2008). The performance and the competitiveness of a seaport depend on accessibility to its hinterland and the quality of the transportation network, the connections to the hinterland plays a crucial role in port competitiveness (Notteboom and Rodrigue, 2008; Merk and Notteboom, 2015). The ports managing to expend their hinterlands will be able to in a more advantageous situation in such competitive environments (Hoshino, 2010).

The containers being carried on the larger vessels require more space in the container terminals (Rodrigue and Notteboom, 2009). The new circumstances have brought in congestion in the ports and there required additional spaces for operational purposes. Similarly, the roads, especially between the ports and the highways, got congested bothering the port cities at certain times. Extra movements have increased the number of heavy vehicles, resulting in increased density on the highways.

With the increase in global trade, it becomes inevitable to develop the facilities (Drewry, 2017) and/or the access to the transportation network for the seaports which are having difficulty to accommodate the increasing throughput (Wang et al., 2018; Woxenius et al., 2004). According to Woxenius et al., (2004) if there is a problem arising from the increased container flows, approaching only from a perspective of seaport will not be sufficient, such a problem will necessitate tackling the problem also from the perspective of the hinterland. Transport plays a crucial role within international trade, which relies on the movement of goods from one point to another (Yercan and Yıldız, 2015).

For a merchant ship calling at multiple ports will increase the carrier's voyage cost. The carrier would prefer concentrating its traffic in a few ports that would be chosen for minimizing the overall costs and providing efficient inland transportation (Hayut, 1981).

The transportation providers scrutinize the overall transportation costs. Among them, inland transportation cost has increasing importance. The ports which will provide with most convenient transportation network with the lowest cost will be the ones chosen by the carriers (Notteboom and Winkelmans, 2001).

Lack of space at maritime terminals and the congestion on the routes in accessing the transportation networks have been arising as the serious problems in container transportation (Ambrosino and Sciomachen, 2011). Such a problem will affect the decision on port choice and force the carriers using new gateway concepts (Notteboom and Rodrigue, 2008). On the other hand, congestion on the roads means the loss of time and increased cost of transportation (Meersman et al., 2012). Improving transport links will be essential (Hanaoka and Regmi, 2011) to deal with such problems. The choice of transportation mode does also requires a decision-making process (Şakar, 2010) similar to the choice of port. According to Lehmusvaara et al., (1999) one primary factor in such a process is to minimize the costs whereas trying to maximize the customer services.

3.1.2. Dry Port Concept, Intermodal Transportation and Relation with Sea Ports

The effects of containerization are not limited to ocean transportation and port functions, it also has altered the extent of the hinterlands activating the intermodal transportation (Hayut, 1981) and inland freight activities (Notteboom and Rodrigue, 2005). While the carriers take into account the total cost of transportation inland transportation is getting higher importance as an important dimension of maritime transportation (Notteboom and Rodrigue, 2005). The increase in demand for inland freight transportation has triggered the emergence of dry ports (Rodrigue et al., 2010). Intermodal transportation enabled the carriers to transport their goods through the environmental and cost-friendly systems, such as railway and inland waterway, to the so-called inland ports (or dry ports, inland terminals, inland clearance depots, etc.) before distributing to the markets.

During the literature review, it has been observed that some confusions have occurred related to the terms indicating the facilities serving as a seaport in the inland locations. Although “Dry port” is a well-accepted term in literature and especially in United Nations (UN) texts, some authors do prefer other similar terms such as inland port, inland terminal, inland clearance depot, and logistics center and so on. For some authors, it may be subject to contention since the term “dry” should specify the locations which are really dry, without water (Rodrigue et al., 2010). Therefore they may prefer the terms inland port or inland terminal. But the term “dry port” also actually involves the ports that are located alongside a river and connected to a seaport by inland waterway. When examining the term “Inland Clearance Depot (ICD)”, it is explained as “a terminal located in the hinterland of a gateway port serving as a dry port for customs examination and clearance of cargoes” in a UN text (UNCTAD, 1991). It is understood that an inland clearance depot is already a dry port, and since the customs procedure is one of the significant functions of a dry port, these terms can be deemed as substitutes of each other. Another term – logistics center – which is a common one in Turkey especially after 2005 also describes the same abilities (Unal and Erdal, 2014).

Nguyen and Notteboom (2019), investigating a total number of 107 dry ports in all over the world, observed that a total of 15 terminologies being in use for those logistics facilities. Among them, the most frequent term was determined as "dry port" with 27,1% followed by "ICD" with 23,4%, "inland port" with 15%, "inland terminal" with 15%, "logistics park" with 5,6% and logistics center with 3,7%.

It was 1982 that the term “Dry Port” first appeared in a United Nations (UN) text. It was defined as “An inland terminal to and from which shipping lines could issue their bills of lading”. Since the concept came into widespread use in a short while it found a refined definition in the UN text (UNCTAD, 1991) as stated below:

“Customs clearance depot located inland away from seaport(s) giving maritime access to it.”

When examining dry port and ICD together with the definitions, it can be deduced that both terms can substitute each other. Because a dry port shall also carry out the customs clearance activities like an ICD beside the other basic services, and a dry port had been regarded as an ICD until publishing the handbook on dry ports (UNCTAD, 1991).

UNCTAD (1991) explains dry port and ICD with a joint definition, as stated below:

> "A common user facility with public authority status, equipped with fixed installations and offering services for handling and temporary storage of any kind of goods carried under customs by any applicable mode of transport, placed under customs control and other agencies competent to clear goods for home use, warehousing, temporary admissions, re-export, temporary storage for onward transit and outright export."

As stated above, dry ports are specific sites to carry out the customs clearance procedures of the import and export goods. UNCTAD (1991) also states that they are located inland but linked directly to the seaport(s), and they will include temporary storage. Public ownership and private operation on a common user base are perfectly feasible.

UNECE (2001) makes a very simple definition for the dry port as stated below:

> "Inland terminal which is directly linked to a maritime port."

This definition mainly emphasizes the direct linkage between the seaport and the dry port. Thus, this very simple definition retains the main idea of supporting the seaport by enabling the flows of the goods between two important logistics nodes. At this stage, it would be beneficial also understanding the term of the terminal. Another simple definition for the terminal is stated below (UN ECE, 2001):

> "A place equipped for the transshipment and storage of intermodal transport units[2]."

When combining the two definitions stated above, it is clearly understood that a dry port must be an intermodal facility.

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[2] Intermodal transport units are defined as units suitable for intermodal transportation such as containers, swap bodies, and semi-trailers (UNECE, 2001).

The term logistics center is also a very similar one which in some cases is used to substitute the terms dry port, inland port and so on. The term logistics center takes a definition as stated below (UN ECE, 2001):

> "Geographical grouping of independent companies and bodies which are dealing with freight transport (for example, freight forwarders, shippers, transport operators, customs) and with accompanying services (for example, storage, maintenance, and repair), including at least a terminal."

In this definition, it is observed that all necessary facilities are mentioned that are also to be involved in a dry port. Two important capabilities are missing in the logistics center which are precise features of a dry port. First, the intermodality is not an obligation for a logistics center. Of course, the examples from all over the world imply that intermodality is a common feature also in logistics centers. But only one type of transportation mode, for example, road transportation ability is sufficient for a logistics center. The second and the more important missing issue is the direct link to the seaport. The reason for the existence of a logistics center is not to support a seaport. But it has been already grasped from the earlier definition that, a direct link to a seaport is one of the indispensable capabilities of the dry port to support the activities of that seaport.

Developments on the dry port concept have made way for generating new definitions. Leveque and Roso (2002) added the quality of the linkage in the definition, which is stated below:

> "A dry port is an integrated intermodal terminal directly connected to the seaport(s) with high capacity transport mean(s) where customers can leave/pick up their standardized units as if directly to/from a seaport."

This definition, which is a simplified version of UNCTAD (1991) but a developed version of (UN ECE, 2001), not only puts emphasis on direct connection with seaport(s) and intermodality but also highlights the quality of the transportation link. According to Leveque and Roso, it should enable high capacity transportation between the seaport and the dry port. Another detail in this definition implies that the direct link should ensure the customers so that their goods will easily flow through it. Although it omits the function of the customs process, it is already known as having the same abilities that an ICD has.

After the progress mentioned above, the Intergovernmental Agreement on Dry Ports developed under the auspices of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) entered into force 23 April 2016. The Agreement is designed to promote international recognition of dry ports, facilitating investment in dry port infrastructure, improving operational efficiency and enhancing the environmental sustainability of transport. The Agreement also signals a move to a more sustainable growth path as dry ports create the conditions for the much-needed shift of cargo flows from road transport alone to intermodal options. Using road services in combination with more energy-efficient, less polluting alternatives such as rail, short sea shipping, and inland waterways will play an important role in ensuring a more sustainable and inclusive Asia-Pacific region (UN ESCAP, 2016).

Article 1 of the Intergovernmental Agreement on Dry Ports (UN ESCAP, 2013) gives another definition for the dry port as stated below:

> “A dry port shall refer to an inland location as a logistics center connected to one or more modes of transport for the handling, storage and regulatory inspection of goods moving in international trade and the execution of applicable customs control and formalities.”

This definition highlights the purposes of international trade and capabilities such as handling, storing and customs clearance. Although it implies the international trade, the direct connection to the seaport is left as an important deficiency in this definition. Another deficiency of this definition is that the intermodality feature is not expressed firmly. As stating "one or more modes of transport" for the handling ability, it means that a dry port might be constituted as having only one mode of transport. But the specialties of intermodality and direct connection with seaport had become prominent features of a dry port in the earlier definitions. However, harmonization and facilitation of intermodal transport in Asia and the Pacific are expressed as one of the targets of this intergovernmental agreement.

Brooks et al. (2014) define the dry port as a consolidation center, serving the cargo transported through the seaport and enabling sufficient economies of traffic density. According to Brooks et al. a dry port not only provides space and equipment for relieving the seaport in activities and sharing its responsibilities but also embeds the seaport more effectively in the supply chain.

The main features of dry ports can be listed as follows (Sağlam et al., 2015):

- Being directly connected to at least one sea port, preferably by rail,
- Ability to execute intermodal operations,
- Ability to provide value-added services,
- Carrying out the main functions implemented in a sea port such as storage, assembly, and distribution,
- Carrying out customs procedures.

Roso et al., (2009) categorized dry ports as distant, mid-range, and close dry ports and described them based upon their location and function. A distant dry port can expand the competitive hinterland of the main port. The mid-range dry port serves as a consolidation point for different rail-related services. It can also serve as a buffer to relieve the main port of stacking areas. Close dry ports can be applied in relieving the stress and congestion on city streets and port gates. Also, it can be helpful to increase the capacity of the main port.

Common positive impacts for all dry port models and related actors can be summarized as in Table 3.1.

Table 3.1. Positive effects of dry port application and actors to be effected.

Nu.	Positive effects of dry port application	Actors to be effected
1	Less congestion in port and gates	Sea port
2	Relieving of traffic and less harmful gas emissions	Port city
3	Gaining market share	Railway operators
4	Saving time caused by congestion	Road operators
5	Advanced accessibility to port and hinterland	Carriers
6	Job opportunities and mitigating environmental damage	Community

(Organized by the author, according to the source of "Roso and Rosa, 2015")

According to Rodrigue et al. (2010), dry ports have three distinctive features. Mostly they are linked with container movement so that most of the added value activities might be transferred to these logistics nodes to alleviate the seaports. Secondly, they must be linked to at least one seaport through a high capacity transportation line. And thirdly, a dry port must allow a large amount of freight movement with both more economical conditions and large stacking and handling capacity.

Nguyen and Notteboom (2019) also introduce three main facets of dry port very similar to these features; (1) being an intermodal terminal, (2) having a strong link to seaport with high capacity, and (3) offering the same services provided by seaports.

The dry port concept is based on constructing intermodal terminals within the hinterland at a distance from the port areas (Jaržemskis and Vasiliauskas, 2007). Dry ports are crucial nodes assisting efficient global freight transportation by connecting the consumption centers, production centers and the seaports (Witte et al., 2014). These inland terminals can be regarded as extended gates of the seaports and they can serve as reducing the dwell time of the containers (Merk and Notteboom, 2015). According to Werikhe and Jin (2015), the evolution of a dry port creates a cycle in the continuous development of containerization and intermodal transport.

According to Cullinane and Wilmsmeier (2011), the dry port concept recently has been being applied mainly for two reasons. One of them is to overcome the problems of capacity constraints (Jaržemskis and Vasiliauskas, 2007) in a container port. This problem is highly important because a seaport might find itself in such a difficult situation that no longer can unload the boxes since there is no more room to stack. The other reason is expanding its hinterland of a container port. A dry port will be able to assist the seaport as if being a forward base of that seaport and expand the limits that the seaport may reach. In addition to those two main features, a dry port should also able to produce a throughput volume at a reasonable level (Rodrigue and Notteboom, 2012). Such productivity will, of course, necessitate a well-established port infrastructure and superstructure in both the seaport and the connected dry port. It will also require a well-established hinterland infrastructure for managing the concentrated flows (Monios et al., 2018).

The extended gate concept is also an associated term with the dry port concept. Extended gateway systems enable customs continuity between seaports and dry ports. The dry port which is qualified by customs authorities acts as an extension of specific seaports (Iannone, 2011).

Notteboom and Rodrigue (2008) assert that scarcity of terminal capacity can open prospects for new cargo routing patterns using new gateway concepts. Supporting this assertion Notteboom and Rodrigue (2008) exemplify the case of LA/Long Beach Port, indicating that congestion in LA/Long Beach Port might bring forth the idea of canalizing the flow of containers to the ports Prince Rupert, Canada and Ensenada, Mexico. The above-mentioned case is matched up with the prediction that the container ports may be substitutes of each other (OECD/ITF, 2008) in some circumstances especially when the capacity constraints emerge.

According to Notteboom and Rodrigue (2009), the capacity constraints of the seaports seem to be one of the main drivers of dry ports. The findings of Roso and Lumsden (2009) support this ascertain stating that a dry port in the seaport's hinterland can enable the seaport to increase its terminal capacity and therefore manage the problem of lack of space. In addition to capacity issues, the complexity of modern freight distribution and the increased focus on intermodal transport solutions also appear to be the main drivers (Notteboom and Rodrigue, 2009).

Roso et al. (2009) suggest that the problems stemming from the increased container flows might be solved from the viewpoint of the joint seaport and hinterland perspective. It is considered that inland ports may provide facilities that will better enable shippers and carriers to handle exports and imports (Walter and Poist, 2003). According to Hesse and Rodrigue (2004), land constraints for expansion, congested traffic and scarce hinterland connections affect adversely the strategy of concentrating the freight at hub locations, which makes the inland hubs more and more important. Dry ports would help to ease road traffic congestion and reduce emissions by encouraging a modal shift (Hanaoka and Regmi, 2011).

Nguyen and Notteboom (2019) studied on generic characteristics of dry ports using a total number of 107 samples. The findings are summarized below:

(1) About half of the dry ports have a total area below 45 ha while two-thirds are smaller than 100 ha. The average size of dry ports is 197.81 ha.

(2) The average distance between dry port and seaport is 424.64 km. While the closest dry port could be situated just a few kilometers from the seaport, the furthest located inland node in the sample group is at a distance of 1741 km from the seaport. About 50% of the dry ports are located less than 300 km from the seaport.

(3) The average annual dry port throughput is about 172,000 TEU. However, the throughput for the majority of the terminals is below the 70,000 TEU threshold. The highest throughput is 3.6 million TEU in the case of Duisport (Germany).

(4) When examining the seaport traffic moving to dry port, based on a sample of 92 dry ports, it was observed that the average value of dry port comparative traffic is 5%. Roughly 50% of the dry ports only serve less than 1.7% of seaport traffic. About 90% of the dry ports have less than 16.44% of seaport traffic. The highest observation is 30.33% in the single case of Duisport (Germany).

Rail-based intermodal freight transport is more environmental friendly than truck-only transport (Hanaoka and Regmi, 2011) and in some countries, it's becoming a strong demand of the society which forces the public authorities to take measures (Roso et al., 2009). Examining the characteristics of inland port development in Latin America, Wilmsmeier el al (2015) found that the port actors are playing a proactive role in response to a changing transport and logistics environment. Studying on the regional patterns of hinterland concentrations of Asian, European and American ports, Lee et al. (2008) observed that European and American ports put their efforts mainly on inland transportation, unlike Asian ports do. Since European ports depended on inland transportation, the ‘gateway’ function is more common in Europe (Chen and Lam, 2018).

The quality of access to a dry port and the quality of the road/rail determines the quality of seaport performance (Woxenius et al., 2004). Therefore a seaport authority needs to take essential precautions to ensure the reliable and high capacity transportation capacity to and from itself.

Conducting an empirical study in Malaysia, Jeevan et al. (2018) demonstrated that dry port operations have an impact on seaport competitiveness. According to Jeevan et al. dry ports have become important in shaping the performance and competitive strategies of container terminals.

The main features of a dry port and their explanations are summarized in Table 3.2.

Table 3.2. The main features of a dry port and their explanations.

Nu.	Feature	Explanation
1	Intermodal terminal	Ability to change the mode of transportation such as road, rail, and inland waterway
2	Direct link to at least one sea port	Preferably by rail, and additionally other modes
3	High capacity transportation corridor with seaport	To be able to relieve the seaport
4	Connecting the consumption centers, production centers and seaports	Providing easy access to each other
5	Expanding the hinterland of the seaport(s) connected to itself (dry port)	Enlarging the range to be able to reach through the seaport
6	Handling	To be able to unload the incoming freight and to load the exiting freight
7	Storage	Providing additional stacking capacity resulting in increased handling volume in the seaport
8	Customs clearance depot	Providing customs clearance service
9	Value added services	Providing value added service
10	Assembly and distribution	Gathering the export goods to transfer to the seaport, and providing distribution of the import goods to the consumption centers
11	Maintenance and repair of the containers	Providing maintenance and repair of the containers
12	Relieving the seaport and port-city	Lessening the congestion in port and at gates of the port, and relieving traffic in port-city
13	Mitigating environmental damage	Reducing the harmful gas emissions by transferring the goods to environmental friendly transportation modes
14	Job opportunities	Providing new job opportunities

(Described by the Author)

3.1.3. Importance of Hinterland

Hinterland is not a new term in the literature. Chisholm (1908), stating that he first noticed at 1884 the usage of the word hinterland in English, which was originally a German term, described this term as follows:

"The land which lies behind a seaport or a seaboard, and supplies the bulk of the exports, and in which are distributed the bulk of the imports ..."

The concept of hinterland, for a long time, had been perceived as a land area on which a single seaport prevails in providing the transportation of traded goods between the nodes on this land and its gateway, and the term "captive hinterland" had been widely used to define the hinterland of a sea port during this time (Sargent, 1938; Weigend, 1956; Ferrari et al., 2011; Bergqvist 2012). With the ease of transport over time, the fact that a single maritime port prevails fully effectively on a hinterland has begun to disappear and the seaports began to compete to be more active on a hinterland towards the end of the 20th century. Thus new terms have appeared such as competitive/contestable hinterland, main/major hinterland, core hinterland and so on.

Today, the magnitude of a seaport's hinterland is not static. Port hinterland can be dynamic depending on economic, sociological and technological developments. Therefore, it is almost not possible to denote the hinterland of a port with precise lines (MTI, 2015). The development of dry ports or any kind of inland terminals has been an active strategy to extend the limits of the hinterlands of the seaports (Rodrigue and Notteboom, 2012). Constructing a dry port at an appropriate location in the hinterland can result in saving the transportation costs (Ng and Cetin, 2012). Guerrero (2018) examined the spatial distribution of freight flows, focusing on the impacts of the network connections on the scope of hinterlands. Normally it is considered that the longer the distance between the seaport and the inland, the more barrier to select that seaport. But in his study, Guerrero (2018) exhibited that the inland distance constraint is significantly lower when intermodal connections are available.

Transportation within a hinterland is mainly influenced by the competition between the seaports. In addition to ports' competition, the efforts for the efficiency of a dry port will also influence the development of the transportation networks within the hinterland (Wilmsmeier el al., 2015).

Dussán (2012) explains the relationship between the dry port and container terminal in terms of the hinterland as stating that while the benefits of the hinterland increase through the dry port the competitiveness of the seaport increases as well. The local hinterland is the framework of the transportation lines of the seaport (Notteboom, 2010). If a terminal has no hinterland connection enabling domestic container transport, it represents a pure transshipment facility (Böse, 2011). A port will naturally dominate over its own local hinterland. On the other side, the evolution of the variety and the flexibility of the transportation routes lead to competition for distant hinterlands between the ports appearing in the same multi-port gateway regions (Notteboom, 2010).

3.1.4. Importance of the Railway Connection

During the industrial revolution, the railways, which were responsible for the cheap and efficient transportation of the raw materials needed by the economy from the ports to the domestic markets, became an indispensable part of mass transportation (TCDD, 2017). Beyond being an interface for international trade, seaports have comprehended the need to expand their hinterlands as much as possible, and for this, the importance of enabling rail transport. Access to railways would not only expand its hinterland but also stimulate intermodal transportation (Roso, 2008) which would make that seaport more competitive than counterparts in the region. According to Roso et al. (2009), a dry port must be directly connected to a seaport by rail as well as being connected to other inland intermodal terminals. Lättilä et al. (2013) also state that transportation between the seaport and dry port is mainly accomplished by rail transportation. The success of a dry port is heavily dependent on rail services (Wilmsmeier el al., 2015). They must have efficient and reliable intermodal transportation lines (Merk and Notteboom, 2015). According to Lättilä et al. (2013), one way to increase rail-based transportation is to construct dry ports.

Some seaports having a poor quality of network connection would bring about congested roads as a consequence causing delays and rising transportation costs. Jaržemskis and Vasiliauskas (2007) suggest the implementation of rail as a strategic decision in order to connect the seaports with their hinterlands. Roso and Lumsden (2009) also support this suggestion indicating that the inland terminals connected to the seaports through railways would be important actors for the efficiency of intermodal transport. Those inland terminals would also strengthen the efficiency of the access for the seaports. Therefore, inland intermodal terminals are important actors in expanding the reach of seaports (Jaržemskis and Vasiliauskas, 2007). The quality of access to a dry port brings in the qualified performance for the seaport. Therefore it is necessary to have reliable high capacity transport systems (Woxenius et al., 2004).

Another problem seaports face today, as a result of growing containerized transport, is lack of space at seaport terminals. An inland port with direct rail to the seaport brings in the opportunity of transporting the containers directly to the inland port, resulting in gaining valuable space at the seaport terminals. In other words, rail transportation provides an opportunity for increased capacity which results in increased productivity (Roso and Lumsden, 2009).

Developed countries have recently developed and implemented policies aimed at increasing the share of rail, maritime and inland waterways, which are environmentally friendly modes of transport due to environmental problems and global climate change, and to ensure a balanced distribution between transport types by reducing the high share of highways (TCDD, 2017). European Commission (2001) advocate rail transportation as being more sustainable traffic mode than the road and therefore propose a shift of volumes from road to rail, which is more energy-efficient and less harmful traffic mode to the environment. Turkey's fast-growing energy demand continues resulting in increased greenhouse gas emissions. To address the increasing environmental pressures Turkey needs to take some precautions including to develop environmentally-friendly transportation modes (OECD, 2019).

By implementing a dry port with a well-established railway network, a seaport's congestion from numerous trucks is avoided since one train can substitute for some 35 trucks in Europe. By reducing the number of trucks on the roads, congestion, accidents, road maintenance costs and local pollution are reduced as well (Roso and Lumsden, 2009).

According to OECD (2011), the current gateway and inland transport infrastructure capacity will not be adequate to meet the 2030 demand. Most of the current gateway and corridor infrastructure could not handle a 50% increase, let alone a tripling of freight in 20 years. Port handling of maritime containers worldwide could quadruple by 2030. Taking into account those predictions, the seaports having a railway connection for mass transportation will be better prepared for future circumstances.

3.1.5. Public Private Partnership (PPP) Model in Port Investment

With the majority of global trade carried by sea, developing strong, well-functioning maritime transport infrastructure is a key element of economic growth for many developing and emerging countries. "Public-Private Partnership (PPP)" in ports has become a means to manage port operations more effectively (PPP LRC, 2019). The analysis of investment in intermodal rail terminals shows that it is a very capital intensive investing in such logistics facilities (Wiegmans and Behdani, 2017). A dry port investment may be realized in the presence of companies that can be partners and if the investment will be more cost-effective compared to the cost of a seaport (Kühn et al., 2012). If there is no partner, such an investment plan will most probably fall down since the sole entrepreneur may not have enough resources.

The privatization of the state ports has accelerated the development in the Turkish port sector as in the world and the weight of the private sector in the port area has increased (Çetin, 2012). However, the financial difficulties experienced in the last 10 years have limited the entrepreneurship of the private sector and revealed the importance and necessity of all kinds of partnerships.

A dry port implementation may be realized by both the private and public sectors. Cullinane et al. (2012) mention that in most cases there are public-private cooperation, collaboration or even partnership. PPP is a financing model. It is being used to prevent the cancellation or postponement of the goods and services to be offered by the state due to lack of budget. Benefits such as the reduction of the costs arising from public investments and the efficient distribution of the risk are the reasons for preference (Uygun, 2013).

If this model is implemented in the port sector, it may be expected that many positive effects will be improved, such as increasing operational efficiency, widening trade, gaining income for the state, abolishing restrictions on investment, dominating commercial management in management, increasing competition between ports and ensuring financial and economic development (Lam et al., 2015).

Hanaoka and Regmi (2011) analyzed five dry ports that are located in the Republic of Korea, Nepal, Thailand, China, and India. Comparing the key features of selected dry ports from those five countries, they observed that all have both rail and road connections, contributing to a reduction in road congestion and emission. From the viewpoint of ownership, it was established that two of them are owned by PPPs, one by the government and the other two by the state railways. On the other hand, in all examples except Indian dry port, there are private or PPP entities carrying out the operational arrangements. Hanaoka and Regmi (2011) emphasize on the case of the Republic of Korea for their successful development of PPP structures and foresee that governments will need to push such initiatives to facilitate such developments.

Considering that the Logistics centers and railway infrastructure belong to TCDD, which is a state institution in Turkey, Public-Private Partnership model can be effectively implemented in dry port development projects in order not to force the institution to excessive financial burden and to ensure the participation of the private sector (Saka and Cetin, 2017).

3.2. Literature Review Related to the Solution of the Problem

As mentioned in the second part of this thesis study, it is planned to design an AHP method to determine the most appropriate location as a dry port candidate to support the

Kocaeli container terminals. The applications through AHP methods for determining a logistics location were searched within the literature. A review related to AHP methods is mentioned in section 3.2.1.

After determining the location for the dry port it is also planned to develop an optimization model to compare the productivity of a container terminal which is about to suffer from lack of the space. The optimization techniques for maximizing and minimizing problems were searched within the literature. Review related to optimization techniques is mentioned in section 3.2.2.

3.2.1. AHP and Similar Methods to Determine Optimal Site

The Analytic Hierarchy Process (AHP) is a scientific method, a theory of measurement through pairwise comparisons (Saaty, 2008) using a principle of hierarchic composition to derive composite priorities of alternatives concerning multiple criteria from their priorities concerning each criterion (Saaty, 2003). Since 1980, AHP is widely used in decision-making processes, especially in the fields of finance, product design, resource distribution, transportation, determination of location and so on. There are many examples that are used to determine the most suitable location. Yang and Lee (1997) developed an AHP model to select a location for a facility. Chatterjee and Mukherjee (2013) applied AHP in the selection of a potential hospital in India. Acar (2016) used the same method to determine an optimal plant location in Turkey. Actually, AHP can be used in every situation as long as the decision-maker can determine the selection criteria and make the order of preference. It is a mathematical method converting the verbal judgments to numerical scales to choose the best one from a number of alternatives which are evaluated regarding a number of criteria (Saaty and Vargas, 2012).

Kayikci (2010) designed a model as combining the techniques of fuzzy-AHP and ANN techniques for decision problems to select the most appropriate location of an intermodal logistics center. She executed a survey to determine the weights of the criteria. The survey targeted the role players such as operators, organizers, community, government, infrastructure operators and customers. Five criteria were determined as economic scale, intermodal operation and management, national stability, international market location, and environmental effect. The system was used in training mode by using random data and found successful with 97% validation.

Nguyen and Notteboom (2016) developed a multi-attribute decision making (MADM) model to evaluate the dry port location in four steps. The first step is searching for alternative locations. The second step is for determining the criteria in relation to the stakeholders which are grouped as the community, dry port service providers and dry port users. The criteria are mainly weighted by directing questionnaires to the experts in the third step. And in the fourth step, the alternatives were analyzed by the MADM technique. This model was used in Vietnam to determine a dry port location among three alternatives. Nguyen and Notteboom in this study lay emphasis on weighting the criteria.

Ka (2011) combined Fuzzy AHP and ELECTRE (Elimination Et Choice Translating Reality) to determine the best alternative among seven sites. The author used six criteria in the assessment process. Those criteria were transportation, economic level, infrastructure facilities, trade level, political environment, and cost.

Hong and Xiaohua (2011) established an AHP model to determine the location of the multi-objective emergency logistics center. Economic, technical, social and natural factors were considered as the criteria of the model. The time minimization was considered as the objective and the location selection process was combined with an optimization model.

Komchornrit (2017) designed an integrated method based on multi-criteria decision making to select a dry port location in a case study of Southern Thailand. In this study, the author determined the main criteria as seaport, airport, highway, industrial area, local market, regional market, and cross-border market. According to the opinions of the experts, seaport and highway got the highest weights with 21% and 20% respectively.

Zak and Weglinski (2014) deem the logistics center location problem as a two-level hierarchical problem; the first level to determine the suitability of the alternatives and the second level to define the most appropriate one by scrutinizing in terms of various factors.

Zak and Weglinski (2014) developed a multi-criteria decision method to find the most appropriate location among ten alternatives and determined nine criteria to use in the decision process. Those criteria were (1) Condition of transportation infrastructure, (2) Economic development, (3) Investment cost, (4) Level of transportation and logistics competitiveness, (5) Investment attractiveness, (6) Transportation and logistics attractiveness, (7) Social attractiveness, (8) Environmental-friendliness, and (9) Safety and security.

The demand for effective port infrastructure increases in parallel to the increase of global trade volumes. Unfortunately, investment for port infrastructure is quite costly. Aerts et al. (2014) made a multi-actor analysis, in order to explore the critical success factors of public-private partnerships stating that implementation of this issue is getting common in the port sector due to the high expenses.

3.2.2. Operation Research and Optimization Techniques

Operations Research (OR) may be defined as the scientific approach to decision making. Its mission is to support solving real-world problems, in a wide variety of application areas, using mathematical and computer modeling (Luss and Rosenwein, 1997). A wide range of areas is available that OR may be applied. Luss and Rosenwein (1997) specify some of those areas as telecommunications, air transportation, water resources, energy, forestry, logistics, manufacturing, marketing, health care, government services, and the military.

Optimization is a mathematical procedure for determining the optimal allocation of scarce resources. Optimization, and its most popular special form, Linear Programming (LP), has found practical application in almost all facets of business, from advertising to production planning. Transportation and aggregate production planning problems are the most typical objects of LP analysis (Lindo Systems, 2006).

Computational optimization, modeling, and simulation form an integrated part of the modern design practice in engineering and industry. As resources are limited, to minimize the cost and energy consumption, and to maximize the performance, profits and efficiency can be crucially important in all designs (Yang et al., 2013).

Reviewing the OR implementations related to intermodal transportation cases, Macharis and Bontekoning (2004) made a classification. According to this classification, the decision-maker may be drayage operator, terminal operator, network operator or intermodal operator, and the goal of the implementation may be about scheduling the transportation, planning transshipment operations, designing the network, planning infrastructure or selecting the routes for the shipments.

Wang et al. (2018) developed a mathematical model for optimizing the dry port location. The objective of their study was to minimize total transportation costs. The problem was developed to identify the dry ports to damp out because of their low throughput level and to determine the new ones to open since their existence will minimize the transport costs. Wang et al. examined this model related to a case study involving the the Tianjin port with 15 dry ports that are in service in coordination with the Tianjin port. Their research related to the case of Tianjin port came up with the idea that "it should plan dry ports that will use of rail effectively". Wang et al. used the ILOG CPLEX[3] algorithm in solving the model problem. As the solution to the problem, the model suggested that two of the dry ports should be closed and three new ones should be opened.

Baykasoglu and Subulan (2016) studied on a mixed-integer mathematical programming model for a multi-objective, multimode and multi-period sustainable load planning problem by considering import/export load flows. The problem was constructed by simulating a case that the freight should be transported to a number of European countries from Turkey. The aim was to help the decision-maker (intermodal operator/transportation provider) to select the routes that minimize the cost of the whole transportation.

[3] CPLEX is an optimization software package providing mathematical programming solvers for linear programming, mixed-integer programming, quadratic programming, and quadratically constrained programming problems.

Yano and Newman (2001) studied a problem to schedule trains and containers between a depot and a destination, applying a fixed-charge transportation cost for each vehicle, and each vehicle having the same capacity. The goal of the optimization model was the same: minimizing the sum of the transportation cost.

Bhattacharya et al. (2014) proposed a model for strategic transport planning, using a mixed-integer programming model to optimize schedules for intermodal transport network by considering various costs and additional capacity constraints. The model was applied in a real transportation network in India with a generic case.

Li et al. (2015) studied another network problem in the Netherlands and applied a linear programming method for controlling the container flow.

Ambrosino et al. (2011) developed a mathematical formulation for a trainload planning problem, to determine how to place a set of containers taking into account their lengths and weights with the capacity constraints of the train cars. Ambrosino et al. solved the problem by using MATLAB[4] and CPLEX 11.0. Bruns and Knust (2012) also studied on a similar project to maximize the utilization of the train and to minimize transportation costs.

3.3. Summary of the Literature Review

The demand for global trade has always given rise to maritime transportation. The developments on this side brought about some innovations. One of the most effective ones is containerization which continuously has caused the developments in shipbuilding, ports, intermodal transportation and inland logistics facilities.

The seaport as being the interface between maritime transportation and inland transportation has become a very important and effective actor in the logistics sector. The increase in the number of ports in time has led to competition between these ports

[4] MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

themselves. The port authorities have seen that they have to develop themselves in many aspects including infrastructure investments, expanding the land area and accessibility to the hinterland transportation network. Because the transportation providers have begun to take into account the total cost and the total time throughout the whole transportation process after the door-to-door concept was adopted. The ports working in high capacity and accessing easily to a high capacity transportation network have been ranked first for preferability. In time the dry port appeared as a facilitator of seaport and transporter. It was found to be useful in carrying the masses. Soon after the ports also found the dry port beneficial from several aspects. A high capacity link would provide a better movement to and from the seaport. Besides that, a close dry port would be able to relieve a seaport especially when it is about to suffer from the lack of space.

Seaport authorities well understood that they can extend their hinterlands even to thousands of kilometers away as long as they have good connections to inland facilities with high capacity corridors. It means that a seaport may attract customers of the competitor seaports provided that it enables the transporter arrives at the destination in a more advantageous condition. The ports, which do not confine itself by only investing in the port infrastructure, but also taking the measures to facilitate access to the hinterland and maintaining the high capacity connection with the dry port will be more competitive.

For a dry port, to be an effective and productive one, some considerations should be taken into account before constructing it. First, its location must be as close as to a high capacity network. Easy access to transportation modes will make the dry port more attractive. Second, it must be designed as an intermodal terminal. When the examples of dry ports in the world are examined, it is seen that the railway option is widely used and the railway operators are important partners in dry port formation. The fact that a dry port having a railway connection will allow for mass transportation and will make it advance as an effective and productive logistics facility. Third, it must have a large area to carry out all procedures that are implemented in a seaport. In other words, a dry port must have all the competencies that a seaport already has. The proximity should also be available for future expansions. When examining the samples in the world it can be deduced that the area of a dry port must be larger than 10 ha.

A dry port construction requires a great value of investments which is very difficult for a single entrepreneur. PPP models are getting widespread in port developments. Similarly, it can be beneficial in many aspects to construct a dry port with a PPP model.

Considering the location of a dry port is a delicate process. Reviewing the literature it's been observed that the multi-criteria decision-making methods were used commonly in such processes. Such methods enable us to evaluate alternative locations with regards to multi-criteria. The examples investigated exhibit that several criteria are used commonly in the applications of analytic hierarchic processes, such as the convenience of transportation, proximity to ports and industrial facilities, centrality, investment cost, and environmental considerations.

The optimization methods related to logistics activities also take a large part in the literature review. It is observed that the subject of minimization of transport cost has been mostly dealt with in the optimization problems. In such problems there are two important stages; first modeling the problem with mathematical expressions, and solving the optimization problem by using a software program that includes mathematical programming solvers. It is understood that the optimization techniques used in many areas of our lives are applied widely and effectively in the field of logistics.

4. RESEARCH METHODOLOGY

Thesis studies have been carried out in seven phases. These phases are listed below:

(1) Defining the research problem,

(2) Literature review,

(3) Formulating the hypothesis of the dissertation,

(4) Designing the research,

(5) Collecting data,

(6) Analyzing the data,

(7) Interpreting the data and report.

These phases are summarized in the following sections.

4.1. Defining the Research Problem

It is expected that the growth in container transportation will continue to increase. It is desired for Kocaeli terminals to be able to meet the projected volumes and to provide easy access to a well-established transportation network. The projections for container transaction volumes state that the current capacity of Kocaeli container terminals may not be adequate to meet future demands. It is almost not possible to enlarge the land areas and to increase the stacking capacities of these terminals, which are located throughout the Kocaeli Gulf. Besides that, the ever-increasing container traffic is expected to bring about more severe congestion problems in the future, especially during the peak periods.

Application of dry port concept can bring in a solution for these problems. A high capacity transportation corridor towards the dry port can relieve the seaport and provide extra stacking capacity. The problems to be researched can be listed as follows:

(1) How should it be designed, the intended dry port, in terms of capabilities to meet the demand in relation to the increasing container transportation in 2035?

(2) Where is the most appropriate location to construct the intended dry port?

(3) How can the seaport authority maximize its productivity and income when it is expecting more volumes than it can store in its container yard?

4.2. Literature Review

As a result of the literature review, it’s been seen that the related subjects and especially the subject of “dry port” have been tackled from many aspects. These aspects can be stated as “concept and theory”, “implementation of the concept”, “case studies”, “models to determine the location for a dry port” and so on. Among them, the “application in Turkey” has a very limited share. The subject of "developing an optimization model to test the benefits of a dry port application" has been detected as a literature gap. This literature gap was especially taken into account in designing the following research studies.

It has been understood that a dry port could support the seaports in some respects. Providing additional stacking capacity is a prominent feature among all. Additionally, provided that there is a high capacity railway link between the seaport and the dry port, it can relieve the congested roads within the port city and provide mass transportation.

4.3. Formulating the Hypothesis of the Thesis

Hypotheses imply that the accuracy of a proposition cannot be accepted without observation and experimental studies (Tryfos, 1996). The hypothesis to be tested should be designed to represent the purpose of the research, theoretical knowledge and conceptual model (Yanık, 2015). In a statistical study, the hypothesis that is constructed in the meaning of “equal, no difference" is called the null hypothesis and is represented by “H_0” (Çil, 2000). In other terms, the hypothesis based on the commonly accepted fact is the null hypothesis. Additionally, an alternative hypothesis should also be formulated to be able to test the null hypothesis (Ünver, 1995). The alternative hypothesis is generally represented by “H_1”.

According to the information obtained from market survey and literature review, it was understood that dry ports are mainly intended to support and relieve the seaports they serve. They provide high capacity transportation corridor, advanced access to the hinterland, and additional storage capacity for the seaports. The null hypothesis (H_0) that the research grounds is formulated as stated below:

"If a container terminal is about to confront the risk of rejecting the call of vessels due to the capacity constraints, collaboration with a dry port with a high capacity transportation corridor and perfect access to the hinterland will result in increased productivity and income."

The alternative hypothesis (H_1) asserting that the null hypothesis would go wrong is formulated as stated below:

“Collaboration with a dry port although having a high capacity transportation corridor and perfect access to the hinterland will not be a remedy to increase the productivity and income of a container terminal, which is about to suffer due to the capacity constraints. The handling volumes cannot be increased over the storage capacity of the container terminal.”

4.4. Designing the Research

The formulation of the hypotheses led the author to design the following research activities. In the designing phase the following subtopics were determined to be studied:

4.4.1. Development in Container Transportation

It was decided to study the statistics of the container throughput values of Kocaeli ports and make predictions for the future volumes. In this way, it has been possible to assess future demands and the capabilities to be gained for the future. The projections were prepared to target 2035 taking into account that Turkey's recent logistics vision is also based on the targets up to 2035.

4.4.2. Designing a Dry Port

A dry port should be designed taking into account the minimum requirements for the future. Therefore, the predictions would shed light on the future demands and the needed capabilities to meet future demands. Other features required for a successful dry port implementation should also be investigated.

4.4.3. Developing an AHP Model

In the literature review, it is inferred that AHP is a useful method to determine a location from a number of alternatives, which will be evaluated regarding some criteria. The problem in this thesis requires to determine the best location to construct a dry port, within the hinterland of Kocaeli ports. To develop a solution model it is necessary to designate a number of alternative locations and also to designate a number of criteria that would be effective in selecting the best alternative. The requirements for the solution of the problem coincide with the stages of an AHP method. Therefore, it is decided to develop an Analytic Hierarchy Process (AHP) model to determine the best location to construct a dry port.

The features as "a high capacity transportation corridor" and "perfect access to the hinterland" took part in formulating the hypotheses. Therefore, the aim of constructing the AHP model is to find the best location which could provide the best conditions in terms of transportation. These features are especially taken into account in designating the decision points and the factors of the AHP model.

The AHP model in this thesis will be the application of an existing scientific method, but a new model to be applied in a different region. This application includes a questionnaire in order to determine the weights of the criteria and coordinated studies with two different institutions in terms of determining the alternatives.

4.4.4. Developing an Optimization Model

The main purpose of developing the optimization model is to test the hypotheses. The hypothesis "H_0" asserts that a container terminal could increase its handling volumes when it is about to confront the risk of rejecting the call of vessels due to the capacity constraints, provided that it collaborates with a dry port that ensures a high capacity transportation corridor. On the other side, the hypothesis "H1" contradicts by stating that collaboration with a dry port cannot be a remedy for such a circumstance and the container terminal cannot overpass its stacking capacity. Therefore, the optimization model was developed to test the validity of "H_0". In case of a proof, this model could be helpful for the decision-maker of the seaport, to be able to maximize productivity when the seaport is about to suffer due to the capacity constraints. The main actors in this model should be a dry port and a seaport. The dry port location would be determined after the application of the AHP which was mentioned in the previous subsection. Another actor, the seaport will be decided according to the assessment of the current capabilities and the recent throughput values. A case study is to be designed related to the predictions that could be realized in the 2030s. For simplicity and lucidity, in the case study and model, it was assumed that the seaport handles only import containers. The optimization model to be developed in this thesis will be the application of an existing scientific method according to the linear techniques, but a new model to be applied for a different purpose.

An important detail in the case study developed in parallel with the optimization model is that the sea port authority is assumed to make an investment in the dry port. This investment related to container handling is expected to reduce the total cost of transportation and consequently increase the profit of the sea port. The cost of a single movement of the handling equipment is calculated and an array of formulas is developed which would be an innovation for the literature.

4.5. Collecting and Analyzing the Data

The collection of the data, and analyzing this data has been carried out in parallel to the design of the research.

The statistics of the throughput volumes were used to make predictions of the future volumes and to evaluate the future requirements.

The requirements for the future helped to determine the characteristics of the dry port to be established. It was calculated in this way how large a dry port should be installed.

For the implementation of the AHP model, the features of the decision points (alternative dry port locations) were studied to constitute the pairwise comparisons. The survey to collect the evaluations of the participators was helpful in grading the criteria. The results of the AHP were verified by implementing consistency ratio analysis and sensitivity analysis. One of the decision points was selected as the best alternative location to construct the intended dry port.

The data to be used in the optimization model was constituted within a case study, which takes into account the possible capabilities of the future and the possible container traffic to arise through the Kocaeli ports. The analysis of the data obtained in the solution indicates that it is possible for a sea port authority to take some necessary measures that can achieve optimum efficiency, as long as the plan of the calling ships is known or it can be accurately predicted.

4.6. Interpreting the Data and Report

The results obtained through the application of scientific methods within the thesis study were interpreted and reflected in the results and proposals section of the thesis study. As a result of the implementation of the optimization model and the analysis of the data, it was understood that the capacity to provide cargo transportation between the sea port and the dry port would also be an important factor.

5. FIELD STUDIES AND RELATED RESEARCH STUDIES

Field studies mainly have primarily been carried out related to Kocaeli ports. Since the thesis studies are closely associated with intermodal transportation, the headquarters of First Regional Directorate of "Turkish Republic State Railways (TCDD)" and Köseköy Logistics Center which is a subordinate unit of TCDD were also visited and researched.

Field studies have been carried out with the aim of understanding the main activities and processes in container transportation. The capacities and the difficulties of the seaports were determined and the following studies were designed according to the observed situations.

The first section of this part involves the assessments about the throughput values of Kocaeli container terminals with a comparison to the sum of Turkey's values. Also, the future throughput values are estimated in this section by using the projections of UNCTAD (UN Conference on Trade and Development) and Lloyd's List Intelligence (LLI).

Kocaeli container terminals individually are dealt with in the second section of this part. The features of the terminals and the findings during the field studies are explained in detail. Following the explanation and calculation of the storage capacity of the container terminals in the third and fourth sections, the future requirements and the minimum requirements for a dry port are assessed in the fifth and sixth sections. Some ideas to support the container transportation in the Kocaeli region, the future plans of "Turkish Republic State Railways (TCDD)", and some general information about TCDD logistics centers are also explained in these sections.

Designing a dry port and calculating the required area for that dry port are mentioned in the seventh and eighth sections.

Possible financing models for dry ports are discussed in the ninth section. PPP model is considered as the most appropriate model because it is a difficult decision for a single entrepreneur as it requires a high amount of investment. The following section explains the customs procedure for the containers being sent directly to a dry port.

The last section summarizes the field studies and the related research studies, proposing a PPP model and stating the possible benefits of this model.

5.1. Statistics and Projections of Container Throughput in Turkey and Kocaeli

The expansion of global seaborne trade was recorded at 4% in 2017. It was the fastest growth witnessed in the last five years (UNCTAD, 2018). According to UNCTAD (2018), container transportation with a rate of 6,4% was the fastest growing one among all modes of maritime transportation. Over the last decade, the global container trade has increased at a great rate. The share of global container transport in tonnage increased to 17% in 2017, but it was only 2.75% in 1980. The share of container transport is at a higher rate in the sum of Turkey's total throughput with 24,8% in 2018. The international container trade volumes tonnage has increased almost 17 times beginning from 1980 to the end of 2017, as seen in Figure 5.1.

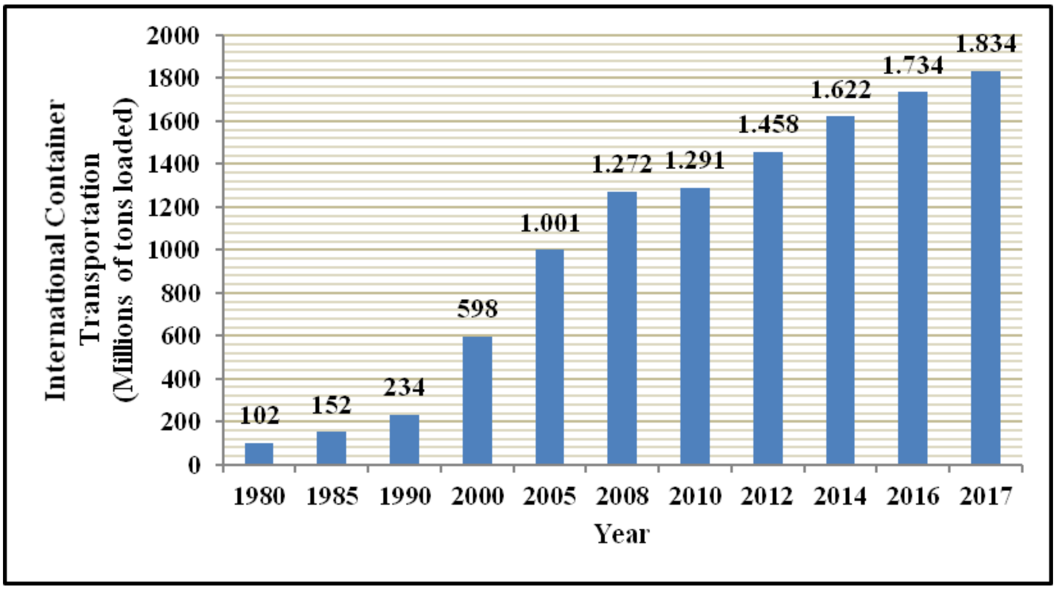


Figure 5.1. International container trade values in selected years (Million Tons).
(**Source:** Review of Maritime Transport, 2018, UNCTAD)

In 2017, the top 20 container ports of the world handled 336.6 million TEUs in total. This value corresponds to approximately 45% of the world's total. These top 20 terminals increased their total throughput volumes at a rate of 5.9% compared to the previous year (UNCTAD, 2018). However, Figure 5.2 exhibits that the ports in Turkey had higher increase rates in the last three years compared to the world total and the total volumes of the top 20s. The world's containerized trade has increased with a CAGR (Compound Annual Growth Rate) of 4,0% over the last ten years, whereas Turkey's total container throughput has increased with a CAGR of 7,8% within the same period.

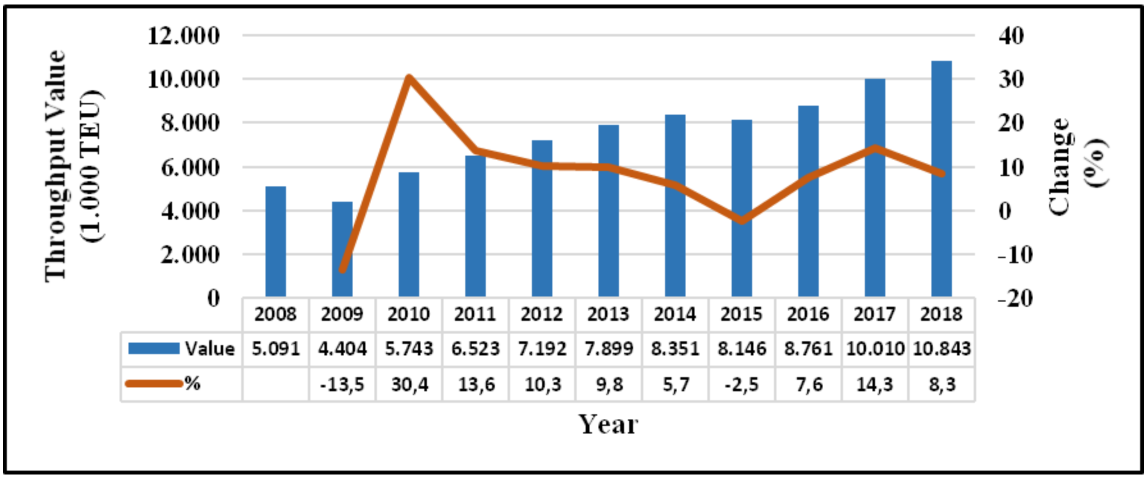
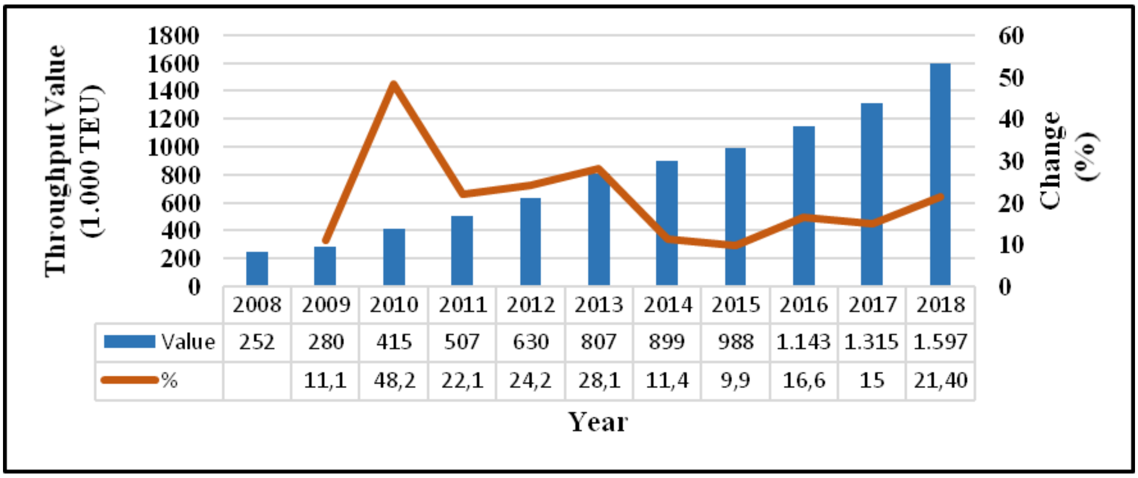


Figure 5.2. Container throughput values and annual change in Turkey.
(**Source:** Maritime Trade General Directorate Statistics Information System)

Among the ports of Turkey, the Kocaeli ports have exhibited a much higher increase rate during the same period compared to the world's average and the total volumes of the top 20 container ports. The CAGR of Kocaeli Ports has been 20,2% in that period. The container throughput values and annual change in Kocaeli ports are seen in Figure 5.3.

There are currently six container seaports located throughout the shores of the Kocaeli Gulf (see Figure 5.4). Except for LİMAŞ, all container ports are located at the northern shores. Among them, the newest one is BELDEPORT, which has been serving with limited capacity since 2018 and continuing some construction activities. Another one on construction is SAFİPORT, which started a modernization phase in 2015 after the privatization and is expected to have the largest capacity in the region.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Value	252	280	415	507	630	807	899	988	1.143	1.315	1.597
%		11,1	48,2	22,1	24,2	28,1	11,4	9,9	16,6	15	21,40

Figure 5.3. Container throughput values and annual change in Kocaeli Ports.
(**Source:** Maritime Trade General Directorate Statistics Information System)

The container seaports located throughout the shores of the Kocaeli Gulf are seen in Figure 5.4.

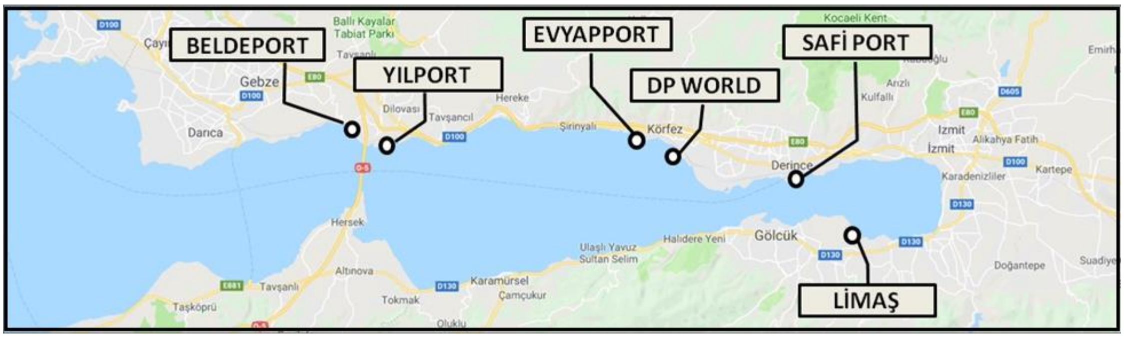
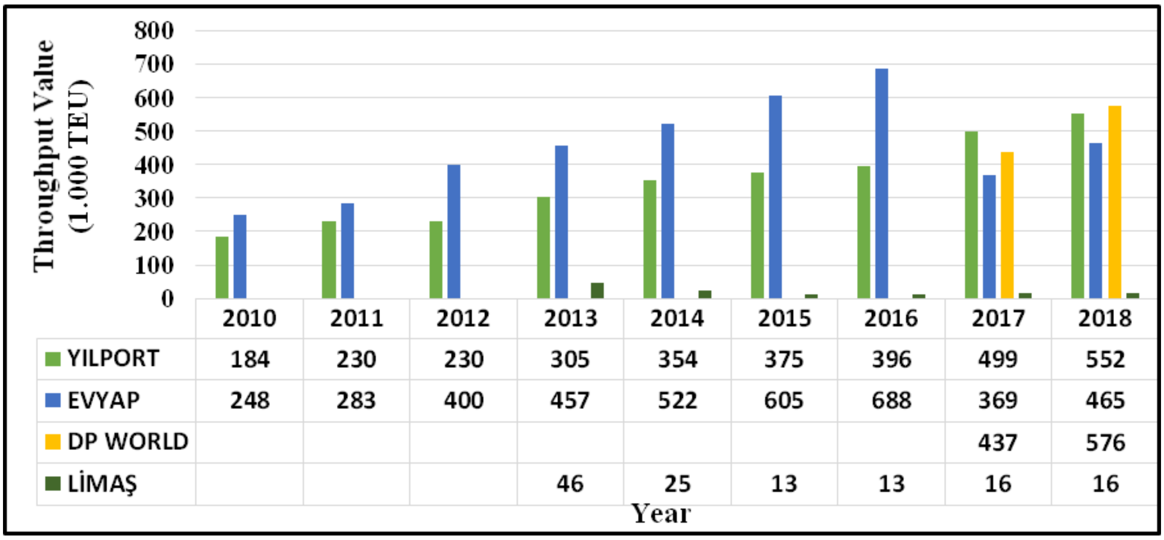


Figure 5.4. The container terminals located within the Kocaeli Gulf. (Described by the Author)

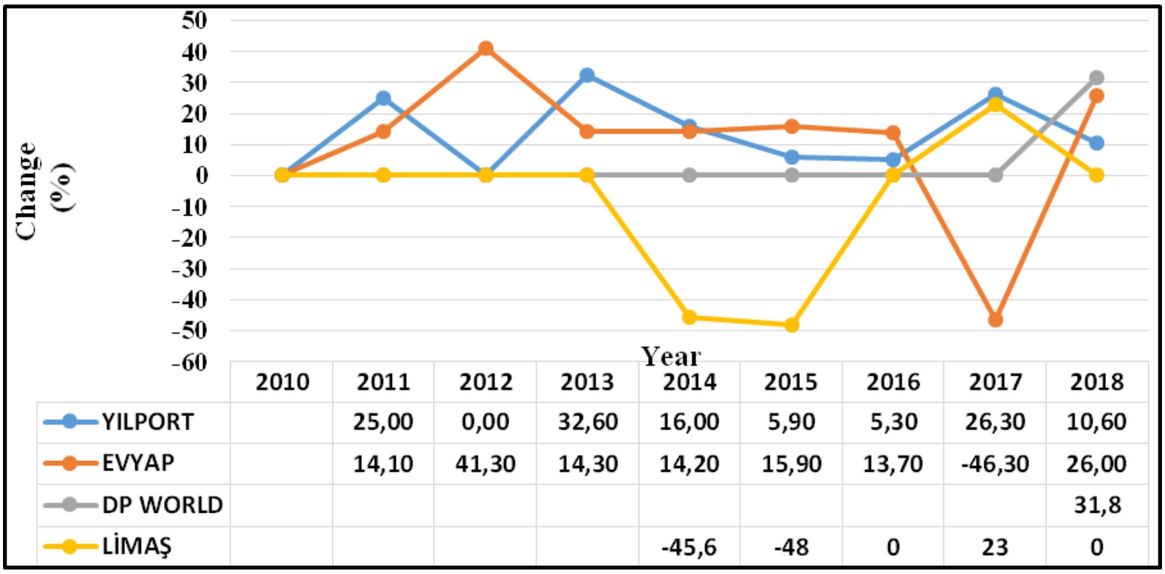
The throughput statistics of these terminals are given in Figure 5.5. BELDEPORT and SAFIPORT are excluded since their facilities are not completed yet. It is observed from Figure 5.5 that EVYAPPORT was the leading container port until the end of 2016. A balance has been observed among three ports after DP WORLD PORT entered in service. EVYAPPORT was affected adversely by the involvement of DP WORLD and experienced a sharp decline in 2017.



	2010	2011	2012	2013	2014	2015	2016	2017	2018
YILPORT	184	230	230	305	354	375	396	499	552
EVYAP	248	283	400	457	522	605	688	369	465
DP WORLD								437	576
LİMAŞ				46	25	13	13	16	16

Figure 5.5. The container throughput values of selected Kocaeli Terminals.
(**Source:** TURKLİM (Port Operators Association of Turkey))

The annual change rates of the selected Kocaeli ports are seen in Figure 5.6. YILPORT with an increase of 26.3% in 2017 and DP WORLD PORT with an increase of 31.8% in 2018 have exhibited remarkable performance. EVYAPPORT also exhibited a remarkable increase with 26.0% in 2018, but it was still under the performance that it reached in 2016.



	2010	2011	2012	2013	2014	2015	2016	2017	2018
YILPORT		25,00	0,00	32,60	16,00	5,90	5,30	26,30	10,60
EVYAP		14,10	41,30	14,30	14,20	15,90	13,70	-46,30	26,00
DP WORLD									31,8
LİMAŞ					-45,6	-48	0	23	0

Figure 5.6. The annual change in container throughput values of selected Kocaeli Terminals.
(**Source:** TURKLİM (Port Operators Association of Turkey))

LİMAŞ handled far below the other ports. It is considered that LİMAŞ is in a disadvantageous position in terms of access to the railway as well as the main roads such as D-110 and TEM. On the other side, all the other ports have easier access to main routes which bring in advantageous situations for them. The ports located on the northern side of the Gulf provide easier access to reach inland locations in the Anatolian part and also to Istanbul.

When examining the last eight years of performance, YILPORT and EVYAPPORT have achieved a CAGR of 14,72% and 8,17% respectively. The throughput values of these both terminals are quite lower than the world's leading ports, but it is observed that Kocaeli ports are on the rise with higher CAGR values than the world average (Saka and Çetin, 2019b). Approximately two-thirds of Turkey's total foreign trade is formed in a region covering Kocaeli and its neighbors (Saka and Çetin, 2017). Thus, the position of the Kocaeli Gulf has a very effective role in this continuous rise. Kocaeli Gulf helps the transporters manage their duty easily to almost every side of Turkey. Taking into account this important role of Kocaeli ports, and based on the assumption that the proportion of foreign trade volume reached by country does not change until 2023, Erdoğan (2011) estimated that the container traffic of the Kocaeli region could reach 4 million TEUs by 2023.

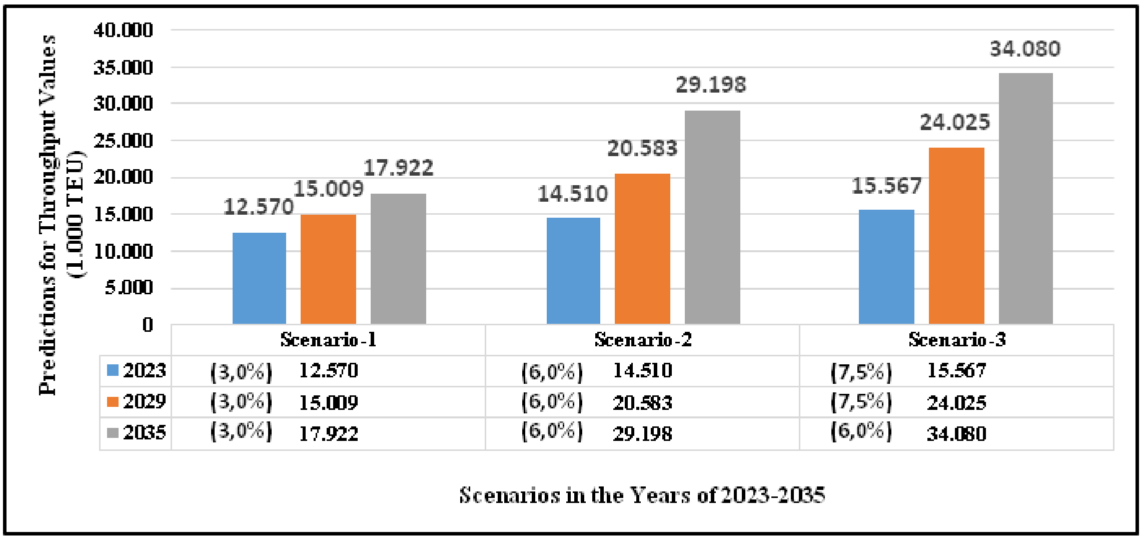
It is expected that maritime transportation and container transportation will continue to grow. The long term forecasts by Lloyd's List Intelligence (LLI) and UNCTAD are given in Table 5.1. According to UNCTAD (2018), the containerized trade is expected to grow an annual growth rate of 6% between 2018 and 2023.

Table 5.1. Forecasts for growth rates of seaborne trade flows.

Forecaster	**Annual Growth Rate (%)**	**Years**	**Seaborne Trade Flows**
Lloyd’s List Intelligence	3.1	2017-2026	Seaborne trade
	4.6	2017-2026	Containerized trade
UNCTAD	3.8	2018-2023	Seaborne trade
	6.0	2018-2023	Containerized trade

(**Source:** Review of Maritime Transport, 2018, UNCTAD)

These estimations being accepted as the average rates, three different scenarios are predicted for the transaction volumes of Turkey's and Kocaeli ports that may be observed in the future. Scenario-I indicates lower rates than LLI and UNCTAD predict, Scenario-II is based on the average rates, and Scenario-III foresees that Turkey's ports will be able to maintain a rate close to the increase they have shown over the last period with an optimistic approach. Figure 5.7 gives predictions for the sum of Turkey's ports. The forecasted annual increase rates are depicted under the columns of scenarios. Turkey handled a total of 10,8 million TEUs of containers in 2018. The average scenario (Scenario-II) predicts that Turkey could handle 29 million TEUs until 2035, and the optimistic scenario (Scenario-III) predicts that this value could reach 34 million TEUs by that time.



	Scenario-1		Scenario-2		Scenario-3	
2023	(3,0%)	12.570	(6,0%)	14.510	(7,5%)	15.567
2029	(3,0%)	15.009	(6,0%)	20.583	(7,5%)	24.025
2035	(3,0%)	17.922	(6,0%)	29.198	(6,0%)	34.080

Figure 5.7. Predictions for throughput values of Turkey's ports in the future.
(Described by the Author)

Figure 5.8 gives the predictions for the sum of Kocaeli ports. The forecasted annual increase rates are depicted under the columns of scenarios. Kocaeli ports handled approximately 1,6 million TEUs of containers in 2018. The average scenario (Scenario-II) predicts that Kocaeli ports could handle 4,3 million TEUs until 2035, and the optimistic scenario (Scenario-III) predicts that this value could reach 8 million TEUs by that time.

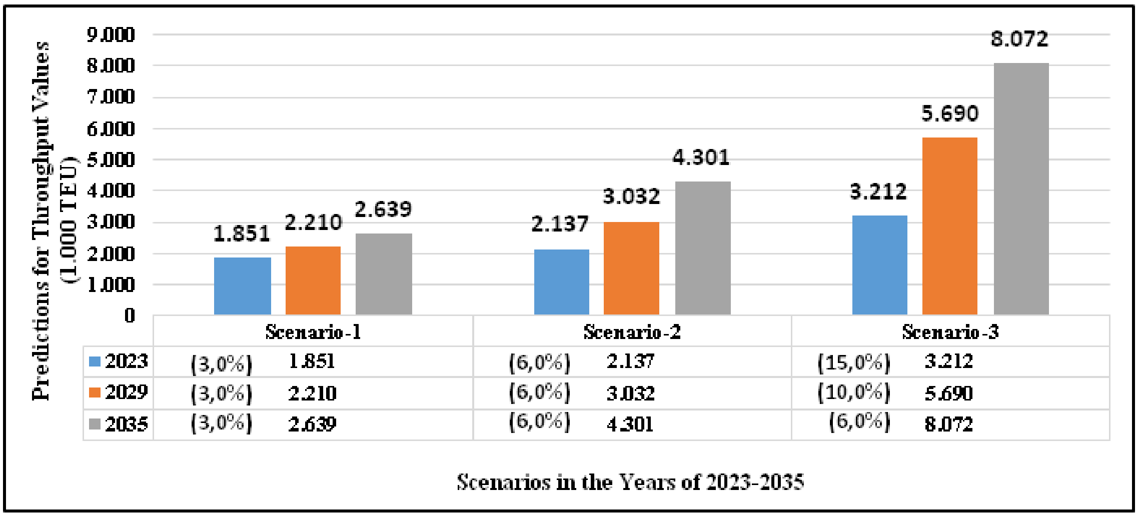


Figure 5.8. Predictions for throughput values of Kocaeli ports in the future. (Described by the Author)

When examining the total capacity of the container terminals, it is seen that the current capacity of Kocaeli container ports may not meet the demand, especially in the 2030s. The throughput capacities of Kocaeli container terminals are given in Figure 5.9.

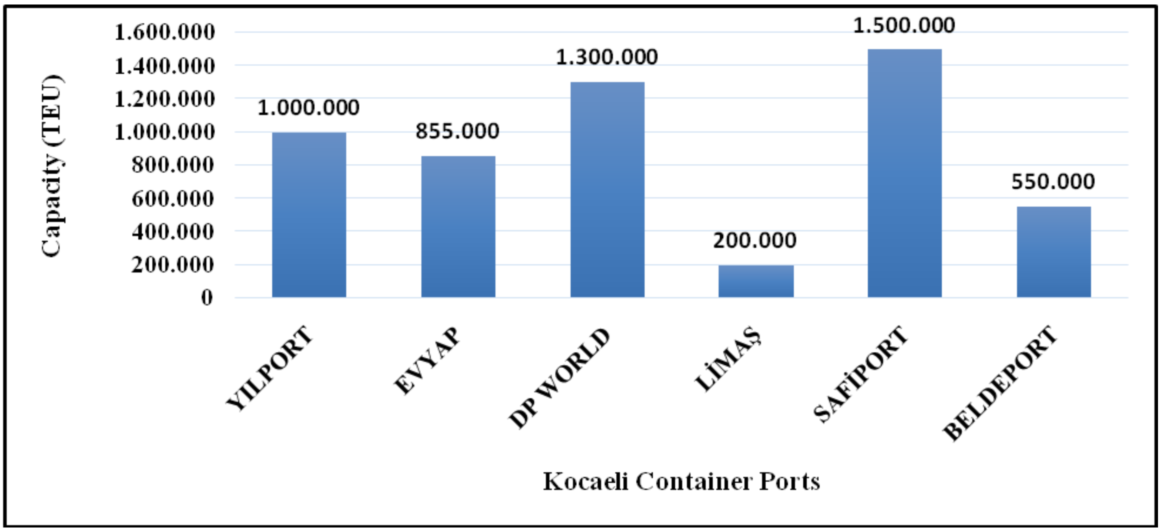


Figure 5.9. The current annual throughput capacity of each Kocaeli container terminal. (**Source:** Author's own source and web sites of the Port Authorities)

The total throughput capacity of the Kocaeli container terminals is 5,4 million TEUs. SAFIPORT authority announced that the capacity will be increased to 2,5 million TEUs at the end of the renovation period. In this way, the total capacity of Kocaeli container terminals is expected to reach 6,4 million TEUs. This capacity would not be sufficient to meet the demand in 2035 according to the optimistic scenario unless necessary precautions are provided. It is understood that a minimum of 25% additional capacity should be provided to be able to meet the possible demand for 2035.

If the three container terminals, that currently have the highest transaction volumes in Kocaeli Gulf, are deemed to have improved their transaction volumes in parallel with their customers' demands, future forecasts for these ports may be realized as in Table 5.2.

Table 5.2. Projections for future throughput values of selected container ports.

		Year	YILPORT	EVYAP	DP WORLD	CAGR %
			Value (1000 TEU)	Value (1000 TEU)	Value (1000 TEU)	
Recent Throughput Value		2018	552	465	576	
Projected Throughput Values in Scenarios	**Scenario-I (Pessimistic)**	2023	640	539	668	3,0
		2029	764	644	798	3,0
		2035	912	769	953	3,0
	Scenario-II (Average)	2023	739	622	771	6,0
		2029	1.048	882	1.094	6,0
		2035	1.487	1.251	1.552	6,0
	Scenario-III (Optimistic)	2023	1.110	935	1.159	15,0
		2029	1.966	1.656	2.053	10,0
		2035	2.790	2.350	2.913	6,0

(Described by the Author)

When applying the scenarios to the selected ports it is seen that even the average scenario will necessitate additional capacity for each terminal. Of course, strict competition is inevitable for this region especially after BELDEPORT and SAFİPORT take the floor with the completion of the renovation and other construction activities. But if it is assumed that any of those three ports given in the table manages to keep going well without losing any of its customers with their ever-increasing demands, it may also manage to reach the volumes projected in Table 5.2. In order to achieve such a goal, it is necessary to take measures and gain very high-level competitiveness.

Considering the majority of ports in Turkey, they are having difficulty to fulfill the functions other than loading and unloading due to insufficient land (Esmer and Oral, 2008). All of the ports located on the shores of the Kocaeli Gulf are surrounded by urban areas. This situation constraints the ports to expand their land areas. The only solution for expanding the land area of the ports could be filling the sea (Saka and Çetin, 2019a). Such a process would absolutely be a very laborious and expensive one.

The Kocaeli container terminals, except LİMAŞ, are located very close to roads and railways. This situation brings an advantage to those ports. However, except for the cases of EVYAP and DP WORLD, it generally requires passing through urban settlements to reach the highway from the ports. Sometimes enormous congestions occur on these routes, which causes a waste of time for transporters. Waste of time means an increase in shipping costs. EVYAP and DP WORLD have advantageous situations as providing direct entrance and output to the highway. But the traffic flowing between Istanbul and Kocaeli is one of the busiest ones in Turkey. The freight transportation to and from these five ports has to be carried out on this route. The increase in container traffic consequently results in an increased number of heavy vehicles on the highway. And the increased number of heavy vehicles brings in a higher risk of an accident.

According to the final report of the planned study of ports' hinterland (MTI, 2015), in Turkey, 97.6% of the cargo moving between the ports and the cities are transported by road, while 2.4% is transported by rail. In Kocaeli, the highways and the railways pass throughout the city. On the other side, transit and urban transportation are carried out on the same route. All these conditions bring in high-level traffic congestion in the city and on the roads.

It is assessed that to transfer as much freight as possible from highway to railway could benefit in many ways. The most valuable benefit would be the reduced cost of transportation. The railway could provide an enormous advantage in mass freight transportation. The cost advantage would be even higher as the distance increases. Another advantage of rail transport is related to its reputation known as an "Environmental friendly transport system". It is the least harmful type of transport in terms of air pollution. It also helps to reduce the turmoil in port cities, and contribute to the reduction of noise and visual pollution as well as air pollution.

A railway connection could provide advantages and competitive power for a seaport. Having easy access to the railway, which will provide economic and safe transportation, will be a preference for transportation providers. When there is more than one alternative providing access to the railways, the seaport which allows a more rapid flow of the cargo and which brings in the minimum cost will be the one to be preferred by the transportation providers. Collaborating with a dry port and providing a high capacity freight transportation to that dry port will provide a great advantage to that seaport in terms of competitiveness. Another advantage that can be offered by a dry port to a sea port is additional room to which would relieve this seaport when having problems in terms of stacking capacity. A well-established dry port could support seaports in terms of every activity that a seaport has to carry on other than loading and unloading to and from the vessels. Such a dry port with a suitable location for the final destination of the cargo would be preferred by the transportation providers. And, collaborating with such a dry port will bring in extra competitive power for the seaport.

The possibility of dry port connection with Kocaeli container terminals, railway connections and access to the network is examined in the following section along with the general characteristics of the ports.

5.2. Kocaeli Container Terminals

As mentioned in the previous section, there are six container terminals currently in Kocaeli Gulf whose locations are seen in Figure 5.1. The features of the container terminals are explained in this section. Before examining Kocaeli container terminals, it would be appropriate to mention brief information about the region where these ports are located.

About half of the gross national product of Turkey is produced in the Marmara region. Considering that most of the production is realized in the Anatolian side and the provinces of Anatolia, the use of terminals in Kocaeli arises as a better option instead of passing through the Bosphorus bridges and entering heavy traffic to use the other terminals in Marmara region. Thus, it will be possible to transport the industrial goods produced in this region in economies of scale by making use of the logistics facilities of the region.

The fact that railways cannot be used effectively in freight transport is seen as an important deficiency. There are approximately 40 port facilities in the area. The rate of having a railway connection is low for these facilities. In terms of the six container terminals in the region, only the ports of SAFIPORT and EVYAPPORT are currently connected to the railways. The works to connect the port of DP WORLD PORT are in progress. It is also in plan session for constructing a junction for BELDEPORT. Beyond these efforts, it is of great importance that the conventional railway line between Köseköy and Gebze has the capacity to meet the freight traffic needs in the region.

The above-mentioned assessments were stated by the Secretary-General of the "Port Operators Association of Turkey (TURKLIM)" during a field study visit to headquarter of TURKLIM in March 2017. It was also mentioned as a very important requirement that the ports be connected to logistics centers through the railways.

5.2.1. YILPORT

It is located at Dilovası, as shown in Figure 5.4, very close to the Osmangazi Bridge and almost at the entrance of the Kocaeli Gulf. The total area of the port is 206.000 m². Fields of activity in the port are a container, general cargo, liquid, and dry bulk. In addition to the stacking capacity in the yard, YILPORT also has an inland depot (land terminal) which is situated 7 km from the main port, covering 90.000 m² area. The main purpose of this inland depot is stacking the empty containers. It also serves for the purposes of container freight station (CFS) stuffing, unstuffing, container washing, and container repair issues. The annual handling capacity of YILPORT is 1.000.000 TEUs. The main terminal involves 1780 ground slots, and the land terminal involves 546 ground slots. In total 2326 ground slots make YILPORT to have an instant capacity of 13.400 TEUs in total. In both terminals RTGs, with stacking capacity of six tiers, are used to stack the containers (YILPORT, 2019).

Annual throughput volumes of YILPORT between 2010 and 2018 are seen in Figure 5.5. YILPORT exhibited remarkable performance in 2017, with an annual increase of 26.3%. For the last eight years, the CAGR of YILPORT has been 14,72%. An image from the land side of YILPORT is seen in Figure 5.10. In this figure, the railways pass just near the gate of YILPORT. But YILPORT does not have a junction to the railways. All the freight transportation from and to the port has to be realized by trucks.

Figure 5.10. An Image from the Land Side of YILPORT.
(**Source:** https://www.yilport.com/en/media/gallery/Gebze-Turkey/200/220/0)

YILPORT is constructed on a limited land area and sometimes having difficulty due to the intense container operations within the terminal. In addition to scarce space for containers, there occurs an important problem for the trucks to find room for maneuver and to have access to highways. Sometimes there occur long queues until arriving at the highway especially for carrying the import containers.

It seems necessary to take some measures to relieve the inside port activities taking into account the projections for the future. It is almost impossible to get a junction for railways over the prevailing circumstances. But it may be possible getting a junction with about 500 meters line by making an arrangement in the area of liquid tanks. If such a measure is not taken YILPORT may lose customers instead of augmenting its throughput volumes in the future.

5.2.2. EVYAPPORT

It is located at Körfez town, as shown in Figure 5.4, almost at the mid of the Kocaeli Gulf. The total area of the port is 265.000 m². An image from the land side of EVYAPPORT is seen in Figure 5.11. Fields of activity in the port are container, general cargo, liquid, and vessel. The annual handling capacity of EVYAPPORT is 855.000 TEUs (EVYAPPORT, 2019). The terminal involves approximately 3900 ground slots.

Figure 5.11. An Image from the Land Side of EVYAPPORT.
(**Source:** https://www.evyapport.com/container-terminal.php)

Annual throughput volumes of EVYAPPORT between 2010 and 2018 are seen in Figure 5.5. For the last eight years, the CAGR of EVYAPPORT has been 8,17%. Although the CAGR of EVYAPPORT was 18,5% between 2010 and 2016, the involvement of DP WORLD, which is located just three km away, has caused a decrease in the throughput volumes of EVYAPPORT. Even the volume of 2018 (465.000 TEUs) was behind that of 2016 (688.000 TEUs). But it is seen that EVYAPPORT is again at rising with the last year's volume, with an annual increase of 26,0%. An important advantage of EVYAPPORT is that there is a junction line entering the port from TCDD railways which later splits up to four lines inside the port. The port already uses the railways to transport some kind of freights. The length of the railway lines inside the port is approximately 600 meters. This length of the line allows a train with a standard length to be loaded and unloaded within the port. The connection of the port to TCDD railways may bring in important advantages for EVYAPPORT in the future if a dry port model in connection with the port is implemented.

5.2.3. DP WORLD PORT

DP WORLD PORT is also located at Körfez, like EVYAPPORT, as seen in Figure 5.4. DP WORLD purchased the Fairview Container Terminal in August 2015. Along with the completion of the renovation phase, the original capacity of 750.000 TEU has been increased to 1.3 million TEU yearly. In addition to extending its existing dock a second dock has been built, making the total dock length 800 meters and the total terminal area 320 thousand square meters. It involves 7.000 ground slots and four RTGs for stacking the containers. DP WORLD PORT came into service in 2016 (DP WORLD, 2019). An image from the seaside of DP WORLD PORT is seen in Figure 5.12.

Figure 5.12. An Image from the Land Side of DP WORLD.
(**Source:** http://www.dpworldyarimca.com/)

The throughput of DP WORLD PORT was 576.000 TEUs with an annual increase of 31,8% (see Figure 5.5 and Figure 5.6). The involvement of DP WORLD PORT affected the performance of EVYAPPORT adversely especially in 2017, in the year just after it came into service. In 2019 DP WORLD PORT gained a new competency, by getting a junction to the railways. It is only one line in 500 meters within the port. Since the area is very limited in the terminal, only one line could be constructed. Being only one line will, of course, may cause hardship to some extent. But the port authority believes that this intermodal characteristic will make DP WORLD PORT more competitive in this region.

5.2.4. SAFİPORT

SAFİPORT is located at Derince, approximately five kilometers away from Izmit, as shown in Figure 5.4. The port was constituted in 1904 and had been managed by State until 2015 as being one of the oldest ports acting in international maritime transportation. It was taken over by Safi Holding in March 2015 through privatization and will be owned for 39 years as SAFİPORT DERINCE. It offers easy access to a multimodal connection for international and domestic destinations, by railway and truck transportation in addition to maritime transportation. Due to the extensive facilities, the port services can accommodate cargo, including Ro-Ro, project cargo, dry bulk, general cargo, liquid cargo, containers, and railway carriages. The present total area of the port is 450.000m². SAFİPORT DERINCE has a railway terminal inside the port area. The port railway connection enables it to handle any type of cargo transported via rail. The rail terminal has eight tracks. The length of the tracks inside the port is approximately 900 meters (SAFİPORT, 2019). It is long enough to constitute a sensible length of the railway car chain. These railway lines, which the port already has, will provide a great convenience for adapting to the dry port concept.

According to the future layout of the port, the development is going on to expand the 450.000 m² current port ground to 1.200.000 m² through land reclamation. The blue dotted lines in Figure 5.13.a indicates the boundaries of the new container terminal after the reclamation is completed. The renovation of the port is planned to be implemented in two steps. In the first step, it is aimed to have a 1.500.000 TEU stacking capacity within the area shown in the dotted part in Figure 5.13.a. And in the second step, it is planned to have a complete very large dock through land reclamation between the old and the new docks. After the completion of the full renovation plan, total container stacking capacity will be increased to 2,5 million TEUs, as seen in Figure 5.13.b.

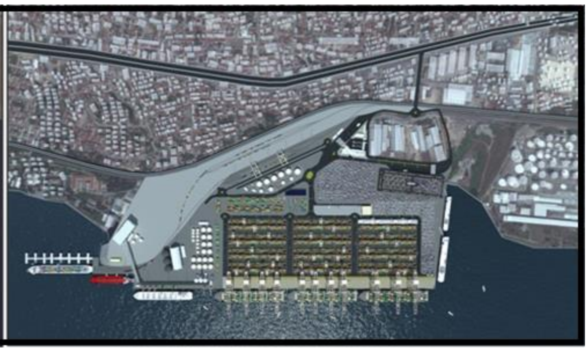


Figure-4.13.a. Image Before the Land Reclamation.

Figure-4.13.b. Image After the Completion of the whole Renovation Processes.

(**Source:** http://www.safiport.com.tr/)

SAFİPORT DERINCE is on a very strategic location with a very large land area and with a very large capacity. Having an intermodal terminal connected with eight tracks gives a privilege to SAFİPORT which also gives huge competitiveness. Taking into account the "One Belt One Road" initiative, it is seen that SAFİPORT might have an important role in connecting the long railway routes with maritime routes.

5.2.5. LİMAŞ

LİMAŞ is located at Yeniköy, approximately five km away from the center of Izmit as seen in Figure 5.4. It was founded in 1992 on an area of 120.000 m^2. After the new pier was built in 2009 LİMAŞ became suitable for container operations. Comparing with the other container terminals in the gulf its equipment and capacity are limited: having two mobile gantries and capable of handling 200.000 TEUs annually (LİMAŞ, 2019).

Container transaction volumes are very low as seen in Table 5.5. The highest volume was recorded as 46.000 TEUs in 2013 and thereafter it's been in decline. When comparing the ports in Kocaeli Gulf in terms of location, it is seen that LİMAŞ is the sole container terminal located at the southern shores of the gulf. Being farther to the main routes is another disadvantage for LİMAŞ. The major disadvantage is that it has almost no possibility to get a junction to the railways. According to the assessment of TCDD Regional Directorate, it is highly unlikely to construct a new railway line that will pass close to LİMAŞ in the near future. In the prevailing circumstances, it is a remote possibility for LİMAŞ to collaborate with a dry port with a high capacity transportation network.

5.2.6. BELDEPORT

It is the youngest container terminal in the Kocaeli Gulf, located just at the foot of Osmangazi Bridge as seen in Figure 5.4. and Figure 5.14.

Figure 5.14. An Image from the Land Side of BELDEPORT.
(**Source:** http://www.beldeport.com.tr/)

BELDEPORT came into service in 2018. It has a fixed depth of 16,5 meters along the 450 meters long dock. The port is on a land area of 581.000 m², involving a customs storage area of 150.000 m² and a 12.000 m² parking area for 45 carrier trucks. Having a potential expansion area of 930.000 m² is one of the most important advantages of the port. BELDEPORT will have a capacity of 550.000 TEUs annually. In addition to the container, it will also have the ability in handling two million tons of bulk and 200.000 Ro-Ro annually. Another advantage of the port is the railways that are passing throughout the northern border. BELDEPORT intermodal yard and junction line are under the planning stage. The port will be connected to the main railways with the help of the intermodal yard which will provide direct access to the railway within the port area and will provide its customers with logistical cost advantages (BELDEPORT, 2019). Intermodal characteristics will give the chance to collaborate with a dry port and make BELDEPORT more competitive in this region.

5.3. Capacity of a Container Terminal

The capacity of a container terminal is the maximum traffic a port terminal can handle in a given scenario (Soberón, 2012). The capacity of a container terminal can be expressed in three separate methods[5]. The first method is based on the capability of the equipment owned by the terminal. The more handling capability in a certain period means a more annual throughput capacity. In other words, the faster you unload the boxes from a vessel the more volume you produce in a year. In addition to the specifications of "Ship to Shore (STS)" gantry cranes[6], the number of yard carriers that will carry the containers to the stacking yard area and the level of the operators using cranes are important in this method. The second method is to calculate the capacity in terms of the number of containers that a terminal can embrace over a designated area. No doubt that the size of the area allocated to stack the containers has a positive impact on the level of capacity. Another factor is the dwell time[7] of the containers. If the containers lie longer time in the stacking area the capacity will be less, on the contrary, the capacity will be higher if the containers lie a shorter time. The third method is to calculate the capacity of port Gates. The more containers on the carriers exit the port gates, the more volume produced by the port. In other words, the port will be more productive by carrying out faster transactions within the port, as a result taking out more trucks through the port gates. In other words, the port will be more productive by carrying out faster transactions within the port, resulting in more trucks going out through the port gates in a certain period.

Among these methods, the most restricting one gives the realistic volume about the capacity of the terminal. For example, if a port has limited equipment although having a very large stacking area, the low processing speed of the equipment will restrict the number of containers to be stacked in a certain period. Therefore, a large storage area will remain dysfunctional. In other words, the port will not benefit from the large stacking area

[5] Those methods were explained by the Chief of Operations of EVYAPPORT during a field study visit in March 2017.

[6] Ship to shore gantry crane is a type of large gantry crane found in port and quayside to load, unload and transport intermodal containers from vessels. It generally travels along two rails that are spaced according to the size of the STS crane. It is equipped with a specialized spreader to handle the stack of containers.

[7] Dwell time can be defined as the amount of time a container waits to get picked up at a marine terminal after being unloaded from a vessel. This time is generally expressed in terms of days.

as much as possible because of the low handling capacity. The port in such a circumstance will need to increase the number of equipment or to have contemporary equipment in order to increase the processing capacity. Similarly, if the capacity of the gate is much more than the handling capacity, the overplus capacity at the gates will not be beneficial either. On the contrary, if the handling capacity is much more than the capacity of the gate, the overplus capacity of handling will not be beneficial because of congestion at the gates.

Nowadays the more common case is that the ports announce their port capacity related to their stacking capacity. It is assumed that the majority of the container terminals have already had contemporary handling equipment and developed gate systems, to reach as high as possible handling capacity and gate capacity. It’s been observed that the majority of the problems at container terminals are due to space constraint. The limited land area within the terminals constraint both the stacking capacity and the speed of the transactions. The stacking capacity of a terminal is closely related to the area which it can allocate for this purpose. Each unit area over which one TEU container can be placed is identified as “Ground slot”. The number of total ground slots indicates how much space of “1 TEU” is allocated to container storage in the terminal yard area. When allocating the ground slots the port authority takes into account the required operations to carry and stack the containers.

Generally, two types of gantry cranes are used to stack the containers: Rail Mounted Gantry (RMG) and Rubber Tired Gantry (RTG) cranes. The rubber tires of RTG cranes allow them to move freely through a container yard—to travel where the work is. But the rubber tires can be limiting. They limit the size and lifting capacity of RTGs. In contrast, RMG cranes are limited to traveling on rails (they can’t move about container yards between stacks like RTGs). But that limitation is also the RMG’s strength. RMGs ride on steel wheels that are capable of supporting far more weight than an RTG and its rubber tires (Libbey, 2019). A typical RTG or RMG may enable stacking the containers with 5-8 rows and 3-7 tiers (see Figure 5.15).

Figure 5.15. An RTG in use for stacking containers.
(**Source:** hhttp://tfdbrasil.com.br/?page_id=110)

The capacity of the RTG or RMG affects the total capacity of the terminal. The more tiers an RTG/RMG constitute the more stacking capacity the terminal gets. So, the number of ground slots and the number of the tiers an RTG/RMG can constitute are important variables in calculating the stacking capacity of a container terminal. The example in Figure 5.16 will be illustrative in this respect.

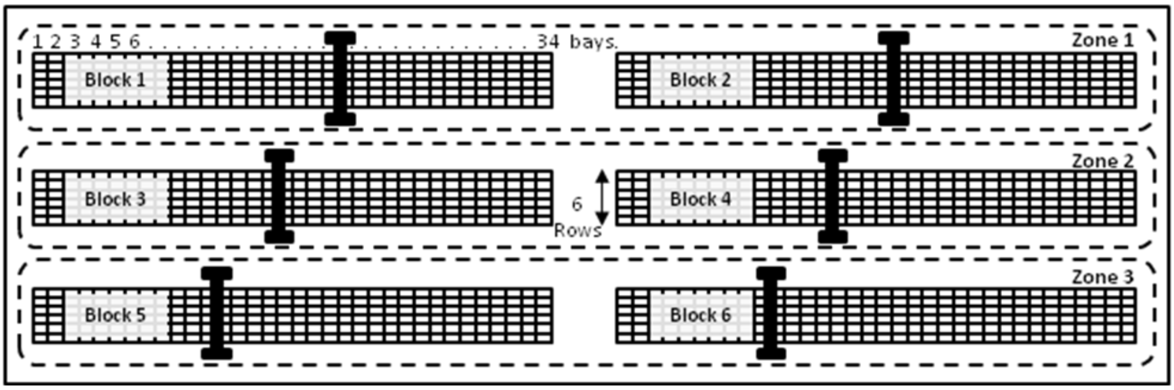


Figure 5.16. An example of a container terminal layout. (Prepared by the Author)

In the example seen in Figure 5.16, there are three zones and 6 blocks for stacking the containers. Each block consists of 6 rows and 34 bays, which means that each block has a capacity of 204 (6 x 34) ground slots. Since each block is equal to another, this terminal has a capacity of 1224 (204 x 6) ground slots in total. The annual capacity/capability of this terminal is calculated related to this number. An imaginary view of container stacks is seen in Figure 5.17.

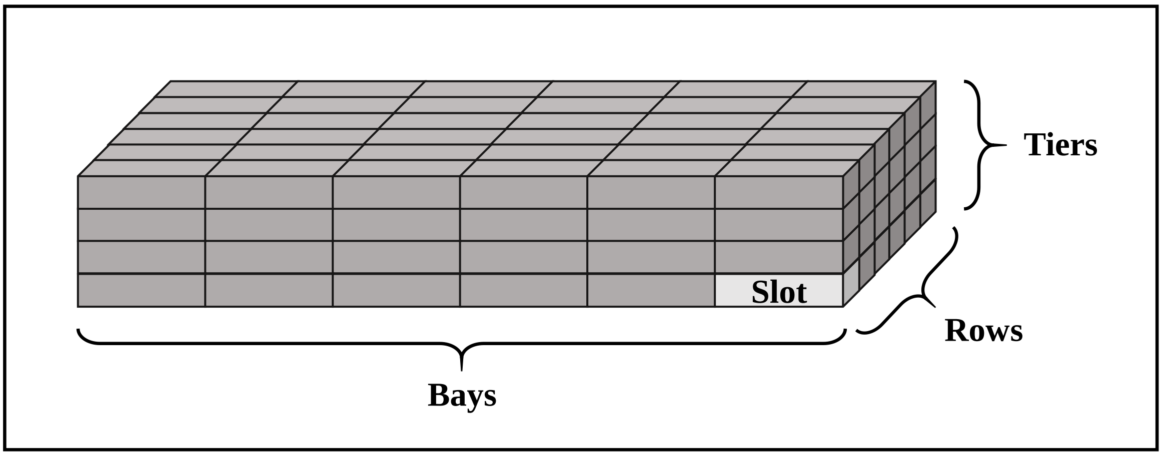


Figure 5.17. An imaginary view of container stacking area. (Prepared by the Author)

The stacks in Figure 5.17 exemplifies a terminal yard area that the containers unloaded from the vessels are being stacked. At the following step, when it's time for a container to be uploaded on a carrier, it would require to move some of the containers before grasping the targeted container. The two terms "retrieving" and "rehandling" are used to imply the movement of the containers in such circumstances; retrieving states the movement of a container from yard to the vessel, whereas the term rehandling indicates the movements of the container for either intra-bay or intra-block movements (Caserta et al., 2011). If the container to be loaded into a carrier is stacked under other containers, it will be necessary to move the containers thereon before moving that container. In other words, it will be necessary to first relocate those containers in order to receive the targeted container. The higher the tiers, the greater the number of such movements. For this reason, stacking made in particular by forming high tiers in a narrow space will then result in a considerable amount of movement in the loading operations to the carriers. If space is limited, this excess movements will also cause maneuvering difficulties within the terminal and slow down the operations.

"Annual capacity of a container terminal (C)" can be calculated by using the formula (5.1) below (Watanabe, 2001; Soberón, 2012; Kourounioti et al., 2016):

$$\boldsymbol{C} = \frac{(\boldsymbol{G} * \boldsymbol{H} * \boldsymbol{S} * \boldsymbol{W})}{\boldsymbol{DT} * \boldsymbol{P}} \qquad (5.1)$$

The variables in formula (4.1) are explained below:

C: annual capability/capacity (TEU/year),

G: number of container ground slots (in TEU),

H: number of tiers/stacking height of containers,

S: operational factor/number of working slots, as a proportion ($0 < S < 1$),

W: total number of working days in the period (365 days per year),

DT: average container dwell time in the container yard,

P: peaking factor, to ensure the yard's efficiency against a peak ($P \geq 1$).

Operational factor (S) serves to reduce the maximum height and keep the system in the operative bands, whereas peaking factor (P) can be considered as a security factor, serving to consider the traffic variations. This factor (P) usually ranges between 1,1 and 1,3 (Gonzalez, 2015).

Assuming that an RTG with a capacity of four tiers is in use in the terminal, the value of "H" will be equal to four. Multiplying this number (H) with the number of ground slots (G) gives the "Static capacity of the terminal (C_S)" (5.2). C_S indicates the maximum number of TEUs that a terminal can stack instantly.

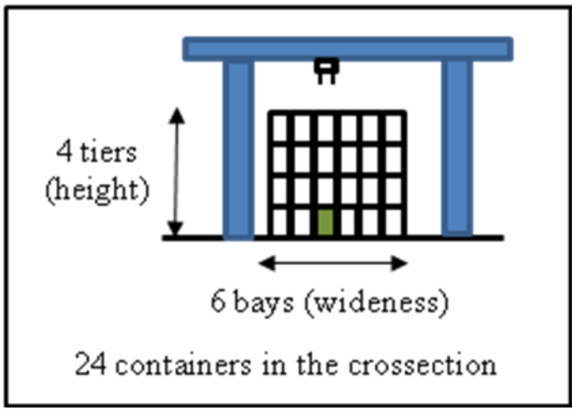
$$\boldsymbol{C_S = G * H} \tag{5.2}$$

If an RTG capable of stacking four tiers is being used in the sample terminal seen in Figure 5.16, the maximum static capacity would be;

C_S = 1224 (number of ground slots) x 4 (stacking height) = 4896 TEUs.

Although 4896 TEUs can be stacked filling all the bays as seen in the example of a cross-section in Figure 5.18.a, it is impossible to move any container from the lower tiers. Therefore, to indicate the maximum stacking capacity, it will be appropriate to ground on the utmost situation in which the gantry can continue its operation as seen in Figure 5.18.b.

If it is required to take out the black colored container which is stacked at the first tier, three containers over this black container should be taken out at first. At the cross-section seen in Figure 5.18.a there are 24 containers (4 tiers and 6 rows).



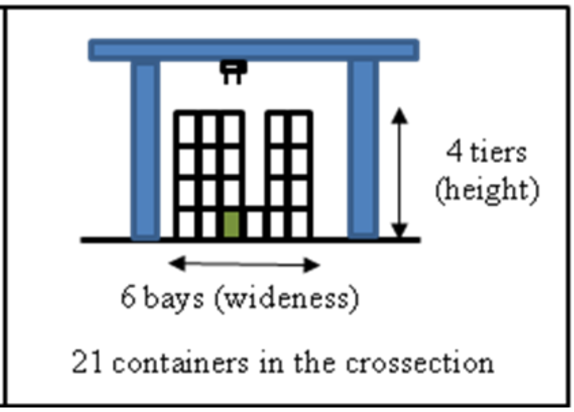


Figure 5.18.a. Schematic display of a cross-section fully stacked.

Figure 5.18.b. Schematic display of a stacking at maximum operable capacity.

(Prepared by the Author)

For the RTG to be able to move a container at the bottom in a situation as seen in Figure 5.18.a, minimum three containers should be diminished, which means that maximum 21 containers in a cross-section shall be stacked for the RTG to be able to carry out its operations, as seen in Figure 5.18.b. But in the situation of Figure 5.18.a, there is no room to translocate the three containers that are stacked over the black container. In this example, the ratio of 21 to 24 equals to the factor (multiplier) that gives the result of the maximum operable stacking capacity, which can be formulated as below:

$$S = \frac{[(R-1) * T\,] + 1}{\mathrm{R} * \mathrm{T}} \tag{5.3}$$

Where:

R is the number of the rows, and

T is the number of the tiers, as indicated in Figure 5.17 and Figure 5.18.

The “operational factor (S)” is a ratio between “0” and “1”. According to the formula given in (5.3), the operational factor of an RTG/RMG exemplified in Figure 5.10, for the maximum operational capacity would be calculated as shown below:

$$S = \frac{[(6-1) * 4] + 1}{(6 * 4)} = \frac{21}{24} = 0{,}875$$

The above-calculated value “0,875” implies that the operation under this RTG can continue unless the ratio of 0,875 is exceeded. In other words, the operation will be no more possible when the ratio of the working slots reaches a value of “0,875”. According to the discussions with the Chief of operations of EVYAPPORT and YILPORT about the stacking capacity and the operational factor, it is possible to indicate two categories of the stacking capacity of a container terminal yard: (1) Maximum (Theoric) operable capacity, indicating the maximum capacity that can be reached at a level so that operating cannot continue anymore, (2) Optimum capacity, allowing the operations continue at optimal level.

The operational factor of an RMG/RTG capable of stacking six and rows four tiers, which was exemplified in Figure 5.18, was calculated as "0,875" above. This ratio implies the rate of the maximum operable capacity that can be managed through this type of RMG/RTG in the terminal. As another example, the operational factor of an RMG/RTG capable of stacking seven rows and tiers, implying the rate of the maximum operable capacity would be calculated as stated below:

$$S = \frac{[(7-1) * 6\,] + 1}{7 * 6} = \frac{37}{42} = 0.88$$

By using the same formula, the operational factor for the maximum operable capacity of a terminal using an RMG with six rows and five tiers would be calculated as "0.86". Therefore, it can be deduced that the operational factor for the maximum capacity of a container terminal could range between "0.86 and 0.88". For the optimum capacity, the operators and ports authorities might treat differently. For example, YILPORT considers a factor of "0.75" whereas EVYAPPORT takes "0.65" as the operational factor for optimum capacity. Apart from these, Soberón (2012) assumes that the operational factor may range between "0.55 and 0.70". Similarly, the Principle Planning Officer of Tanzania Port Authority, Hebel Mwasenga (2012) states that "*The maximum storage capacity for Dar es Salaam port is set to 65% to avoid yard congestion, and if yard capacity is over 65%, containers are transferred to Inland Clearance Depots (ICDs)*". It is understood that the operators may refrain from using a high operational factor since the operation will slow down and the maneuverability within the port would become more difficult if the capacity usage rate is at a high factor. Instead, it is preferable to send the excess quantity to an inland terminal, to sustain the high-level operation capability.

The value of "W" in formula (4.1) implies the total number of working days in a certain period, generally referring a year. If the work continues on all days of the year, the "W" equals 365.

To calculate "Annual Capacity (C)" of the terminal two other variables are required; the container Dwell Time (DT) and the Peaking factor (P). Dwell Time (DT) is defined as “the total time a container spends in one or more terminal stacks” (Ottjes et al., 2007). Container DT may be influenced by several factors such as gate operations, availability, and efficiency of hinterland connections and customs regulations. Consignee, namely the receiver of the goods can be identified as one of the key stakeholders who determine DT since he decides when to pick-up import containers or when to deliver export containers (Kourounioti et al., 2016).

If the containers stacked in the terminal wait for a long time, it will result in low efficiency of the stacking area in the terminal. In other words, dwell time will adversely affect the capacity of the terminal: a longer dwell time will result in more intensive use of the stacking area, while a shortened dwell time will allow the capacity to be used more efficiently. There are a variety of determinants for the container dwell time. Kourounioti et al. (2016) designate the most important determinants of the DT as (1) the day and month of discharge; (2) the port of origin; (3) the size and the type of container and; (4) the type of cargo transferred. Those determinants may also vary from country to country. UNCTAD, by using its port performance measurement component, related to the data gathered from 48 ports in 24 countries between 2010 and 2017, made analyses over various subjects of port performance. Results show that the mean container dwell time is six days according to the collected data (UNCTAD, 2018). Another study about container dwell time was executed by Kourounioti et al. (2016) to observe the dwell time distribution of a port in the Middle East for a 35 days period. According to the results of this study, approximately 30% of the import containers were processed within the first seven days and nearly 50% were processed between the 8^{th} and 18^{th} days. For a small part, 5% of the sample container group, dwell time was between days 31 and 35. On the other side, during the field studies to Kocaeli ports in 2017, the container dwell time was identified mainly in three categories: (1) The export containers, approximately 5 to 6 days, (2) The import containers, approximately 7 to 8 days, and (3) Empty containers, approximately with an average of 12 days. It can be deduced that the average container dwell time for the full containers may be deemed as 7 days and for the empty containers 10 days.

The Peaking factor (P) is another adverse affecting variable of the annual capacity. Although some authors exclude this factor, it would be appropriate to take into consideration, as excessive increases are observed in some periods. This factor will not make any sense if the transaction volume of the port continues around the same average value. However, in the face of an excessive increase in transaction volume, port management will need a stacking area beyond its recent need. For example, if a port has a stacking area that can handle 100,000 TEUs each month when the demand for this port is 150,000 TEUs the next month, it may not be able to find stacking areas for 50,000 TEUs, which will be a surplus volume compared to the previous month. Or, the port authority will seek different measures to process this surplus amount. In this example, the peak factor will be 1,5. If the port management calculates its capacity by taking this possible peak factor into account, it will be able to understand that this sudden increase will require additional stacking capacity in the future. One of the most suitable methods for such situations is to direct the surplus load to a close dry port. Figure 5.19 exhibits the total container throughput volumes of Turkey’s ports throughout the year of 2017.

Turkey's container ports' total performance exhibited an increase of 14.3% in throughout 2017 in comparison with the previous year. When comparing the lowest and highest volumes during the year, it is seen that a peak occurred from February to October with an increase of 31.4%. Although the yearly increase was 14.3%, there occurred a much higher increase making the peak in the same year.

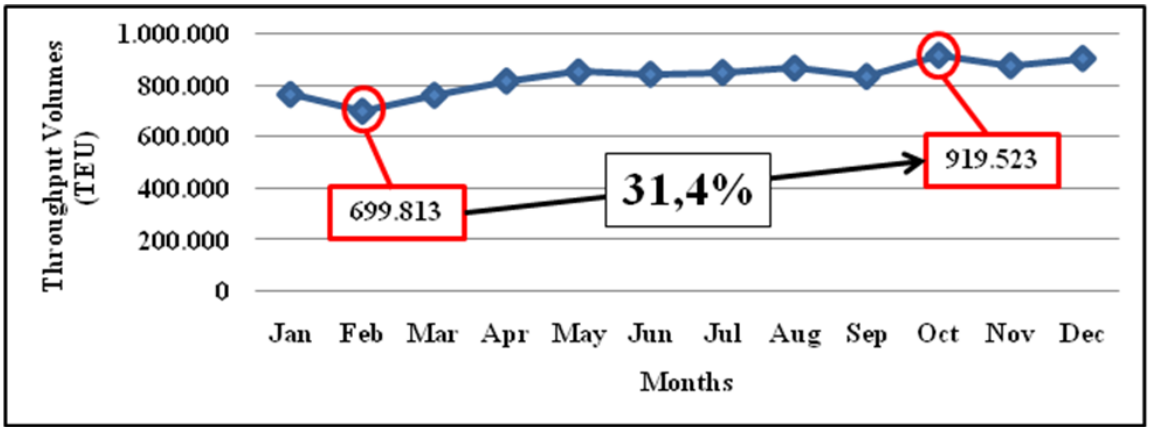


Figure 5.19. Container throughput volumes of Turkey's ports in 2017.
(**Source:** Maritime Trade General Directorate Statistics Information System)

Another sample is seen in Figure 5.20, the container throughput volumes of YILPORT in the same year. YILPORT achieved an annual increase of 26.3% in 2017. When comparing the lowest and highest volumes during the year, it is seen that a peak occurred from February to June with an increase of 31%, and the other peak occurred from September to November with an increase of 21.8%.

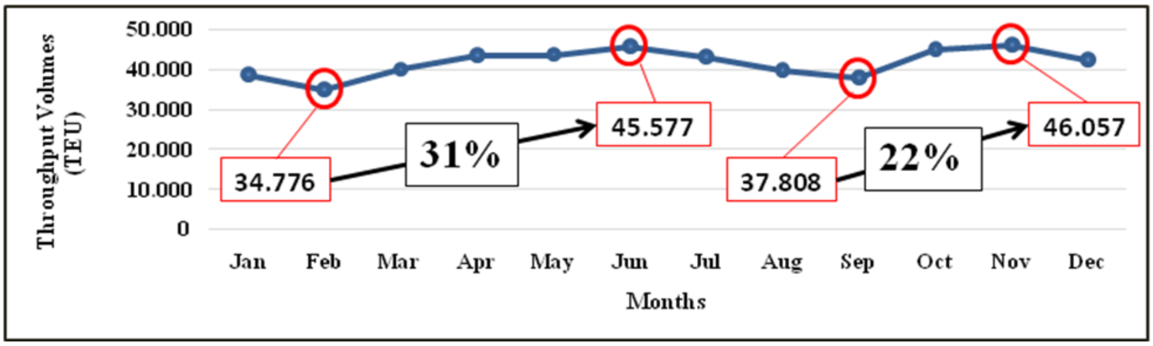


Figure 5.20. Container throughput volumes of YILPORT in 2017. (**Source:** YILPORT)

The examples mentioned above put forward that a higher increase value than the annual increase shall be expected to occur during the period. Taking into account the volumes occurred in 2017, it would be sensible to value the peak factor as “1,3”. In light of the information described above, the following values might be used to calculate the annual stacking capacity of the container terminal exemplified in Figure 5.16.

G = 1.224 TEUs (number of container ground slots),
H = 4 (number of tiers/stacking height of containers),
S = 0.7 (operational factor),
W = 365 (total number of working days in a year),
DT = 10 (average container dwell time),
P = 1.3 (Peaking factor).

The equality for the annual stacking capacity of the terminal is stated below:

$$C = \frac{(1224 * 4 * 0.7 * 365)}{(10 * 1.3)} = 96.225 \text{ TEUs}$$

In this example, if the average dwell time is reduced to five days, to a value of half, the annual capacity will increase, with a rise to double:

$$C = \frac{(1224 * 4 * 0.7 * 365)}{(5 * 1.3)} = 192.450 \text{ TEUs}$$

The example above demonstrates that container dwell time is an important factor affecting the capacity of a container terminal. The increased dwell time will lower the stacking capacity. In other words, taking some measures to decrease the dwell time will result in a rise in the capacity of the port. Therefore, the ports working with high operational factors, which means that already using the majority of the stacking capacity, should take some measures before placing the operable level of the terminal at risk. Those measures may either be decreasing the dwell time of the containers or transporting some of the containers directly to a dry port. Sending the containers directly to a dry port will produce an effect as if the dwell time of those directed containers are less than a day.

5.4. Calculating the Annual Stacking Capacity of Kocaeli Terminals

The factors of the stacking capacity of a container terminal were discussed in the previous section. The calculation of three container terminals' annual stacking capacities is explained in section. The three container terminals, YILPORT, EVYAPPORT, and DP WORLD PORT were selected due to the availability of their statistics and the data about ground slots. The stacking capacities of these terminals were calculated depending on some assumptions related to the factors. The factors other than the ground slots are assumed as stated below:

H = 6 (The maximum number of tiers of the operating RMG/RTG).

S = 0.88 for the maximum capacity of main terminals in relation to the formula (5.3), and S = 0.70 for the optimum capacity of these terminals.

W = 365 days, assuming that every day throughout the year is working days.

DT = 7 days.

P = 1.1 (Although higher peak factors were observed in some terminals in certain periods, it is assumed that the average increase will be about 10% between the two successive months of any terminal).

The annual stacking capacities of the selected container terminals were calculated by utilizing the formula (4.1) in the following subsections.

5.4.1. Calculating the Annual Stacking Capacity of YILPORT

G = 2332 (the sum of the main terminal and the inland depot).

<u>Maximum capacity of YILPORT:</u>

$$C = \frac{(2332 * 6 * 0.88 * 365)}{(7 * 1.1)} = \frac{(4.494.230)}{(7{,}7)} = 583.666 \text{ TEUs}$$

Optimum capacity of YILPORT:

$$C = \frac{(2332 * 6 * 0.70 * 365)}{(7 * 1.1)} = \frac{(3.574.956)}{(7{,}7)} = 464.280 \text{ TEUs}$$

YILPORT, as exhibited in Figure 5.5, realized a throughput volume of 552.000 TEUs in 2018, although its calculated optimum capacity was below this volume. This situation can be explained in two ways: (1) The average dwell time in YILPORT may be less than the adopted values. For example, if the dwell time were about five days in YILPORT's terminals, the total maximum stacking capacity would be 817.132 TEUs. In other words, if it is managed to bring the container dwell time down to five days in YILPORT, the annual stacking capacity will increase by about 40%. (2) The other consideration may be that YILPORT is operating over its capacity. Actually, during a field study visit, it was observed that some containers were stacked on the land area that was not allocated for ground slots. This situation was implying that the terminal needed extra stacking area in addition to the marked ground slots. YILPORT has a very limited land area. It has no possibility to expand its area towards the land. The only possible option to expand the area is filling the sea.

YILPORT states its annual capacity as 1.000.000 TEUs. Actually, the calculated maximum and optimum stacking capacities are below this value. But according to the assumption that the average DT is five days without any peaking period, the full capacity[8] of YILPORT would be calculated as 1.021.416 TEUs. This situation puts forward the importance of each variable in calculating the stacking capacity of a terminal.

[8] The term "Full Capacity" implies the situation that all slots (see Figure-4.17) within the capacity of the gantry’s stacking limits are completed with containers. Therefore it is impossible to stack any more container. This situation can be expressed numerically as S = 1.

5.4.2. Calculating the Annual Stacking Capacity of EVYAPPORT

G = 3900.

Maximum capacity of EVYAPPORT:

$$C = \frac{(3900 * 6 * 0.88 * 365)}{(7 * 1.1)} = \frac{(7.516.080)}{(7{,}7)} = 976.114 \text{ TEUs}$$

Optimum capacity of EVYAPPORT:

$$C = \frac{(3900 * 6 * 0.70 * 365)}{(7 * 1.1)} = \frac{(5.978.700)}{(7{,}7)} = 776.454 \text{ TEUs}$$

EVYAPPORT states its annual capacity as 855.000 TEUs, which is within the range of its calculated maximum and optimum capacities. As exhibited in Figure 5.5, EVYAPPORT realized a throughput volume of 688.000 TEUs in 2016, as the highest volume in the last three years. This value corresponds to 70% of its maximum capacity and 88% of its optimum capacity, regarding the assumptions stated above.

5.4.3. Calculating the Annual Stacking Capacity of DP WORLD

G = 7000.

Maximum capacity of DP WORLD:

$$C = \frac{(7000 * 6 * 0.88 * 365)}{(7 * 1.1)} = \frac{(13.490.400)}{(7{,}7)} = 1.752.000 \text{ TEUs}$$

Optimum capacity of DP WORLD:

$$C = \frac{(7000 * 6 * 0.70 * 365)}{(7 * 1.1)} = \frac{(10.731.000)}{(7{,}7)} = 1.393.636 \text{ TEUs}$$

DP WORLD PORT states its annual capacity as 1,3 million TEUs, which is close to its calculated optimum capacity. As exhibited in Figure 5.5, DP WORLD PORT realized a throughput volume of 576.000 TEUs in 2018. This value corresponds to 33% of its maximum capacity and 41% of its optimum capacity, regarding the assumptions stated above.

5.5. Evaluating the Current Capabilities and the Future Requirements to Support Container Transportation in Kocaeli Region

The statistics given in Section 4.1 implies that the Kocaeli ports have been increasing their transaction volumes at higher rates than the average of Turkey and the World. The Kocaeli ports are expected to play more active roles in the future. But on the other side, it is a fact that those ports and consequently the Kocaeli region are having problems especially in terms of limited land areas and poor transportation systems. Kocaeli Chamber of Industry takes the initiative to find solutions to those problems. In a forum held in 2011, connecting the Kocaeli ports with industrial organizations through railways and constructing dry ports have been specified as the prominent requirements of the region (Erdoğan, 2011).

The Secretary-General and the Board Chairman of TURKLİM also highlight the railway connection of the ports[9], indicating that "For the overall facilities in Kocaeli Gulf, railway connection stands as an important requirement to transport the cargoes handled in ports to the provinces and Organized Industrial Zones".

The opinions of TURKLİM about logistics villages and dry ports can be summarized as stated below:

Logistics villages regulate the flow of goods as domestic and overseas and provide direct access to products to global and regional markets. If they are in close relationship with all transportation modes, those logistics facilities provide the most efficient use of

[9] Information gathered during the interviews at Headquarters of TURKLİM on 5th April 2017.

resources by gathering the basic services of transportation in a single point, consequently reduce transportation costs. When establishing a logistic village or dry port, the following should be considered (TÜRKLİM, 2010):

i. It should be located close to the ports with high transaction volume,
ii. It should have a good road and, if possible, a railway connection with ports, collection and distribution channels,
iii. Depending on the volume of cargo that will increase in the future, these transport connections should be able to be improved,
iv. It should have sufficient land area and future growth possibilities should be considered,
v. It should not require field regulations that might increase the investment cost,
vi. Construction density related to urbanization should be low,
vii. Development projects of ports and future freight traffic should be considered,
viii. It should be suitable for carrying out the hinterland operations of ports,
ix. Ports should be able to operate in the location allocated to them within the establishment/logistics village, and even a structure (such as PPP) should be established in which they can take part in financing and management.

In Europe, dry ports are generally managed by PPP structures. Generally, the local authorities, the railway operators and the seaport authorities take part as partners of such PPP structures. The chambers of commerce and industry of the region, various companies interested in investing in the region also participate in those partnerships.

In Turkey, there is still no dry port serving in accordance with the concept. In this regard, TCDD has been constructing logistics centers and trying to encourage railway freight transportation. By now, a total of nine logistics centers have been put into service. TCDD is targeting to put into service a total of 21 logistics centers as seen in Figure 5.21.

There are three railway lines between Köseköy and Gebze, two lines for high-speed train, and the third one conventional line, which is also used for freight transportation. Since it would be very constraining to operate over only one line, TCDD is planning to construct some siding sites[10] to support the freight transportation on this third line. It was stated by the Capacity Department Manager[11] of "First Regional Directorate of TCDD" that, "the capacity of the line could rise to 72 train services reciprocally in a day, provided that all of the planned siding sites are completed on this conventional line".

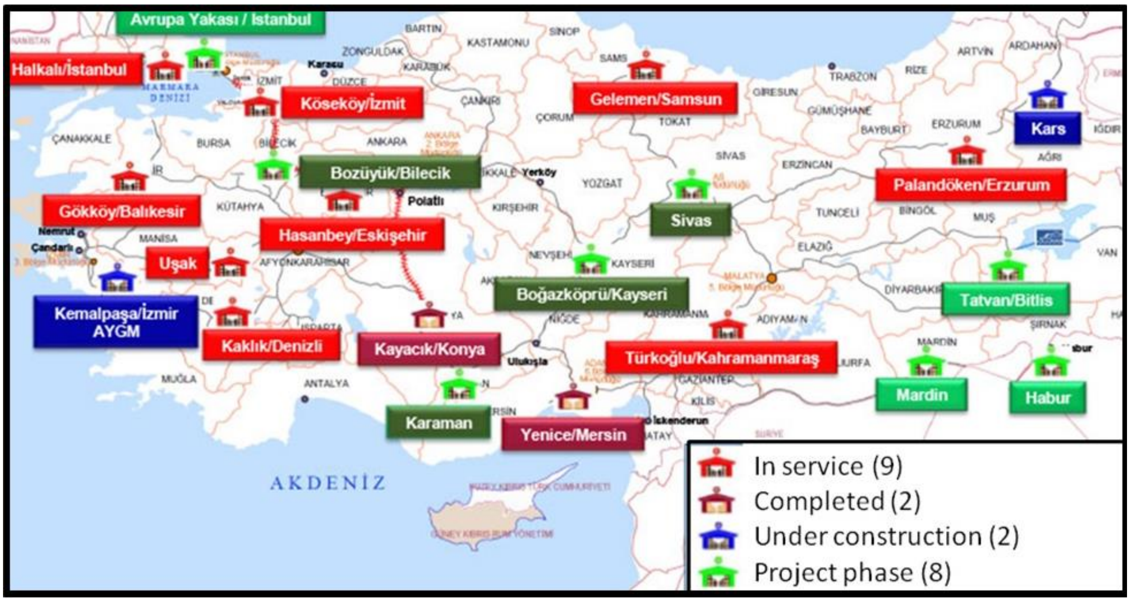


Figure 5.21. The locations of TCDD logistics centers.
(**Source:** http://www.tcdd.gov.tr/content/33)

The capacity of the locomotive is the essential factor in determining a total load of a train shuttle. With a general acceptance, the total load of the train shuttle should be a maximum of 2000 tons (Saka and Çetin, 2019b).

The dimensions of the containers are taken into account in producing the railway cars. The length of a railway car (between the two-car bumpers) carrying 40 feet container is approximately 13.86 meters whereas that of 60 feet container carrying car is about 19.64 meters (TUDEMSAŞ). An image of such a railway car is seen in Figure 5.22.

[10] Siding sites providing meeting points and consequently ensure the traffic flow and increase the capability of the line.

[11] Stated during a field study visit on 13th February of 2019.

Figure 5.22. A typical railway car to transport container.
(**Source:** http://www.tudemsas.gov.tr/)

A 60 feet container carrying railway car can haul a total weight up to 80 tons. A train shuttle can carry up to 90 TEUs of containers in total depending on the weights of the containers. A train shuttle with 26 railway cars, each capable of carrying 60 feet container, including the locomotive would have a total length of about 530 meters. Since the length of the railway lines is 600 meters or more in EVYAPPORT and SAFİPORT, they could accommodate such a train shuttle. But it would be impossible for DP WORLD PORT, which has only one railway line with 500 meters. Therefore, the intermodal transaction capacity of DP WORLD PORT will be less than EVYAPPORT and SAFİPORT. On the other side, there is still no clear information about the future intermodal capability of BELDEPORT. However, it is expected to have sufficient capability due to the availability of the land area.

If a train shuttle is constituted with a total of 26 railway cars each carrying 60 feet length of containers, a total of 78 TEUs of load could be transported by each shuttle. If two-thirds of the capacity of the conventional railway line between Gebze and Köseköy is allocated for freight transportation, a total of 48 train shuttles reciprocally could be managed daily. By allocating the two-thirds of the capacity for freight transportation would make it possible to transport 3744 (78*48) TEUs of containers from seaports to inland terminals every day. This amount of daily capacity creates a total of 1.366.560 (365*3744) TEUs capacity in a year.

The share of the railways in Turkey to transport the cargo between ports and cities is very limited, only 2.4% according to a study having made by the general directorate of infrastructure investments of the Ministry of Transportation and Infrastructure in 2015 (MTI, 2015). But the logistic vision of Turkey indicates the target of 2035 as increasing the share of railway transportation of goods to 20% (MTI, 2018). Therefore, it is assessed that TCDD will provide higher transportation capacity in the future.

5.6. The Required Capabilities of a Dry Port to Support Container Transportation in Kocaeli Region

The Kocaeli container terminals currently have a total capacity of 5,4 million TEUs as indicated in Figure 5.9. After completing the modernization project SAFİPORT this total capacity is expected to rise up to 6,4 million TEUs. Besides that, additional capacity could be acquired by filling the sea by some of the port authorities. Such efforts could create about 10% additional stacking capacity for the region. In this way, Kocaeli container terminals might realize a total of 7 million TEUs capacity by 2035. But an optimistic scenario given in Figure 5.8 indicates that the demand for Kocaeli ports arising from the increasing container traffic might rise up to 8 million TEUs in 2035, which means that the total capacity of the Kocaeli terminal could come short for approximately one million TEUs.

According to the assumptions mentioned above, it is assessed that an additional one million TEUs of container stacking area could be necessary for the Kocaeli region in the years of the 2030s. Sending the overplus amount of containers directly to a dry port while stacking approximately 7 million TEUs of containers in the Kocaeli container terminals sounds like the best solution. Approximately one million TEUs of containers might be directed to a dry port in this circumstance. According to a calculation stated in the previous section, a capacity of more than 1,3 million TEUs can be provided for the railway transportation between Gebze and Köseköy. This capacity would suffice to accommodate the overplus demand. This situation also necessitates a well-established dry port to be able to handle about one million TEUs of containers within a well-established transportation network.

From a general point of view, a dry port must have almost every capability that a container terminal has, except the ability of unloading cargo from the vessels. The required capabilities and the specialties of the dry port in supporting container transportation through Kocaeli ports are stated in the following subsections.

5.6.1. Location

The distance between the seaport and the dry port is an important factor. Although there are numerous examples of inland ports located quite far from the seaports, when the primary issue is supporting the seaports, the dry port is preferred to be located close to the seaport(s). Wiegmans et al., (2015) states that it should also enable mass transportation between these two logistics nodes. Therefore when determining the location of the dry port, it should be taken into account that the location should enable easy and large capacity access to the transportation systems.

5.6.2. Handling Capability

The capabilities of a dry port have already been studied by many researchers. The specialty of transshipment and cargo handling facilities have been highlighted by some of these researchers (Ng and Gujar, 2009; Roso and Lumsden, 2010; Korovyakovsky and Panova, 2011; Beresford et al., 2012).

It was mentioned in “Section 4.5” that it could be possible to transport about 3744 TEUs of containers daily on the conventional railway line between Gebze and Köseköy provided that TCCD completes the required infrastructure constructions. If it is assumed that half of the containers are 20 feet (1 TEU) and the other half 40 feet (2 TEU), approximately 2496 containers could be transported to dry port and be handled by the equipment in the terminal. In this case, it is understood that the equipment to be installed in order to unload the incoming containers should operate at a speed of a minimum of 100 movements per hour. On the other side, another equipment group with similar capacity will also be needed to load the containers on to the carriers (trucks or railway cars) to transport the goods to their final destinations.

5.6.3. Storage of the Containers

It can be considered that a dry port is a developed version of a freight terminal. Slack (1999) states that the storage of the cargo is one of the essential functions of a freight terminal. Similarly, a dry port has to allocate an available room to unload the cargo from its carrier, to stack it and store throughout its dwell time, and to prepare it to be delivered. The type of container (empty, filled, and refrigerated, etc.) also has to be taken into account when stacking.

For the dry port to be constructed in the Kocaeli region it should be regarded that the storage area in total should be able to accommodate at least one million TEUs of containers annually or 3744 TEUs of containers daily. The storage area should be designed to facilitate unloading from railway cars and to load on to the other carriers.

5.6.4. Railway Lines

As mentioned in the literature review (Third part) a dry port is also an intermodal terminal generally having additional modes such as railway or inland waterway other than the road. Since the geographical features of the region are not attractive in terms of inland waterway transport, the dry port should have the capability to change the mode from/to railway transportation. This specialty necessitates a minimum three railway lines within the dry port; one for unloading purposes, one for loading purposes, and the other for immediate maneuver purposes. Additional railway lines would absolutely facilitate the processes in the dry port terminal. The railway lines for unloading and loading purposes should have length preferably more than 600 meters.

5.6.5. Customs Procedure

One of the most important features of the dry port is the possibility of customs inspection. Otherwise, it would be nonsense and even impossible to send the containers directly to the dry port without making customs inspections in the seaport. A separate area should be allocated for the customs procedures and also adequate office areas should be allocated for the authorized customs inspection companies.

5.6.6. Container Freight Station

A dry port should provide some other facilities related to containers in addition to the ones for unloading and loading activities, storage, and customs procedures. Among them, container freight station aims at the activities for stuffing/stripping the containers and the "Value-added logistics services[12]".

5.6.7. Maintenance/Repair of Containers

Another separate station would be necessary for the containers got damaged or need some maintenance. This station should provide a service to repair the containers and to carry out maintenance of the containers.

5.6.8. Parking Area for Carriers

The incoming containers would be transported to their final destinations after the dwell time. While some of them would continue their routes on railways, some others would be transferred to the trucks. Making a rough estimation, it can be assumed that half of the cargo would be transported by trucks from the dry port to their final destinations. In this case, as an average number, 1248 containers could be loaded to the trucks in a day[13]. It can be estimated that on average, 52 containers per hour will be loaded on to trucks. Assuming that a truck could arrive at the parking area 3 hours prior to the loading activity, a parking space large enough to accommodate at least 156 trucks would be needed.

[12] Value-added logistics services refer to some detailed logistics activities such as labeling, combining the freight, manufacturing on a small scale and some other customized services related to the needs of the customers.

[13] "In sub-section 4.6.2." it was calculated that 2496 containers could be transported to dry port in a day. It can be assumed that this number of containers would leave the dry port after the dwell time. Half of this number equals to 1248, indicating the number of containers to be loaded on to the trucks.

5.6.9. Other Facilities

Additionally, offices and/or buildings for the logistics companies should be allocated within the dry port. Social facilities should also be taken into account both for the customers and the personnel.

5.7. Designing a Dry Port

Saka and Çetin (2019b) studied on designing a dry port and calculated the required area to construct that dry port. The study grounds that the total terminal area involves three main sections. The main sections are the apron, container storage area (primary yard area), and the secondary yard area including all other facilities (Thorosen, 2003) explained in the previous section.

The following formula (5.4) and explanations were adapted from the studies of Thorosen (2003).

$$Y_T = Y_S + Y_F + Y_E + Y_O \tag{5.4}$$

Where,

Y_T = Total yard area.

Y_S = Container stacking area (Yard area for container stacking), generally corresponding to a rate between 50-75% of Y_T.

Y_F = Container freight station (CFS) area, generally corresponding to a rate between 15-30% of Y_T.

Y_E = Area for storing empty containers and for the facility to carry on maintenance and repair of the containers, generally corresponding to a rate between 10-20% of Y_T.

Y_O = Area for other facilities such as entrance, working offices, customs inspection, parking, etc. This area generally corresponds to a rate between 5-15% of Y_T.

Taking into account this information, a general design of a dry port can be exemplified as seen in Figure 5.23.

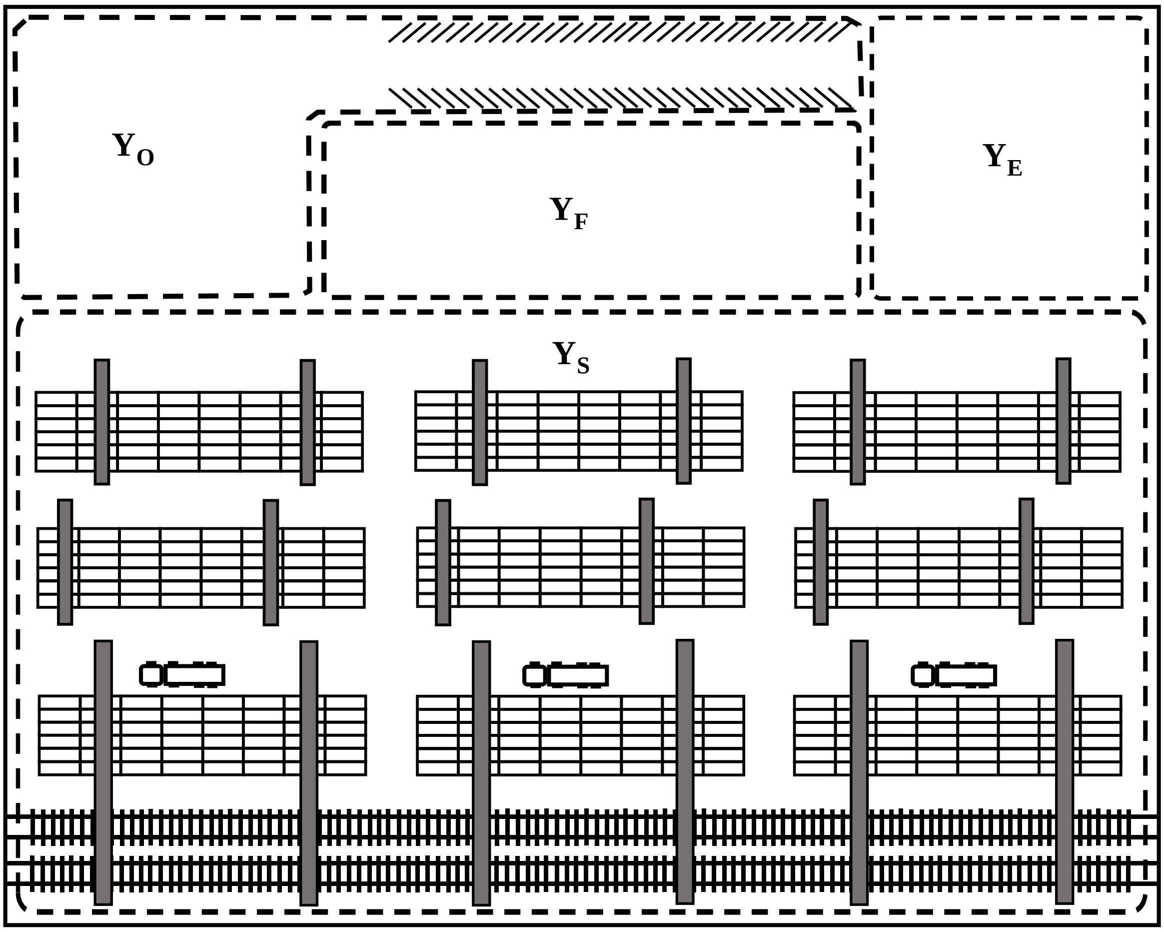


Figure 5.23. A general model of a dry port terminal yard.
(Prepared by the Author)

5.8. Calculating the Required Storage Area of a Dry Port

Calculation of a yard area that will be used for stacking the containers has been studied by various authors and some formulas have been developed in their studies (Chu and Huang, 2007; Hoffmann, 1987; UNCTAD, 1985; Frankel, 1987; Güler, 2001; Tsinker, 2004; Thoresen; 2003). The below stated formula (5.5) is a harmonization of those authors' studies. Saka and Çetin (2019b) used this formula (5.5) to calculate the "Required storage area (A)" (as a value in m^2) of the prospective dry port that would be constructed to support the container transportation through Kocaeli container terminals.

$$A = \frac{C * a * DT * P}{W * S * H * U} \tag{5.5}$$

The explanations of the variables (Var.) in formula (5.5) and the values taken to calculate the required storage area are seen in Table 5.6.

Table 5.6. The explanation of the variables and the values assumed for calculation of the required storage area of the prospective dry port.

Var.	Explanation	Value Assumed	Note
C	Container volume expected in the period (TEU)	1.000.000	
a	Area per one TEU container (m^2). (A constant value indicating the area allocated for 1 TEU, as a ground slot)	21,6	(1)
DT	Average container Dwell Time (day)	7	
P	Peaking factor ($P \geq 1$)	1,1	
W	Total number of working days in the period	365	
S	Storage utilization/operational factor, as a proportion ($0 < S < 1$)	0,75	
H	Height of stacked containers/ Number of tiers	6	
U	Total area utilization factor, as a proportion ($0 < U < 1$)	0,6	(2)

(**Source:** Güler, 2001).

Notes:

(1) 1 TEU container is assumed to cover an area of 21,60 m^2 (Güler, 2001).

(2) The total area utilization factor (U) is usually taken between 0,4 and 0,6 (Güler, 2001).

Using the values given in Table 5.6, Saka and Çetin (2019b) calculated the required terminal yard area as 168.767 m^2 (approximately 17 ha) for the container storage purposes in the prospective dry port.

$$A = \frac{1.000.000 * 21,6 * 7 * 1,1}{365 * 0,75 * 6 * 0,6} = \frac{166.320.000}{985,5} = 168.767$$

After determining the size of the container stacking area (Y_S) it is possible to calculate the total area of the dry port by using the formula (4.4) and designating the proportions for each section in this dry port. The proportions of the four sections below are considered to take into account the ranges explained by Thorosen (2003).

Y_S : 65%,

Y_F : 15%,

Y_E : 10%,

Y_O : 10%.

Knowing the volume of Y_S as approximately 17 ha, it is possible to calculate the total area of the dry port by creating the proportion stated below:

$$\frac{65\%\ of\ YT}{100\%\ of\ YT} = \frac{17\ ha}{?}$$

$$Y_T = (17 * 100) / 65 = 26,15 \text{ ha}$$

According to the calculation stated above, it is understood that the prospective dry port to be constructed for supporting container transportation through Kocaeli terminals should have a total area of 261.500 m^2, in other terms 26 ha.

The other parts of the dry port are calculated as follows:

Y_F = 0,15 * 26 ha = 3,9 ha,

Y_E = 0,10 * 26 ha = 2,6 ha,

Y_O = 0,10 * 26 ha = 2,6 ha.

5.9. Financing Models for Dry Ports

The establishment of dry ports requires high investments. The acquisition of land, the realization of infrastructure, the establishment of intermodal facilities, warehouses, and other logistics facilities, the provision of technological infrastructure and other related works require high financial resources. Such a high-level financial resource requirement makes it difficult to realize such investments as direct private investment. Since a dry port would bring in benefits for logistics service providers, logistics service purchasers, and society, public authorities become important actors in realizing such high-level investment requiring projects (Ünal and Erdal, 2014).

Since the private sector refrains from because of the high investment requirement, and the public sector has a deficiency of financial budget and sectorial specialty, the Public-Private Partnership model is getting the most appropriate model to finance high-level investments such as constructing a dry port. It is seen that many successful PPP models are realized in dry port projects all over the world, especially in Europe. On the public side of the partnership, municipalities are generally seen. On the other side, seaport authorities, railway operators, logistics companies and any company located in the region are observed as taking place as partners in such projects.

For the case of the thesis study, it is assessed that the municipality whose borders involve the location of the prospective dry port should be the primary public partner of the model. The partnership of the municipality would bring in benefits especially for new posts of employments, and being a source of income which in turn would be useful for the development of the environment that the municipality is responsible for. It would also be beneficial in terms of keeping the dry port authority within an environmentalist approach. Another public institution that may be a partner in such a model is considered as TCDD. The involvement of TCDD in this partnership will allow it to take a greater role in transport, resulting in more revenue. If the location of the dry port is determined to be a logistics center of TCDD, this partnership would be more effective and more meaningful.

In terms of the private sector, it is considered that the port authorities should primarily take part in such a partnership. Because the necessary coordination between the dry port and the seaport will be able to be managed quite easily in this case. A partner seaport authority may more easily take the necessary measures in the dry port area too, to ease the flows of the goods and storage of them in the yard area of the dry port, according to customer's demand. Perhaps the most important benefit is that it can provide faster processing of commercial loads, thus providing a competitive advantage over its competitors and ultimately increasing productivity and revenue. Kocaeli Chamber of

Industry or a group within this chamber may take part in the PPP model. In this way, the industrial companies could have the chance to ease the transportation of their products and to gain revenue. Any transportation company may also take part in such a partnership. In this circumstance, the transportation company will gain a competitive advantage since it will have the chance to transport the goods more quickly and providing its customers with a more economical choice. Freight forwarder companies also may take part in this model. This time the customers of that company might benefit by using the dry port and the freight forwarder company might be preferable. Besides the companies mentioned above, any company with the intent of making a profit may be a partner within this model. Any company that has analyzed the needs of the region well and anticipates that there will be intense demand for dry port implementation may consider taking part in such a model with the idea of making a profit by benefiting from its tangible assets.

The PPP constituted for the purpose of implementing a dry port would not only invest for the infrastructure and the equipment but also could invest for the transportation line and the carriers that would carry the goods on this line. For example, the Barcelona Port Authority, as the major partner of a PPP model, made its biggest investment for constructing an intermodal station in developing the Zaragoza Maritime Terminal, which is, in fact, a dry port and approximately 300 km from the port of Barcelona.

In the case of this thesis study, TCDD is considered to be the major partner in the proposed PPP model. It could provide benefits in terms of transportation and intermodal terminal within the dry port.

The involvement of the municipality could bring in benefit in the acquisition of the land area on which the dry port is planned to be constructed, in regulating and supervising the environmentalist rules, and creating new jobs for the community living in the region. Therefore, the municipality is also considered to be a partner, even if with a small share, to provide the above-mentioned benefits.

For the private sector, it sounds important and beneficial to the participation of the port sector. If only one seaport becomes a partner, it could gain a hugely competitive position over the others. If all container terminals participate in the partnership model, then they might arrange an equitable organization. This model might open a road to combine the Kocaeli container terminals in a sole platform, combining their abilities and power to be able to compete with other ports located in the Marmara Sea. By the way, each container terminal can benefit from the increased transaction volumes equally.

A PPP model with participation from both the port and the transport sector is considered a remote possibility. Because it seems difficult to reach a line where their interests overlap. In some circumstances, the port sector's earnings will increase, while the transport sector's earnings will decline, and vice versa.

If only one transportation company participates in the PPP model from the private sector, this company will gain a huge competitive advantageous over the others. If more than one company participates, this time those companies might arrange an equitable organization and may benefit from the increased transaction volumes equally.

Developing a PPP model to construct a dry port for supporting the container transportation through the Kocaeli container terminals will absolutely have a multiplier effect due to the combination of Powers. Investment by each partner alone will result in a low level of earnings, but as a result of the merger of powers, the rates of earnings will rise.

5.10. Customs Procedures in Dry Port System

The custom procedure is an inescapable stage for the foreign trade cargoes. An import container arriving at a seaport is generally undergone a custom inspection procedure during its stay in that seaport terminal. But a slightly different application is required for the dry port system since the purpose of the dry port concept is to send the container directly to the dry port. In this way, the seaport will carry out only the activities of unloading the container from the vessel and loading it to the railway carrier. All the other activities, including the customs procedures that were used to be applied by seaports, will be carried out in the dry port.

As stated in section "4.6" a dry port should have the ability of customs procedures. According to the Turkish Customs Law No. 4458, if there is an authorized customs mechanism, it is possible to transport the cargo subject to the transit regime from one internal customs administration to another internal customs administration by rail. In the section of the law concerning the transit regime, the relevant points referred to in Article 84 are set out below:

> “1. Transit regime is applied for the items, to be moved from a point within the Customs Territory of Turkey to another.
> 2. The customs authorities allow the goods, which is subject to a transit regime, to be moved in the customs territory of Turkey, …
> d) From one internal customs administration to another internal customs administration,
> 3. The products subject to the transport by rail transit procedure in the customs territory of Turkey, CIM [14] transport document is used.”

According to this provision of the Law, a cargo arriving at the sea port can be shipped directly to the dry port on the railway without being subject to any customs inspection at the sea port, provided that a CIM certificate is issued.

5.11. Summary of the Field Studies and the Related Research Studies

Global seaborne trade continues to expand. While the ports all over the world strive to get more share of the growing maritime transport, Turkey's ports have exhibited better performance than that of the world average in recent years. Especially the Kocaeli ports have recorded remarkable performance in this period.

Container transportation is expected to grow increasingly. The fact that general cargo loads are transformed into container loads is thought to be effective in this increase. This development is expected to be realized at a higher rate for Kocaeli ports. While it is estimated that the total capacity of the Kocaeli container terminals might reach seven million TEUs per year until 2035, the demand for those ports is expected to increase to

[14] An internationally standardized freight document issued in rail transport. CIM stands for “Convention Internationale concernant le transport des Marchandises par chemin de fer”. The agreement has been in force since 1965, and constitutes the legal basis for the conclusion of freight contracts in international rail goods transport using one freight document.

eight million TEUs in that time with an optimistic projection. It would be appropriate to take measures to meet this possible surplus. The construction of a dry port to support container transportation through Kocaeli container terminals is considered a viable option.

It is obvious that rail transport will be the most important means for Kocaeli container terminals to adapt to the dry port concept. Currently, two ports have railway connections, construction for one port is in progress and a connection for one port is within the planning stage. On the other hand, TCDD is planning to increase the transportation capacity between Gebze and Köseköy. It is assessed that the railway capacity will be able to meet the possible demand in 2035, provided that those projects are completed.

The container storage area is an important factor for the annual capacity of a container terminal. While the volume of the stacking area affects the capacity linearly, dwell time has an adverse effect on capacity. That means, decreasing the average dwell time of the container will result in increased capacity, which provides working at operative levels in the terminal. For a seaport which is about to suffer because of the lack of space, the collaboration with a dry port will produce an effect as if rescuing from chaos.

Kocaeli region has an important role in both transferring the export products to the seaports and transporting the import goods to inland locations. Kocaeli ports have a very large hinterland and they are expected to become more competitive with the improved network quality. In the studies carried out under the coordination of the Kocaeli Chamber of Industry, transportation was determined as a priority need and especially the need for infrastructure investment in order to benefit more from railway transportation was emphasized. TURKLİM has similar opinions with additionally highlighting the need for logistics villages or dry ports.

A dry port constructed with the intent of supporting container transportation should have almost all abilities that a seaport has, except the capability of loading and unloading to and from a vessel. Therefore, a dry port terminal might be designed similar to a container terminal. Approximately two-thirds of a terminal shall be allocated for the purpose of storage. Taking into account this approximate ratio, it’s been calculated that a minimum land area of 17 ha is required for container stacking, whereas a minimum 26 ha land area in total is needed to constitute such a dry port.

Since it requires a huge amount of investment to construct a dry port, a PPP model could help to constitute the needed dry port which is envisaged to support the container transportation through Kocaeli ports. It would be appropriate to constitute such a model with the initiative of TCDD. Besides TCDD, it is considered appropriate that the seaports and the municipality also participate in this partnership. Another option could be the participation of one or more transportation companies. By creating a PPP model, the actors involved in the process will be able to adopt the issue in a more comprehensive way and ensure that the investment that a partner cannot make alone can be realized with the help of other partners.

The dry port application could relieve the sea ports by transferring most of the procedures to its own responsibility. The customs procedure is among those activities. According to the Turkish Customs Law No. 4458, it is possible to ship a container directly to the dry port without having to wait in the sea port for customs control, and customs inspection can be carried out in the dry port. This application will be beneficial more to transport companies. Transport companies will have more economical transportation options. Besides, a carrier will pay less warehouse fees for the freight that will wait in the dry port. The reason for this is that the land on which the sea port is located is more valuable than the location of inland. On the other side, a dry port could help a seaport which is about to suffer from the lack of space.

6. DETERMINING THE DRY PORT LOCATION

Determining the location for the dry port that will support the Kocaeli container terminals constitutes the first research objective. The location is determined by applying an Analytic Hierarchic Process (AHP). Detailed information on AHP applications is described under the heading "6.2. Planning and Preparatory Phase of AHP" of this section.

Kocaeli ports are the most important gates for global trade not only for Kocaeli city but also for Turkey (MARKA, 2015). Marmara region hosting the Kocaeli ports is also a region that contributes significantly to Turkey's foreign trade. About 30% of Organized Industrial Zones (OIZ) in Turkey are located in this region. Transporting the export/import goods to/from the ports to inner regions requires a very good logistic integration. A dry port within this integration might contribute significantly to support the seaports and the transportation of the goods.

Two aspects may be considered in determining the location of a dry port. First, it may be considered to be located very close to the production centers. On this occasion, it might be easy grouping the goods and mass transportation to the ports. As the second aspect, it may be considered to be located close or in mid-range to the seaport. On this occasion, the dry port might function as increasing the stacking capacity of the seaport and relieve the seaport in some other functions. In this study, the possible locations on which a dry port might be constructed are specified as alternatives at first step, and in the following steps they're analyzed and one of them is selected as the best alternative by applying AHP.

6.1. Investigating the Possible Land Areas for Dry Port Location

First of all, an ideal dry port must have a large enough land area and connection to a satisfactory transportation network that will easily connect it to the local ports, to the production centers and to the consumption centers. The size of a dry port may differ related to the needs, but after examining the current examples in the world it's been observed that dry port should have a uniform land area with more than 10 hectares. The proximity of the area shall not be surrounded especially by urban settlements and by other facilities that may obstruct the expansion of the prospective dry port. Access to transportation networks is another fundamental feature in determining the area of a prospective dry port. Especially the possibility of a railway connection will enrich the area since it will have the chance to develop as an intermodal logistics facility.

The studies for determining the alternative locations have been carried out in three steps. In the first step, a working group meeting was held at the "East Marmara Development Agency (MARKA)" on the 4th February of 2019 in Kocaeli to search for the possible locations. Four alternative land areas were suggested in this working meeting. In the second step, another working group meeting was held at the "First Regional Directorate of TCDD" on the 13th of February 2019 in Haydarpaşa/Istanbul to evaluate the possibilities of railway connections. In this meeting, two of them were assessed possible and three other alternatives were offered. The overall evaluation has been carried out by the author taking into account some criteria and the features of the alternatives in the third step. The details of these studies are explained in the following subtitles.

6.1.1. Possible Locations on Which a Dry Port can be Established in East Marmara Region

Detecting an area large enough especially close to the industrial areas is a very hard job. Four locations were adopted as possible locations for a dry port at the working meeting at MARKA. These locations are seen in Figure 6.1 and explained below.

Figure 6.1. The potential land areas for a dry port in East Marmara region.
(Prepared by the Author)

6.1.1.1. Darıca. Above the facilities of Aslan Cement, there is a large area of about 50 hectares of state land in this location, which is a quarry. The size of this area and its proximity to the ports in Dilovası are advantageous in terms of a logistics facility, but its proximity to the residential area, the distance to the industrial zone and the difficulties in providing the railway connection arise as disadvantages.

6.1.1.2. Dilovası OIZ. It is a fairly large area of about 140 hectares with an approximate shape of a triangle between the Trans European Motorway (TEM) and the D-100 motorway. It is considered that the state has a policy of shifting the industrial facilities easterly from this region and the industrial facilities here will be taken out of the region in the long term. However, due to the assumption that this movement can be carried out one by one, not as a whole, it would take a long time to prepare a large piece of land area to build a dry port. If this area is completely emptied, an ideal dry port area will be reached in size. The proximity to TEM and D-100 motorways will bring advantages in terms of transportation. It is also close to the ports of Kocaeli, especially the ports in Diliskelesi.

6.1.1.3. Asım Kibar OIZ. There is an empty land area approximately 25 hectares at South-East of the Asim Kibar OIZ. Since the land is private property, the cost of the purchase will be quite high. It is estimated that the North Marmara Highway, which is planned to be constructed in the future, will divide this land. A two-piece land on both sides of such a highway can be considered as an advantage to establish a logistics facility.

6.1.1.4. Cengiz Topel Airport. There is an empty land area of private property which is about 13 hectares on the north of Cengiz Topel airfield. Its size is sufficient to establish a logistics facility. However, there are plenty of residential areas around. This situation makes it very troubled to provide a railway connection to this area. In addition, since the area is private property, the purchase cost will be very high.

6.1.2. Evaluating the Feasibility of Railway Connection of the Alternative Locations

The possible dry port locations suggested by MARKA were assessed in terms of the railway connection feasibility in a working group meeting with the Deputy Regional

Director of TCDD First Region and other authorities from the regional directorate on 13th Feb of 2019. The authorities of the TCDD First Regional Directorate have been in agreement with the location adjacent to "Asım Kibar OIZ" but expressed the difficulties for the other alternatives. On the other hand, they proposed another location further north of Dilovası OIZ. In addition to these two locations they proposed three logistics centers (see Figure 6.2.) in the hinterland of Kocaeli ports: firstly, the Kosekoy logistics center whose land area is planned to be expanded and located very close to Kocaeli city; secondly the Hasanbey logistics center very close to Eskisehir; and thirdly Bozüyük logistics center, which is still under planning session and located close to Bozüyük.

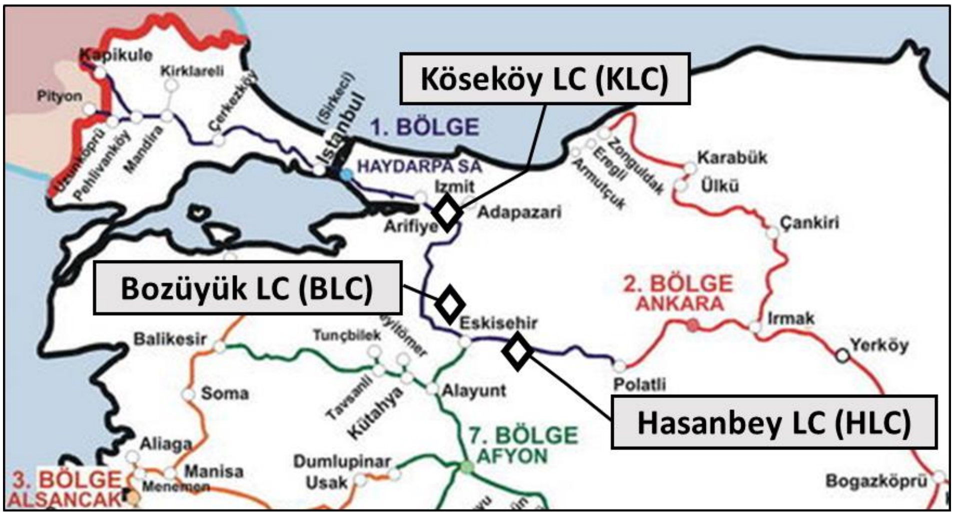


Figure 6.2. TCDD logistics centers as probable dry ports in the hinterland of Kocaeli ports and the railways map. (**Source:** http://www.tcdd.gov.tr/)

The evaluations of all alternatives in terms of railway connectivity are explained below:

6.1.2.1. Darıca. The suggested area is far from the railways. There are lots of urban areas between the railways and the quarry. Besides, there is a big difference between the altitudes of those areas. The density of the urban areas and big altitude differences make it very hard and very expensive work to connect the railways towards that land area.

6.1.2.2. Dilovası OIZ. The altitudes of the area are between 5 and 10 meters, as well as the distance from the south edge to the main railways is about 700 meters, which seems as a very close distance and as an advantageous condition. But the fact is that the vacant area through which the railway connection may be applied is a hilly area on which the altitude makes a peak towards 90 meters. Constructing a railway connection to this area is a very hard job as it is for the area at Darıca.

On the other hand, there is another OIZ which is a larger one and about 9 kilometers north-east of this one. The authorities of the TCDD First Regional Directorate expressed that the "North Marmara Highway" which is on the planning stage will pass from the north of this large OIZ. TCCD is also planning to construct a railway with at least three lines alongside this new highway. When those plans will have been put into practice, the north side of this large OIZ may be a very good alternative to construct a dry port since it will be both close to the transportation lines and to a big industrial zone.

6.1.2.3. Asım Kibar OIZ. The projected "North Marmara Highway" and the prospective railway lines are predicted to pass from the north side of Asım Kibar OIZ. In the future when these plans are put into practice, it will be possible to connect the transportation lines to the industrial zone and to the prospective dry port area. Being adjacent to the industrial area will still bring in an advantageous situation for this land area.

6.1.2.4. Cengiz Topel Airport. This area may be considered to have similar conditions with the one near to Asım Kibar OIZ. But it has not any additional features such as being close to an industrial zone or being close to a seaport. On the other side, there is already a logistics center that may easily develop to become a well-established dry port, Köseköy Logistics Center, which is just several kilometers away.

6.1.2.5. Köseköy Logistics Center (KLC). It is one of the nine logistics centers of TCDD that has been put into service by now. Located approximately five kilometers east of Kocaeli, it has a good connection possibility to highways with about one-kilometer distance to D-100 and 2,5 kilometers to TEM. This center is a continuing project, the first section has been entered into service on 25 February 2010 on an area with about 90.000 m^2 and for the second section the study on the project is still going on. In the first stage, 5 loading and unloading roads and 60.000 m^2 concrete fields were constructed and 10.000 m^2 of this area has been being operated as Customs temporary storage area.

For the construction of the second project of Köseköy Logistics Center, an expropriation decision was made with the decision of the Council of Ministers published in the Official Gazette dated 11 January 2012, numbered 28170 and the expropriation process of the 286.000 m^2 area adjacent to the center was completed. Through the implementation of a good plan this center can serve as a well-established dry port.

6.1.2.6. Bozüyük Logistics Center (BLC). It is planned to be constructed between two OIZs in Bozüyük on a land area of about 650.000 m^2 and still on the project phase. The land area allocated for the project is not on the route of the railways. Since the location is about 4,5 kilometers north of the main railways, it is required to construct a junction to the prospective logistics center as well as to construct connections to both OIZs. It is planned to have 10 railway lines and eight loading docks.

6.1.2.7. Hasanbey Logistics Center (HLC). It is another logistics center that has been put into service by TCDD on the 19th of March, 2014. It is located on a land area of 540.000 m^2, 11 kilometers away from the center of Eskişehir and nine kilometers away from Eskişehir OIZ. It has seven railway lines and eight loading docks. HLC is directly connected to the main railways between Eskişehir and Ankara. There is a huge industrial area of more than 1,700 hectares close to HLC. But there is no connection between the HLC and the OIZ. The construction of a junction or junctions to the OIZ may boost especially the export goods transportation through the railways.

6.1.3. Assessment of the Author to Determine the Alternative Dry Port Locations

Having provided the relevant information from experts of MARKA and TCDD the possible dry port locations were examined in terms of several criteria explained in Table 6.1 to make a full appraisal of the possibility of being developed as a dry port.

The assessment of the author for the possible dry port locations in relation to these criteria is explained below. Five of them were deemed suitable and determined as the dry port location alternatives.

Table 6.1. The criteria to assess the probable dry port locations.

Criteria	**Explanation of the Criteria**
Size of the area	The size of a dry port must be more than 10 hectares for the necessary installations.
Providing the area	If it is a public land it will be easier to provide and use the area for the purposes of logistics provided that the government supports this idea. But it may be too expensive to provide the area if it is private property.
Surroundings	The area in the vicinity shall not be occupied by urban settlements. On the contrary, an empty area in the vicinity is a preference for the possible enhancements in the future.
Connection for transportation networks	It would be better to get connected to at least two different modes of transportation networks such as railway and highway. These networks should also be connected to the ports, production centers, and the consumption centers.
Proximity to seaport	A close dry port will provide more load distribution than a distant dry port within the hinterland of the sea port, because it would not be economical to transport the load through a distant dry port if the final destination of this load is at a place between that distant dry port and the sea port. The possible load distribution to the possible consumption centers and the hinterland of Kocaeli container terminals shall be taken into account in considering the proximity to the seaport.
Proximity to industry	Being close to an industrial area may be an advantageous situation for connecting the seaports with industry for the transportation of raw materials and the export goods.

(Prepared by the Author)

6.1.3.1. Darıca. The area is large enough to construct a dry port and since it is state land it may be easy to acquire the land for logistics purposes. It's close to the seaports located around Dilovası and might be helpful for transferring the goods among urban areas, industrial zones, and the seaports. But it is too difficult to connect the railways since the urban areas build a barrier between them and the big difference of altitudes also complicates the construction of the railways in this region. This area is eliminated because of the difficulty and complexity of constructing and connecting railway lines.

6.1.3.2. Dilovası OIZ. The southern part of this industrial zone is very close to the seaports but surrounded by urban areas and it's almost impossible to provide a junction from the main railways. On the other side, it's uncertain when the whole area may be appropriate to be utilized as a dry port. But another section of this OIZ located about nine kilometers at the further northern side will be lying close to the southern part of the North Marmara Highway and the new railway lines which are undergoing projects.

The area between the prospective North Marmara Highway and Dilovası OIZ is state land. This area might be beneficial for the industrial facilities in this zone. North Marmara Railway is not a remote possibility related to the North Marmara Highway and for a prospective dry port in this area, it is most likely to get connections with both transportation modes. This area will be far away from urban settlements. So, the north of Dilovası OIZ is deemed as a suitable alternative for dry port location.

6.1.3.3. Asım Kibar OIZ. The south of Asım Kibar OIZ will be most probably divided by the projected North Marmara Highway and the prospective North Marmara Railway. Being close to a large industrial zone area and to both prospective transportation lines are deemed to be the advantageous features of this area. Although the acquisition may be highly expensive since it is private property, being close to an OIZ and to the prospective transportation lines give advantageous features to this area. This area is also deemed as a suitable alternative for dry port location.

6.1.3.4. Cengiz Topel Airport. The north of Cengiz Topel Airport has some similar conditions with the previous alternative but it is more distant to prospective North Marmara Highway and it does not have a proximity situation to any OIZ. On the other side, it’s almost impossible to have a connection with railways because of residential areas. The existence of KLC already makes it unnecessary. So, the area on the north side of Cengiz Topel Airport is eliminated.

6.1.3.5. Köseköy Logistics Center (KLC). This area is already located on the railways with the possibility to enhance on a land area more than 30 hectares. There will be no additional cost for the acquisition of the land area. Although it is more close to the urban areas than the previous probable dry port locations, its location makes it easy to pass to both highways. The most advantageous feature of KLC is that it is only within 20-50 kilometers from the seaports located at Dilovası, Körfez, and Derince. It may develop as a well-established dry port with good planning. KLC is deemed to be a strong alternative for dry port location.

6.1.3.6. Bozüyük Logistics Center (BLC). It has not been put into service yet. After the completion of the project, it is supposed to have connections with two different industrial areas. The main railways pass 4,5 kilometers south of it. BLC is planned to be connected to the main railways. BLC is also deemed to be a good alternative for dry port location.

6.1.3.7. Hasanbey Logistics Center (HLC). It has a similar feature with KLC as being just on the main railways between Eskişehir and Ankara, locates only 11 kilometers away from the center of Eskişehir. It diverges from KLC because of that it does not have proximity to any seaport but to an industrial zone. The area of HLC makes it possible to construct a well-established dry port like KLC. HLC is deemed to be a good alternative for dry port location.

6.2. Developing an AHP Model

This section includes a theoretical background of AHP, an explanation of the stages of an analytic hierarchy process, stating the objective, structuring the hierarchy, designating and prioritization of the criteria of the AHP model.

6.2.1. Theoretical Background of AHP

A detailed literature review of AHP was explained in the third chapter (section 2.2.1). AHP is a multi-criteria decision-making approach introduced by Saaty in the 1970s to help decision-makers find the most suitable alternative in achieving their objectives. It is a quantitative method for organizing the alternatives and ranking them related to multiple criteria. In other terms, it is a method converting the verbal judgments to numerical values to compare the advantages of alternatives to each other. The superiority of alternatives to each other is clarified through pairwise comparisons related to each criterion. AHP is applicable for any kind of problem requiring a decision when there are some alternatives to be evaluated related to some criteria (Saaty, 1980; Saka and Çetin, 2019c).

The problem defined in this thesis requires a decision to find the best site as a dry port location. Five alternative locations were designated in the previous section. These alternatives will be evaluated related to some criteria. The criteria are determined as having been inspired by literature review and expert opinions. Thus, the AHP stands as an appropriate method to solve the research problem.

6.2.2. The Stages to Conduct an AHP Study

The stages of an AHP study are explained under the following subheadings.

6.2.2.1. Defining the Problem. The problem to be analyzed is chosen and defined. This problem will be the objective of the study that should be achieved by applying AHP.

6.2.2.2. Structuring the Decision Hierarchy. A hierarchical framework of an AHP begins with defining the objective or the problem as illustrated in Figure 6.3.

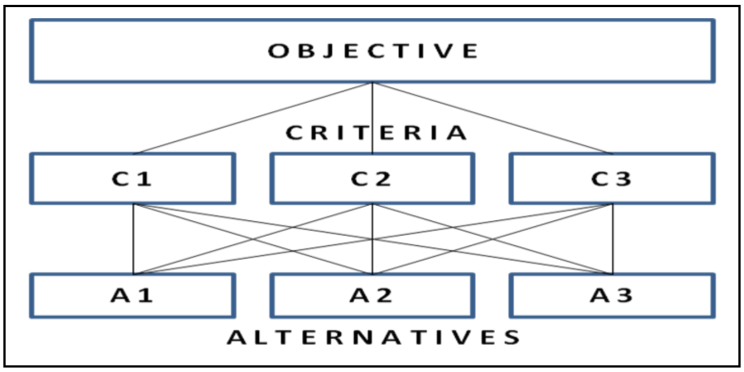


Figure 6.3. A sample for hierarchical framework of an AHP.
(**Source:** Mu and Pereyra-Rojas, 2017; Tütek, 2012)

The alternatives that will be analyzed in order to reach the goal and the criterion that will be taken into account when analyzing those alternatives are designated in this structure.

6.2.2.3. Constructing Matrices to Calculate a Set of Pairwise Comparison. Each criterion is used to compare all alternatives (decision points). It means that one matrix must be formed for each criterion. The comparison of the alternatives is done mutually by values related to the importance scale. The importance scale to be utilized in comparing the pairwise alternatives and the importance value attributed to each number are illustrated in Table 6.2.

Table 6.2. Importance scales to be used in pairwise comparison.

Importance Scale	Definition of Importance Scale
1	Equal importance
2	Weak/slight importance of one over another
3	Moderate importance of one over another
4	Moderate plus importance of one over another
5	Strong or essential importance of one over another
6	Strong plus importance of one over another
7	Very strong or demonstrated importance of one over another
8	Very strong to extremely importance of one over another
9	Extreme importance of one over another

(**Source:** Saaty, 2008)

6.2.2.4. <u>Calculation of the Relative Weight of the Elements</u>. The original pairwise comparison matrix (P) shows the importance levels of the factors relative to each other in a certain logic. P matrices are prepared as "m x m" dimensional, where "m" indicates the number of decision points (alternatives). All the mathematical procedures required for this stage can be defined in general as follows:

- **<u>First Step</u>**: The sum of each column of each P matrix is calculated.

- **<u>Second Step</u>**: Each matrix element is divided by this column sum. This operation is performed for each column. The resulting matrix is the normalized matrix (N).

- **<u>Third Step</u>**: The average of the row elements of the N matrix is calculated. These average values are determined as percentages. These averages form the final vector (F). F vector provides an estimate of the priorities of alternatives compared to each other. This step is repeated for each criterion "n" times, where "n" indicates the number of the criteria (conditioning factors) (Nefeslioglu et al., 2013).

6.2.2.5. <u>Calculation of the Consistency Ratio</u>. Although the AHP has a systematic coherence within itself, the realism of the results will naturally depend on the consistency of the decision-making between factors. AHP proposes a process for measuring consistency in these comparisons. The resultant Consistency Ratio (CR) provides the possibility to test the consistency of the priority vector found and hence the comparisons between factors (Saaty, 1980). AHP bases the essence of the CR calculation on the comparison of a number of factors with a coefficient (λ). For the calculation of λ, firstly, the "weighted sum matrix (S)" is obtained by multiplying the matrix (P) and vector (F). The sum of the rows results in weighted sum vector (S). Secondly, the consistency vector (C) is obtained by dividing (S) to (F). The maximum eigen value "λ_{max}" (6.1) and the consistency index "CI" (6.2) are calculated according to the formulas below, where "n" indicates the number of the alternatives. This stage is also repeated for each criterion.

$$\lambda_{max} = \left(\sum_{i=1}^{n} C_i\right) / n \quad (6.1)$$

$$CI = (\lambda_{max} - n) / (n - 1) \quad (6.2)$$

The Consistency Ratio "CR" (6.3) is calculated by dividing CI to the value of Random Consistency Index (RI) which is seen in Table 6.3 related to the number of the alternatives.

$$CR = CI / RI \quad (6.3)$$

Table 6.3. The value of random consistency index.

n	1, 2	3	4	5	6	7	8	9	10
RI	0	0.5799	0.8921	1.1159	1.2358	1.3322	1.3952	1.4537	1.4882

(**Source:** Golden and Wang, 1990)

The calculated CR value will shed light on whether the results obtained as a result of the AHP application are consistent. The CR value of less than 0.10 indicates that the comparisons made by the decision-maker are consistent. A CR value greater than 0.10

indicates either a calculation error in AHP or the inconsistency of the decision-maker in comparisons.

6.2.2.6. Weighting the Criteria. The priority of each criterion is calculated as a percentage. When grading the priorities of the criteria consulting the experts of the related sector might be the best method. If there is no data from experts to prioritize the criteria, the decision-maker shall make pairwise comparisons as applied in the third and fourth stages. The vector W, which contains the weights of each criterion, is obtained at the end of this phase.

6.2.2.7. Constructing the Decision Matrix. The weights of the decision points are combined to create the decision matrix (D) by using the F vectors which are obtained at the end of the fourth stage. The dimensions of the D matrix will be "n x m".

6.2.2.8. Obtaining the Resultant Vector. The resultant vector (R) is obtained by multiplying S matrix with the W matrix. Vector R exhibits the importance distribution of the alternatives for the objective. The values included in this vector represents the weights of the alternatives that have been gained at the end of the calculations of AHP.

6.2.3. The Objective of the AHP in this Study

The objective of the AHP in this study is to determine the most appropriate dry port location within the hinterland of Kocaeli ports. The alternative dry port locations have been determined by the assessment of the author explained in the article “6.1.3.”. Those alternatives were evaluated related to the criteria determined for the AHP of this study.

6.2.4. Designating and Weighting the Criteria of the AHP

Yang and Lee (1997) put emphasis on the location site characteristics in designating the criteria of their AHP model. In some other previous studies (Chatterjee and Mukherjee, 2013; Acar, 2016; and Abdoulkarim et.al., 2019) it has been observed that the features such as "transportation possibilities, cost of land, land ownership, space for future construction, availability of existing infrastructure, proximity to raw material, proximity to market, import and export" were taken into account in designating the criteria of their models.

In this thesis study, the criteria that will affect the decision-making process have been determined by taking the opinions of the experts from relevant sectors and by considering the literature. The main considerations for determining the relevant criteria are explained in the following paragraphs.

UNCTAD (1991) puts emphasis on the quality of the transport network in which the prospective dry port will take part in. The centrality of the location and road/rail connectivity of the new facility must be carefully considered during the decision making phase. According to Roso (2008) a dry, the port should absolutely have a railway connection for both mass transportation and a healthy environment. A dry port must contribute to environmental conditions by reducing the congestion in the city with the transition from road transport to rail and consequently reducing the CO2 emissions. Ministry of Transport and Infrastructure, evaluating the requirements for well-established transport networks, develops projects and encourages the entrepreneurs to connect as many as ports and industrial zones with the railways. The strategic plans on logistics indicate the aim of increasing the share of rail transportation to 20% in freight transportation until 2035 (MTI, 2018).

The investment on a sea port or a dry port necessitates a huge amount of financial resources. Public-Private Partnership model is a more common investment model recently since it makes it possible to invest in with a lower financial resource and to develop a joint venture to earn with a higher percentage for each partner. However, the cost of investment seems a very important subject of consideration in establishing any logistics facility. It is evident that the construction of a dry port will at first necessitate an appropriate land area. Some future-oriented plans may bring in some opportunities for some locations. Such possibilities will be dependent on mostly the strategic plans including the infrastructure investments such as highway and railway constructions. Such investments will absolutely bring in attractiveness for some locations, but the time to reach that situation may take a long way. In other words, some locations may already be appropriate to build some facilities whereas some locations must wait a long time to gain the similar features.

The opinions and considerations explained above lead to list the criteria that should be taken into account in the AHP study under seven headings. These criteria and the considerations that shall be taken into account when evaluating the alternatives are explained below:

6.2.4.1. Centrality of the Location in Transport Network. The location of a dry port should bring in some advantages in transporting the goods towards their destinations. Those destinations may either be a seaport, an industrial area or a consumption center.

6.2.4.2. Convenience for Transportation within the Hinterland. dry port should facilitate the transportation of goods by means of very well-established transportation networks. The intermodal capability and especially the railway connection will heighten the affordance of the location.

6.2.4.3. Environmental Effect on Urban Areas. It is anticipated that the negative effects caused by road transportation (harmful gas emission, health problems, noise, traffic chaos, etc.) in the sea port city can be minimized by means of dry port application and railway transportation.

6.2.4.4. Proximity to the Port. A close dry port can support the sea port more effectively especially in speeding up freight transportation and increasing the productivity of the sea port. A very close dry port can effectively serve the hinterland completely but a distant dry port may do that for a limited part of the hinterland.

6.2.4.5. Proximity to the Industry. A close dry port to the industry can support the mass transportation of the production both inland destinations and to the ports. Additionally, a dry port may serve in the transportation of raw materials from sea port to the industry that is to be used in production.

6.2.4.6. <u>Cost of Investment</u>. The total cost of investment to carry into effect a dry port will depend on the circumstances which will differ for each alternative. The processes such as acquiring the land, constructing the facilities, providing the operating equipment and having access to transportation networks will all be the items that will affect the sum of the investment costs. As an example, if the process has to begin by land acquisition, the cost of the land area will differ related to its ownership; if it is a state property it will be cheaper than that of private property.

6.2.4.7. <u>Process of Establishing Dry Port</u>. If the prospective land area is being utilized for other purposes and to be transformed until a certain time, such a transformation will certainly affect the process of establishing the dry port. On the other side, the strategic plans of the government for investing in transport infrastructure will also affect the prospective dry port in gaining the capabilities required for freight transportation.

6.2.5. A Survey to Grade the Priorities of the Criteria

To perform an AHP it is necessary to determine the priorities of the criteria. This can be carried out by either considering the practitioners' self-assessment or gathering the experts' ideas through a survey. The latter was applied to constitute the priorities of the criteria.

The questionnaire was prepared on 12 February 2019 and sent to experts from eleven different sectors (see Table 6.4) within the following three months. The introduction part of the survey specifies that the dry port to be created is assumed to have almost all the capabilities that a container terminal has and preferably to have accessibility with more than one transport mode. The participators of the survey were asked to grade seven criteria explained in article 6.2.3 to prioritize them. The result of the survey is exhibited in Table 6.5.

The ratings seen in Table 6.5 are applied in the AHP to determine the most appropriate dry port location within the hinterland of Kocaeli ports. The questionnaire can be seen in Appendix-A, and the participants of the survey are listed in Appendix-B. The result of the survey demonstrates that the "Convenience for transportation within the hinterland" has been designated as the highest priority criterion among the seven criteria.

Table 6.4. Sectors of the participators for the questionnaire.

Nu.	Related Intuitions/Sectors of the Participators	Total Number of Participators	Percentage of the Sector (%)
1	Transportation Sector	26	27,66
2	Researcher/Scholar	16	17,02
3	Port Sector	13	13,83
4	Ministry of Transport and Infrastructure	9	9,57
5	Railway Infrastructure / Rail Freight	8	8,51
6	Industry	8	8,51
7	Logistics Center/Logistics Facility	4	4,26
8	Investor/Investment Specialist/Investment Planning	3	3,19
9	Ministry of Customs and Trade	3	3,19
10	Municipality	2	2,13
11	Ministry of Environment and Urbanization/Environment Volunteer	2	2,13
Total		94	100

(Prepared by the Author)

The results of the survey to grade the criteria of the AHP model is seen in the following table.

Table 6.5. Result of the survey for grading the criteria related to their priority.

Rank	Criteria	Abbr.	Rating %
1	Convenience for transportation within the hinterland	TRA	16,45
2	Proximity to the port	POR	14,76
3	Proximity to the industry	IND	14,37
4	Cost of investment	COS	14,16
5	Environmental effect on urban areas	ENV	14,12
6	Centrality in transport network	CEN	13,78
7	Process of establishing dry port	EST	12,36

(Prepared by the Author)

6.3. Surveying the Alternative Locations Related to the Criteria of the AHP

The assessment of the author in article 6.1.3. states that five alternative locations in total are included within the AHP to evaluate each alternative related to the criteria to find the most appropriate one. In this section, each alternative is surveyed in relation to the criteria. The survey made in this phase is taken into account when making pairwise comparisons in the following phase of AHP.

6.3.1. Surveying the Alternatives in Relation to the Criterion of "Centrality of the Location in Transport Network"

Centrality as a criterion would enable a potential dry port site to be evaluated in terms of its position relative to that of existing inland production and consumption centers and ports. One of the methods which can be used to assess centrality involves the use of Koning numbers (UNCTAD, 1991). Koning number is a measure for a vertex denoting the number of the edges in the shortest path from that vertex to the most distant vertex within the network (GITTA, 2019). The centrality position of the alternative locations is assessed by applying the Koning numbers procedure. To be able to make an assessment in terms of centrality, the possible alternative dry port locations and the production and the consumption centers within the hinterland of Kocaeli ports are be counted in a transportation network. In order to carry out this study, it is necessary to determine the hinterland of Kocaeli ports.

Chisholm (1908), stating that he first noticed at 1884 the usage of the word hinterland in English, which was originally a German term, described this term as follows:

> "The land which lies behind a seaport or a seaboard, and supplies the bulk of the exports, and in which are distributed the bulk of the imports ..."

The concept of hinterland, for a long time, had been perceived as a land area on which a single seaport prevails in providing the transportation of traded goods between the nodes on this land and its gateway, and the term "captive hinterland" had been widely used to define the hinterland of a sea port during this time (Sargent, 1938; Weigend, 1956;

Ferrari et al., 2011; Bergqvist 2012). With the ease of transport over time, the fact that a single maritime port prevails fully effectively on a hinterland has begun to disappear and the seaports began to compete to be more active on a hinterland towards the end of the 20th century. Thus new terms have appeared such as competitive/contestable hinterland, main/major hinterland, core hinterland and so on. Today, the magnitude of a seaport's hinterland is not static. Port hinterland can be dynamic depending on economic, sociological and technological developments. Therefore, it is almost not possible to denote the hinterland of a port with precise lines (MTI, 2015). The fact that not only a port is the sharer in the freight transportation carried out based on a city, makes it even more difficult to form such a border to denote the hinterland. In Turkey, there are lots of examples for that a single province lies within a number of seaports' hinterlands, which means that there are overlapping hinterlands belonging to more than one seaports. Even the hinterlands of Kocaeli and Mersin ports, which have a distance of more than 800 kilometers between each other, might overlap. Ankara is an example of being supported by both of these ports.

Two types of data were used to determine the hinterland of Kocaeli ports. The first one is the data indicating the freight distribution of EVYAP port stating the approximate values in 2017[15]. According to the data given in Table 6.6 most of the freight arriving at EVYAP port was distributed outside the Marmara region.

Table 6.6. The freight distribution of EVYAPPORT in 2017.

Destination (City)	**Freigt Carried %**	**Destination (City)**	**Freigt Carried %**
Ankara	17%	Düzce	5%
Bolu	12%	Bursa	4%
Sakarya	11%	Bilecik	3%
Konya	7%	Eskişehir	3%
Kütahya	6%	Total	68%
Explanation: The remaining amount of cargo goes to the Marmara, Western Black Sea, Aegean and Mediterranean regions.			

(Prepared by the Author)

[15] Information obtained on 22 December 2017 in a field study at EVYAP port.

On the other side, the coordinator of "Derince Freight Forwarders Cooperative" mentioned that approximately two-thirds of the freight arriving at Derince is distributed within the Marmara region and the rest to other regions.

According to the information and explanation that are given in Table 6.4 the hinterland of Kocaeli ports may reach out to very distant locations including Konya which is about 600 kilometers away from Kocaeli. Since the purpose at this stage is to shape the transportation network within the hinterland of Kocaeli ports, all the cities in the table and additionally the cities within an approximate range of 400 kilometers are included in this transportation network.

The second data taken into account in shaping this network is foreign trade values. The cities contributing the foreign trade with reasonable values were also included in this network if they are within an approximate range of 400 kilometers to Kocaeli ports. The meaning of the abbreviations used in Figure 6.4 and the rest of this thesis is explained in Table 6.7. The transportation network within this major hinterland is exhibited in Figure 6.4. The contribution of each city in this network is seen in Table 6.8.

Table 6.7. The meaning of the abbreviations used on Figure 6.4 and Figure 6.5.

Port Locations		**Cities (Production and Consumption Centers)**					
AIZ	(A.Kibar IZ)	AFY	(Afyonkarahisar)	CAN	(Çanakkale)	SAK	(Sakarya)
BLC	(Bozüyük LC)	ANK	(Ankara)	ESK	(Eskişehir)	USA	(Uşak)
DIZ	(Dilovası IZ)	BAL	(Balıkesir)	IST	(İstanbul)	ZON	(Zonguldak)
HLC	(Hasanbey LC)	BIL	(Bilecik)	KOC	(Kocaeli)	BAR	(Bartın)
KLC	(Köseköy LC)	BOL	(Bolu)	KON	(Konya)	YAL	(Yalova)
PORT	(Kocaeli Ports)	BUR	(Bursa)	KUT	(Kütahya)	DUZ	(Düzce)

(Prepared by the Author)

It is assumed that origins and destinations in a network are vertices while the road and rail linking them are edges. The numbers in Figure 6.4 represent the total number of edges that must be traveled along in order to reach each of the vertices from the most distant location. For locating a dry port, the lowest number gives the best site from the point of centrality. In other words, the sites with the lowest numbers are deemed to be the most central points within this network.

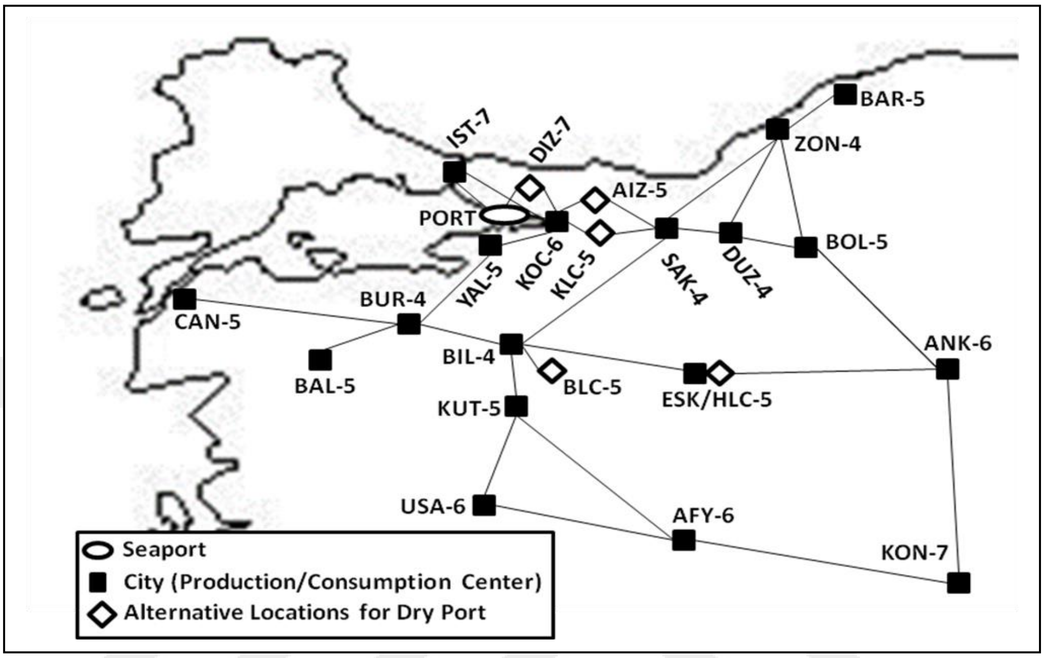


Figure 6.4. Alternative dry port locations and cities within the major hinterland of Kocaeli ports with Koning numbers in its transport network. (Prepared by the Author)

When examining Figure 6.4 it is seen that all alternative dry port locations except DIZ have the same Koning number. It means that the four alternative locations (AIZ, KLC, BLC, and HLC) have approximately the same worth as for the centrality criterion within the major hinterland of Kocaeli ports and they each have a better site from DIZ.

Examining the contributions to the foreign trade of Turkey, it is observed that the cities within the major hinterland of Kocaeli ports have a share that accounts for approximately three-fourths of the total foreign trade of Turkey in 2018 as seen in Table 6.8. As it is observed in Table 6.8, the most distant cities (AFY, BAL, BAR, CAN, KON, KUT, and USA) in this major hinterland have a limited contribution to the foreign trade of Turkey with a total share of 1,33%, which can be neglected. When excluding those most distant cities from the major hinterland of Kocaeli ports, the transportation network is formed as seen in Figure 6.5. The cities in this network are deemed to constitute the core hinterland of Kocaeli ports.

Table 6.8. Foreign trade statistics of turkey and the cities within the hinterland of Kocaeli ports in 2018.

Hinterland/City			Import (1000 USD)	Export (1000 USD)	Total Foreign Trade (1000 USD)		Ratio of Foreign Trade (%)
Cities in the Major Hinterland	Mid-Range and Close Cities	Ankara	13.449.307	7.613.120	21.062.427	283.585.264	72,53
		Bilecik	150.018	101.448	251.466		
		Bolu	180.605	143.073	323.678		
		Bursa	8.517.369	11.149.894	19.667.263		
		Eskişehir	918.391	1.060.819	1.979.210		
		İstanbul	120.575.709	85.060.132	205.635.841		
		Kocaeli	13.977.033	8.904.222	22.881.255		
		Sakarya	3.182.919	5.639.445	8.822.364		
		Zonguldak	1.334.001	504.469	1.838.470		
		Yalova	623.892	312.172	936.064		
		Düzce	80.156	107.068	187.224		
	Most Distant Cities	Afyon	83.100	341.752	424.852	5.206.232	1,33
		Balıkesir	416.806	608.814	1.025.620		
		Çanakkale	76.168	152.730	228.898		
		Konya	908.548	1.785.166	2.693.714		
		Kütahya	108.722	217.542	326.264		
		Uşak	214.317	245.506	459.823		
		Bartın	13.477	33.584	47.061		
Total of Major Hinterland			164.810.539	123.980.956	288.791.495		73,86
Total of Turkey			223.046.481	167.967.219	391.013.700		100,00

(**Source:** Statistics of Ministry of Commerce <https://www.ticaret.gov.tr/>)

According to the Koning numbers of the locations within the transport network seen in Figure 6.5, it is observed that AIZ and KLC have the lowest numbers, which means that these two alternative locations have the best sites as for the centrality criterion.

When comparing the major and the core hinterlands of Kocaeli ports, it is observed that a total of seven cities are excluded in core hinterland. Since the cities excluded in the core hinterland have a very limited contribution to foreign trade, the transportation to and from these cities will also be very limited when compared with the cities included in the core hinterland. Therefore it seems the most logical way to neglect the cities with a very limited contribution to foreign trade. In this way, the centrality positions of the alternatives are assessed in detail.

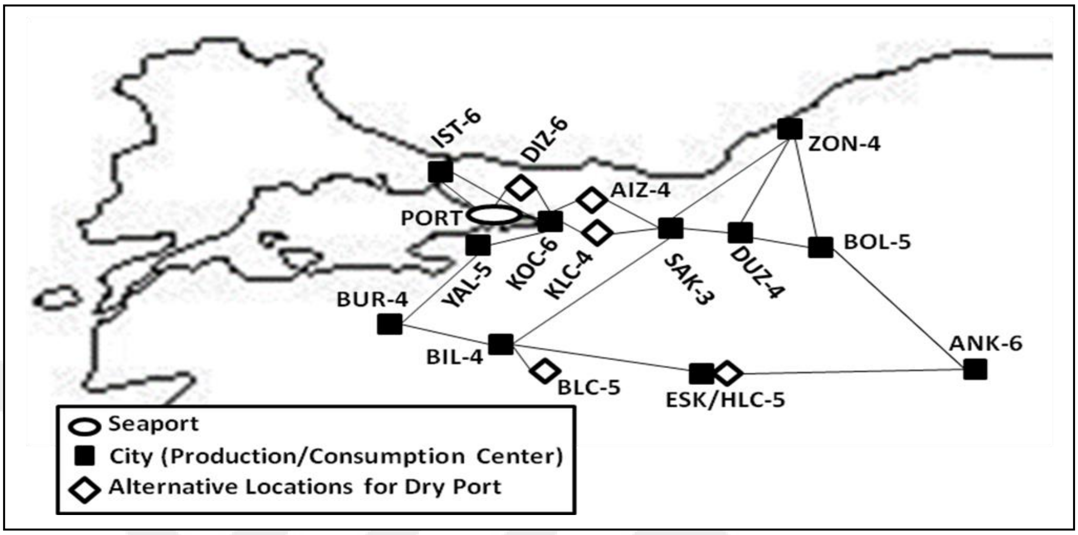


Figure 6.5. Alternative dry port locations, mid-range and close provinces within the core hinterland of Kocaeli ports with Koning numbers in its transport network.
(Prepared by the Author)

According to the criterion of "Centrality of the Location in Transport Network" the alternative locations are arrayed and assessed as follows:

(1) AIZ (South of A.Kibar Industrial Zone) and KLC (Köseköy Logistics Center): Having the best central sites within the transportation network,

(2) BLC (Bozüyük Logistics Center) and HLC (Hasanbey Logistics Center): Having the secondary good sites as for centrality within the transportation network,

(3) DIZ (North of Dilovası Industrial Zone): Having an appropriate but not a central position within the transportation network.

6.3.2. Surveying the Alternatives in Relation to the Criterion of "Convenience for Transportation within the Hinterland"

If an alternative location contemplated as a dry port takes part in a well-established transportation network it will absolutely facilitate the transportation of the goods. Especially the railway connection of a dry port and railway transportation would improve the quality of that transportation network. Among the alternatives, KLC and HLC are located on the main railway line, whereas BLC is still on construction and will have a connection to the main railway line. On the other side, DIZ and AIZ do not have any connection to the main railway lines but the North Marmara line will pass close to these locations. Another consideration is about the position of the alternative locations related to both the seaports and the production and consumption centers. For example, a distant dry port from a seaport would be favorable for transporting the goods towards the consumption centers which are located beyond that dry port, but it would not be beneficial for the consumption centers located in the area between the seaport and itself. Because it would be more expensive first transporting to a further place and then backhaul to backward. Figure 6.6 exhibits an example for a transportation network including one seaport (PORT), two dry ports (D1 and D2) and nine cities (C1-C9).

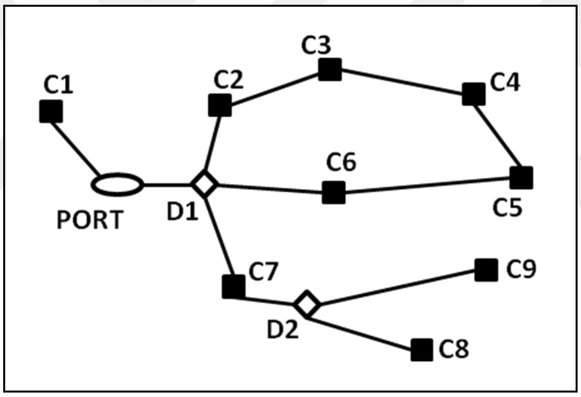


Figure 6.6. A sample transportation network including seaport, dry ports and cities. (Prepared by the Author)

Examining the Figure 6.6 it is seen that the dry port D1 is beneficial for all cities (except C1) since they are on the way after D1, but dry port D2 may be beneficial only for C8 and C9 since all the other cities are in the area between the seaport and itself. So it can be deduced that especially in transporting the import goods from seaport to the consumption centers, a dry port closer to the seaport would be more convenient rather than the ones located further away.

On the other side, a dry port which is close to production centers and can be utilized as a convening center could be convenient especially in transporting the export productions to the seaport. Besides that, a dry port could also be beneficial for transporting raw materials from seaport to the production centers. In this circumstance a close dry port would be more convenient to distribute the raw materials to different industrial areas.

The distances from the alternative dry port locations to the seaports[16] and the cities are given in Table 6.9.

Table 6.9. Distances from alternative dry port locations to ports, production and consumption centers (distances in km).

Port/City	Alternative Dry Port Locations and Distances in km				
	DIZ	**AIZ**	**KLC**	**BLC**	**HLC**
DIL	16	56	48	221	266
DER	43	22	17	188	233
IST	80	127	125	270	325
KOC	52	7	5	170	225
SAK	90	36	45	134	189
DUZ	167	116	123	204	259
BOL	198	163	165	246	301
ZON	259	225	237	317	372
BAR	375	330	341	422	477
YAL	122	70	65	171	226
BUR	198	136	131	106	161
BAL	330	274	270	266	321
CAN	449	393	388	384	439
BIL	183	104	102	35	90
ESK	260	186	185	48	10
ANK	385	339	351	283	235
KUT	287	240	241	77	89
USA	432	378	390	217	226
AFY	385	333	345	171	143
KON	645	539	551	402	340

(Prepared by the Author)

Distances between the seaports and the alternative dry port locations are seen as blue colored in the table. Some of the dry port alternatives within the transportation network (see Figure 6.4) will not be appropriate for some cities, considering the transportation between the seaport and the city. The options which require extra travel in a different direction outside the transportation route between the port and the dry port are marked with

[16] The port facilities in Kocaeli Gulf spreads between Dilovası and Derince. In Table-5.6, "DIL "corresponds to Dilovası zone and "DER" to Derince zone.

a dark color in the table. The alternative dry port locations of the thesis study are assessed in relation to the criteria such as the accessibility to highways and railways and the ranges to the seaports and the cities.

6.3.2.1. DIZ (North of Dilovası Industrial Zone). The projected location to be a dry port is a spare area at the moment that currently has no access to either a highway or a railway line. But in the near future, it is planned to pass the North Marmara highway very close to this area. The North Marmara railway line will also pass through the same area afterward. So, DIZ will most probably have easy access to both a highway and a railway line (see Figure 6.7).

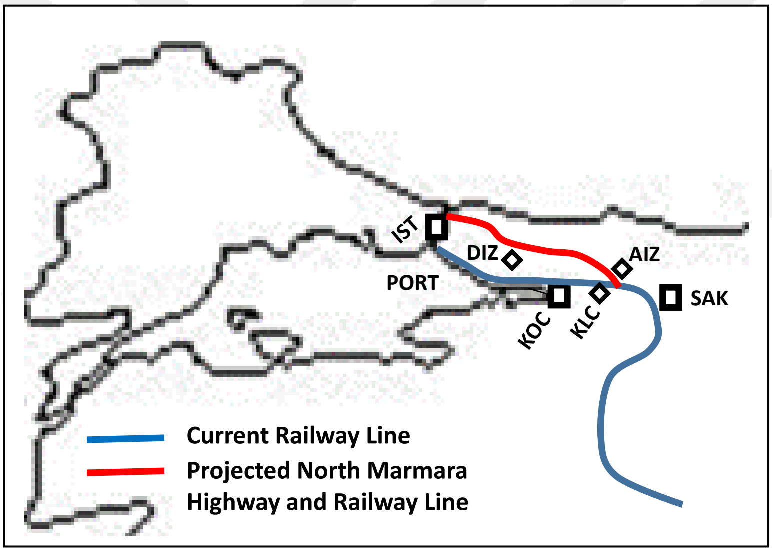


Figure 6.7. Current and projected railway lines between Istanbul and Kosekoy. (Prepared by the Author)

The North Marmara railway line is projected to get connected to the current railway at a position around Köseköy[17]. The projected location of DIZ is approximately 10 kilometers north of the Diliskelesi coast and it can be connected to Kocaeli ports through a short distance road way. But the railway connection to these ports will have a long-distance through the North Marmara line. In order to reach the Kocaeli ports by train from DIZ, it will require proceeding on the North Marmara line to eastern direction until the

[17] Information was obtained at the working group meeting held at the "First Regional Directorate of TCDD" on 13th Feb of 2019.

intersection point and turn to the opposite direction. This movement in total will take 60 to 90 kilometers which is quite longer than road transportation for the same purpose.

Taking into account the future opportunities it is understood that the presumptive dry port DIZ will have a good location for transporting the import goods inland locations either to western or eastern side through both highway and railway, also for gathering the export goods from both directions through the same modes. But access to the ports seems to be dependent on the roadway since railway transportation will necessitate extra effort compared to road transportation. Besides this dependency, the narrow roads from DIZ to the highway and the very intense traffic on this highway will most probably affect adversely the transportation to and from the Kocaeli ports.

6.3.2.2. AIZ (East of A. Kibar Industrial Zone). The projected location is anticipated to be a good dry port location with similar features of DIZ. At the moment it is a spare area and currently has no access to either a highway or a railway line. But in the future, it will most probably have easy access to both the North Marmara highway and the North Marmara railway as seen in Figure 6.7. The accessibility to both modes gives an important advantageous feature to AIZ. In addition to the North Marmara highway and railway, its position is very close to the other highway and railway lines. Transportation from AIZ to Kocaeli ports through the railway will not be difficult as it is from DIZ.

For transporting the import goods from Kocaeli ports to inland locations, AIZ will provide advantageous situations for all cities except Istanbul and Kocaeli within the transportation network.

6.3.2.3. KLC (Köseköy Logistics Center). This location is already on the railway line which lies between Haydarpaşa and Eskişehir (see Figure 6.2). Among all the alternative locations it’s the closest point to Kocaeli ports. By the way, it has already rail access to the seaports that have a junction to the railways. Besides that, it also has easy access to both highways known as D-100 motorway and TEM whose distance is only one and 2,5 kilometers respectively.

KLC has an advantageous situation similar to AIZ in transporting the import goods from Kocaeli ports to inland locations.

6.3.2.4. BLC (Bozüyük Logistics Center). BLC is not on the main railway line, which is located approximately five kilometers north of that line. It is still on construction as an ongoing project of TCDD is planned to have a junction to the main railway. The E-90 highway just strolls along with this location. When put into service it is anticipated to serve effectively since having good access both to the highway and the railway.

The situation of BLC is not as advantageous as AIZ and KLC have in transporting the import goods from Kocaeli ports, because some consumption centers such as of Istanbul, Kocaeli, Sakarya, Duzce, Bolu, Zonguldak, Bartin and Yalova stay beyond the BLC when considering the transportation between dry port and seaport.

6.3.2.5. HLC (Hasanbey Logistics Center). HLC is on the main railway line like KLC. The distance from the E-90 highway is about five kilometers. The location has good access both to the railway and the highway.

The situation of HLC is not as advantageous as AIZ and KLC either. Its position would be beneficial for transporting the import goods to some cities such as Eskisehir, Ankara, Kutahya, Usak, Afyonkarahisar, and Konya that constitute only one-third of the cities in the network.

6.3.3. Surveying the Alternatives in Relation to the Criterion of "Environmental Effect"

A dry port is expected to lessen the negative effects (harmful gas emission, health problems, noise, traffic chaos, etc.) caused by road transportation in the sea port city. To realize such expectation it should have the ability to change the mode to/from railway transportation which is environment-friendly transportation mode.

The alternative dry port locations of the thesis study are assessed in relation to the criteria in supporting the environmental purposes mentioned above.

6.3.3.1. <u>DIZ (North of Dilovası Industrial Zone)</u>. The projected location is a spare area at the moment. There are industrial facilities west and south of the location. The residential area is very limited at the proximity. If determined to be dry port it is predicted to have easy access to both railway and highway which will pass very close to this area. It is expected to support environmental purposes at the highest level.

6.3.3.2. <u>AIZ (East of A.Kibar Industrial Zone)</u>. The projected location is surrounded by industrial facilities from two sides, and there is a very small residential area at a distance of 500 meters. If determined to be dry port it is also predicted to have easy access to both railway and highway which will pass very close to this area. It is expected to support environmental purposes at a high level.

6.3.3.2. <u>KLC (Köseköy Logistics Center)</u>. Already located on the railway line KLC has a very advantageous situation in accessing an environment-friendly transportation mode. Although not very intense, there are some residential settlements around it in addition to some industrial facilities. The road transportation to/from the dry port will affect adversely the residential area to some extent. But the railway option and very easy access to the railway makes it an attractive location because of that a large amount of freight can be transported by train cars. KLC is expected to support environmental purposes at a high level.

6.3.3.4. <u>BLC (Bozüyük Logistics Center)</u>. BLC is planned to be constructed between two industrial zones, which are about two kilometers away. There is no residential area around BLC. In addition to the highway which strolls along the railway to railway lines and to the industrial facilities will carry it in a very advantageous position as having easy access to both transportation modes. BLC is expected to support environmental purposes at the highest level.

6.3.3.5. <u>HLC (Hasanbey Logistics Center)</u>. Being located on the main railway lines like KLC, HLC has a very advantageous position. There is a small residential area very close to HLC. Except for the west side, on which the airport is located one kilometer away, all sides are empty areas. HLC is expected to support environmental purposes at a high level.

6.3.4. Surveying the Alternatives in Relation to the Criterion of "Proximity to the Port"

Proximity to the port would be beneficial in speeding up freight transportation and increasing the productivity of the sea port especially when there is a well-established railway network. In certain circumstances such as when the sea port is about to suffer from the lack of space, a close dry port with a large capacity of railway transportation will support the seaport in increasing the throughput. A close dry port may provide an advantage in terms of transporting imported cargo to the hinterland. Thus, it will be possible to transport all points on the route in the most economical way from the dry port location. However, for a distant dry port, transporting the import goods to the points between itself and the sea port will not as economical as a close dry may provide.

The distances from each alternative dry port location to the zones of Diliskelesi and Derince, which are assumed to be the beginning point and the termination point along the north shore of the Kocaeli Gulf are given in Table 6.9. Among them, the close dry port alternatives are seen in Figure 6.8.

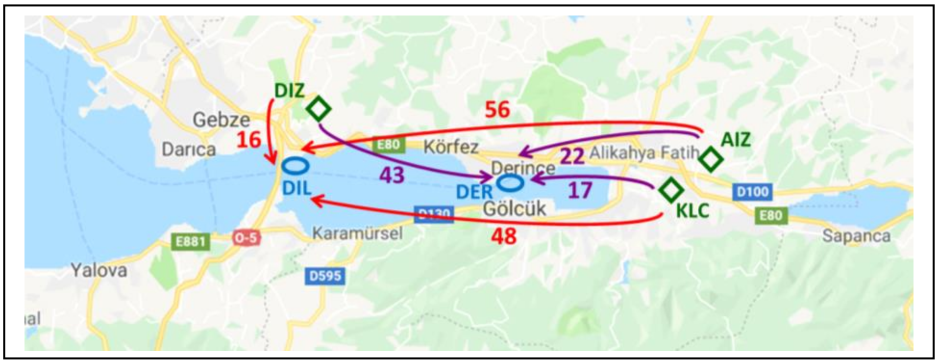


Figure 6.8. The distances (km) from the close dry port alternatives to the port zones of Diliskelesi and Derince along the north shore of Kocaeli Gulf. (Prepared by the Author)

The mid-range dry port alternatives are seen in Figure 6.9.

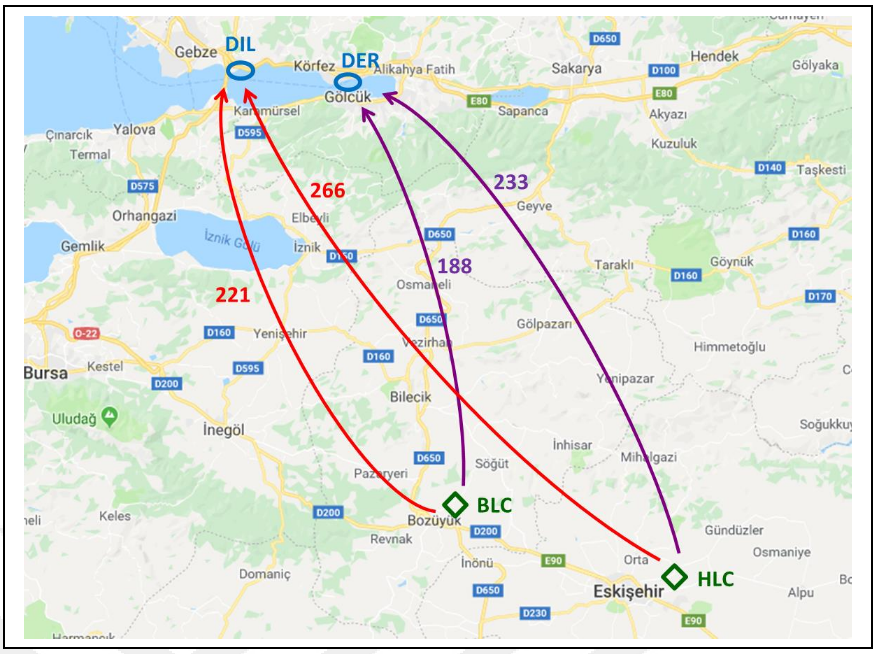


Figure 6.9. The distances (km) from mid-range dry port alternatives to the port zones of Diliskelesi and Derince along the north shore of Kocaeli Gulf. (Prepared by the Author)

When assessing the alternative dry port locations in relation to the criteria of “proximity to the port”, the alternatives DIL, AIZ, and KLC are seen having a more advantageous location compared to the alternatives BLC and HLC.

6.3.5. Surveying the Alternatives in Relation to the Criterion of "Proximity to the Industry"

A dry port near industrial facilities may be beneficial in two aspects. First, it enables the export products to be gathered in a center and transported "en masse"[18] to the seaports. Secondly, it facilitates the transportation of raw materials or intermediate goods that will be used in production from the sea port to the dry port and from there to the industrial facility.

There are 308 OIZs totally in Turkey according to the information shared in the OIZ information portal (OSBÜK, 2019). A total of 121 OIZs, which is equivalent to 39% of

[18] The adverb "en masse" can be defined as follows: all together as a group; as a whole; in a body; all together; collectively; as one.

Turkey's total, are located within the hinterland of Kocaeli ports. The number of OIZs pertaining to the cities in this hinterland is seen in Figure 6.10.

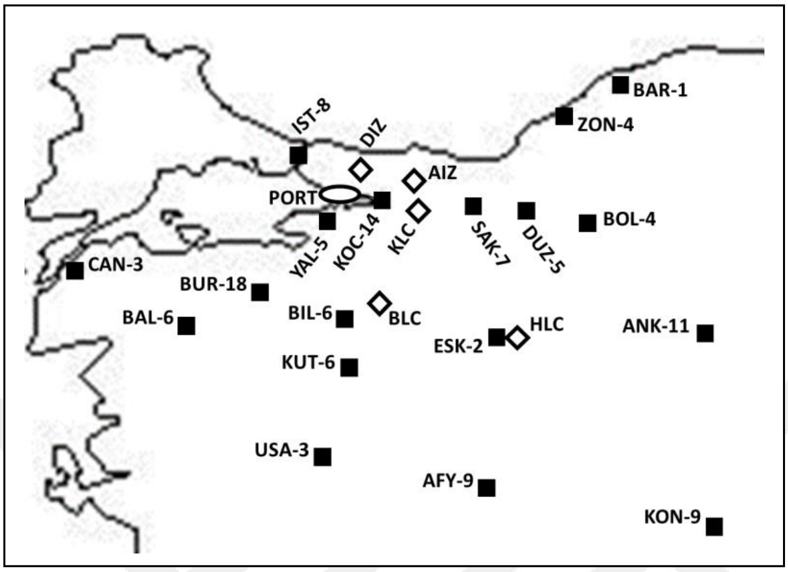


Figure 6.10. The position of the alternative dry port locations and the cities that include the OIZs within the hinterland of Kocaeli ports. (Prepared by the Author)

The list of these OIZs is given in Appendix-C. The size of these OIZs, the city that they are located in its boundaries and the export performance of that city in 2018 are also given in the same table in Appendix-C. Of course, the production centers are not limited to those OIZs. There are lots of production facilities large and small in addition to those. But the OIZs expressed at this point are of great importance because they are accommodating a wide range of production facilities and provide a convenient environment for mass transportation. Each alternative dry port location is assessed related to its proximity to the OIZs. The positions of the alternative dry port locations are seen in Figure 6.10. The numbers accompanying the name of the cities indicate the number of OIZs located within this city.

6.3.5.1. <u>DIZ (North of Dilovası Industrial Zone)</u>. DIZ is the closest alternative dry port location to the OIZs located in Istanbul and some of the OIZs in Kocaeli. These OIZs constitute roughly 10% of the total OIZs located within the hinterland of Kocaeli ports. However, as can be seen from the railway scheme mentioned in Figure 6.7, it is understood that railway transportation will not be meaningful when transporting the goods to and from seaports through the railways. For this reason, it would be a more sensible method to transport directly to the sea port via the highway instead of collecting the goods in the dry port to be established in the DIZ location. Similarly, rail transport from sea port would not be used effectively in the transportation of intermediate goods to be used in OIZs.

6.3.5.2. AIZ (East of A. Kibar Industrial Zone) and KLC (Köseköy Logistics Center). AIZ and KLC are the closest alternative dry port locations to the OIZs located in Sakarya, Düzce, Bolu, Zonguldak, Yalova and some of the OIZs in Kocaeli. These OIZs constitute roughly one-third of the total OIZs located within the hinterland of Kocaeli ports. Figure 6.7 shows that the KLC will be more advantageous than AIZ in transporting the cargoes that will be transferred to the sea port over the railway. Because it will be necessary to change the line from the North Marmara line to the current line by altering the direction to the opposite side when transporting the goods from AIZ to the sea port. Both alternatives seem good locations to gather the goods from different industrial facilities located around the East Marmara region and for mass transportation to and from seaports.

6.3.5.3. BLC (Bozüyük Logistics Center). BLC is the closest alternative dry port location to the OIZs located in Bilecik, Bursa, Çanakkale, Balıkesir, Kütahya, and Uşak. These OIZs constitute roughly 34% of the total OIZs located within the hinterland of Kocaeli ports. In addition to this feature, the intended dry port BLC is being built between two OIZs. It is at the planning stage to connect these two industrial zones to BLC through railways and to create a junction for BLC from the main railways which will be about five kilometers. BLC may be a good alternative location to gather the goods from different industrial facilities located around South Marmara and North-West Aegean regions and provide mass transportation to Kocaeli ports through railways.

6.3.5.4. HLC (Hasanbey Logistics Center). HLC is the closest alternative dry port location to the OIZs located in Eskişehir, Ankara, Afyonkarahisar, and Konya. These OIZs constitutes roughly one-quarter of the total OIZs located within the hinterland of Kocaeli ports. In addition to this feature, the intended dry port HLC is planned to be connected by railways to the “Eskişehir Chamber of Industry OIZ” which is only 10 kilometers away. HLC may be a good alternative location to gather the goods from different industrial facilities located around the Central Anatolia region and provide mass transportation to Kocaeli ports through railways.

6.3.6. Surveying the Alternatives in Relation to the Criterion of "Cost of investment"

All alternatives have different conditions and different capabilities as of the moment. Necessary investment stages and expense items can be sorted as below:

- Cost for land acquisition,
- Cost for the construction of infrastructure facilities,
- Cost for procurement of operating equipment,
- Cost for connection of the transport system.

The possible investment requirements to be carried out for each alternative location to be converted as a dry port are explained below.

6.3.6.1. DIZ (North of Dilovası Industrial Zone). If it is determined to constitute a dry port in the north of Dilovası which will be very close to the North Marmara Highway and Railway, the dry port will be built from the ground up. It means that all stages have to be carried out to construct a dry port in the location named as DIZ.

It is expected that the cost of land acquisition will not be very high since the land in consideration is treasury land. It is assumed that the decision to create a dry port on this land would be within the scope of a strategic plan of the government. The decision will result in a very huge investment cost including the construction of infrastructure facilities, procurement of operating equipment and connection of both the railway and highway transport systems. As a whole, it will require a very large amount of investment to build a dry port on the location of DIZ.

6.3.6.2. AIZ (East of A. Kibar Industrial Zone). The conditions of AIZ are very similar to DIZ, except for the first stage. The North Marmara Highway and Railway are expected to pass very close to the location of AIZ on which a dry port will be built from the ground up if it is decided on.

Unlike the alternative of DIZ, the cost of land acquisition is expected to be very high since the land in consideration is private property. The following stages are cast in the same mold as of DIZ. As a whole, it will require a very large amount of investment to build a dry port on the location of AIZ, even a higher cost than that of DIZ.

6.3.6.3. KLC (Köseköy Logistics Center). For this alternative, three stages over the four have already been passed. The KLC, which has been designed as a load station in the past, is currently able to reach both ports and production and consumption centers via both rail and road networks. There is no need to acquire a land area nor to connect railways to this location. The expropriation process of the 286.000 m^2 area adjacent to this area will enable the establishment of additional facilities and gaining the capabilities needed for converting this facility to a dry port. The investment cost for KLC will be very low in comparison to the other alternatives.

6.3.6.4. BLC (Bozüyük Logistics Center). Construction is an ongoing process in this area. There will not be a cost for land acquisition but there are many investment expenditures waiting in the line such as the construction of infrastructure facilities, procurement of operating equipment and connection of the transport system. The land area is just near the highway, but it requires a junction to get connected to the main railways. On the other hand, to be connected with two different industrial zones from two opposite sides are also among the future investment requirements. The investment cost for BLC will be less than DIZ and AIZ but more than KLC.

6.3.6.5. HLC (Hasanbey Logistics Center). The conditions of HLC are similar to KLC as both are logistics centers that have been put into service by TCDD. Both of them are already on the main railways and they’re both very close to the highways. They both require a good investment to procure the necessary operating equipment and to gain additional facilities within their boundaries to reach the capabilities of a dry port.

6.3.7. Surveying the Alternatives in Relation to the Criterion of "Process of Establishing Dry Port"

It’s a strategic decision to create a dry port. Generally, it’ll take a long time to put into service such a logistics facility. If it will be built on an empty area it’ll take a long time to prepare the prospective dry port to service. The most important specialty for such a logistics plant is its capabilities in serving its customers. The capabilities possessed within the logistics plant are not adequate alone, it is also an inevitable necessity to flow on the fairways of the transportation network. But if there are already some facilities and infrastructure in the area, it’ll be easier to convert that logistics facility to a dry port. If the facility to be converted has a connection to railway and highway, this specialty will ease the process.

The assessment of each alternative location in relation to the criterion of "Process of Establishing Dry Port" is explained below.

6.3.7.1. <u>DIZ (North of Dilovası Industrial Zone)</u>. For this alternative, the construction of the dry port process will start from the ground up. The ground has to be flattened at first. The altitude of this area is highly variable, it varies between 280 meters to 350 meters, which complicates the process for flattening. The construction of the facilities and equipping each facility will follow in this process. On the other side, the DIZ will need to be connected to the transportation networks for both highway and railway systems. The project of North Marmara Highway is an ongoing project and it will take some several years more to get into service. This new highway will, of course, enable the prospective DIZ for freight transportation through highway towards the inner locations. In addition to this capability, it is still in a planning session to build the North Marmara Railways which is intended to be constructed alongside the North Marmara Highways. But it is uncertain when it will be ready to use for transportation. It seems that the process of the establishment will take a very long time for the DIZ alternative.

6.3.7.2. <u>AIZ (East of A. Kibar Industrial Zone)</u>. The conditions of AIZ are very similar to DIZ, except for the altitudes of the land. It varies between 17 and 20 meters the altitudes of the land. So, the form of the land will not constrain the construction process. Except for this feature, the advantages and disadvantages of the process to become a dry port will be the same as in DIZ.

6.3.7.3. KLC (Köseköy Logistics Center). KLC has a very advantageous condition since it is already a logistics center although it needs a huge amount of investment. It needs a detailed plan to have every kind of capability to develop as a well-established dry port. It already has a railway passing through itself. It has a large enough land area to construct the necessary facilities. As a result, the process of the establishment will be much easier than previous alternatives.

6.3.7.4. BLC (Bozüyük Logistics Center). It is actually a planned logistics center of TCCD but still in the construction process. It is uncertain when it might be put into service but it will require additional capabilities to develop as a dry port. The most important requirement is that it will need a junction to be connected to the main railways. Although it is estimated that its establishment process will be shorter than the first two alternatives, it is assessed that this process will be longer compared to KLC.

6.3.7.5. HLC (Hasanbey Logistics Center): The conditions of HLC is similar to KLC in terms of this criterion. It already has a railway passing through itself too. But a connection to Eskişehir OIZ is necessary to become an effective dry port. And, it also needs a detailed plan to develop as a well-established dry port. The process of establishment of HLC looks like that of KLC, except the need for railway connection to OIZ.

6.4. Defining the Problem and Structuring the Decision Hierarchy of the AHP Model

An AHP model has been applied to determine the most appropriate location as a dry port alternative. The steps of an analytic hierarchy were explained in section 6.2.2. The AHP model has been implemented in parallel with these steps. In this section, the problem of the AHP model is defined and the hierarchy of the model is explained.

6.4.1. Defining the Problem

The problem of this AHP model is defined as the "Determination of the most appropriate dry port location within the hinterland of Kocaeli ports". This definition takes part in the decision hierarchy as the first stage.

6.4.2. Structuring the Decision Hierarchy

A decision hierarchy of an AHP model involves three main stages: the objective, the criteria (or the factors), and the alternatives (or decision points). The objective was defined in the previous section. The criteria and the alternatives of this model were explained in sections 6.1 and 6.2. All these elements take part in the decision hierarchy of this AHP model as seen in Figure 6.11.

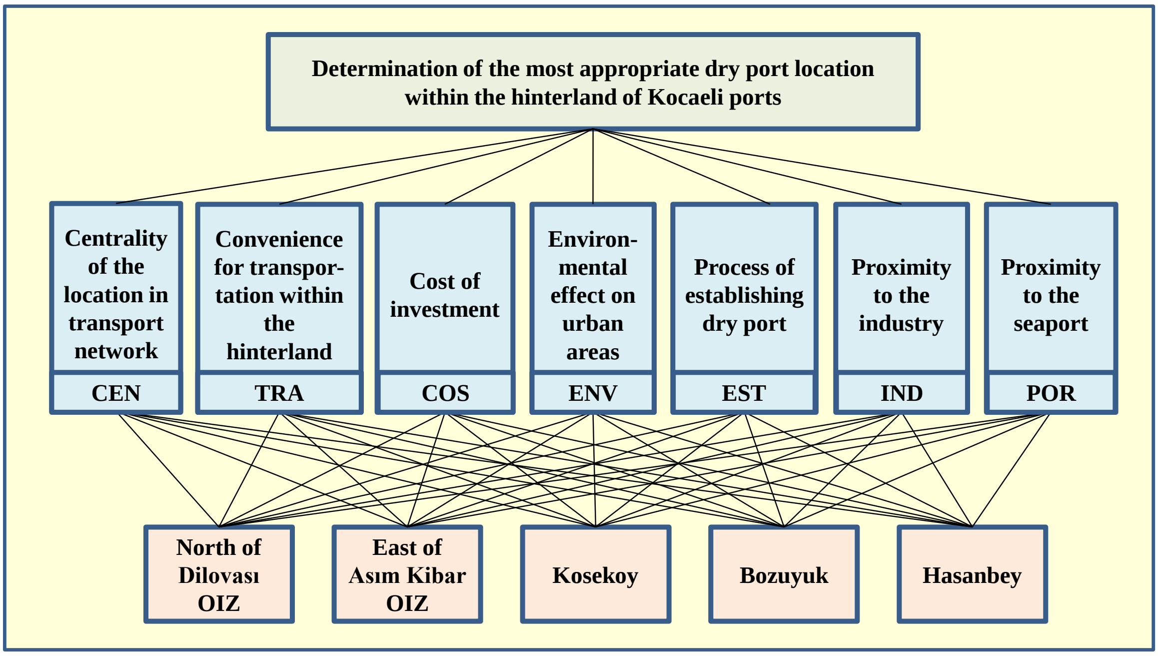


Figure 6.11. The structure of the decision hierarchy of this AHP model. (Prepared by the Author)

At the top of this structure, it is seen the objective as stated in section 6.4.1. At the mid-level are seen seven criteria (conditioning factors) which are explained in sections 6.2.3. and 6.2.4. These criteria were determined to assess alternative dry port locations (decision points). At the bottom level are five alternatives, one of which will be selected as the most appropriate alternative at the end of AHP implementation. These alternatives were investigated in section 6.1.

6.5. Pairwise Comparisons and Analyzing the Consistency of the Comparisons

For the pairwise comparison matrices (P) with the dimension of "m x m" have been constructed for each criterion seen in Figure 6.11. The number "m" means the number of decision points or alternative dry port locations in this thesis study. A matrix P is shaped as seen in Table 6.10. The values of the cells are entered according to the assessments stated in section 6.3. The scale given in Table 6.2 is used in grading the importance of the alternatives in parallel to the assessments.

Table 6.10. The shape of a matrix P.

	DIZ	AIZ	KLC	BLC	HLC
DIZ					
AIZ					
KLC					
BLC					
HLC					
Sum					

(Prepared by the Author)

In this section, the weight of the alternatives is obtained and the consistency of the pairwise comparisons is analyzed.

6.5.1. Constructing the Matrix P in Relation to the Criterion of "Centrality of the Location in Transport Network (CEN)" and Calculating the Consistency Ratio

The assessments related to this criterion which are stated in section 5.3.1 are summarized in Table 6.11.

Table 6.11. Summary of the assessments related to the criterion of "CEN".

Alternatives	**Advantages (+) and Disadvantages (-)**
DIZ	Having an appropriate but not a central position within the network (-)
AIZ	Having the best central site as for centrality within the network (+++)
KLC	Having the best central site as for centrality within the network (+++)
BLC	Having the secondary good site as for centrality within the network (+)
HLC	Having the secondary good site as for centrality within the network (+)

The "Pairwise comparison matrix for criterion CEN (P1)" is constructed in parallel to this assessment (section 5.3.1) as seen in Table 6.12.

Table 6.12. The pairwise comparison matrix for the criterion of "CEN".

P1	DIZ	AIZ	KLC	BLC	HLC	Explanation
DIZ	1	1/5	1/5	1/3	1/3	Strong importance of AIZ and KLC over DIZ; Moderate importance of AIZ and KLC over BLC and HLC; Moderate importance of BLC and HLC over DIZ.
AIZ	5	1	1	3	3	
KLC	5	1	1	3	3	
BLC	3	1/3	1/3	1	1	
HLC	3	1/3	1/3	1	1	
Sum	17	2,8667	2,8667	8,3333	8,3333	

The "Normalized matrix for criterion CEN (N1)" is formed by dividing each element by the sum of its column as seen in Table 6.13.

Table 6.13. The matrix N1.

N1	DIZ	AIZ	KLC	BLC	HLC
DIZ	1/17	1/5/2,8667	1/5/2,8667	1/3/8,3333	1/3/8,3333
AIZ	5/17	1/2,8667	1/2,8667	3/8,3333	3/8,3333
KLC	5/17	1/2,8667	1/2,8667	3/8,3333	3/8,3333
BLC	3/17	1/3/2,8667	1/3/2,8667	1/8,3333	1/8,3333
HLC	3/17	1/3/2,8667	1/3/2,8667	1/8,3333	1/8,3333

The calculation of matrix N1 results in the final matrix as seen in Table 6.14. The average of each row results in the F1 vector, containing the weights of each alternative.

Table 6.14. The calculation of matrix N1 and the weights of the alternatives (F1 vector).

N1	DIZ	AIZ	KLC	BLC	HLC
DIZ	0,0588	0,0698	0,0698	0,0400	0,0400
AIZ	0,2941	0,3488	0,3488	0,3600	0,3600
KLC	0,2941	0,3488	0,3488	0,3600	0,3600
BLC	0,1765	0,1163	0,1163	0,1200	0,1200
HLC	0,1765	0,1163	0,1163	0,1200	0,1200

Sum		Weights (F1)
0,2784	f1	0,0557
1,7118	f2	0,3424
1,7118	f3	0,3424
0,6490	f4	0,1298
0,6490	f5	0,1298

In the next stage, the "Weighted sum matrix (S1)" is constructed by multiplying each element of P1 with the weights of the alternatives (F1). The sum of the rows gives the vector (S1) (Table 6.15). The consistency vector (C1) is obtained by dividing (S1) to (F1).

Table 6.15. The calculation of matrix S1 and the consistency vector (C1 vector).

S1	DIZ	AIZ	KLC	BLC	HLC
DIZ	0,0557	0,0685	0,0685	0,0433	0,0433
AIZ	0,2784	0,3424	0,3424	0,3894	0,3894
KLC	0,2784	0,3424	0,3424	0,3894	0,3894
BLC	0,1670	0,1141	0,1141	0,1298	0,1298
HLC	0,1670	0,1141	0,1141	0,1298	0,1298

Sum	
0,2792	s1
1,7419	s2
1,7419	s3
0,6549	s4
0,6549	s5

Vector C1	
s1/f1	5,01
s2/f2	5,09
s3/f3	5,09
s4/f4	5,04
s5/f5	5,04
Sum	25,28

The λ_{max} is found by dividing "Sum C1" to "n": λ_{max} = 25,28 / 5 = 5,056

The consistency index CI = (λ_{max} - n) / (n-1) = (5,056 - 5) / 4 = 0,014

The consistency ratio CR = CI / RI[19] = 0,014 / 1,1159 = 0,0126

CR < 0,1

It is understood that the comparisons among the five decision points were reasonably consistent since the consistency ratio is less than 0,1.

[19] RI (Random Consistency Index) is found from Table-5.3.

6.5.2. Constructing the Matrix P in Relation to the Criterion of "Convenience for Transportation within the Hinterland (TRA)" and Calculating the Consistency Ratio

The assessments related to this criterion which are stated in section 5.3.2 are summarized in Table 6.16.

Table 6.16. Summary of the assessments related to the criterion of "TRA".

Alt.	Advantages (+) and Disadvantages (-)
DIZ	Close to Diliskelesi coast (+); access to new highway and railway in the future (+); possible to reach all points economically (+++); access to ports via rail is problem (--)
AIZ	Close to D-100 and TEM (+); access to new highway and railway in the future (+); possible to reach most points economically (++); minor problem in access to ports via rail (-)
KLC	Very close to D-100 and TEM (++); already on the main railways (+++); possible to reach most points economically (++); easy access to ports having junction (+++)
BLC	Very close to E-90 (++); connection required to main railways (-/+); possible to reach only half of the points economically (-); easy access to some OIZs nearby (++)
HLC	Close to E-90 (+);already on the main railways (+++); possible to reach only one third of the points economically (--); easy access to one OIZ nearby (+)

The "Pairwise comparison matrix for criterion TRA (P2)" is constructed in parallel to this assessment (section 5.3.2) as seen in Table 6.17.

Table 6.17. The pairwise comparison matrix for the criterion of “TRA".

P2	DIZ	AIZ	KLC	BLC	HLC	Explanation
DIZ	1	1/3	1/5	1	3	Very strong importance of KLC over HLC; strong importance of KLC over DIZ and BLC; moderate importance of KLC over AIZ; strong importance of AIZ over HLC; moderate importance of AIZ over DIZ and BLC; moderate importance of DIZ and BLC over HLC.
AIZ	3	1	1/3	3	5	
KLC	5	3	1	5	7	
BLC	1	1/3	1/5	1	3	
HLC	1/3	1/5	1/7	1/3	1	
Sum	10,3333	4,8667	1,8762	10,3333	19	

The "Normalized matrix for criterion TRA (N2)" is formed by dividing each element by the sum of its column as seen in Table 6.18.

Table 6.18. The matrix N2.

N2	DIZ	AIZ	KLC	BLC	HLC
DIZ	1/10,3333	1/3/4,8667	1/5/1,8762	1/10,3333	3/19
AIZ	3/10,3333	1/4,8667	1/3/1,8762	3/10,3333	5/19
KLC	5/10,3333	3/4,8667	1/1,8762	5/10,3333	7/19
BLC	1/10,3333	1/3/4,8667	1/5/1,8762	1/10,3333	3/19
HLC	1/3/10,3333	1/5/4,8667	1/7/1,8762	1/3/10,3333	1/19

The calculation of matrix N2 results in the final matrix as seen in Table 6.19. The average of each row results in the F2 vector, containing the weights of each alternative.

Table 6.19. The calculation of matrix N2 and the weights of the alternatives (F2 vector)

N2	DIZ	AIZ	KLC	BLC	HLC	Sum		Weights (F2)
DIZ	0,0968	0,0685	0,1066	0,0968	0,1579	0,5265	f1	0,1053
AIZ	0,2903	0,2055	0,1777	0,2903	0,2632	1,2269	f2	0,2454
KLC	0,4839	0,6164	0,5330	0,4839	0,3684	2,4856	f3	0,4971
BLC	0,0968	0,0685	0,1066	0,0968	0,1579	0,5265	f4	0,1053
HLC	0,0323	0,0411	0,0761	0,0323	0,0526	0,2344	f5	0,0469

In the next stage, the "Weighted sum matrix (S2)" is constructed by multiplying each element of P2 with the weights of the alternatives (F2). The sum of the rows gives the vector (S2) (Table 6.20). The consistency vector (C2) is obtained by dividing (S2) to (F2).

Table 6.20. The calculation of matrix S2 and the consistency vector (C2 vector)

S2	DIZ	AIZ	KLC	BLC	HLC	Sum		Vector C2	
DIZ	0,1053	0,0818	0,0994	0,1053	0,1406	0,5325	s1	s1/f1	5,06
AIZ	0,3159	0,2454	0,1657	0,3159	0,2344	1,2773	s2	s2/f2	5,21
KLC	0,5265	0,7362	0,4971	0,5265	0,3281	2,6145	s3	s3/f3	5,26
BLC	0,1053	0,0818	0,0994	0,1053	0,1406	0,5325	s4	s4/f4	5,06
HLC	0,0351	0,0491	0,0710	0,0351	0,0469	0,2372	s5	s5/f5	5,06
								Sum	25,64

The λ_{max} is found by dividing "Sum C2" to "n": 25,64 / 5 = 5,128

The consistency index CI = (λ_{max} - n) / (n-1) = (5,128 - 5) / 4 = 0,032

The consistency ratio CR = CI / RI[20] = 0,032 / 1,1159 = 0,0286

CR < 0,1

It is understood that the comparisons among the five decision points were reasonably consistent since the consistency ratio is less than 0,1.

[20] RI (Random Consistency Index) is found from Table-5.3.

6.5.3. Constructing the Matrix P in Relation to the Criterion of "Environmental Effect (ENV)" and Calculating the Consistency Ratio

The assessments related to this criterion which are stated in section 5.3.3 are summarized in Table 6.21.

Table 6.21. Summary of the assessments related to the criterion of "ENV"

Alt.	**Advantages (+) and Disadvantages (-)**
DIZ	Very limited residential area (++); to have easy access to both railway and highway in the future (+); supports the environmental purposes at the highest level (+++)
AIZ	Very small residential area (+); to have easy access to both railway and highway in the future (+); supports the environmental purposes at a high level (++)
KLC	Very easy access to an environment-friendly transportation mode (+++); some residential settlements around (--); supports the environmental purposes at a high level (++)
BLC	No residential area around (+++); easy access to highway, and to have easy access to railway (+); supports the environmental purposes at the highest level (+++)
HLC	Very easy access to an environment-friendly transportation mode (+++); small residential area (-);supports the environmental purposes at the highest level (+++)

The "Pairwise comparison matrix for criterion ENV (P3)" is constructed in parallel to this assessment (section 5.3.3) as seen in Table 6.22.

Table 6.22. The pairwise comparison matrix for the criterion of "ENV"

P3	DIZ	AIZ	KLC	BLC	HLC	Explanation
DIZ	1	5	5	1	3	Strong importance of DIZ and BLC over AIZ and KLC; moderate importance of DIZ and BLC over HLC; moderate importance of HLC over AIZ and KLC.
AIZ	1/5	1	1	1/5	1/3	
KLC	1/5	1	1	1/5	1/3	
BLC	1	5	5	1	3	
HLC	1/3	3	3	1/3	1	
Sum	2,7333	15	15	2,7333	7,6667	

The "Normalized matrix for criterion ENV (N3)" is formed by dividing each element by the sum of its column as seen in Table 6.23.

Table 6.23. The matrix N3.

N3	DIZ	AIZ	KLC	BLC	HLC
DIZ	1/2,7333	5/15	5/15	1/2,7333	3/7,6667
AIZ	1/5/2,7333	1/15	1/15	1/5/2,7333	1/3/7,6667
KLC	1/5/2,7333	1/15	1/15	1/5/2,7333	1/3/7,6667
BLC	1/2,7333	5/15	5/15	1/2,7333	3/7,6667
HLC	1/3/2,7333	3/15	3/15	1/3/2,7333	1/7,6667

The calculation of matrix N3 results in the final matrix as seen in Table 6.24. The average of each row results in the F3 vector, containing the weights of each alternative.

Table 6.24. The calculation of matrix N3 and the weights of the alternatives (F3 vector).

N3	DIZ	AIZ	KLC	BLC	HLC	Sum		Weights (F3)
DIZ	0,3659	0,3333	0,3333	0,3659	0,3913	1,7897	f1	0,3579
AIZ	0,0732	0,0667	0,0667	0,0732	0,0435	0,3232	f2	0,0646
KLC	0,0732	0,0667	0,0667	0,0732	0,0435	0,3232	f3	0,0646
BLC	0,3659	0,3333	0,3333	0,3659	0,3913	1,7897	f4	0,3579
HLC	0,1220	0,2000	0,2000	0,1220	0,1304	0,7743	f5	0,1549

In the next stage, the "Weighted sum matrix (S3)" is constructed by multiplying each element of P3 with the weights of the alternatives (F3). The sum of the rows gives the vector (S3) (Table 6.25). The consistency vector (C3) is obtained by dividing (S3) to (F3).

Table 6.25. The calculation of matrix S3 and the consistency vector (C3 vector).

S3	DIZ	AIZ	KLC	BLC	HLC	Sum	
DIZ	0,3579	0,3232	0,3232	0,3579	0,4646	1,8268	s1
AIZ	0,0716	0,0646	0,0646	0,0716	0,0516	0,3241	s2
KLC	0,0716	0,0646	0,0646	0,0716	0,0516	0,3241	s3
BLC	0,3579	0,3232	0,3232	0,3579	0,4646	1,8268	s4
HLC	0,1193	0,1939	0,1939	0,1193	0,1549	0,7813	s5

Vector C3	
s1/f1	5,10
s2/f2	5,01
s3/f3	5,01
s4/f4	5,10
s5/f5	5,04
Sum	25,28

The λ_{max} is found by dividing "Sum C3" to "n": 25,28 / 5 = 5,056

The consistency index CI = (λ_{max} - n) / (n-1) = (5,056 - 5) / 4 = 0,014

The consistency ratio CR = CI / RI[21] = 0,014 / 1,1159 = 0,0125

CR < 0,1

It is understood that the comparisons among the five decision points were reasonably consistent since the consistency ratio is less than 0,1.

[21] RI (Random Consistency Index) is found from Table-5.3.

6.5.4. Constructing the Matrix P in Relation to the Criterion of "Proximity to the Port (POR)" and Calculating the Consistency Ratio

The assessments related to this criterion which are stated in section 5.3.4 are summarized in Table 6.26.

Table 6.26. Summary of the assessments related to the criterion of "POR"

Alt.	Advantages (+) and Disadvantages (-)
DIZ	Very close to the ports (+++)
AIZ	Very close to the ports (+++)
KLC	Very close to the ports (+++)
BLC	At a mid range from the ports (-)
HLC	At a distant range from the ports (--)

The "Pairwise comparison matrix for criterion POR (P4)" is constructed in parallel to this assessment (section 5.3.4) as seen in Table 6.27.

Table 6.27. The pairwise comparison matrix for the criterion of "POR"

P4	DIZ	AIZ	KLC	BLC	HLC	Explanation
DIZ	1	1	1	5	7	Very strong importance of DIZ, AIZ and KLC over HLC; strong importance of DIZ, AIZ and KLC over BLC; moderate importance of BLC over HLC.
AIZ	1	1	1	5	7	
KLC	1	1	1	5	7	
BLC	1/5	1/5	1/5	1	3	
HLC	1/7	1/7	1/7	1/3	1	
Sum	3,3429	3,3429	3,3429	16,3333	25	

The "Normalized matrix for criterion POR (N4)" is formed by dividing each element by the sum of its column as seen in Table 6.28.

Table 6.28. The matrix N4

N4	DIZ	AIZ	KLC	BLC	HLC
DIZ	1/3,3429	1/3,3429	1/3,3429	5/16,3333	7/25
AIZ	1/3,3429	1/3,3429	1/3,3429	5/16,3333	7/25
KLC	1/3,3429	1/3,3429	1/3,3429	5/16,3333	7/25
BLC	1/5/3,3429	1/5/3,3429	1/5/3,3429	1/16,3333	3/25
HLC	1/7/3,3429	1/7/3,3429	1/7/3,3429	1/3/16,3333	1/25

The calculation of matrix N4 results in the final matrix as seen in Table 6.29. The average of each row results in the F4 vector, containing the weights of each alternative.

Table 6.29. The calculation of matrix N4 and the weights of the alternatives (F4 vector)

N4	DIZ	AIZ	KLC	BLC	HLC	Sum		Weights (F4)
DIZ	0,2991	0,2991	0,2991	0,3061	0,2800	1,4836	f1	0,2967
AIZ	0,2991	0,2991	0,2991	0,3061	0,2800	1,4836	f2	0,2967
KLC	0,2991	0,2991	0,2991	0,3061	0,2800	1,4836	f3	0,2967
BLC	0,0598	0,0598	0,0598	0,0612	0,1200	0,3607	f4	0,0721
HLC	0,0427	0,0427	0,0427	0,0204	0,0400	0,1886	f5	0,0377

In the next stage, the "Weighted sum matrix (S4)" is constructed by multiplying each element of P4 with the weights of the alternatives (F4). The sum of the rows gives the vector (S4) (Table 6.30). The consistency vector (C4) is obtained by dividing (S4) to (F4).

Table 6.30. The calculation of matrix S4 and the consistency vector (C4 vector)

S4	DIZ	AIZ	KLC	BLC	HLC	Sum		Vector C4	
DIZ	0,2967	0,2967	0,2967	0,3607	0,2641	1,5149	s1	s1/f1	5,11
AIZ	0,2967	0,2967	0,2967	0,3607	0,2641	1,5149	s2	s2/f2	5,11
KLC	0,2967	0,2967	0,2967	0,3607	0,2641	1,5149	s3	s3/f3	5,11
BLC	0,0593	0,0593	0,0593	0,0721	0,1132	0,3633	s4	s4/f4	5,04
HLC	0,0424	0,0424	0,0424	0,0240	0,0377	0,1889	s5	s5/f5	5,01
								Sum	25,36

The λ_{max} is found by dividing "Sum C4" to "n": 25,36 / 5 = 5,072

The consistency index CI = (λ_{max} - n) / (n-1) = (5,072 - 5) / 4 = 0,018

The consistency ratio CR = CI / RI[22] = 0,018 / 1,1159 = 0,0161

CR < 0,1

It is understood that the comparisons among the five decision points were reasonably consistent since the consistency ratio is less than 0,1.

[22] RI (Random Consistency Index) is found from Table-5.3.

6.5.5. Constructing the Matrix P in Relation to the Criterion of "Proximity to the Industry (IND)" and Calculating the Consistency Ratio

The assessments related to this criterion which are stated in section 5.3.5 are summarized in Table 6.31.

Table 6.31. Summary of the assessments related to the criterion of "IND"

Alt.	Advantages (+) and Disadvantages (-)
DIZ	Closest alternative of roughly the 10% of the total OIZs (+)
AIZ	Closest alternative of roughly one-third of the total OIZs (+++)
KLC	Closest alternative of roughly one-third of the total OIZs (+++)
BLC	Closest alternative of roughly 34% of the total OIZs (++++); direct rail connection to the two current OIZs in plan (++++)
HLC	Closest alternative of roughly one quarter of the total OIZs (++); direct rail connection to the one current OIZ in plan (++)

The "Pairwise comparison matrix for criterion IND (P5)" is constructed in parallel to this assessment (section 5.3.5) as seen in Table 6.32.

Table 6.32. The pairwise comparison matrix for the criterion of "IND"

P5	DIZ	AIZ	KLC	BLC	HLC	Explanation
DIZ	1	1/5	1/5	1/7	1/3	Very strong importance of BLC over DIZ; strong importance of BLC over HLC; strong importance of AIZ and KLC over DIZ; moderate importance of BLC over AIZ and KLC; moderate importance of AIZ and KLC over HLC.
AIZ	5	1	1	1/3	3	
KLC	5	1	1	1/3	3	
BLC	7	3	3	1	5	
HLC	3	1/3	1/3	1/5	1	
Sum	21	5,5333	5,5333	2,0095	12,3333	

The "Normalized matrix for criterion IND (N5)" is formed by dividing each element by the sum of its column as seen in Table 6.28.

Table 6.33. The matrix N5

N5	DIZ	AIZ	KLC	BLC	HLC
DIZ	1/21	1/5/5,5333	1/5/5,5333	1/7/2,0095	1/3/12,3333
AIZ	5/21	1/5,5333	1/5,5333	1/3/2,0095	3/12,3333
KLC	5/21	1/5,5333	1/5,5333	1/3/2,0095	3/12,3333
BLC	7/21	3/5,5333	3/5,5333	1/2,0095	5/12,3333
HLC	3/21	1/5/5,5333	1/5/5,5333	1/7/2,0095	1/12,3333

The calculation of matrix N5 results in the final matrix as seen in Table 6.34. The average of each row results in the F5 vector, containing the weights of each alternative.

Table 6.34. The calculation of matrix N5 and the weights of the alternatives (F5 vector)

N5	DIZ	AIZ	KLC	BLC	HLC	Sum		Weights (F5)
DIZ	0,0476	0,0361	0,0361	0,0711	0,0270	0,2180	f1	0,0436
AIZ	0,2381	0,1807	0,1807	0,1659	0,2432	1,0087	f2	0,2017
KLC	0,2381	0,1807	0,1807	0,1659	0,2432	1,0087	f3	0,2017
BLC	0,3333	0,5422	0,5422	0,4976	0,4054	2,3207	f4	0,4641
HLC	0,1429	0,0602	0,0602	0,0995	0,0811	0,4439	f5	0,0888

In the next stage, the "Weighted sum matrix (S5)" is constructed by multiplying each element of P5 with the weights of the alternatives (F5). The sum of the rows gives the vector (S5) (Table 6.35). The consistency vector (C5) is obtained by dividing (S5) to (F5).

Table 6.35. The calculation of matrix S5 and the consistency vector (C5 vector)

S5	DIZ	AIZ	KLC	BLC	HLC	Sum		Vector C5	
DIZ	0,0436	0,0403	0,0403	0,0663	0,0296	0,2202	s1	s1/f1	5,05
AIZ	0,2180	0,2017	0,2017	0,1547	0,2664	1,0426	s2	s2/f2	5,17
KLC	0,2180	0,2017	0,2017	0,1547	0,2664	1,0426	s3	s3/f3	5,17
BLC	0,3052	0,6052	0,6052	0,4641	0,4439	2,4237	s4	s4/f4	5,22
HLC	0,1308	0,0672	0,0672	0,0928	0,0888	0,4469	s5	s5/f5	5,03
								Sum	25,64

The λ_{max} is found by dividing "Sum C5" to "n": 25,64 / 5 = 5,128

The consistency index CI = (λ_{max} - n) / (n-1) = (5,128 - 5) / 4 = 0,032

The consistency ratio CR = CI / RI[23] = 0,032 / 1,1159 = 0,0286

CR < 0,1

It is understood that the comparisons among the five decision points were reasonably consistent since the consistency ratio is less than 0,1.

[23] RI (Random Consistency Index) is found from Table-5.3.

6.5.6. Constructing the Matrix P in Relation to the Criterion of "Cost of Investment (COS)" and Calculating the Consistency Ratio

The assessments related to this criterion which are stated in section 5.3.6 are summarized in Table 6.36.

Table 6.36. Summary of the assessments related to the criterion of "COS"

Sort of Investment Costs	Advantages (+) and Disadvantages (-) of Alternatives				
	DIZ	AIZ	KLC	BLC	HLC
Cost for acquisition of land from owner of …	state (-)	private (---)	no need (+++)	no need (+++)	no need (+++)
Cost for infrastructure investment	very high (---)	very high (---)	very high (---)	high (--)	moderate (-)
Cost for equipment procurement	very high (---)	very high (---)	very high (---)	very high (---)	very high (---)
Cost for transportation system investment	very high (---)	very high (---)	very low (++)	very high (---)	low (+)

The "Pairwise comparison matrix for criterion COS (P6)" is constructed in parallel to this assessment (section 5.3.6) as seen in Table 6.37.

Table 6.37. The pairwise comparison matrix for the criterion of "COS"

P6	DIZ	AIZ	KLC	BLC	HLC	Explanation
DIZ	1	1	1/9	1/4	1/6	Extreme importance of KLC over DIZ and AIZ; strong to very strong importance of HLC over DIZ and AIZ; strong importance of KLC over BLC; moderate to strong importance of BLC over DIZ and AIZ; moderate importance of KLC over HLC; equal to moderate importance of HLC over BLC.
AIZ	1	1	1/9	1/4	1/6	
KLC	9	9	1	5	3	
BLC	4	4	1/5	1	1/2	
HLC	6	6	1/3	2	1	
Sum	21	21	1,7556	8,5	4,8333	

The "Normalized matrix for criterion COS (N6)" is formed by dividing each element by the sum of its column as seen in Table 6.38.

Table 6.38. The matrix N6

N6	DIZ	AIZ	KLC	BLC	HLC
DIZ	1/21	1/21	1/9/1,7556	1/4/8,5	1/6/4,8333
AIZ	1/21	1/21	1/9/1,7556	1/4/8,5	1/6/4,8333
KLC	9/21	9/21	1/1,7556	5/8,5	3/4,8333
BLC	4/21	4/21	1/5/1,7556	1/8,5	1/2/4,8333
HLC	6/21	6/21	1/3/1,7556	2/8,5	1/4,8333

The calculation of matrix N6 results in the final matrix as seen in Table 6.39. The average of each row results in the F6 vector, containing the weights of each alternative.

Table 6.39. The calculation of matrix N6 and the weights of the alternatives (F6 vector)

N6	DIZ	AIZ	KLC	BLC	HLC	Sum		Weights (F6)
DIZ	0,0476	0,0476	0,0633	0,0294	0,0345	0,2224	f1	0,0445
AIZ	0,0476	0,0476	0,0633	0,0294	0,0345	0,2224	f2	0,0445
KLC	0,4286	0,4286	0,5696	0,5882	0,6207	2,6357	f3	0,5271
BLC	0,1905	0,1905	0,1139	0,1176	0,1034	0,7160	f4	0,1432
HLC	0,2857	0,2857	0,1899	0,2353	0,2069	1,2035	f5	0,2407

In the next stage, the "Weighted sum matrix (S6)" is constructed by multiplying each element of P6 with the weights of the alternatives (F6). The sum of the rows gives the vector (S6) (Table 6.40). The consistency vector (C6) is obtained by dividing (S6) to (F6).

Table 6.40. The calculation of matrix S6 and the consistency vector (C6 vector)

S6	DIZ	AIZ	KLC	BLC	HLC	Sum		Vector C6	
DIZ	0,0445	0,0445	0,0586	0,0358	0,0401	0,2235	s1	s1/f1	5,02
AIZ	0,0445	0,0445	0,0586	0,0358	0,0401	0,2235	s2	s2/f2	5,02
KLC	0,4004	0,4004	0,5271	0,7160	0,7221	2,7659	s3	s3/f3	5,25
BLC	0,1779	0,1779	0,1054	0,1432	0,1203	0,7248	s4	s4/f4	5,06
HLC	0,2669	0,2669	0,1757	0,2864	0,2407	1,2366	s5	s5/f5	5,14
								Sum	25,49

The λ_{max} is found by dividing "Sum C6" to "n": 25,49 / 5 = 5,098

The consistency index CI = (λ_{max} - n) / (n-1) = (5,098 - 5) / 4 = 0,0245

The consistency ratio CR = CI / RI[24] = 0,0245 / 1,1159 = 0,0219

CR < 0,1

It is understood that the comparisons among the five decision points were reasonably consistent since the consistency ratio is less than 0,1.

[24] RI (Random Consistency Index) is found from Table-5.3.

6.5.7. Constructing the Matrix P in Relation to the Criterion of "Process of Establishing Dry Port (EST)" and Calculating the Consistency Ratio

The assessments related to this criterion which are stated in section 5.3.7 are summarized in Table 6.41.

Table 6.41. Summary of the assessments related to the criterion of "EST"

Alt.	**Advantages (+) and Disadvantages (-)**
DIZ	Quite difficult work for flattening the land (---); very long time to built facilities (---); connection to new highway and railway uncertain, most probably a very long time (---)
AIZ	Very long time to built facilities (---); connection to new highway and railway uncertain, most probably a very long time (---)
KLC	Much easier establishment process compared to other alternatives (+++)
BLC	Long time to built facilities (--); requiring connection to railways, but not difficult process as it is for DIZ and AIZ (-)
HLC	Much easier establishment process compared to other alternatives except KLC (+++); additionally requires a railway connection to OIZ (-)

The "Pairwise comparison matrix for criterion EST (P7)" is constructed in parallel to this assessment (section 5.3.7) as seen in Table 6.42.

Table 6.42. The pairwise comparison matrix for the criterion of "EST"

P7	DIZ	AIZ	KLC	BLC	HLC	Explanation
DIZ	1	1/2	1/9	1/4	1/6	Extreme importance of KLC over DIZ; extreme to very strong importance of KLC over AIZ; strong to very strong importance of HLC over DIZ; strong importance of KLC over BLC, and HLC over AIZ; moderate to strong importance of BLC over DIZ; moderate importance of KLC over HLC, and BLC over AIZ; equal to moderate importance of KLC over HLC.
AIZ	2	1	1/8	1/3	1/5	
KLC	9	8	1	5	3	
BLC	4	3	1/5	1	1/2	
HLC	6	5	1/3	2	1	
Sum	22	17,5	1,7694	8,5833	4,8667	

The "Normalized matrix for criterion EST (N7)" is formed by dividing each element by the sum of its column as seen in Table 6.43.

Table 6.43. The matrix N7

N7	DIZ	AIZ	KLC	BLC	HLC
DIZ	1/22	1/2/17,5	1/9/1,7694	1/4/8,5833	1/6/4,8667
AIZ	2/22	1/17,5	1/8/1,7694	1/3/8,5833	1/5/4,8667
KLC	9/22	8/17,5	1/1,7694	5/8,5833	3/4,8667
BLC	4/22	3/17,5	1/5/1,7694	1/8,5833	1/2/4,8667
HLC	6/22	5/17,5	1/3/1,7694	2/9,5833	1/4,8667

The calculation of matrix N7 results in the final matrix as seen in Table 6.44. The average of each row results in the F7 vector, containing the weights of each alternative.

Table 6.44. The calculation of matrix N7 and the weights of the alternatives (F7 vector)

N7	DIZ	AIZ	KLC	BLC	HLC	Sum		Weights (F7)
DIZ	0,0455	0,0286	0,0628	0,0291	0,0342	0,2002	f1	0,0400
AIZ	0,0909	0,0571	0,0706	0,0388	0,0411	0,2986	f2	0,0597
KLC	0,4091	0,4571	0,5651	0,5825	0,6164	2,6303	f3	0,5261
BLC	0,1818	0,1714	0,1130	0,1165	0,1027	0,6855	f4	0,1371
HLC	0,2727	0,2857	0,1884	0,2330	0,2055	1,1853	f5	0,2371

In the next stage, the "Weighted sum matrix (S7)" is constructed by multiplying each element of P7 with the weights of the alternatives (F7). The sum of the rows gives the vector (S7) (Table 6.45). The consistency vector (C7) is obtained by dividing (S7) to (F7).

Table 6.45. The calculation of matrix S7 and the consistency vector (C7 vector)

S7	DIZ	AIZ	KLC	BLC	HLC	Sum	
DIZ	0,0400	0,0597	0,0585	0,0457	0,0474	0,2513	s1
AIZ	0,0400	0,0597	0,0585	0,0457	0,0474	0,2513	s2
KLC	0,3603	0,5375	0,5261	0,6855	0,7112	2,8207	s3
BLC	0,1201	0,1792	0,1052	0,1371	0,0790	0,6206	s4
HLC	0,2002	0,2986	0,1754	0,4113	0,2371	1,3226	s5

Vector C7	
s1/f1	6,28
s2/f2	4,21
s3/f3	5,36
s4/f4	4,53
s5/f5	5,58
Sum	25,95

The λ_{max} is found by dividing "Sum C7" to "n": 25,95 / 5 = 5,19

The consistency index CI = (λ_{max} - n) / (n-1) = (5,19 - 5) / 4 = 0,0475

The consistency ratio CR = CI / RI[25] = 0,0475 / 1,1159 = 0,0425

CR < 0,1

It is understood that the comparisons among the five decision points were reasonably consistent since the consistency ratio is less than 0,1.

[25] RI (Random Consistency Index) is found from Table-5.3.

6.5.8. Assessment for the Pairwise Comparisons and the Consistency Analyses

During the implementation of the analytic hierarchy process, a total of seven pairwise comparison matrices (one for each criterion) have been constructed until this stage. After the calculation of the normalized matrices, the weights of the alternatives for each criterion were obtained. It was established that the alternative KLC had the highest weights for the criteria of CEN, TRA, POR, COS, and EST while the alternative BLC had that of for the criteria of ENV and IND. In this circumstance, it can be inferred that the KLC is the most powerful alternative.

After calculating the weights of the alternatives the consistency analyses were implemented to assess whether the comparisons were consistent or not. The consistency ratios were calculated between a range of "0,0125" through "0,0425". Since the results are less than "0.1" the inconsistencies are acceptable and the comparisons are deemed to be executed consciously (Saaty, 1994). Understanding that the pairwise comparisons were made within the acceptable ranges, the analytic hierarchy process proceeds by weighting the criteria.

6.6. Obtaining the Results by Putting into Process the Criteria

In the following stages, the decision matrix is obtained, and then each element of that matrix is multiplied by the weights of the criteria to obtain the resultant matrix.

6.6.1. Weighting the Criteria of this AHP Study

In order to determine the priority values of the criteria, the survey method was used to gather expert opinions. Another method is the pairwise comparison method in which the decision maker's own assessment will be reflected. If it is decided to implement this method, a similar implementation of the pairwise comparison which was applied for the decision points will be required to be, applied for the criteria. In this case, a matrix of with dimensions of "n x n" shall be formed, the weight of each criterion shall be calculated by making pairwise comparisons. The sum of these weights should be equal to "1".

As the comparison of both methods, in the latter one, only the expertness of the decision-maker could take part in the assessment process (in making pairwise comparisons) whereas the former one would engage the contributions of the experts from various sectors in that process.

As mentioned in section 6.2.4, a survey was carried out to grade the priorities of the criteria. Gathering the opinions of 94 experts from eleven sectors (see Table 6.4) which are relevant to the objective of the study, the ratings for each criterion were obtained as seen in Table 6.5. According to the ratings in Table 6.5 the vector W (the weights of the criteria) is reflected as seen in Table 6.46.

Table 6.46. The weights of the criteria (W vector) according to the questionnaire.

W Vector	Weights	Explanation of the Elements (Criteria)
w1	0,1378	Centrality in the transport network (CEN)
w2	0,1645	Convenience for transportation within the hinterland (TRA)
w3	0,1412	Environmental effect on urban areas (ENV)
w4	0,1476	Proximity to the port (POR)
w5	0,1437	Proximity to the industry (IND)
w6	0,1416	Cost of investment (COS)
w7	0,1236	Process of establishing dry port (EST)

Table 6.46 implies that the highest weight among the seven criteria pertains to vector w2, representing the criterion of "Convenience for transportation within the hinterland". In other terms, the respondents of the survey assessed the ability for freight transportation within the hinterland as the most important factor.

6.6.2. Constructing the Decision Matrix

The weights of the decision points (alternatives) have been obtained in consequence of pairwise comparisons in section 5.4.3. Those weights which are included in vectors[26] F1, F2, F3, F4, F5, F6, and F7 are combined in decision matrix D in Table 6.47.

[26] F vectors include the weights of the alternatives related to the criteria: F1 for "Centrality in transport network"; F2 for "Convenience for transportation within the hinterland"; F3 for "Environmental effect on

Table 6.47. Decision matrix D.

	CEN	TRA	ENV	POR	IND	INV	EST	Sum
DIZ	0,0557	0,1053	0,3579	0,2967	0,0436	0,0445	0,0400	**0,9438**
AIZ	0,3424	0,2454	0,0646	0,2967	0,2017	0,0445	0,0597	**1,2550**
KLC	0,3424	0,4971	0,0646	0,2967	0,2017	0,5271	0,5261	**2,4558**
BLC	0,1298	0,1053	0,3579	0,0721	0,4641	0,1432	0,1371	**1,4096**
HLC	0,1298	0,0469	0,1549	0,0377	0,0888	0,2407	0,2371	**0,9358**
Sum	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	**7,0000**

In this table, the rows imply the alternatives, and the columns represent the F vectors implying the power of the alternatives related to the factors (criteria). In other terms, the values in Table 6.47 exhibit the power of the alternatives in relation to the criteria. The KLC is seen as the most powerful alternative as having the highest value (2,4558) in the sum column.

6.6.3. Obtaining the Resultant Vector and Determining the Most Appropriate Decision Point

The resultant matrix R is obtained by multiplying matrix D with vector W (see Table 6.48). Vector W, copied from Table 6.46, represents the weights of the criteria which were taken into account when applying the pairwise comparisons. Each element in column F1 is multiplied with w1 and similar operations are carried out for each column respectively.

Table 6.48. Vector W (Weights of the criteria)

W	w1	w2	w3	w4	w5	w6	w7
	0,1378	0,1645	0,1412	0,1476	0,1437	0,1416	0,1236

The resultant matrix R, which is obtained by multiplying the “Decision Matrix D” (see Table 6.47) with the “Vector W” (see Table 6.48) is seen in Table 6.49.

urban areas"; F4 for "Proximity to the port"; F5 for "Proximity to the industry"; F6 for "Cost of investment" and F7 for "Process of establishing dry port".

Table 6.49. Matrix R (Resultant weights of the decision points)

Alt.	r1	r2	r3	r4	r5	r6	r7	Sum
DIZ	0,0077	0,0173	0,0505	0,0438	0,0063	0,0063	0,0049	0,1368
AIZ	0,0472	0,0404	0,0091	0,0438	0,0290	0,0063	0,0074	0,1831
KLC	0,0472	0,0818	0,0091	0,0438	0,0290	0,0746	0,0650	0,3505
BLC	0,0179	0,0173	0,0505	0,0106	0,0667	0,0203	0,0169	0,2003
HLC	0,0179	0,0077	0,0219	0,0056	0,0128	0,0341	0,0293	0,1292
Sum	0,1378	0,1645	0,1412	0,1476	0,1437	0,1416	0,1236	1,0000

The values in the column "Sum" gives the resultant weights of the alternative dry port locations. The process to obtain the Matrix R can be stated as multiplying the powers of the alternatives with the power of the criteria. The values seen in the sum column of this matrix represent the final weights of the alternatives, which are obtained after another process applying the weights of the criteria. The ranking of these alternatives with the percentage of their weights is seen in Table 6.50.

Table 6.50. Ranking of the decision points

Rank	**Decision Points (Alternative Dry Port Locations)**	**Rating %**
1	KLC (Kosekoy Logistics Center)	35,05
2	BLC (Bozuyuk Logistics Center)	20,03
3	AIZ (East of A.Kibar OIZ)	18,31
4	DIZ (North of Dilovası OIZ)	13,68
5	HLC (Hasanbey Logistics Center)	12,92

The Köseköy Logistics Center, among the five alternatives, is seen as the best alternative dry port location.

6.7. Sensitivity Analysis of the AHP and Decision-Making

After determining the best alternative a sensitivity analysis can be applied to observe in which circumstances the selection could change (Erkut and Tarımcılar, 1991). To observe the changes when altering the weights of the criteria, and to find the smallest change in the weights which could change the ranking may be the targets of the sensitivity analysis. Especially when there is a minor difference between the top-ranking alternative and its succeeding alternative, the sensitivity analysis might be a needed process to understand how a minor change could cause a change at the top ranking.

At the end of this study, it is seen that KLC is at the top ranking with a huge difference between its competitors. So it is not considered that a minor change could change the top ranking. When analyzing the weights of the decision points, it is seen that KLC has got the top weights related to the criteria of "Convenience for transportation within the hinterland", "Proximity to port", "Cost of investment", "Centrality in the transport network", and "Process of establishing dry port". It means that the KLC has got the top weights related to five criteria in seven, whereas the other two criteria, "Environmental effect" and "Proximity to industry" have brought the highest weights to the BLC. Therefore, it is understood that the only alternative that can change the selected alternative could be BLC. This change can only be possible by increasing the weight of the two criteria on which the BLC outperformed. However, before increasing the weights of these two criteria, some other steps were implemented to observe the impact of other criteria.

Table 6.51 exhibits five different cases. In each case, one of the criteria that KLC got the top weights were assumed to be excluded. Thus it was examined to what extent it could change the results dismissing criteria on which the KLC was powerful compared to other alternatives. The weight of the excluded criterion was added equally to the other criteria. Case-1 assumes to exclude the criterion of "Centrality in the transport network", and the other cases (Case-2 through Case-5) do the same for the criteria of "Convenience for transportation within the hinterland", "Proximity to port", "Cost of investment", and "Process of establishing dry port" respectively.

In the cases exhibited in Table 6.51, it is observed that excluding any criteria on which the KLC had the top weights is not able to change the top-ranking but do some insignificant changes in Case-2 and Case-3.

Table 6.51. Results of the sensitivity analyses according to the cases that exclude one criteria on which KLC had top weight

Cases		Case-1	Case-2	Case-3	Case-4	Case-5
The Shifted Weights of the Citeria (Weights in %)	CEN	0,00	13,78	13,78	13,78	13,78
	TRA	18,75	0,00	16,45	16,45	16,45
	ENV	16,42	30,57	14,12	14,12	14,12
	POR	17,06	14,76	0,00	14,76	14,76
	IND	16,67	14,37	29,13	28,53	26,73
	INV	16,46	14,16	14,16	0,00	14,16
	EST	14,66	12,36	12,36	0,12	0,00
Ranking the Alternatives with their Resultant Weights (Weights in %)	1	KLC	KLC	KLC	KLC	KLC
		35,19	27,94	35,65	30,44	31,04
	2	BLC	BLC	BLC	BLC	BLC
		21,18	24,19	25,82	24,58	24,07
	3	AIZ	DIZ	AIZ	AIZ	AIZ
		15,69	17,84	16,91	20,54	20,07
	4	DIZ	AIZ	HLC	DIZ	DIZ
		14,96	15,34	13,67	13,67	13,73
	5	HLC	HLC	DIZ	HLC	HLC
		12,98	14,69	9,95	10,77	11,08

In Case-2, where the criterion of "Convenience for transportation within the hinterland (TRA)" is excluded, it is seen that DIZ increases its resultant weight and takes over the third rank from AIZ. This shift stems from excluding the effect of the "TRA" criterion which brought in lower weight to DIZ compared to AIZ. Thus, DIZ had a chance to ascend and get ahead of AIZ in Case-2. To recall, in the pairwise comparison process for the criterion of "TRA" it was stated that “AIZ had moderate importance over DIZ” (see Table 6.17) and the weight of DIZ was calculated lower than that of AIZ in Table 6.19. Similarly, in Case-3, where the criterion of "Proximity to port (POR)" is excluded, it is seen that HLC increases its resultant weight and takes over the fourth rank from DIZ. This shift stems from excluding the effect of the criterion of "POR" which brought in much lower weight to HLC compared to DIZ. When this effect is excluded as in Case-3, HLC had a chance to ascend and get ahead of DIZ. To recall, in the pairwise comparison process for the criterion of "POR" it was stated that “DIZ had very strong importance over HLC” (see Table 6.27) and the weight of HLC was calculated much lower than DIZ in Table 6.29.

Table 6.52 exhibits two other cases in which two criteria are assumed to be excluded. The excluded two criteria are selected as "Cost of investment (COS)" and "Process of establishing dry port (EST)" among the ones that KLC got the top weights. In Case-6, the total weight of the excluded criteria was added equally to the other criteria. On the other side, in Case-7 the total weight of the excluded criteria was added only to the selected two criteria, “Environmental effect on urban areas (ENV)” and “Proximity to the industry (IND)”, which are the ones that BLC got the top weights.

Table 6.52. Results of the sensitivity analyses according to the cases that exclude two criteria on which BLC had top weights

Cases		**Case-6**	**Case-7**
The Shifted Weights of the Citeria (Weights in %)	**CEN**	19,08	13,78
	TRA	21,75	16,45
	ENV	19,42	28,28
	POR	20,06	14,76
	IND	19,67	26,73
	INV	0,00	0,00
	EST	0,00	0,00
Ranking the Alternatives with their Resultant Weights (Weights in %)	**1**	KLC	BLC
		28,53	27,11
	2	AIZ	KLC
		23,05	24,49
	3	BLC	AIZ
		22,3	20,35
	4	DIZ	DIZ
		17,12	18,17
	5	HLC	HLC
		9,01	9,87

In Case-6, it is observed that excluding two selected criteria while adding their weights equal to the other criteria is not sufficient to change the top ranking, but is having an impact to change between the second and the third ranks. This shift stems from excluding the effects of criteria "Cost of investment (COS)" and “Process of establishing dry port (EST)” which brought in lower weight to AIZ compared to BLC. To recall, it was stated that “BLC had moderate to strong importance over AIZ” (see Table 6.37) in the pairwise comparison process for the criterion of "COS", and that “BLC had moderate importance over AIZ” (see Table 6.42) in the pairwise comparison process for the criterion of "EST". Consequently, the weight of AIZ was calculated lower than that of BLC in Table 6.39 and Table 6.42. But if the total weights of the two criteria, "COS" and “EST”, are added only to the selected two criteria, “Environmental effect on urban areas (ENV)” and “Proximity to the industry (IND)”, which are the ones that BLC got the top weights, it would be sufficient to change the top ranking as in Case-7. Since BLC is more powerful than the other candidates related to the two criteria, “ENV” and “IND”, increasing the weights of these criteria would make the alternative BLC approach towards the top rank.

Table 6.53 exhibits two other cases in which one criterion is increased while the others are decreased equally. In these cases, the selected criteria are “Environmental effect on urban areas (ENV)” and “Proximity to the industry (IND)”, which are the ones that BLC got the top weights. The aim to examine Case-8 and Case-9 is to find out the level at which it could be possible to change the selected alternative. In the examination of Case-8, it is understood that the weight of the criterion “ENV” should be increased until 44% to change the top ranking. This requires the addition of 29,88% to the original weight. From another aspect, the original weight of this criterion should be increased to a weight greater than three times. On the other hand, the examination of Case-9 indicates that a little bit more increase would require to provide a similar result. It is seen that the weight of the criterion “IND” should be increased by 46% to change the top ranking. This requires the addition of 31,63% to the original weight. It also means that the original weight of the "IND" criterion should be increased to a weight greater than three times.

When examining the resultant weights of the decision points in Table 6.49 and Table 6.50 it was clear that there was a sizeable difference between the top rank and the others. The results of the AHP indicate a 15% difference between the KLC and the BLC. The resultant weight of KLC was calculated at 35% whereas that of BLC was 20%. Five out of seven criteria were in favor of KLC.

Table 6.53. Results of the sensitivity analyses to find the minimum change in weights of the criteria to change the top rank

Cases		Case-8	Case-9
The Shifted Weights of the Citeria (Weights in %)	CEN	8,80	8,51
	TRA	11,47	11,18
	ENV	44,00	8,84
	POR	9,78	9,49
	IND	9,39	46,00
	INV	9,18	8,89
	EST	7,38	7,09
Ranking the Alternatives with their Resultant Weights (Weights in %)	1	BLC	BLC
		25,49	29,73
	2	KLC	KLC
		25,08	29,55
	3	DIZ	AIZ
		21,46	19,14
	4	AIZ	HLC
		14,32	11,26
	5	HLC	DIZ
		13,66	10,32

It was already clear that minor corrections in the weight of the criteria could not be sufficient to close the gap in such a case. The results of the sensitivity analyses have exhibited that, the changes to the weights of the criteria should be quite far beyond the reasonable values to be able to change the decided alternative of the AHP solution. Therefore, it is considered to be the most logical solution to construct the dry port in the location of the "Köseköy Logistics Center (KLC)" to support container transportation in the Kocaeli region by abiding by the result obtained in AHP solution.

7. DEVELOPING AN OPTIMIZATION MODEL

It is a high probability that the current storage capacities of Kocaeli container terminals will not be adequate to meet the demand in the 2030s. Those terminals may have trouble even if they expand their storage area of about 10%. As explained in the third part (literature review) of this study, a dry port is expected to support seaports in almost every kind of service issues that are carried out in seaports. Especially when a seaport is about to suffer from lack of space, a close dry port may act as a savior.

In this part, being inspired by the possible projections, a dry port model is imagined. As explained in the fifth part of this study, Köseköy Logistics Center (KLC) is determined as the best location to construct a dry port to support Kocaeli container terminals. The first section of this part explains the possible requirements and lays out a model that a dry port serves in collaboration with at least one seaport. An optimization model is developed in the second section. The optimization model is considered to be helpful for the decision-makers when taking some measures about storing are needed in a case that the seaport authority has the absolute right in deciding to transport some containers to the dry port. The third section creates a case study to run the optimization model. The case study is designed in relation to the possible projections for the 2030s. The fourth section puts forward the numerical experiments that are obtained after running the optimization model.

7.1. Designing a Dry Port Model

Köseköy Logistics Center, located 20 to 50 km away from the Kocaeli container terminals is determined as the dry port of this model since it is considered as the best alternative among five candidates. The section "4.6" of the thesis study puts forward that the conventional railway line between Gebze and Köseköy towns could produce a total capacity of approximately 1,3 million TEUs provided that the TCDD's projects of siding sites are completed. On the other side, it is estimated that a total of one million TEUs could be transported between the seaports and the dry port in relation to the circumstances that could be prevailing in the 2030s. The model is designed taking into account these assumptions.

A prototype of the dry port model is seen in Figure 7.1. This prototype indicates that a number of import containers are transported to KLC after being unloaded from the vessel(s). The crucial point in this model is that those containers are not stored in the seaport, instead, they are directly transferred to the dry port KLC for every kind of activities including customs inspection.

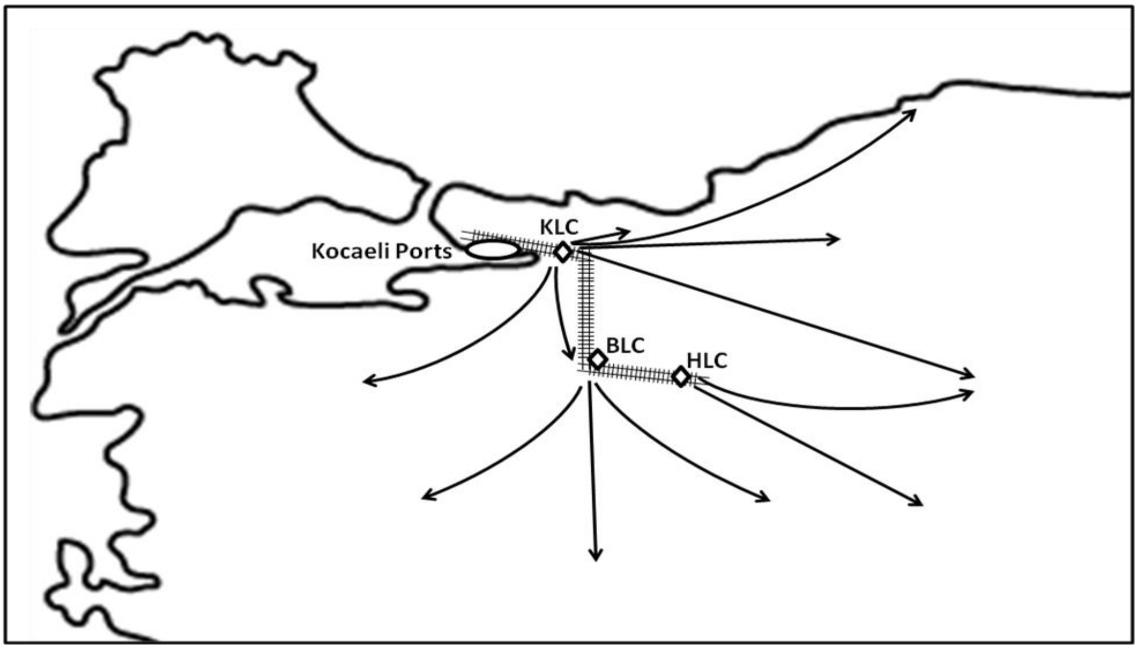


Figure 7.1. A schematic view of transportation system in dry port model. (Prepared by the Author)

The freight distribution of EVYAPPORT given in Table 6.6 provides an insight that a considerable amount of the cargo arriving at Kocaeli ports is transported to some distant cities such as Ankara, Bolu, Sakarya, Konya, Kütahya, Düzce, Bursa, Bilecik, and Eskişehir. Figure 7.1 implies that a number of containers could be transported to the receivers after mode switching at KLC, which means that a number of containers having been transferred to KLC by railways would be loaded to trucks to be carried until their final destinations. On the other side, for some of the containers, rail transportation may continue to more distant locations which are intermodal terminals. For example, the Bozüyük Logistics Center (BLC) could facilitate the transportation of the freight to some points such as Bilecik, Kütahya, Konya, and the Hasanbey Logistics Center (HLC) could do the same for Eskişehir, Ankara, and Konya. Therefore, a close dry port would both alleviate the congested seaports and facilitate transportation to distant points.

According to the optimistic scenario for the projections of future throughput volumes explained in section "4.6", it is assessed that the Kocaeli container terminals might need an extra storage capacity that accounts for approximately one million TEUs in about 2035. Therefore, KLC is assumed to have a storage capacity for about one million TEUs. In addition to the storage capability, KLC is assumed to have the capabilities listed in section "4.6". Although the law of the Liberalization of Railways (Law number 6461) came into force in 2013, in this model it is assumed that the freight will be transported by the trains of TCDD. So, the tariff of TCDD will be based on calculating both of the transportation expenses on railways and the warehouse expenses in dry port KLC.

One of the most important advantages of a dry port is that the land is not as valuable as it is in a seaport, so the warehouse fee in a dry port is generally much lower than it is in a seaport. It means that a dry port provides support to the economy in terms of transportation expenses and warehouse fees. But on the other hand, switching the transportation mode requires additional unloading and loading operations, which in turn bring in additional expenses as seen in Figure 7.2. The costs of the modes and intermodal transportation can be compared by using Figure 7.2.

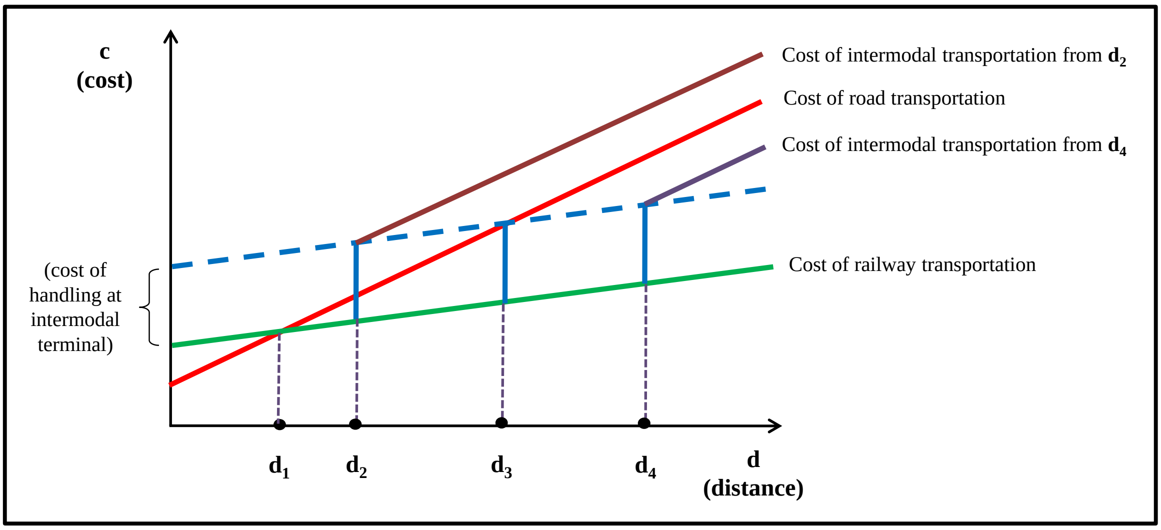


Figure 7.2. Comparing the costs of road, railway and intermodal transportation.

The red line implies the cost of road transportation whereas the green line implies that of railway transportation. Point "d_1" is the "break-even point[27]" for both transportation modes. In other terms, point "d_1" indicates the distance where the total costs of two different modes come to an equilibrium. The points "d_2" to "d_4" illustrates the intermodal nodes where the freight is transferred to road transportation mode from railway mode. Point "d_3" forms another equilibrium between road transportation and intermodal transportation. Switching the mode earlier than point "d_3" will not be economical as it does at point "d_2", but it will be economical after "d_3" as it does at point "d_4".

It is apparent in Figure 7.2 that the cost of handling at the intermodal terminal is an important factor for the total cost of the transportation process. The cost of handling involves unloading the container from a railway car and loading the same container onto a truck. Reducing the handling cost in an intermodal terminal would certainly reduce the total cost of transportation and carry the break-even point to a shorter distance. Searching the examples in the world, it is seen that a single movement of a full container in a dry port costs about 30 €. Thus, switching the transportation mode for a full container in a dry port would cost about 60 € only for unloading and loading movements.

Of course, there may be some options to lower the cost depending on the circumstances. When considering the dry port example in this thesis study, KLC is a logistics center which belongs to TCDD. In the prevailing circumstances, neither TCDD nor the KLC generates income at a reasonable level through container transportation. Above all, the KLC does not have the required capabilities for a great quantity of container transportation. But it is desired to have the necessary specialties and expected to serve as a well-established dry port in the medium term. If some measures are taken to attract customers, it will be possible for KLC to be in demand in the near future and TCDD will be able to generate more revenue from both transportation and dry port services. If any seaport works in collaboration with KLC, it could gain a competitive advantage over the other seaports.

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[27] The break-even point is found by setting the total cost of the two options equal to one another. Break-even analysis is a handy tool for computing the cost-effectiveness of sourcing decisions when the cost is the most important criterion (Wisner et al., 2012).

In the thesis study, it is assumed that at least one seaport is in collaboration with KLC. As mentioned in the fourth part, currently EVYAPPORT and SAFİPORT have a railway connection whereas the construction for DP WORLD continues and the connection of BELDEPORT is in the planning phase. Since LİMAŞ is located at the southern coast of Kocaeli Gulf, it is almost impossible to provide a connection to LİMAŞ. However, considering the possibility of the unification of the ports in the following years and the possibility of new arrangements on the land area of the port, it is possible that YILPORT would have a railway connection.

Analyzing the recent throughput data and the projections for future throughput values, it is seen that three container terminals including YILPORT, EVYAPPORT, and DP WORLD Port might experience capacity constraints in the 2030s. When considering the intermodal capability of these ports, YILPORT does not have such a capability at the moment, DP WORLD Port is going to have a limited capability with only one railway line but not more than 500 meters in length. Among them, EVYAPPORT has the best intermodal capability with four railway lines each having a minimum 600 meters length. As having adequate capability and as being predicted to experience capacity constraints in the future, EVYAPPORT is designated as the seaport that will be in collaboration with KLC within the optimization model of the thesis study. It is considered that the numerical results of the optimization model would encourage all seaport authorities and the General Directorate of TCDD, in completing the railway connections of the seaports and applying the dry port concept.

It is also considered that the seaport authority has the right to decide which containers should be stacked in the seaport terminal, and which containers should be directly transferred to the dry port provided that the final destination of the containers directed to the dry port is ahead of KLC.

As a general approach, port authorities would prefer to stack as many containers as possible in their terminal areas. Because, in addition to the money they earn by handling, they will also earn warehouse fees through the containers waiting in the terminal. Because, in addition to the money they earn by handling, they will also earn warehouse fees through the containers waiting in the terminal. However, the greater the number of containers held at the terminal, the lesser the maneuverability within the port. So, the port authority needs to equilibrate in benefiting from its stacking capacity and in maintaining a good level of maneuverability. In particular, the port authority should refrain from filling the terminal stacking area so that it cannot receive the cargo of vessels which are planned to call at the port in the future. The best option to maintain the seaport terminal work efficiently might be collaborating with a dry port to be able to transfer the surplus volumes to another place which would serve as if the satellite terminal of that seaport, located outside of the seaport. By having such an opportunity, the sea port would be able to provide a balance in relation to the cargo volume that will be stacked in its own terminal and the volume that will be sent to the dry port.

The TCDD (2019) specifies the tariff to be applied for railway transportation. According to the domestic freight transportation tariff, when the freight is transported by the wagons of TCDD, the shipper is required to pay 476.28 TL (approximately 80 €) per wagon for the transportation of the freight which does not exceed 57 tons in wagons up to 60 feet long. Besides that, TCDD implements a different pricing policy in order to encourage container transportation with railway cars in short distances. The TCDD's tariff states that a fixed price will be charged per carriage regardless of the weight and type of goods for the full container transport to be made up to 60 feet (incl. 60 feet) and within the minimum transport distance (1-150 km.) provided that not to exceed the wagon capacity and axle pressure. In accordance with the above description, within the distances 11 to 60 km 150 TL (approximately 25 €) will be charged for the transportation of full containers on a railway car[28]. As a result of the comparison of the two prices mentioned above according to TCDD tariff, the price applied to short-distance container transport such as 11-60 km seems to be very advantageous for the shippers. Since the distance of KLC from the Kocaeli container terminals is within the distance of 20 through 50 km, two containers (one 20 feet and the other 40 feet) on a railway car would be transported to 150 TL (25 €).

[28] This information was confirmed on 03.07.2019 by telephone interview with Aynur Turan, the tariff expert in charge of logistics department of TCDD General Directorate.

Although the price for container load to be transported at short distances is attractive, the total cost incurred will not be encouraging if the cost of handling at the dry port costs about 60 € as described in this section. In order for the service to be provided by KLC to be more attractive, the handling costs need to be significantly reduced. According to TCDD's tariff, companies can rent open and closed spaces within the logistics center, as well as to unload and load their cargo by using their own vehicles and equipment. In the model developed within the scope of this thesis study, a sea port collaborates with TCDD and KLC, having the required cargoes transported to KLC, where it carries out loading and unloading activities by using its own teams and vehicles. It is assumed that it will pay the warehouse fee to the KLC and transfer the cargo to the shipper within the KLC after the customs inspection to be carried out at the KLC. In accordance with the designed dry port model, the expenditures to be made for unloading, transporting, handling, storage of cargo are examined in the following sections considering the current conditions.

7.1.1. Expenditures in the Seaport

The income and expenditure items to be realized in a sea port is explained related to the following figure. For a sea port collaborating with a dry port, containers unloaded from the vessel, as shown in Figure 7.3, will either be stacked at the terminal area or loaded onto railway wagons to be sent directly to the dry port. Therefore, the "number of boxes unloaded (U)" at the seaport will be equal to the sum of the "number of warehoused boxes (W)" at the terminal and the "number of the boxes directed to the dry port (D)" through the railway cars.

The sea ports charge a fee of "Terminal Handling Cost (THC)" for boxes to be unloaded from and to be loaded onto the vessels. This fee may vary depending on the size and characteristics (such as dry, reefer or out-of-gauge (OOG) container) of the container. Some ports may charge the same fee for containers of the same type but of different sizes. This type of fee is an income item for the seaports. Another income item is the warehouse fee. As the area they occupy is proportional to their size, different warehouse fees are applied depending on the size and type of container waiting in the storage area. Containers directed to the dry port will also be subject to a fee of THC, such as the containers stacked at the terminal. However, for such containers, the warehouse fee will not be applied since they are not stacked at the terminal, but a fee of handling will be applied as they will be loaded onto the railway cars before leaving the port.

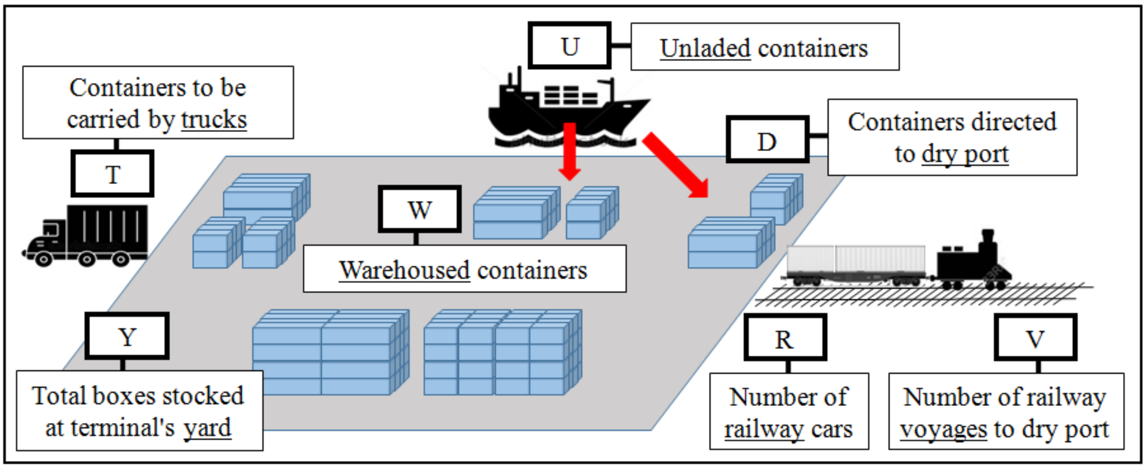

Figure 7.3. Schematic view of a seaport having road and rail connections.

The shuttle of a railway voyage will involve a number of railway cars depending on some circumstances such as the length of the railway line within the port, the number of containers to be sent to the dry port and the capacity of the railway between the seaport and the dry port. To minimize the expense of railway transportation it would be wise to include as many railway cars as possible.

Containers stacked at the terminal will wait for a number of days, namely for a Dwell Time (DT) period, for customs and other transactions. Each container will be loaded onto a truck at the end of this DT period and transported to its final destination. Additionally, for a working container terminal, there will always be a number of containers (Y) in the terminal yard area. While each container stacked at the yard after being transported by a vessel increases the number "Y", every container loaded onto a truck to leave the terminal at the end of the DT period will have a decreasing effect.

7.1.2. Cost of Transportation

Companies carrying freight calculate the transportation costs per km. In this calculation, they take into account various items such as purchase costs of the vehicle, maintenance costs, fuel costs, and drivers' fees. The cost of transport per km varies from country to country due to various factors, including working conditions and employee wages. For example, Ekol Logistics Company states that the average transportation cost of a container carrying truck in Europe is 1,00 Euro per km whereas the cost of the same container on a railway car is 0,75 Euro. The General Manager of Freight Department proposes a bit less value to take a base for freight transportation in Turkey[29] since the driver fee and the maintenance cost are less in Turkey than those of in Europe. It was seen that the freight transportation cost calculated by the Arkas Logistics Company is close to the figures expressed by Ekol Logistics Company. It was calculated as approximately 0,80 Euro per km according to the value stated in TL by the operations manager[30] on 14.02.2018.

For railway freight transportation in Turkey, the domestic tariff published by TCDD Transportation is used. In the pricing, the weight of the transported container and the total distance to be transported are taken into consideration. It would be advantageous to carry two containers, (one 20 feet and the other 40 feet) on a railway car which has a length of 60 feet, provided that the vehicle does not exceed the maximum carrying weight.

As mentioned above, the tariff of TCDD indicates that when carrying two boxes in total 60 feet on a railway car within the distances 11 to 60 km, 150 TL (approximately 25 €) will be charged provided that the total weight of the boxes do not exceed the wagon capacity.

7.1.3. Expenditures in the Dry Port

Since the Köseköy Logistics Center (KLC) is a facility of TCDD, the Customs Warehouse Tariff of TCDD is applied for the warehouse fee as seen in Table 7.1. The tariff encourages the transporters to take the container in seven days after arriving at the logistics

[29] This information was obtained on 26.01.2018 at Ekol Logistics headquarters during a working meeting with the General Manager of Freight Transport M.BOĞ and the Fleet Process Development Manager K.TUNA.

[30] Arkas Logistics Road Transport Operations Manager Y.SARAÇ, stated that the cost of transporting a container by a truck was approximately 0.80 euro per km as of February 14, 2018, considering all the costs such as depreciation, fuel and driver costs.

center. The fees in this table are quite cheaper than the fees implemented by the seaports. The main reason stems from the worthlessness of the land area which is located inland. On the other hand, it is assessed that TCDD tries to encourage the transporters to use TCDD logistics centers and the railways.

Table 7.1. The customs warehouse tariff of TCDD for logistics centers (in Euro).

Cargo	Waiting Period	Full Container	Empty Container
Import	First 7 days	3 €	1 €
	8th and following days	6 €	1 €
Export	First 7 days	2 €	1 €
	8th and following days	4 €	1 €

Source: The Customs Warehouse Tariff of TCDD, 2007.

According to the same tariff, the handling of the container from any truck or railway car to be stacked is 30 Euros for a full container. But the tariff also states that, if this service cannot be provided by TCDD, it may be allowed by TCDD to provide this service by the business owners, provided that they are responsible for all kinds of tools, equipment, and personnel (TCDD, 2007). Therefore it is possible for the transporters to handle their cargoes by their own equipment. It is assessed that the cost of handling operations for containers might be minimized for the transporters by operating their own team and using their own equipment within the dry port area. In this circumstance, the company would need to rent an area and an office. It is considered that using one or more reach stackers[31] is the most economical way to handle the containers.

The possible costs and some operating characteristics of an LRS 545 model reach stacker are described by the Sales Manager[32] of Liebherr Machinery Trade Service Ltd.as follows:

(i) Lifetime: Although it varies depending on many factors, it is accepted that it has a working life of at least 15,000 hours. While the upper limit is difficult to determine, it is possible to use it over 30,000 hours.

[31] A reach stacker is a vehicle used for handling containers in ports. Reach stackers are able to transport a container short distances very quickly and pile them in various rows depending on its access.

[32] This information was obtained from M.Gürses, the Sales Manager of Liebherr, through messaging on April 24, 2018.

(ii) Need for maintenance: It should be taken to service every 1.000 hours.

(iii) Fuel consumption: The amount of diesel to be consumed under normal use conditions is 12-14 liter / hour.

(iv) Maintenance and Repair Costs: Considering the service life of 15,000 hours, the total cost of maintenance is expected to be around 70,000-75,000 Euros.

(v) Purchase Price: The purchase price of an LRS 545 model reach stacker including tax is around 415.000-430.000 Euro.

It is assumed that a sea port authority collaborates with the dry port authority and will provide services with a team and equipment within the dry port for the purpose of unloading containers from the railway cars to the ground and loading these containers to a truck or a wagon at the end of the DT period. It is expected that by applying this method the operating cost for loading or unloading can be reduced to a very low level. In order to calculate the cost of this application it is also required to determine some other side costs as explained below:

(i) Working hours per day: It is necessary to decide how many hours per day the machine will work. Since one operator is assumed to work eight hours per day, it could be assumed that two operators run a machine in total 16 hours per day.

(ii) The number of operations (movements for loading or unloading containers): It is necessary to know how many movements can be implemented in a day. Experience has shown that a reach stacker can achieve an average of 12-15 container loading or unloading movements per hour[33]. It is assumed that a reach-stacker will be able to make a total of 200 movements in a day.

(iii) Expenditure for fuel consumption: The price of diesel is approximately 1,00 Euro per liter.

(iv) The wage of the operators: It is predicted that the wage of an operator may vary between 1.000 to 1.500 Euros in Turkey. In this study it is assumed that an operator will be paid 1.200 Euros per month, therefore the total wages of two operators who will operate a single reach-stacker throughout a month, will be 2.400 Euros per month.

(v) Renting area within the dry port: According to the tariff, the places such as open area, closed area, land, ramp, hangar etc. belonging to the "TCDD Transportation"

[33] This information was obtained from interviews with YILPORT and EVYAPPORT operators.

can be rented for complementary, supportive or attractive purposes (TCDD Transportation, 2018). TCDD transportation might rent its facilities for the purposes of keeping the reach-stackers and providing an office for the operators and liaison personnel of the seaport. It is assumed that the rental costs will amount to approximately 1,200 Euro.

(vi) Cost of insurance: It is assumed that the amount to be paid each year for the insurance of the machine will be around 5% of the purchase cost. If it is provided for 420,000 Euros, it is estimated that 21,000 Euros will be paid each year as insurance costs.

The "Cost of the single movement of the Reach-Stacker (CsmRS)" can be formulated as below in relation to the information given above:

$$CsmRS = \frac{\left(\frac{LTC}{dLT}\right) + FC + OC + RC}{md} \tag{7.1}$$

Where;

LTC = Life Time Cost in total,

dLT = Expected working days throughout the life time,

FC = Cost of fuel consumption in a day,

OC = Daily cost of operators derived from their wages,

RC = Daily cost of the renting of the open and closed areas within the dry port,

md = Total movements of the reach-stacker in a day.

The LTC includes the initial purchase cost, insurance and maintenance costs throughout the lifetime of the reach-stacker. The LTC can be formulated as below:

$$LTC = PC + (IC * LTY) + MC \tag{7.2}$$

Where;

PC = Cost for purchasing the reach-stacker,

IC = Cost of insurance per year,

LTY = Lifetime in terms of years,

MC = Total maintenance cost throughout the lifetime.

To calculate the LTY, it is required to predict the total working days throughout the lifetime and the working days in a year. The LYT can be formulated as below:

$$LTY = \frac{\mathrm{dLT}}{\mathrm{dY}} \tag{7.3}$$

Where;

dLT = Total working days throughout the life time,

dY = Working days in a year.

The number of dLT is closely related to the total working hour of the machine throughout the life time. Also, the daily working hour is required to calculate the dLT. The dLT can be formulated as below:

$$dLT = \frac{\mathrm{LT}wh}{\mathrm{d}wh} \tag{7.4}$$

Where;

LTwh = Total working hour of the machine throughout the life time,

dwh = Daily working hour.

The "CsmRS" is calculated by using the formulas 7.1 through 7.4 as explained below. In the first step, it is required to predict the LTwh and the dwh. It was mentioned that an LRS 545 model reach-stacker can work at least 15.000 hours and the maximum working hour may exceed 30.000 hours. In this study, for the reach-stacker that will be used in dry port, it is assumed that its lifetime will long until 28.000 hours. On the other side, it is assumed that a reach-stacker will work 16 hours a day. Therefore, dLT (total working days throughout the life time) is calculated by using the formula (7.4).

$$dLT = \frac{\mathrm{LTwh}}{\mathrm{dwh}} = \frac{28.000}{16} = 1.750\ days$$

In the second step, it is required to predict the dY (Working days in a year) to calculate the LTY (Lifetime in terms of years). Since it will require some maintenance periods throughout its lifetime approximately every 1.000 hours, it can be interpreted that approximately once at a period of two months it will require to be taken to maintenance service. Considering interruptions in maintenance and other needs, it can be assumed that the reach-stacker would operate on average 350 days per year. Therefore, LTY is calculated by using the formula (7.3).

$$LTY = \frac{\text{dLT}}{\text{dY}} = \frac{1.750}{350} = 4\ years$$

In the third step, it is required to know the PC (cost for purchasing the reach-stacker), the IC (cost of insurance per year), and to predict the MC (total Maintenance Cost throughout the lifetime) to calculate the LTC (Life Time Cost in total). For this study, it is assumed that the purchase cost is 420.000 Euros and the insurance cost per year is equal to 5% of the purchase cost (21.000 Euros). The total maintenance cost can be calculated by a proportion as stated below, taking into account that the total maintenance cost of a reach-stacker for a 15.000 hours life cycle is 75.000 Euros.

$$\frac{15.000\ hours}{28.000\ hours} = \frac{75.000\ Euros}{?\ Euros\ (MC)}$$

$$MC = \frac{28.000\ \text{hours} * 75.000\ \text{Euros}}{15.000\ \text{hours}} = 140.000\ Euros$$

According to the data and the predictions mentioned above, the LTC is calculated by using the formula (7.2).

$$LTC = 420.000 + (21.000 * 5) + 140.000 = 665.000\ Euros$$

In the last step, it is required to know the FC (Cost of fuel consumption in a day), the OC (Daily cost of operators derived from their wages), and the RC (Daily cost of the renting of the open and closed areas within the dry port) to calculate the LTC (Lifetime cost in total). For our study it is assumed that the fuel consumption of the reach-stacker is 13 liters/hour, the wage of one operator is 1.200 Euros/month, and the renting cost is 1.200 Euros/month. According to the knowledge mentioned above, the daily costs are stated as below:

FC = 13 liters/hour * 1.00 Euro/liter * 16 hours/day = 208 Euros/day,
OC = (2 * 1.200)/30 = 80 Euros/day,
RC = 1.200/30 = 40 Euros/day.

As mentioned above, the reach-stacker is assumed to make a total of 200 movements in a day. Therefore; md = 200. The "Cost of the single movement of the reach-stacker (CsmRS)" is calculated by using the formula (7.1).

$$CsmRS = \frac{\left(\frac{LTC}{dLT}\right) + FC + OC + RC}{md} = \frac{\left(\frac{665.000}{1750}\right) + 208 + 80 + 40}{200} = 3{,}54\ Euros$$

According to the calculation above, it is understood that, if the seaport authority rents a place within the dry port to carry out the unload and load operations for the containers transported from its terminal, by means of its own personnel and equipment, the cost of a single movement by the reach-stacker will be about 3,54 Euros. In the optimization model, the CsmRS will be taken "4 Euros" as the most approximate integer value to the calculated one.

7.2. Formulating An Optimization Model

A Linear Programming (LP) model has been developed in order to find a solution for the container terminal which is about to suffer because of the limited stacking capacity. The model also aims to maximize the revenue of that container terminal. The definition, assumptions, indices, parameters, decision variables and constraints of this problem are explained below.

7.2.1. Problem Description

A port with limited capacity in terms of container stacking will have difficulty in meeting the increasing demands in the future. In order to reach a capacity to meet the expected overload cargo, and not to lose its customers, the seaport will begin to collaborate with a dry port. The port authority is authorized either to stack the imported boxes (containers) at the terminal or to send them directly to the dry port. In doing so, it will take into account the need to make room for imported cargoes expected to arrive at the port in the following days. The Port Authority wants to use its facilities optimally and to maximize revenue. In these conditions, the number of stacks at the terminal and how many will be sent to the dry port will be determined by solving an LP problem.

7.2.2. Assumptions

- A 60 days period is considered at or after the year 2030.
- The port is only engaged in import container handling.
- Each container stacked and waiting at the port will be transported by trucks outside the port at the end of the Dwell Time (DT) period.
- The average DT in the seaport is 6 days, which means that every container warehoused at the terminal will leave the port after a 6 days DT period.
- There is a well-established railway connection and it is possible to realize 12 train shuttles between the seaport and the dry port every day. Each shuttle will be operated with 26 railway cars. Each railway car must be carrying two containers, with a total of 60 feet of length. One container will be 20 feet and the other 40 feet.
- Turkish Republic State Railways (TCDD) operates the train shuttles. The cost of the railway transportation and dry port warehouse cost will be paid to TCDD and the dry port authority according to the tariff of TCDD.
- Each container carried by railway cars, either 20 or 40 feet, weighs between 18 and 26 tons.
- The aggregate cost of a truck (including driver's wage, depreciation, and the diesel) carrying any type of box is 0.8 €/km.

- Seaport earns through Terminal Handling Cost (THC) and warehouse fee for the containers unladed and warehoused in its terminal. Seaport also earns the same price through boxes transported to dry port, but the transportation cost and the costs in the dry port belong to the seaport.
- TCDD earns through railway transportation. Seaport authority makes payment to TCDD for transportation.
- Dry Port earns through the warehousing of the containers. It may also earn through renting open or closed areas within its borders.
- Seaport authority rents area within the dry port and manages a team to carry on the load/unload operations by reach stackers.

7.2.3. Sets

$$D = \{1 \ldots |D|\} \text{ set of days - indexed by } \mathbf{d}. \quad (7.5)$$

$$V = \{1 \ldots |V|\} \text{ set of container size - indexed by } \mathbf{v}. \quad (7,6)$$

7.2.4. Parameters

U: Number of containers **unladed** at the seaport each day,

$T_{v,d}$: Number of containers of size v going out of terminal by **trucks** in day d,

Cap: Stacking **capacity** of seaport in terms of TEU,

B: Container stock in the **beginning** of the period, in terms of TEU,

C_v: Container size of type v (C_{v1}: 1 TEU, C_{v2}: 2 TEU),

E_v: Earning through **container with size v stacked** at sea terminal,

E_r: Earning through one **railway car** carrying 2 boxes (60 feet in total).

7.2.5. Decision Variables

Y_d: Total number TEUs being stocked at sea terminal's **yard**, d ϵ D

$W_{v,d}$: Number of **warehoused** containers size in that day, v ϵ V, d ϵ D

V_d: Number of railway **voyage** to dry port, d ϵ D

$R_{v,d}$: Number of **railway** cars including containers' size in that day, v ϵ V, d ϵ D

7.2.6. Objective Function

$$Z_{max} = \sum_v \sum_d (E_v * W_{v,d}) + \sum_d (E_r * 26 * V_d) \qquad (7.7)$$

The objective function maximizes the total income of seaport. **Ev** includes THC and warehouse fees in seaport. **Er** indicates the income through 2 boxes after subtracting the expenses of transportation on railway, warehouse fee and reach stacker operations.

7.2.7. Constraints

$$W_{v,d} + R_{v,d} = U \qquad \forall\ v,d \qquad (7.8)$$

$$Y_d \leq Cap \qquad \forall\ d \qquad (7.9)$$

$$Y_1 = B + \sum_v C_d * (W_{v1} - T_{v1}) \qquad (7.10)$$

$$Y_d = Y_{d-1} + \sum_v C_v * (W_{v,d} - T_{v,d}) \qquad \forall\ d \in \{2\ldots6\} \qquad (7.11)$$

$$Y_d = Y_{d-1} + \sum_v C_v * (W_{v,d} - W_{v,d-6}) \qquad \forall\ d \in \{7\ldots D\} \qquad (7.12)$$

$$\sum_v C_v * T_{v,d} = W_{v,d-6} \qquad \forall\ d \in \{1\ldots6\} \qquad (7.13)$$

$$V_d \leq 12 \qquad \forall\ d \qquad (7.14)$$

$$R_{v,d} = 26 * V_d \qquad \forall\ v,d \qquad (7.15)$$

$$Y_d, W_{v,d}, V_d, R_{v,d}, \in Z^+ \qquad (7.16)$$

- Constraint (6.8) indicates that the number of containers unloaded at the port will be equal to the sum of the TEU-denominated amounts that are warehoused in the terminal and sent to the dry port within that day.
- Constraint (6.9) ensures that the amount of containers having been stacked at the terminal cannot be more than the capacity.
- Constraint (6.10) explains that, the difference between the number of warehoused containers at terminal's yard and the number of exiting containers through the trucks will be added to the stock number indicating the present containers at the beginning of the period, to calculate the number of waiting containers at the yard, at the end of the first day.

- Constraint sets (7.11) and (7.12) explain the similar process to calculate the number of waiting containers in the yard, at the end of the day. After the first six days, the number of exiting containers through the trucks will be equal to the number of warehoused containers at the terminal's yard six days ago. Similarly, the number of exiting containers in the first six days will be equal to the number of warehoused containers six days ago as indicated in constraint (7.13).
- Constraint (7.14) limits the number of freight voyages on the railway not to be more than 12 times a day.
- Constraint (7.15) ensures that each shuttle involves 26 cars to provide railway transportation in an economic and optimal level.
- Constraint (7.16) explains that all decision variables will be natural and positive numbers.

The CPLEX codes for this optimization model can be seen in Appendix-D.

7.3. Case Study for the Optimization Model

EVYAPPORT is a container terminal whose throughput volume is constantly increasing. But on the other side, it is about to experience capacity problems in the years of 2030s. Köseköy Logistics Center (KLC) is a dry port candidate located close to the Kocaeli ports. It is considered to gain the ability to support Kocaeli ports with the completion of the renovation project.

A case is imagined with the assumption that the KLC would be capable of supporting seaports through a well-established railway and road network. Additionally, EVYAPPORT is assumed to meet a demand as predicted in Table 5.5. An optimization model will be used to solve this case study problem. The other assumptions and parameters for this case study are described below.

- Currently (at the beginning of the day "d1") there are 11.700 TEUs (7.17) stacked in EVYAPPORT. Each day over the next six days, one-sixth of those (7.18) will exit the terminal by trucks to be transported to the final destinations through roads and highways.

- Beginning from "d1" until the end of "d60", EVYAPPORT will meet a total of 126.000 containers. The half of these containers will be 20 feet (1 TEU) and the other half 40 feet (2 TEU). In other words, EVYAPPORT will handle 189.000 TEUs during the 60 days, provided that it has adequate capacity.

- Every day only one container vessel is going to call at EVYAPPORT to offload a total value of 2700 to 3600 TEU containers.

It is aimed to solve the problem related to four different options summarized in Table 7.2. In the first option, the container traffic occurs without any fluctuation. In the second option, it is assumed to occur a slight increase with a rate of 10% between the first and the last days of the period. In the third option, it is assumed to occur a high increase with a rate of 21%, and in the fourth option a more sharp increase during the same period, with a rate of 33%.

Table 7.2. Options with assumed number of unladed containers at EVYAPPORT.

Period/Option	**Option-I**		**Option-II**		**Option-III**		**Option-IV**	
Interval between days	1 TEU	2 TEU	1 TEU	2 TEU	1 TEU	2 TEU	1 TEU	2 TEU
d1 to d10 (each day)	1.050	1.050	1.000	1.000	950	950	900	900
d11 to d20 (each day)	1.050	1.050	1.000	1.000	1.000	1.000	950	950
d21 to d30 (each day)	1.050	1.050	1.000	1.000	1.000	1.000	1.000	1.000
d31 to d40 (each day)	1.050	1.050	1.100	1.100	1.100	1.100	1.100	1.100
d41 to d50 (each day)	1.050	1.050	1.100	1.100	1.100	1.100	1.150	1.150
d51 to d60 (each day)	1.050	1.050	1.100	1.100	1.150	1.150	1.200	1.200
Total number (60 days)	63.000	63.000	63.000	63.000	63.000	63.000	63.000	63.000
Total in TEU (60 days)	189.000 TEUs		189.000 TEUs		189.000 TEUs		189.000 TEUs	
Rate of increase	0%		10%		21%		33%	
P (Peak factor)	1,00		1,10		1,21		1,33	

- In each party; half of the freight will be distributed in Istanbul and Kocaeli, and the rest will be transported to other locations in eastern and southern directions from KLC.

- The stacking capacity is 14.400 TEUs (6.19). If there is not adequate space to stack the total freight carried on a vessel to be unloaded at EVYAPPORT, the port authority will not allow that vessel to berth, or the vessel calling at the port will need to wait until enough room becomes available for unlading.

- The earnings of EVYAPPORT are based on THC (Terminal Handling Cost) and warehouse fees as indicated in Table 7.3. According to this tariff, the port authority will earn 130 € for each 20 feet container (6.20) and 178 € for each 40 feet container, provided that the average container DT (dwell time) is six days.

Table 7.3. The income of EVYAPPORT related to the service type

Service provided by Seaport	1 TEU	2 TEU
THC (terminal handling cost)	52 €	52 €
Warehouse fee (for each day)	13 €	21 €

- EVYAPPORT authority has the right to either stack the containers in its terminal or transfer them to KLC. The only thing to consider is that the final transport destination of the container to the dry port is not Istanbul or Kocaeli. For the containers directly transferred to dry port, the EVYAPPORT authority will pay the transportation fee to TCDD and pay the warehouse fee to the authority of KLC. But EVYAPPORT will charge the warehouse fee as stated in Table 7.3 from its customers.

- The cost of a railway car with a length of 60 feet (carrying 2 containers) from EVYAPPORT to KLC is 25 € related to the tariff of TCDD. EVYAPPORT authority will pay the warehouse fee of each container to KLC authority related to the tariff summarized in Table 7.1. The cost of each handling operation, which is calculated as 4 €, will be at the expense of EVYAPPORT. After subtracting these expenses (Transportation + Warehouse fee + Cost of load/unload operations) from the earnings mentioned in Table 7.3 (308 € for a total of 60 feet long 2 containers), EVYAPPORT will earn 231 € for a pair boxes carried on a railway car (6.22).

- The aforementioned issues can be formulized and expressed as equations as follows:

$$B = 11.700 \quad (7.17)$$

$$T_d = 1.950; \forall D \in \{1 \ldots 6\} \quad (7.18)$$

$$Cap = 14.400 \quad (7.19)$$

$$E_{v1} = THC + (DT * 13) \quad (7.20)$$

$$E_{v2} = THC + (DT * 21) \quad (7.21)$$

$$E_r = (E_{v1} + E_{v2}) - [25 + 2 * (DT * 3) + 2 * (2 * 4)] \quad (7.22)$$

The "Data Set" for this optimization model can be seen in Appendix-E.

7.4. Numerical Experiment

The experimental studies are carried out through a solver program, namely IBM ILOG CPLEX 12.6, on a computer of Intel(R) Core(TM) i7-4700MQ CPU 2.40 GHz processor - 4 GB RAM. IBM ILOG CPLEX 12.6 is a commercial optimization solver based on the Simplex Algorithm.

According to the case study there is limited room for the incoming cargo in the seaport terminal, and limited railway transportation capacity to transfer the cargo directly do the dry port. Four different options were constructed within the case study as seen in Table 7.2. It is assumed that the total amount of cargo that would arrive at the seaport is the same in all options for a 60-day period. In Option-I, it is assumed that the amount of arriving cargo is steady for all periods, that is, there is no increase throughout the 60-day period. In other options, different amounts of cargo are expected to arrive at the seaport for each 10-day period depending on the increasing peak factors, respectively. The purpose of designing the options in this way is to examine how the rate of increase in the arriving cargo may affect the use of capacity in the seaport, and to examine the need for using the dry port and accordingly that of railway transportation. The solutions for each option are dealt with in the following sections.

7.4.1. Numerical Experiment for Option-I of the Case Study

The decision variables of the solution for Option-I are given in Table 7.4. The meaning of the abbreviations on the columns of the tables, which are presenting the solutions for the options of the case study is explained below:

- "D" indicates the days, beginning from d1 to d60.
- "Ye" gives the value of total waiting boxes in TEU at the end of the day.
- "V" indicates the railway voyages and "R" gives the total value of containers in TEU to be transported to KLC on that day.
- "W" explains the value in TEU of the boxes that should be warehoused at the terminal on that day.
- "U" explains the total value of containers in TEU unladed from the vessel at the seaport terminal.

As indicated in constraint (7.14), the model assumes a railway capacity up to 12 shuttles a day. On the other side, according to Option-I of the case study, steady container traffic is assumed as stated in Table 7.2. Each day throughout the 60 days period, the same value is expected to arrive at the seaport, namely 3.150 TEU containers a day. In this way, a total of 189.000 TEUs of containers are expected to be unloaded from the vessels arriving at the seaport terminal in this period.

At the beginning of the period, EVYAPPORT is using its terminal capacity at a rate of 81% (11.700/14.400). This program proposes a solution that enables the use of terminal capacity at a high level as much as possible and thus aims to maximize the profit of the port. It is seen that the use of capacity reaches a level of 90% on the third day. Thereafter the seaport uses its capacity over the level of 90% until the end of the 60 days period.

Since the railway capacity is 12 shuttles a day, it is possible to run 720 shuttles in total during the 60 days period. The solution proposes 580 shuttles in total to be executed between the seaport and the dry port. This number corresponds to 80,5% of the total railway capacity. By using this capacity, EVYAPPORT will directly transport a total of

"45.240 TEU" containers to KLC. Since each shuttle involves 26 railway cars, a total number of "15.080 (580 * 26)" railway cars will be operated.

Table 7.4. The Solution for Option-I related to the case study ($V_d \leq 12$)

D	Ye	V	R	W	U	D	Ye	V	R	W	U
1	12120	10	780	2370	3150	31	14376	10	780	2370	3150
2	12384	12	936	2214	3150	32	14376	12	936	2214	3150
3	13584	0	0	3150	3150	33	14376	0	0	3150	3150
4	13848	12	936	2214	3150	34	14376	12	936	2214	3150
5	14112	12	936	2214	3150	35	14376	12	936	2214	3150
6	14376	12	936	2214	3150	36	14376	12	936	2214	3150
7	14376	10	780	2370	3150	37	14376	10	780	2370	3150
8	14376	12	936	2214	3150	38	14376	12	936	2214	3150
9	14376	0	0	3150	3150	39	14376	0	0	3150	3150
10	14376	12	936	2214	3150	40	14376	12	936	2214	3150
11	14376	12	936	2214	3150	41	14376	12	936	2214	3150
12	14376	12	936	2214	3150	42	14376	12	936	2214	3150
13	14376	10	780	2370	3150	43	14220	12	936	2214	3150
14	14376	12	936	2214	3150	44	14376	10	780	2370	3150
15	14376	0	0	3150	3150	45	14376	0	0	3150	3150
16	14376	12	936	2214	3150	46	14376	12	936	2214	3150
17	14376	12	936	2214	3150	47	14376	12	936	2214	3150
18	14376	12	936	2214	3150	48	14376	12	936	2214	3150
19	14376	10	780	2370	3150	49	14376	12	936	2214	3150
20	14376	12	936	2214	3150	50	14376	10	780	2370	3150
21	14376	0	0	3150	3150	51	14376	0	0	3150	3150
22	14376	12	936	2214	3150	52	14376	12	936	2214	3150
23	14376	12	936	2214	3150	53	14376	12	936	2214	3150
24	14376	12	936	2214	3150	54	14376	12	936	2214	3150
25	14376	10	780	2370	3150	55	14376	12	936	2214	3150
26	14376	12	936	2214	3150	56	14376	10	780	2370	3150
27	14376	0	0	3150	3150	57	13440	12	936	2214	3150
28	14376	12	936	2214	3150	58	14376	0	0	3150	3150
29	14376	12	936	2214	3150	59	14376	12	936	2214	3150
30	14376	12	936	2214	3150	60	14376	12	936	2214	3150
Z_{MAX} = 18.242.840 €						**Total:**		**580**	**45.240**	**143.760**	**189.000**

According to the equation (7.22), EVYAPPORT will earn 231 € for a pair of boxes carried on a railway car. Therefore, the total railway cars operated to transport the containers to KLC during the 60 days period will bring in a total of **3.483.480 €** (231 * 15.080) income to EVYAPPORT. It can be asserted that the EVYAPPORT authority would not be able to earn this value if it were not be collaborating with KLC and TCDD.

According to the solution, a total volume of 143.760 TEUs of containers should be stacked and warehoused at the terminal yard during the 60 days period. Since the number of both volumes (20 feet and 40 feet) would be equal to each other, the total number for each volume would result as 47.920 containers. Related to the equations (7.20) and (7.21) the earnings of EVYAPPORT through the warehoused containers would be **14.759.360 €** (47.920 * [130 + 178]) in this period. The maximized revenue of EVYAPPORT for this 60-day period could be **18.242.840 €** (3.483.480 + 14.759.360) according to the solution of the problem.

In the explanation of the case study, it is stated that the seaport would be able to unload the cargo from the vessel provided that it has adequate capacity. If there is not enough space, there would be a risky situation to reject the arriving vessel and to lose the customer. Table 7.5 put forwards such a situation, that the seaport does not have the intermodal capability and not collaborate with a dry port.

The explanation of the additional abbreviations in this table are as follows:

- "Yb" indicates the beginning value of the day, whereas "Ye" indicates the ending value at the end of the day, following all loading and unloading operations.
- "T" gives the total value exiting the seaport by trucks after a 6 days DT.
- "NAU" means "Not Available to Unload", indicating a situation that there is not adequate space to stack the arriving containers on that day.

At the beginning of d1, there are already 11.700 TEUs (equation 7.17) in the terminal yard. Within the first six days, 1,950 TEUs a day (equation 7.18) will be exiting the port by trucks. Thereafter, the exiting number of containers by trucks will be equal to the number of containers that were unloaded and warehoused at the terminal six days ago, as indicated in the constraint (7.12). Each unladed freight will exit the port six days after it was stacked at the terminal yard. When the expected value would cause to exceed the capacity of the yard, as an example in the third day, the vessel planned to call at the port will be rejected or this vessel will have to wait for the required space occur since there is "Not Availability to Unload (NAU)" the expected freight. In this manner, a total of 20 days during the 60 days period will be passed without unloading the expected cargo. Consequently, there will be no leaving container on some days, in total 18 days, since there was no container entry on the days corresponding to 6 days prior to those days.

Table 7.5. The use of yard capacity related to Option-I, except the railway capacity

D	Yb	T	U	Ye	D	Yb	T	U	Ye
1	11700	1950	3150	12900	31	12600	3150	3150	12600
2	12900	1950	3150	14100	32	12600	3150	3150	12600
3	14100	1950	NAU	12150	33	12600	0	NAU	12600
4	12150	1950	3150	13350	34	12600	3150	3150	12600
5	13350	1950	NAU	11400	35	12600	0	NAU	12600
6	11400	1950	3150	12600	36	12600	3150	3150	12600
7	12600	3150	3150	12600	37	12600	3150	3150	12600
8	12600	3150	3150	12600	38	12600	3150	3150	12600
9	12600	0	NAU	12600	39	12600	0	NAU	12600
10	12600	3150	3150	12600	40	12600	3150	3150	12600
11	12600	0	NAU	12600	41	12600	0	NAU	12600
12	12600	3150	3150	12600	42	12600	3150	3150	12600
13	12600	3150	3150	12600	43	12600	3150	3150	12600
14	12600	3150	3150	12600	44	12600	3150	3150	12600
15	12600	0	NAU	12600	45	12600	0	NAU	12600
16	12600	3150	3150	12600	46	12600	3150	3150	12600
17	12600	0	NAU	12600	47	12600	0	NAU	12600
18	12600	3150	3150	12600	48	12600	3150	3150	12600
19	12600	3150	3150	12600	49	12600	3150	3150	12600
20	12600	3150	3150	12600	50	12600	3150	3150	12600
21	12600	0	NAU	12600	51	12600	0	NAU	12600
22	12600	3150	3150	12600	52	12600	3150	3150	12600
23	12600	0	NAU	12600	53	12600	0	NAU	12600
24	12600	3150	3150	12600	54	12600	3150	3150	12600
25	12600	3150	3150	12600	55	12600	3150	3150	12600
26	12600	3150	3150	12600	56	12600	3150	3150	12600
27	12600	0	NAU	12600	57	12600	0	NAU	12600
28	12600	3150	3150	12600	58	12600	3150	3150	12600
29	12600	0	NAU	12600	59	12600	0	NAU	12600
30	12600	3150	3150	12600	60	12600	3150	3150	12600
Total value of containers to be unloaded at EVYAPPORT:								**126.000**	**TEUs**

During the whole period, it is expected to arrive a total of 189.000 TEU containers at the seaport. But because of the unavailability, the port will be able to unload a total of 126.000 TEU containers (42.000 containers as 20 feet, and 42.000 containers as 40 feet) corresponding to the two-thirds of the total expected cargo. It means that a total of 63.000 (189.000 - 126.000) TEU containers would have been missed if the seaport had no railway connection and had no collaboration with a dry port.

The earnings of the seaport, in this circumstance, through these containers can be calculated by using the equations (6.20) and (6.21) as stated below:

- Ev_1 = 42.000 * [THC + (DT * 13)] = 42.000 * 130 € = 5.460.000 €
- Ev_2 = 42.000 * [THC + (DT * 21)] = 42.000 * 178 € = 7.476.000 €
- Total Earning = 5.460.000 € + 7.476.000 € = **12.936.000 €**

As stated in Table 7.4, the seaport could maximize its earnings up to **18.242.840 €** provided that it sent 45.240 TEU of containers to dry port by operating a total of 580 railway shuttles. When comparing the two situations it is understood that EVYAPPORT can produce a 50% more throughput value in the 60 days period and **boost its earnings 41% up,** by collaborating with KLC related to the case study including the assumptions of Option-I.

According to the solution given in Table 7.4, 45.240 TEU of containers would be transported on the railway, whereas 143.760 would be transported by trucks on the highway. If there were no chance to transport the goods on railways from Kocaeli container terminals, all containers would have to be transported by trucks. Since the storage capacity of EVYAPPORT would not be enough to accommodate all containers without a dry port option related to the case study, some containers would be taken by other ports in the Kocaeli region. In such a circumstance, a total of 189.000 TEU containers (a total number of 126.000 containers) would be departed from different Kocaeli container terminals to be transported on the highway. But when the dry port option is valid, this time a total volume of 45.240 TEUs (a total number of 30.160 containers) would be withdrawn from trucks to be carried on railway cars. In other terms, 30.160 trucks among a total number of 126.000 trucks could be substituted by a total of 580 railway shuttles during the 60 days period. It means that approximately a quarter of the freight would be transferred to the environmentally friendly transportation system by applying a dry port system for the Kocaeli ports.

7.4.2. Numerical Experiment for Option-II of the Case Study

The decision variables of the solution for Option-II are given in Table 7.6. The meaning of the abbreviations in the table is the same as explained in section “7.4.1”. According to Option-II of the case study, a slightly increasing container traffic is assumed to occur with a rate of 10% between the first and the last days of the period, as stated in Table 7.2.

In the first half of the period it is expected to arrive 3000 TEU of containers a day, and in the second half, it expected to increase to 3300 TEU of containers a day. About the capacity usage of EVYAPPORT, a similar situation is observed as occurred in the solution of Option-I. It is observed that the use of capacity reaches at a level of 90% on the third day as like in the previous option and, thereafter the seaport uses its capacity over the level of 90% until the end of the 60 days period.

The solution proposes 585 shuttles in total, just a little bit more than the first option, to be executed between the seaport and the dry port. This corresponds to 81,25% of the total railway capacity. By using this capacity, EVYAPPORT will directly transport a total of "45.630 TEU" containers to KLC. It means that a peak factor of 1.1 (increase at a rate of 10%) within the period will result in a requirement of 130 more railway cars (5 shuttles * 26 railway cars) than the first option during the same period.

A total number of "15.210 (585 * 26)" railway cars will be operated according to the solution of Option-II. Through these railway cars, EVYAPPORT will earn a total of "3.513.510 € (231 * 15.210)" income, which would be a more 30.030 € income than it would be in the case of the first option. But it should be noted that the total number of containers warehoused within this period would decrease compared to the first option. The number of decrease in the total number of warehoused containers is equal to the number of increases in the total number of containers directed to the dry port, corresponding to 390 TEU of containers. The decrease in the total number of warehoused containers will result in a decrease in the revenue of EVYAPPORT. The maximized revenue of EVYAPPORT could be **18.232.830** € according to the solution of the problem. This revenue is 10.010 €

less than the revenue that could be obtained in Option-I. The decline of the revenue stems from the fluctuation of the container traffic, which is assumed to make a peak at a rate of 10% during the period.

Table 7.6. The solution for Option-II related to the case study ($V_d \leq 12$)

D	Y	V	R	W	U	D	Y	V	R	W	U
1	12120	0	0	3000	3000	31	14376	10	780	2520	3300
2	12384	11	858	2142	3000	32	14376	12	936	2364	3300
3	13584	0	0	3000	3000	33	14376	12	936	2364	3300
4	13848	12	936	2064	3000	34	14376	12	936	2364	3300
5	14112	12	936	2064	3000	35	14376	12	936	2364	3300
6	14376	12	936	2064	3000	36	14376	12	936	2364	3300
7	14376	0	0	3000	3000	37	14376	10	780	2520	3300
8	14376	11	858	2142	3000	38	14376	12	936	2364	3300
9	14376	0	0	3000	3000	39	14376	12	936	2364	3300
10	14376	12	936	2064	3000	40	14376	12	936	2364	3300
11	14376	12	936	2064	3000	41	14376	12	936	2364	3300
12	14376	12	936	2064	3000	42	14376	12	936	2364	3300
13	14376	0	0	3000	3000	43	14220	10	780	2520	3300
14	14376	11	858	2142	3000	44	14376	12	936	2364	3300
15	14376	0	0	3000	3000	45	14376	12	936	2364	3300
16	14376	12	936	2064	3000	46	14376	12	936	2364	3300
17	14376	12	936	2064	3000	47	14376	12	936	2364	3300
18	14376	12	936	2064	3000	48	14376	12	936	2364	3300
19	14376	3	234	2766	3000	49	14376	10	780	2520	3300
20	14376	12	936	2064	3000	50	14376	12	936	2364	3300
21	14376	8	624	2376	3000	51	14376	12	936	2364	3300
22	14376	8	624	2376	3000	52	14376	12	936	2364	3300
23	14376	8	624	2376	3000	53	14376	12	936	2364	3300
24	14376	8	624	2376	3000	54	14376	12	936	2364	3300
25	14376	7	546	2454	3000	55	14376	10	780	2520	3300
26	14376	8	624	2376	3000	56	14376	12	936	2364	3300
27	14376	8	624	2376	3000	57	13440	12	936	2364	3300
28	14376	8	624	2376	3000	58	14376	12	936	2364	3300
29	14376	8	624	2376	3000	59	14376	12	936	2364	3300
30	14376	8	624	2376	3000	60	14376	12	936	2364	3300
Z **MAX** = 18.232.830 €						**Total:**		**585**	**45.630**	**143.370**	**189.000**

To make a comparison between the situation that EVYAPPORT is in collaboration with KLC and the situation that EVYAPPORT does not have the intermodal capability, the use of yard capacity related to the latter situation is given in Table 7.7. The abbreviations used in this table are as explained in Table 7.5.

As in the first option, the beginning value of “Yb” is 11.700 TEUs and 1.950 TEUs a day will be transported by trucks from the seaport within the first six days. Beginning from the seventh day, the value of leaving container will change to 3.000 TEUs since this amount had entered the seaport six days ago. It is observed on Table 7.7 that this value continues until d35 excluding some days, which corresponds to a total of nine days (between d9 and d36), and it changes to 3.300 TEUs beginning from d37 except some days, which corresponds to a total of eight days (between d39 and d60).

Table 7.7. The Use of Yard Capacity Related to Option-II, Except the Railway Capacity

D	Yb	T	U	Ye	D	Yb	T	U	Ye
1	11700	1950	3000	12750	31	12000	3000	3300	12300
2	12750	1950	3000	13800	32	12300	3000	3300	12600
3	13800	1950	NAU	11850	33	12600	0	NAU	12600
4	11850	1950	3000	12900	34	12600	3000	3300	12900
5	12900	1950	3000	13950	35	12900	3000	3300	13200
6	13950	1950	NAU	12000	36	13200	0	NAU	13200
7	12000	3000	3000	12000	37	13200	3300	3300	13200
8	12000	3000	3000	12000	38	13200	3300	3300	13200
9	12000	0	NAU	12000	39	13200	0	NAU	13200
10	12000	3000	3000	12000	40	13200	3300	3300	13200
11	12000	3000	3000	12000	41	13200	3300	3300	13200
12	12000	0	NAU	12000	42	13200	0	NAU	13200
13	12000	3000	3000	12000	43	13200	3300	3300	13200
14	12000	3000	3000	12000	44	13200	3300	3300	13200
15	12000	0	NAU	12000	45	13200	0	NAU	13200
16	12000	3000	3000	12000	46	13200	3300	3300	13200
17	12000	3000	3000	12000	47	13200	3300	3300	13200
18	12000	0	NAU	12000	48	13200	0	NAU	13200
19	12000	3000	3000	12000	49	13200	3300	3300	13200
20	12000	3000	3000	12000	50	13200	3300	3300	13200
21	12000	0	NAU	12000	51	13200	0	NAU	13200
22	12000	3000	3000	12000	52	13200	3300	3300	13200
23	12000	3000	3000	12000	53	13200	3300	3300	13200
24	12000	0	NAU	12000	54	13200	0	NAU	13200
25	12000	3000	3000	12000	55	13200	3300	3300	13200
26	12000	3000	3000	12000	56	13200	3300	3300	13200
27	12000	0	NAU	12000	57	13200	0	NAU	13200
28	12000	3000	3000	12000	58	13200	3300	3300	13200
29	12000	3000	3000	12000	59	13200	3300	3300	13200
30	12000	0	NAU	12000	60	13200	0	NAU	13200
Total value of containers to be unloaded at EVYAPPORT:								**126.000**	**TEUs**

Similar to the situation that occurred in Option-I, in a total of 20 days the vessels planned to call at the port would be rejected because of the unavailability of the stacking capacity in the terminal. EVYAPPORT would be able to unload a total of 126.000 TEU containers similar to the case of Option-I. Consequently, the revenue of the seaport will be equal to that of Option-I **(12.936.000 €)** since the same amount of cargo will have been handled and warehoused.

As stated in Table 7.6, the seaport could maximize its earnings up to **18.232.830 €** provided that it sent 45.630 TEU of containers to dry port by operating a total of 585 railway shuttles. When comparing the two situations it is understood that EVYAPPORT can produce a 50% more throughput value in the 60 days period and **boost its earnings 40% up,** by collaborating with KLC related to the case study including the assumptions of Option-II.

If there were no chance to transport the goods on railways from Kocaeli container terminals, all containers would have to be transported by trucks, as mentioned for the first option. In such a circumstance, a total of 189.000 TEU containers (a total number of 126.000 containers) would be departed from different Kocaeli container terminals to be transported on the highway. But when the dry port option is valid, this time the value of 45.630 TEU containers (a total number of 30.420 containers) would be withdrawn from trucks to be carried on railway cars, according to the solution of Option-II of the case study. In other terms, 30.420 trucks among a total number of 126.000 trucks could be substituted by a total of 585 railway shuttles during the 60 days period. It means that approximately a quarter of the freight would be transferred to the environmentally friendly transportation system by applying a dry port system for the Kocaeli ports.

7.4.3. Numerical Experiment for Option-III of the Case Study

According to Option-III of the case study, a higher increasing container traffic is assumed to occur with a rate of 21% between the first and the last days of the period, as stated in Table 7.2. In the first half of the period it is expected to arrive 2.850 to 3.000 TEU of containers a day, and in the second half it expected to increase to 3.300 to 3.450 TEU of containers a day.

As the constraints of the developed optimization model, it was stated that the railway capacity would be available to operate a maximum 12 railway shuttles a day (Constraint 7.14). Running the optimization solver program it was observed that there is no solution to Option-III of the case study through the developed optimization model. It means that when experiencing such a constraining situation the EVYAPPORT would not be able to sustain its operations without any deficiency. Two measures to cope with this constraining situation can be stated as (1) Increasing the stacking capacity of the terminal, and (2) Increasing the railway capacity between the seaport and the dry port.

Assuming that the seaport has tried its best to expand its terminal area and to increase its stacking capacity by that time, it was determined to increase the railway capacity. In the following stage, the solver program was run by increasing the constraint (7.14) from “12” to “13”. Observing that there is still no solution, the constraint was increased once more, to “14”. The solver found a solution by the increased railway capacity. The decision variables of the solution for Option-III, assuming that “$V_d \leq 14$” are given in Table 7.8.

About the capacity usage of EVYAPPORT, a different situation is observed compared to Option-I and Option-II. It is observed that the use of capacity reaches a level of 90% just in the second, thereafter the seaport uses its capacity over the level of 90% until the end of the 60 days period. This situation stems from the number of arriving containers. In the first half of the period, especially in the first 10 days due to the arrival of fewer containers, it is seen that the port needs less rail transport and gets the opportunity to use its capacity more intensively.

The solution proposes 583 shuttles in total, just a little bit less than the second option, to be executed between the seaport and the dry port. This corresponds to 80,97% of the total railway capacity. A notable issue is that 36% of the total railway shuttles (215 shuttles) are applied in the first half of the period. This amount is almost half of the amount of the shuttles applied in the second half of the period. Especially within the first 10 days, the rate of that is extremely low. Only 47 shuttles are applied which corresponds to 8% of the total number. On the other side, the number of arriving containers is also very low in the first half and especially in the first 10 days.

Table 7.8. The solution for Option-III related to the case study ($V_d \leq 14$)

D	Y	V	R	W	U	D	Y	V	R	W	U
1	12600	0	0	2850	2850	31	14400	7	546	2754	3300
2	13500	0	0	2850	2850	32	14388	14	1092	2208	3300
3	13620	10	780	2070	2850	33	14376	10	780	2520	3300
4	14364	2	156	2694	2850	34	14364	14	1092	2208	3300
5	14328	12	936	1914	2850	35	14352	13	1014	2286	3300
6	14370	11	858	1992	2850	36	14340	12	936	2364	3300
7	14370	0	0	2850	2850	37	13950	12	936	2364	3300
8	13590	10	780	2070	2850	38	14340	9	702	2598	3300
9	14370	0	0	2850	2850	39	14340	10	780	2520	3300
10	14370	2	156	2694	2850	40	14340	14	1092	2208	3300
11	14364	14	1092	1908	3000	41	14340	13	1014	2286	3300
12	14358	13	1014	1986	3000	42	14340	12	936	2364	3300
13	14352	2	156	2844	3000	43	14340	12	936	2364	3300
14	14346	12	936	2064	3000	44	14340	9	702	2598	3300
15	14340	2	156	2844	3000	45	14340	10	780	2520	3300
16	14334	4	312	2688	3000	46	14340	14	1092	2208	3300
17	14334	14	1092	1908	3000	47	14340	13	1014	2286	3300
18	14334	13	1014	1986	3000	48	14340	12	936	2364	3300
19	14334	2	156	2844	3000	49	14340	12	936	2364	3300
20	14334	12	936	2064	3000	50	14340	9	702	2598	3300
21	14022	6	468	2532	3000	51	14178	14	1092	2358	3450
22	13554	10	780	2220	3000	52	14328	14	1092	2358	3450
23	14334	4	312	2688	3000	53	14400	14	1092	2358	3450
24	14334	13	1014	1986	3000	54	14394	14	1092	2358	3450
25	14178	4	312	2688	3000	55	14388	14	1092	2358	3450
26	14334	10	780	2220	3000	56	14382	11	858	2592	3450
27	14334	6	468	2532	3000	57	14382	14	1092	2358	3450
28	14334	10	780	2220	3000	58	14382	14	1092	2358	3450
29	13944	9	702	2298	3000	59	14382	14	1092	2358	3450
30	14334	8	624	2376	3000	60	14382	14	1092	2358	3450
Z MAX = 18.236.834 €						**Total:**		**583**	**45.474**	**143.526**	**189.000**

In addition to the available capacity, in the beginning, the lower amount of freight arriving in the first days results in a low rate of railway usage. By using a total of 583 railway shuttles, EVYAPPORT will directly transport a total of "45.474 TEU" containers through 15.158 railway cars to KLC. This amount is a little bit less than that of Option-II, but it should be taken into account that Option-III is able to respond only after increasing the railway capacity from 12 to 14. Through these railway cars, EVYAPPORT will earn a total of **3.501.498 €** (231 *15.158) income.

With the increased railway capacity, seaport gets the chance to spread the use of railway shuttles over a long period while having the opportunity to take the advantage of its capacity especially in the first half of the period. Thereby it could store more containers during the first half of the period without being constrained since the arriving number of containers is not so high. And during the second half of the period, when it feels more constrained because of the increased traffic, it uses the railway capacity as much as possible to get relieved. When scrutinizing the table it is easily observed that almost all of the railway capacity is being used during the last 10 days when the container traffic makes a peak. Under these prevailing circumstances, the dry port and the railway act as rescuers for the sea port. The maximized revenue of EVYAPPORT could be **18.236.834 €** according to the solution of the problem. This revenue is 4.004 € more than the revenue that could be obtained in Option-II. The opportunity in using its own capacity at a higher level brings in more revenue for the seaport.

The use of yard capacity related to the situation that EVYAPPORT does not have the intermodal capability is given in Table 7.9.

Different from the other two options, the total number of days that the terminal yard is constrained due to insufficient storage area will be less one day than the previous options. Since the arriving number of containers in the first 10 days is lower than that of the other two options, only one day occurs as the constraining days in that period whereas the other two options experience two constraining days. By this means the number of unavailable days for unloading is lowered, resulting in a total of 19 days. Consequently, the total value of containers to be unloaded at EVYAPPORT becomes higher compared to the first two options, resulting in a total of 128.700 TEUs. The revenue of the seaport in these circumstances (not in a collaboration with a dry port) would be a little higher than that of the other two options, resulting in 13.213.200 €.

Table 7.9. The use of yard capacity related to Option-III, except the railway capacity

D	Yb	T	U	Ye	D	Yb	T	U	Ye
1	11700	1950	2850	12600	31	12000	3000	3300	12300
2	12600	1950	2850	13500	32	12300	3000	3300	12600
3	13500	1950	2850	14400	33	12600	3000	3300	12900
4	14400	1950	NAU	12450	34	12900	0	NAU	12900
5	12450	1950	2850	13350	35	12900	3000	3300	13200
6	13350	1950	2850	14250	36	13200	0	NAU	13200
7	14250	2850	2850	14250	37	13200	3300	3300	13200
8	14250	2850	2850	14250	38	13200	3300	3300	13200
9	14250	2850	2850	14250	39	13200	3300	3300	13200
10	14250	0	NAU	14250	40	13200	0	NAU	13200
11	14250	2850	3000	14400	41	13200	3300	3300	13200
12	14400	2850	NAU	11550	42	13200	0	NAU	13200
13	11550	2850	3000	11700	43	13200	3300	3300	13200
14	11700	2850	3000	11850	44	13200	3300	3300	13200
15	11850	2850	3000	12000	45	13200	3300	3300	13200
16	12000	0	NAU	12000	46	13200	0	NAU	13200
17	12000	3000	3000	12000	47	13200	3300	3300	13200
18	12000	0	NAU	12000	48	13200	0	NAU	13200
19	12000	3000	3000	12000	49	13200	3300	3300	13200
20	12000	3000	3000	12000	50	13200	3300	3300	13200
21	12000	3000	3000	12000	51	13200	3300	3450	13350
22	12000	0	NAU	12000	52	13350	0	NAU	13350
23	12000	3000	3000	12000	53	13350	3300	3450	13500
24	12000	0	NAU	12000	54	13500	0	NAU	13500
25	12000	3000	3000	12000	55	13500	3300	3450	13650
26	12000	3000	3000	12000	56	13650	3300	3450	13800
27	12000	3000	3000	12000	57	13800	3450	3450	13800
28	12000	0	NAU	12000	58	13800	0	NAU	13800
29	12000	3000	3000	12000	59	13800	3450	3450	13800
30	12000	0	NAU	12000	60	13800	0	NAU	13800
Total value of containers to be unloaded at EVYAPPORT:								**128.700**	**TEUs**

As stated in Table 7.8, the seaport could maximize its earnings up to **18.236.834 €** provided that it sent 45.474 TEU of containers to dry port by operating a total of 583 railway shuttles. When comparing the two situations it is understood that EVYAPPORT can produce a 46% more throughput value in the 60 days period and **boost its earnings 38% up,** by collaborating with KLC related to the case study including the assumptions of Option-III.

If there were no chance to transport the goods on railways from Kocaeli container terminals, all containers would have to be transported by trucks. In such a circumstance, a total of 189.000 TEU containers (a total number of 126.000 containers) would be departed from different Kocaeli container terminals to be transported on the highway. But when the dry port option is valid, this time the value of 45.474 TEU containers (a total number of 30.316 containers) would be withdrawn from trucks to be carried on railway cars. In other terms, 30.316 trucks among a total number of 126.000 trucks could be substituted by a total of 583 railway shuttles during the 60 days period. It means that approximately a quarter of the freight would be transferred to the environmentally friendly transportation system by applying a dry port system for the Kocaeli ports.

7.4.4. Numerical Experiment for Option-IV of the Case Study

According to Option-IV of the case study, it is assumed to occur a more sharp increase compared to other options during the same period, with a rate of 33%. In the first half of the period it is expected to arrive 2700 to 3000 TEU of containers a day, and in the second half, is expected to increase to 3300 to 3600 TEU of containers a day as stated in Table 7.2.

The solver program could not find a solution related to Option-IV of the case study, for the constraint (7.14) even if it was assumed that “$Vd \leq 14$". The solver could find a solution only after assuming that "$Vd \leq 16$". Although the same amount of freight is planned to arrive at the terminal during the same period, it is understood that a higher peak factor constraints the seaport to find available room for the containers, especially at peak periods. Because of that reason, the increased railway capacity comes into view as a reliever of the seaport. The decision variables of the solution for Option-IV, assuming that “$Vd \leq 16$” are given in Table 7.10.

A situation similar to Option-III is observed about the capacity usage of EVYAPPORT. The use of capacity reaches a level of 90% just in the second, thereafter the seaport uses its capacity over the level of 90% until the end of the 60 days period. Since the amount of cargo arriving at the port within the first 30 days is not so high to constraint its capacity, EVYAPPORT will need less rail transportation within this period. According to the solution of the problem for Option-IV, within the first 10 days only 39 shuttles (7%

of the total), within the second 10 days 59 shuttles (10% of the total) and within the third 10 days 78 shuttles (13% of the total) would be applied to transfer the containers to KLC. In this first half of the period, the number of rail shuttles will be 176 (30% of the total), the lowest number for that period among all options. A similar situation was observed for Option-III. Similarly, it should be taken into account that for the third and fourth options to able to find a solution it becomes necessary to increase the railway capacity. By the way, while using this railway capacity at the highest rates for the last 30 days period, the seaport uses its terminal yard capacity as many as possible within the first 30 days due to the lower amount of arriving freight.

Table 7.10. The solution for Option-IV related to the case study ($V_d \leq 16$)

D	Y	V	R	W	U	D	Y	V	R	W	U
1	12600	0	0	2700	2700	31	14400	9	702	2598	3300
2	13500	0	0	2700	2700	32	14388	14	1092	2208	3300
3	13620	14	1092	1608	2700	33	14376	14	1092	2208	3300
4	14364	0	0	2700	2700	34	14364	12	936	2364	3300
5	14328	0	0	2700	2700	35	14352	5	390	2910	3300
6	14370	10	780	1920	2700	36	14340	16	1248	2052	3300
7	14370	2	156	2544	2700	37	13950	9	702	2598	3300
8	13590	6	468	2232	2700	38	14340	14	1092	2208	3300
9	14370	6	468	2232	2700	39	14340	14	1092	2208	3300
10	14370	1	78	2622	2700	40	14340	12	936	2364	3300
11	14364	0	0	2850	2850	41	14340	11	858	2592	3450
12	14358	12	936	1914	2850	42	14340	14	1092	2358	3450
13	14352	4	312	2538	2850	43	14340	10	780	2670	3450
14	14346	8	624	2226	2850	44	14340	16	1248	2202	3450
15	14340	8	624	2226	2850	45	14340	16	1248	2202	3450
16	14334	3	234	2616	2850	46	14340	14	1092	2358	3450
17	14334	0	0	2850	2850	47	14340	11	858	2592	3450
18	14334	12	936	1914	2850	48	14340	14	1092	2358	3450
19	14334	4	312	2538	2850	49	14340	14	1092	2358	3450
20	14334	8	624	2226	2850	50	14340	14	1092	2358	3450
21	14022	10	780	2220	3000	51	14178	16	1248	2352	3600
22	13554	5	390	2610	3000	52	14328	16	1248	2352	3600
23	14334	2	156	2844	3000	53	14400	13	1014	2586	3600
24	14334	14	1092	1908	3000	54	14394	16	1248	2352	3600
25	14178	6	468	2532	3000	55	14388	16	1248	2352	3600
26	14334	10	780	2220	3000	56	14382	16	1248	2352	3600
27	14334	10	780	2220	3000	57	14382	16	1248	2352	3600
28	14334	5	390	2610	3000	58	14382	16	1248	2352	3600
29	13944	2	156	2844	3000	59	14382	16	1248	2352	3600
30	14334	14	1092	1908	3000	60	14382	13	1014	2586	3600
Z MAX = 18.236.834 €						**Total:**		**583**	**45.474**	**143.526**	**189.000**

With the increased railway capacity to 16 shuttles a day, seaport gets the chance to spread the use of railway shuttles over a long period as can be done in Option-III. Seaport catches the opportunity to take advantage of its capacity especially in the first half of the period. Compared to the other options, it could be possible to store many more containers during the first half of the period without being constrained since the arriving number of containers is the lowest among all the options. And during the second half of the period, it uses the railway capacity at the highest level. When scrutinizing the table it is easily observed that almost all of the railway capacity is being used during the last 10 days at a rate of 96,25% when the container traffic makes a peak. Especially within the last 10 days period, both the dry port and the railway act as rescuers for the sea port, as observed in the case of Option-III.

The solution proposes 583 shuttles in total, the same as observed in Option-III, to be executed between the seaport and the dry port. This corresponds to 80,97% of the total railway capacity. By using a total of 583 railway shuttles, EVYAPPORT will directly transport a total of "45.474 TEU" containers through 15.158 railway cars to KLC. Through these railway cars, EVYAPPORT will earn a total of **3.501.498 €** (231 *15.158) income. The maximized revenue of EVYAPPORT could be **18.236.834 €**, same as in the solution of Option-III.

The use of yard capacity related to the situation that EVYAPPORT does not have the intermodal capability is given in Table 7.11.

The total number of days that the terminal yard is constrained due to insufficient storage area will be less than the other options. Since the arriving number of containers in the first 30 days period is less than that of the other options. In this option, a total of 17 days become unavailable for unloading operations. Consequently, the total value of containers to be unloaded at EVYAPPORT becomes higher compared to the other options, resulting in a total of 134.100 TEUs. The revenue of the seaport in these circumstances (not in a collaboration with a dry port) would higher than that of the other options, resulting in 13.767.600 €.

Table 7.11. The use of yard capacity related to Option-IV, except the railway capacity

D	Yb	T	U	Ye	D	Yb	T	U	Ye
1	11700	1950	2700	12450	31	12000	3000	3300	12300
2	12450	1950	2700	13200	32	12300	3000	3300	12600
3	13200	1950	2700	13950	33	12600	3000	3300	12900
4	13950	1950	NAU	12000	34	12900	0	NAU	12900
5	12000	1950	2700	12750	35	12900	0	NAU	12900
6	12750	1950	2700	13500	36	12900	3000	3300	13200
7	13500	2700	2700	13500	37	13200	3300	3300	13200
8	13500	2700	2700	13500	38	13200	3300	3300	13200
9	13500	2700	2700	13500	39	13200	3300	3300	13200
10	13500	0	NAU	13500	40	13200	0	NAU	13200
11	13500	2700	2850	13650	41	13200	0	NAU	13200
12	13650	2700	2850	13800	42	13200	3300	3450	13350
13	13800	2700	2850	13950	43	13350	3300	3450	13500
14	13950	2700	2850	14100	44	13500	3300	3450	13650
15	14100	2700	2850	14250	45	13650	3300	3450	13800
16	14250	0	NAU	14250	46	13800	0	NAU	13800
17	14250	2850	2850	14250	47	13800	0	NAU	13800
18	14250	2850	2850	14250	48	13800	3450	3450	13800
19	14250	2850	2850	14250	49	13800	3450	3450	13800
20	14250	2850	2850	14250	50	13800	3450	3450	13800
21	14250	2850	3000	14400	51	13800	3450	3600	13950
22	14400	0	NAU	14400	52	13950	0	NAU	13950
23	14400	2850	NAU	11550	53	13950	0	NAU	13950
24	11550	2850	3000	11700	54	13950	3450	3600	14100
25	11700	2850	3000	11850	55	14100	3450	3600	14250
26	11850	2850	3000	12000	56	14250	3450	3600	14400
27	12000	3000	3000	12000	57	14400	3600	3600	14400
28	12000	0	NAU	12000	58	14400	0	NAU	14400
29	12000	0	NAU	12000	59	14400	0	NAU	14400
30	12000	3000	3000	12000	60	14400	3600	3600	14400
Total value of containers to be unloaded at EVYAPPORT:								**134.100**	**TEUs**

As stated in Table 7.10, the seaport could maximize its earnings up to **18.236.834 €** provided that it sent 45.474 TEU of containers to dry port by operating a total of 583 railway shuttles. When comparing the two situations it is understood that EVYAPPORT can produce a 40,9% more throughput value in the 60 days period and **boost its earnings 32,4% up,** by collaborating with KLC related to the case study including the assumptions of Option-III.

If there were no chance to transport the goods on railways from Kocaeli container terminals, all containers would have to be transported by trucks. In such a circumstance, a total of 189.000 TEU containers (a total number of 126.000 containers) would be departed from different Kocaeli container terminals to be transported on the highway. But when the dry port option is valid, this time the value of 45.474 TEU containers (a total number of 30.316 containers) would be withdrawn from trucks to be carried on railway cars, as it is in Option-III. In other terms, 30.316 trucks among a total number of 126.000 trucks could be substituted by a total of 583 railway shuttles during the 60 days period. It means that approximately a quarter of the freight would be transferred to the environmentally friendly transportation system by applying a dry port system for the Kocaeli ports.

7.5. Comparison of the Solutions of the Options and Conclusions

Four options were designed in relation to the case study and the solutions were obtained by running the optimization model which was developed for this purpose. Table 7.12 is prepared to compare some basic features of the options and the results obtained as a result of the solution computed with the optimization model. The interpretation of the values observed in Table 7.12 is described below in the order of the table.

7.5.1. Arriving/Unloaded Value (U) in TEU

It is assumed that the same number of 20 feet (1 TEU) and 40 Feet (2 TEU) containers arrive at EVYAPPORT. The first six rows in this part of the table give the daily total volumes in TEU in relation to the options. It was designed that the total volumes within the 60 days period for all options are the same, as a total volume of 189.000 TEU. The main difference for the options is the variance of the volume related to the intervals.

In Option-I there is no variance of container traffic, in all intervals, the same amount of freight arrives at EVYAPPORT. Hence there is no increase among the intervals and the peak factor occurs as “1” throughout the whole period.

In Option-II there occurs a variance between the two half periods. During the second 30-days period, an increase at a rate of 10% is observed in container traffic. Hence the peak factor occurs as “1,1” throughout the whole period.

Table 7.12. Comparison of the features and the solutions of the options

Nu.	Features/Solutions		Option-I	Option-II	Option-III	Option-IV
1	Arriving/Unladed Value (U) in TEU	d1 to d10 (each day)	3.150	3.000	2.850	2.700
		d11 to d20 (each day)	3.150	3.000	3.000	2.850
		d21 to d30 (each day)	3.150	3.000	3.000	3.000
		d31 to d40 (each day)	3.150	3.300	3.300	3.300
		d41 to d50 (each day)	3.150	3.300	3.300	3.450
		d51 to d60 (each day)	3.150	3.300	3.450	3.600
		Total U in 60 days	189.000	189.000	189.000	189.000
	Rate of increase in values		0%	10%	21%	33%
	P (Peak factor)		1	1,1	1,21	1,33
2	Solution With Dry Port Application	Railway capacity/day	$Vd \leq 12$	$Vd \leq 12$	$Vd \leq 14$	$Vd \leq 16$
		Total Railway capacity	720	720	840	960
		V (Rail voyages)	580	585	583	583
		Rate of rail use	80,55%	81,25%	69,40%	60,72%
		R (TEU on rail cars)	45.240	45.630	45.474	45.474
		Rate of R to U	23,94%	24,14%	24,06%	24,06%
		E_r (€)	3.483.480	3.513.510	3.501.498	3.501.498
		Z_{max} (€)	18.242.840	18.232.830	18.236.834	18.236.834
		Rate of E_r to Z_{max}	19,09%	19,27%	19,20%	19,20%
		W (TEUs at yard)	143.760	143.370	143.526	143.526
		Rate of W to U	76,06%	75,85%	75,93%	75,93%
3	Without Dry Port Appl.	NAU days	20	20	19	17
		W (TEUs at yard)	126.000	126.000	128.700	134.100
		Rate of W to U	66,66%	66,66%	68,09%	70,95%
		Total E_v (€)	12.936.000	12.936.000	13.213.200	13.767.600
		Rate of E_v to Z_{max}	70,91%	70,94%	72,45%	75,49%
4	Dry port effect on total U		50,00%	50,00%	46,85%	40,93%
	Dry port effect on Z_{max}		41,02%	40,94%	38,01%	32,46%
5	Nu. of trucks substituted (TS)		30.160	30.420	30.316	30.316
	Nu. of arriving containers (A)		126.000	126.000	126.000	126.000
	TS / A		23,93%	24,14%	24,06%	24,06%

In Option-III there occurs a higher variance, beginning from 2.850 TEU reaching a peak, 3.450 TEU, within the period. Thus an increase at a rate of 21% is observed in container traffic. Hence the peak factor occurs as “1,21” throughout the whole period.

In Option-IV there occurs an extremely high variance, beginning from 2.700 TEU reaching to a peak, 3.600 TEU, within the period. Thus an increase at a rate of 33% is observed in container traffic. Hence the peak factor occurs as “1,33” throughout the whole period.

7.5.2. Solution with Dry Port Application

Only the first two options were able to provide a solution according to the model's maximum 12 shuttle capacity per day. In other words, it was understood that Option-III and IV were not able to provide a solution for a maximum of 12 railway shuttles constraints per day. As it is known, railway shuttles to the dry port also create additional stacking capacity. For this additional capacity, it is needed higher railway transportation capacity. With a peak factor of "1,21", as in the third option, it is needed two more shuttles a day. And with a peak factor of "1,33", as in the fourth option, it is needed four more shuttles a day, to be able to find a solution for the case study. Since the maximum of 12 railway shuttles constraint per day is not sufficient for the third and the fourth options, it assumed to increase to 14 and 16 shuttles a day respectively. In the first and second options, the rate of using railway capacity becomes 80,55% and 81,25% respectively. For the other options, it decreases to 69,4% and 60,72%. Although the number of rail voyages is very close to each other among all options, more shuttles are needed in the second half period of the third and fourth options.

Since the number of rail voyages is very similar for all options, the volumes carried on railway cars (R) are also similar, varying from 45.240 TEU to 45.630 TEU in total. Rate of "R" to the total volume of arriving/unloaded containers (U) are similar as well, ranging from 23,94% to 24,14%. According to the model and the case study, the railway transportation also brings in earning for the seaport authority. While the port authority applies its own tariff to its customers, it will cover the transportation cost on the railway, warehouse fee and cost of handling operations in the dry port, and the difference between its earnings and the costs will be the "Earning of the port through railways (Er)". The value of Er is in direct proportion to the volumes carried on railway cars (R).

The solver aims at maximizing the earnings of the seaport according to the developed optimization model. When doing this, it tries to find the optimum values to be stored in the terminal yard and the values to be sent to the dry port. By finding these values the solver also calculates the "Maximum earning that can be realized by the seaport (Z_{max})". As in real life, containers stored in the terminal yard provide more revenue for the seaport authority. In the first option, which will perform fewer rail voyages than other options, it is seen that the Z_{max} value will be at the highest level. However, the value of Z_{max} is close to each other in all options.

As stated in the equation of the objective function (6.7), there are two decision variables affecting the Z_{max}, one is the number of the rail voyages (V) and the other is the "Value of the warehoused containers in the terminal yard (W)". The value of the W is the highest in Option-I among all options. This situation brings in the highest Z_{max} as well. Since that in Option-I there exists no pressure which is effective in all other options, it is possible to use the stacking capacity in a balanced way and to be more productive. Accordingly, the W value can reach the largest value in the first option. As a result, the option with the highest ratio of W to U is the first option.

7.5.3. Solution With Dry Port Application

If the seaport did not have the intermodal capability and not collaborate with a dry port, it would have not been able to accommodate all of the arriving containers due to the limited stacking capacity. On the days when the seaport does not have adequate space, it will not be possible to unload the freight arriving on that day. In such a circumstance, either the arriving vessel is rejected to berth or the vessel would need to wait until adequate space gets available. The days not available to unload (NAU) the arriving freight related to the case study are depicted on Tables-5, 7, 9 and 11, and summarized in Table 7.12. It is understood that on some days ranging between 17 to 20 as total, it would not be available to accept the arriving freight and accordingly some amount of income, ranging between 25% to 30% would be missed related to the lower number of warehoused containers.

7.5.4. The Effect of Dry Port Application

The optimization model developed in this thesis study put forward that it is possible to increase the production of the seaport through a dry port application. In this way, the seaport would be able to send some containers directly to the dry port and open more room on its terminal yard to be able to accommodate extra volumes. It is observed that it is possible to increase the throughput values of the seaport between the ranges of 40% to 50% related to the options. Depending on the increased production, the seaport would be able to increase its revenue at a rate between 32% to 41% compared to the situation when the seaport does not collaborate with a dry port.

The case study is based on possible future values just as stated in Table 5.2. The actors involved in this case study are likely to face a similar situation in the future. In this respect, the numerical experiments are considered important in terms of providing insight to the real operators and to the decision-makers. According to this case study, the EVYAPPORT would earn a total of 18.242.000 € instead of earning 12.936.000 €. It means that EVYAPPORT could increase its income more than five million € for a 60-day period by collaborating with the dry port KLC.

7.5.5. Substituting the Trucks by Railway Cars

In the case study, it is assumed that a total number of 126.000 containers, corresponding to a value of 189.000 TEUs, is planned to arrive at EVYAPPORT. In the case of without dry port application, the whole number of containers would be transported to inland locations by trucks. Even though the EVYAPPORT might not have the capacity to accommodate all numbers within the period, those containers will be unloaded at any port located in Kocaeli Gulf. It means that a total of 126.000 trucks would move from Kocaeli ports to inland destinations.

When examining the case that EVYAPPORT collaborates with KLC, it is seen in Table 7.12 that some containers, corresponding to an approximate number of 30.000, could be transported by railway cars instead of trucks. In other terms, 580 through 585 railway shuttles would substitute for about 30.000 trucks within the 60 days period. This substitution means that about 24% of the trucks would be substituted by railway cars. This result can be interpreted that, the dry port application will reduce the number of trucks entering the traffic in order to transport cargo from the port by approximately 24% in this period.

8. CONCLUSIONS AND PROPOSALS

This thesis examines the cooperation between a sea port and a dry port. For this study, container terminals in Kocaeli Gulf have been taken as a basis and a dry port system that can support container transportation through these ports has been envisaged. This study is divided into three main phases:

(1) Estimation of future container traffic and determination of minimum capabilities for a dry port capable of supporting Kocaeli container terminals under these conditions,

(2) Determination of the most suitable location for the establishment of the required dry port system, and

(3) Development of an optimization model that will reveal the level of productivity and profitability of a sea port that may experience capacity problems due to increased container traffic in the future, provided that cooperating with a dry port.

8.1. Summary and Contribution of the Thesis

With the introduction of the door-to-door concept in the logistics sector, transportation providers began to take into account the total cost of transportation as well as considering the duration. Within this context, the sea ports, which makes it easier to connect to cheaper transport routes, have become more competitive. For a transportation provider to choose a seaport, the feature of providing mass transportation to far destinations as long as possible in minimum expense has appeared to be the most important criterion in the decision-making process. In order to provide this feature, it is seen that the dry ports, which are located within the transportation networks and as close as possible to the junction points, have appeared to be very important actors.

Dry ports serve to facilitate the logistics processes. They mainly help the seaports expand their hinterlands. A well-established dry port within a well-established transportation network would benefit the transporters as well as seaports. One of the most important benefits of a close dry port is to provide additional storage capacity for the seaports. The railway transportation has been assessed as the most appropriate mode to provide mass transportation between Kocaeli ports and the destinations anywhere within the Anatolian peninsula.

In the world, it is seen that the Public-Private Partnership (PPP) model is widely used in projects requiring a high amount of financial investment. This model not only combines the financial powers but also harmonizes the advantageous specialties of both the public and the private sectors. It is considered that the PPP model would be appropriate for also Turkey as observed in the examples all over the world, for the dry port projects which will require huge investments.

The three main phases of the study are explained in the following sections.

8.1.1. Determination of Minimum Capabilities of the Dry Port Capable to Support Kocaeli Container Terminals in the Future

Container transportation, which is the fastest-growing marine transportation mode in recent years, is expected to continue to grow also for the next years. Based on Lloyd's List Intelligence and UNCTAD estimates, the annual transaction volume of Kocaeli container terminals in total is expected to reach, from 1,6 million TEU today, to 8 million TEU by 2035. It is seen that the current total capacity of Kocaeli container terminals is not sufficient to meet this expected value. It is considered that the additional capacity requirement could be met if the proposed dry port is constructed close to Kocaeli container terminals. It should have a total size of a minimum of 26 ha and should have an annual capability to handle at least one million TEU containers. It should also have almost all abilities that a seaport has, except the capability of loading and unloading to and from a vessel.

8.1.2. Determination of the Most Suitable Location for the Dry Port

The most appropriate location to construct the proposed dry port was determined through an Analytic Hierarchic Process (AHP). Designating the decision points (alternative dry port locations) and the factors (criteria) have been the most important stages within this process.

Two separate working group meetings were carried out with the “East Marmara Development Agency (MARKA)” and “First Regional Directorate of TCDD” to be able to designate the candidate locations for a dry port. These studies were considered necessary to get expert opinions on the subject.

Another stage was to designate the criteria of the AHP model. Literature review and expert opinions were the determinants of these criteria. Determining the priority of these criteria also required an important and delicate process. The weights of the criteria were determined by a questionnaire method with 94 experts from 11 different sectors. "Convenience for transportation within the hinterland" was determined as the most important criterion, although there were no significant differences between the weight values. All pairwise comparison stages were tested in terms of consistency and it was confirmed that each comparison step was consistent. As a result of the process, it was seen that the Köseköy Logistics Center was determined as the most appropriate alternative dry port location to support container transportation through the Kocaeli ports.

It is seen that the logistics center of Köseköy might play an important role in the future to ensure that the container traffic passing through the ports of Kocaeli will spread to the hinterland. In order to achieve this, it is important to plan carefully and strictly and implement the infrastructure and superstructure investments that will enable the Köseköy Logistics Center to develop as a well-established dry port.

8.1.3. Development of an Optimization Model to Support Decision-Making Process of Seaport

The developed optimization model aims both to test the hypotheses and to support the decision-making process of a seaport authority that is about to experience capacity problems. In the case study, it is assumed that a seaport that cannot create additional capacity will not be able to unload any more cargo onto its terminal after a short time, in other words, it cannot accept the load transported by its customer. The results are discussed from the point of view of testing the hypotheses in Section 8.2, and the other results regarding the solution of the optimization model are explained in this section.

The optimization model was run according to four different options. The results showed that the increase rate at peak periods is an important factor in determining the capacity to be needed. As a result of the analysis of the statistics of the previous years, it was observed that there were peak periods reaching 30%. More efforts would be required at peak periods to be able to find room for the arriving containers.

It is understood that the usable capacity in the transportation line between the port and the dry port is also very important. Running the optimization model exhibited that if there is not sufficient railway capacity to transfer the goods to the dry port, the seaport which experiences capacity problems may not find a proper solution. Such circumstance was observed for the options III and IV of the case study. The solution to these options was able to be obtained only after increasing the railway capacity.

Another conclusion obtained from the solution is that the number of trucks departing from the ports of Kocaeli to move the containers to the inland destinations could be reduced by approximately 24% depending on the case study. It would be possible to transfer some 30 thousands of containers from that number of trucks to about 580 railway shuttles. Such a transfer to the environmentally friendly transportation mode would absolutely result in less congestion on city and highways, reduced risk of accidents and less air pollution.

Generally, unload and load operations carried out by dry port authorities are costly operations that increase the total transportation cost and deterring the transporters from using railway transportation for short distances. But the dry port system assumed in parallel with the optimization model demonstrates that there may be some methods to reduce some costs. In the case study, it is assumed that the port authority manages a team with its own equipment in the dry port to reduce the cost of unloading and load operations from and to the railway cars. A mathematical model was developed within the thesis study to calculate the cost of a single movement of a reach stacker. By using this model it was calculated that each movement of a reach-stacker would cost less than 4 €. It should be taken into account that such a circumstance can only be assured when the seaport is in collaboration with the dry port.

This study put forward the possibility of a collaboration between a seaport and a dry port. A seaport authority may invest to complete the required capabilities of a dry port candidate. In this way, it may provide some services in more economic conditions. Such an initiative would make the seaport authority involve in some other activities which help ease the transportation process. The prominent field of activity in this regard will be the loading and unloading of containers on vehicles. Because these operations are quite costly in dry ports providing this service. By minimizing this cost, a transport line in the form of a "seaport-rail transport-dry port" may be more attractive to transportation providers.

The solution of the optimization problem made it clear that a seaport can increase its throughput volumes and consequently increase its income by collaborating with a dry port when it experiences capacity problems. Besides the benefits that the seaport gains, the dry port and the railway operator will also gain additional income through such collaboration. In this respect, a partnership initiative in which these three actors will participate will benefit both themselves and the other actors.

8.2. Examining the Validity of the Hypotheses

The null hypothesis (H_0) of the thesis was formulated as stated below:

"If a container terminal is about to confront the risk of rejecting the call of vessels due to the capacity constraints, collaboration with a Dry Port with a high capacity transportation corridor and perfect access to the hinterland will result in increased productivity and income."

And the alternative hypothesis (H_1) was formulated as stated below:

“Collaboration with a dry port although having a high capacity transportation corridor and perfect access to the hinterland will not be a remedy to increase the productivity and income of a container terminal, which is about to suffer due to the capacity constraints. The handling volumes cannot be increased over the storage capacity of the container terminal."

The optimization model developed in this thesis was run regarding a case study involving a circumstance that the seaport had a very limited capacity, and it might reject the call of some vessels since it had no more room to stack the arriving containers. The case study involved four options. In each option, the same number of containers in a 60 days period is assumed to arrive at the seaport. The first option had a stable freight rate whereas the other options had increasing amounts from day to day. The increase rates were assumed to occur at 10%, 21%, and 33% respectively in Options II, III, and IV. The statistics obtained from the solution were explained in Sections 7.4 and 7.5. The effects of the results in terms of examining the validity of the hypotheses are explained in the following paragraphs.

8.2.1. Examining the Situation that the Seaport has no Collaboration with Dry Port

In a situation that the seaport has no collaboration with a dry port, it is seen that approximately one-third of the vessels intending to call at the seaport to unload the containers would, unfortunately, be rejected due to the lack of space. Under these circumstances, the seaport would be able to unload a total of 126.000 TEUs of containers instead of 189.000 TEUs of containers, according to the Options I and II. In other terms, the seaport would miss a chance to unload and stack 63.000 more TEUs of containers. The rate of unloaded number of containers to the expected number of containers would be 66%. In both options, the income of the seaport would be realized as 12.936.000 €.

In Options III and IV, since the arriving number of containers is less at the beginning of the period, it would be possible to unload and stack a bit more containers in the whole period, namely 128.700 TEUs and 134.100 TEUs respectively. In other terms, the seaport would miss a chance to unload and stack 60.300 or 54.900 more TEUs of containers. The rate of the unloaded number of containers to the expected number of containers would be around 68-71%. In these options, the income of the seaport would be realized as 13.213.200 € and 13.767.600 € respectively.

8.2.2. Examining the Situation that the Seaport Collaborates with Dry Port

In a situation that the seaport has collaboration with a dry port, it is seen that 580 or 585 railway shuttles would run from seaport to dry port to transport 45.240 or 45.630 TEUs of containers in Options I and II respectively. These values correspond to approximately one-quarter of the freight that arrives at the seaport terminal. Under these circumstances, the seaport would be able to unload all containers that are planned to arrive at the seaport. The total income of the seaport exceeded 18 million € in both options.

The optimization solver program was not able to obtain a solution for the Options III and IV due to the limited rail shuttles. These options were assuming higher peak factors, in other terms, there were bigger differences between the beginning and the ending of the period. Just after increasing the daily railway capacity from 12 shuttles to 14 shuttles a solution was obtained for Option III, and for Option IV only after 16 shuttles, it was possible to obtain a solution. Such consequences indicate that **"A high capacity transportation corridor"** is needed between the seaport and the dry port to realize a proper solution when **"The container terminal is about to confront the risk of rejecting the call of vessels due to the capacity constraints"**.

Examining the results of the solution of the optimization problem it is seen that the collaboration with the dry port brought in an increase of 50% in the number of unloaded and stocked containers in Options I and II. On the other side, approximately 41% increase was realized in the total income of the seaport through this collaboration for the same options. To sum up these results, it was observed that **"Collaboration with a Dry Port with a high capacity transportation corridor resulted in increased productivity and income"**.

It is seen that if the seaport collaborates with a dry port, it can create additional capacity, avoid the risk of rejecting its customers and even increase the transaction volume and accordingly increase its income. As a result of the numerical analysis performed based on the case study, it was concluded that the null hypothesis (H_0) was valid. These results invalidate the alternative hypothesis (H_1).

8.2. Proposals

Considering that the existing capacities of Kocaeli container terminals will be insufficient to meet the demand in the 2030s, it is necessary to establish a dry port close to these ports. In addition to meeting the additional capacity requirements of sea ports, the dry port to be established will also benefit other actors. In order to realize these expected benefits, Köseköy Logistics Center (KLC), which is identified as the most appropriate alternative in this study, should be prepared for the 2030s as a well-established and well-connected dry port.

The dry port to be established should have sufficient stacking area and modern crane systems to achieve an estimated one million TEU container transaction volume per year. For this purpose, necessary construction works should be carried out on an area of at least 26 ha of total size, with a minimum of 17 ha of the area being used as a container stacking area. Advanced stacking cranes and systems such as RTG or RMG should be used over this stacking area to carry out container operations as quickly as possible.

Minimum 48 train services reciprocally per day should be allocated to transport cargo between Gebze and Köseköy. In this way, it could be possible to create an annual transportation capacity of 1.3 million TEUs. In this way, it could be possible to create an annual transportation capacity of 1.3 million TEUs. Such a railway capacity would be sufficient to manage the possible demand in the 2030s. In order to reach this capacity, TCDD should complete the necessary infrastructure investments. It is considered that this need can be met if the current project of TCDD, which aims to make 72 reciprocal shuttles per day on this line, is completed.

Since it requires a huge amount of investment to construct a dry port, a PPP model should be formed to rebuild and prepare the Köseköy Logistics Center for the future. TCDD should take initiative to form a PPP model since it already is the main body as owning the prospected dry port and providing the railway services. Primarily, the Kocaeli container terminals as the actors that will need most of the additional capacity, should join this partnership.

It is assessed that the AHP model, the optimization model and the related case study, which were developed during this thesis study can be taken as an example for the other dry port implementations in the world.

8.3. A Guide for Future Researches

This thesis study and its conclusions might give some ideas about the issues that should be researched in connection with this subject. This study has developed research in terms of container terminals located in the Kocaeli Gulf and container transportation through these ports. It is considered necessary to carry on research about the transportation of other types of goods and the situations of other regions.

When developing the optimization model and the case study, it was assumed that the seaport is collaborating with the dry port as a partner. While making payment to the rail operator and dry port authority for the containers directly transferred to dry port, it earns money as if the containers are warehoused at its own terminal. It has absolute authority to determine which containers should be directly transferred to dry port and which should be kept to be stacked at its terminal yard. In other terms, the transportation provider does not have any right to choose that its good shall be transferred to dry port or to be stacked at the seaport terminal. It is considered necessary to develop another optimization model relevant to a case study that the transportation provider is a partner with a dry port and it has the absolute authority to determine which containers should be directly transferred to dry port and which should be kept in the seaport terminal. The variety of relevant research topics and their conclusions would possibly attract some actors to take part in the possible PPP formations.

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APPENDIX A: QUESTIONNAIRE FOR GRADING THE CRITERIA OF THE AHP MODEL

Subject of the Survey: Grading the criteria that will help us determine the most appropriate location for establishing a dry port (or a logistics village).

It is assumed that the dry port to be established will have all the capabilities (loading / unloading, storage, repair, customs, value added services, etc.) required in a container terminal. In addition, it is preferable that this facility is accessible by multiple modes of transport, with railway connection and ability to change modes.

The assessment will be made according to seven different criteria in order to determine the most suitable place for establishing a dry port. These criteria are described below (listed in alphabetical order):

(1) ENVIRONMENTAL EFFECT: It is considered that transportation from a seaport would cause some adverse impacts (harmful gas emissions, health problems, noise, traffic confusion, etc.) on the port city and other urban locations. It should be taken into account that to which extent such adverse impacts might be reduced through dry port application and railway transport.

(2) PROXIMITY TO THE SEA PORT: The advantage of the distance between sea port and dry port should be evaluated in terms of transporting commercial products to consumption centers or production facilities.

(3) CENTRAL LOCATION: The advantage of the central location of the dry port should be evaluated within the transport network of sea port, dry port, production facilities and consumption centers.

(4) PROCESS OF ESTABLISHMENT: Difficulties and factors for the facility to be fully operational should be evaluated. These may be the difficulties related to the provision of the land (such as obtaining the parcel from different landowners in a long process or the existence of a long-term transformation project related to the land), or the difficulties that may be encountered in connection with the necessary transportation lines (other long-term strategic plans for the construction of railways or highways), or else other factors that may affect the fully operational operation of the facility.

(5) CONVENIENCE FOR TRANSPORTATION WITHIN THE HINTERLAND: The benefits that the dry port (as an intermodal terminal) will provide in the logistics transport activity between the inner regions (consumption centers), sea port and production facilities through the transport networks should be evaluated. It should be taken into account that railway mode could facilitate the mass transportation.

(6) PROXIMITY TO THE INDUSTRY: The advantage of the location of the dry port should be evaluated for logistical transport between production facilities and dry port.

(7) COST OF INVESTMENT: The total investment cost required for the proposed location to become a dry port should be evaluated. Investment costs should be taken into consideration in matters such as acquisition of land, establishment of facilities, connection of transport networks, and intermodal capability.

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1. Grade the following criteria in accordance with the degree of importance you consider to designate the priority of the criteria when determining the most suitable location for establishing a dry port (logistic village). The most important criterion should be given the highest score (9) and the least important criterion should be given the lowest score (1). Other criteria should be given between 2 and 8 different scores according to their significance.

Criteria/Grades	9	8	7	6	5	4	3	2	1
Environmental effect	○	○	○	○	○	○	○	○	○
Proximity to the port	○	○	○	○	○	○	○	○	○
Central location	○	○	○	○	○	○	○	○	○
Process of establishment	○	○	○	○	○	○	○	○	○
Convenience for transport	○	○	○	○	○	○	○	○	○
Proximity to the industry	○	○	○	○	○	○	○	○	○
Cost of investment	○	○	○	○	○	○	○	○	○

2. Which of the following is the institution / sector you are working with or related to?

- ○ Transportation Sector
- ○ Researcher/Scholar
- ○ Port Sector
- ○ Railway Infrastructure / Rail Freight
- ○ Ministry of Transport and Infrastructure
- ○ Logistics Center/Logistics Facility
- ○ Industry
- ○ Investor/Investment Specialist/Investment Planning
- ○ Ministry of Customs and Trade
- ○ Municipality
- ○ Ministry of Environment and Urbanization/Environment Volunteer

3. Name and Surname of the Participant

....

4. Name of Institution / Company of Participant

....

Submit

APPENDIX B: LIST OF THE PARTICIPATORS OF THE QUESTIONNAIRE APPLIED TO DETERMINE THE WEIGHTS OF THE AHP CRITERIA

Nu.	Related Institution/Sector of the Participator	Name of the Participator	Time of reply	Instution
1	Industry	Ayhan Zeytinoğlu	14.2.2019 16:34	Kocaeli Chamber of Industry
2	Logistics Center	Kerem Tuna	14.2.2019 19:35	Ekol Logistics
3	Port Sector	Ali Keskin	15.2.2019 08:58	EVYAP Port
4	Researcher/Scholar	N.G. Gidener Özaydın	17.2.2019 22:36	Dokuz Eylül Univertsity
5	Researcher/Scholar	Dinçer Bayer	18.2.2019 09:13	Piri Reis Univertsity
6	Municipality	Ferda Özparlak Şahin	18.2.2019 09:13	Kartepe Municipality
7	Railway Sector	Tuncer Kemal	18.2.2019 10:13	TCDD Transportation
8	Railway Sector	Mustafa Kıylıoğlu	18.2.2019 10:14	TCDD Transportation
9	Researcher/Scholar	Ergün Demirel	18.2.2019 10:31	Piri Reis Univertsity
10	Transportation Sector	Merve Çolakoğlu	18.2.2019 11:48	CMA CMG/APL
11	Transportation Sector	F. Ural	18.2.2019 11:49	N/A
12	Researcher/Scholar	Soner Esmer	18.2.2019 12:51	Dokuz Eylül Univertsity
13	Researcher/Scholar	Hüseyin Gencer	18.2.2019 16:50	Piri Reis Univertsity
14	Transportation Sector	Murat Boğ	18.2.2019 17:01	Ekol Logistics
15	Railway Sector	Mustafa Kemal Tuncer	19.2.2019 09:14	TCDD Transportation
16	Ministry of Transport	Ahmet Saygın Ulus	19.2.2019 12:42	Kocaeli Port Authority
17	Investment	Muhammet Bayrak	19.2.2019 13:13	MARKA
18	Ministry of Environment	Rahşan Bukni Ulus	19.2.2019 13:19	Ulus Env. Consulting
19	Ministry of Transport	İsmail Hakkı Başoğlu	19.2.2019 13:27	Kocaeli Port Authority
20	Port Sector	Ali Yıldız	19.2.2019 13:31	MARPORT
21	Ministry of Transport	Ebru Sude	19.2.2019 14:09	Kocaeli Port Authority
22	Ministry of Transport	Gürkan Akyüz	19.2.2019 14:12	Kocaeli Port Authority
23	Ministry of Transport	Berat Geyik	19.2.2019 14:12	Kocaeli Port Authority
24	Ministry of Transport	Alper Tunga Anıker	19.2.2019 14:46	Kocaeli Port Authority
25	Ministry of Transport	Deniz Atıcı	19.2.2019 14:55	Kocaeli Port Authority
26	Ministry of Transport	Behçet Çelebi	19.2.2019 15:11	Kocaeli Port Authority
27	Ministry of Customs	Halil Koral	19.2.2019 15:42	Ünsped Customs Brokerage
28	Railway Sector	Gökçe Ceren Baydar	19.2.2019 16:49	TCDD Transportation
29	Railway Sector	Metin Artar	19.2.2019 20:45	TCDD Transportation
30	Ministry of Transport	Kemal Sarısözen	19.2.2019 21:12	Kocaeli Port Authority
31	Port Sector	Ayhan Turna	19.2.2019 21:30	YILPORT
32	Transportation Sector	Yaşar Türker	19.2.2019 22:49	Türker Tourism
33	Port Sector	Veysel Sekin	20.2.2019 08:23	YILPORT
34	Port Sector	Hakan Akyol	20.2.2019 09:41	SAFİPORT
35	Transportation Sector	Murat Hatabay	20.2.2019 09:44	Martı Konteyner

Nu.	Related Institution/Sector of the Participator	Name of the Participator	Time of reply	Instution
36	Port Sector	Faris Tunç	20.2.2019 10:26	SAFİPORT
37	Railway Sector	Yaşar Öztürk	20.2.2019 12:04	Köseköy Logistics Dir.
38	Railway Sector	Yılmaz Acar	20.2.2019 12:51	TCDD Infrastructure
39	Transportation Sector	Mehmet Özdayan	20.2.2019 14:15	Eti Logistics
40	Researcher/Scholar	Avni Zafer Acar	20.2.2019 14:42	Piri Reis Univertsity
41	Transportation Sector	Murat Karaman	20.2.2019 15:28	Medkon Lines
42	Port Sector	Kadir Uzun	20.2.2019 15:45	ASYAPORT
43	Investment	Fatma Avşar	20.2.2019 16:17	MARKA
44	Researcher/Scholar	Ayşe Güngör	20.2.2019 16:33	Toros Univertsity
45	Researcher/Scholar	Didem Çavuşoğlu	20.2.2019 16:44	Celal Bayar Univertsity
46	Transportation Sector	Gökçe Ildır	20.2.2019 17:26	N/A
47	Transportation Sector	Ece Simge	20.2.2019 17:30	N/A
48	Transportation Sector	Emre Taşdelen	20.2.2019 17:48	Hapag Lloyd AG
49	Transportation Sector	Bahadır Abul	20.2.2019 17:50	Hapag Lloyd AG
50	Transportation Sector	Hakan Ilgıt	20.2.2019 17:52	Bulung
51	Researcher/Scholar	Barbaros Büyüksağnak	20.2.2019 20:45	Piri Reis Univertsity
52	Ministry of Customs	Ali Orhan	20.2.2019 21:29	Ünsped Customs Brokerage
53	Researcher/Scholar	Tolga Öz	20.2.2019 23:31	Milli Savunma Univertsity
54	Municipality	M. Yıldız	21.2.2019 10:03	N/A
55	Transportation Sector	Selim Altay Havlioğlu	21.2.2019 10:21	Evolog Logistics
56	Researcher/Scholar	G. Serap Çekerol	21.2.2019 10:21	Anadolu Univertsity
57	Transportation Sector	Cihan Yusufi	21.2.2019 11:31	Globelink Unimar Logistics
58	Transportation Sector	Sinan Yılmaz	21.2.2019 11:44	N/A
59	Transportation Sector	Seyfi Arıcı	21.2.2019 11:45	N/A
60	Transportation Sector	Ali Ekber	21.2.2019 12:20	SIMCELL
61	Transportation Sector	F.Onur Yılmaz	21.2.2019 13:57	ZAFER Transport
62	Transportation Sector	Serdar Gürbüzceylan	21.2.2019 14:06	Borusan Logistics
63	Transportation Sector	Kosta Sandalcı	21.2.2019 14:19	MİLİTZER & MÜNCH A. Ş.
64	Transportation Sector	Uğur Sadettin Alikoç	21.2.2019 14:41	Demtaş Logistics
65	Railway Sector	Barış Polat	21.2.2019 16:12	Rail Cargo Logistics
66	Researcher/Scholar	Özgür Özpeynirci	21.2.2019 16:44	İzmir Ekonomi Univertsity
67	Investment	Cem Bayrak	21.2.2019 17:25	MARKA
68	Port Sector	Cumhur Çakan	22.2.2019 10:37	MARPORT
69	Researcher/Scholar	Dilara B. Tarhan	22.2.2019 15:08	Toros Univertsity
70	Port Sector	Özge Tunçay	22.2.2019 15:37	MARPORT
71	Transportation Sector	Cihan Özkal	22.2.2019 17:17	ARMADA
72	Transportation Sector	Kayıhan Turan	23.2.2019 11:57	KeyLine
73	Logistics Center	Murat Gürel	24.2.2019 20:01	ARKAS
74	Transportation Sector	Mahmut Işık	25.2.2019 09:17	Medkon Transport
75	Transportation Sector	Erhan Uğur	25.2.2019 14:39	GALATA TAS TIC A.S.

Nu.	Related Institution/Sector of the Participator	Name of the Participator	Time of reply	Instution
76	Logistics Center	Mesut Uysal	25.2.2019 15:22	TCDD Eskişehir Log.Dir.
77	Logistics Center	Mücahit Garip	25.2.2019 15:39	TCDD Bozuyuk Log.Dir.
78	Researcher/Scholar	Ali Cem Kuzu	25.2.2019 21:15	Piri Reis Univertsity
79	Industry	İhsan Yanık	26.2.2019 08:24	İstanbul Anadolu OSB Dir.
80	Transportation Sector	Cavit Uğur	26.2.2019 16:59	UTİKAD
81	Port Sector	Halil Veysel Taşay	27.2.2019 07:57	MARPORT
82	Researcher/Scholar	Batuhan Kocaoğlu	28.2.2019 14:22	Piri Reis Univertsity
83	Port Sector	Gülem Canbolat	1.3.2019 12:15	TÜRKLİM
84	Port Sector	Zeynep Şahin Taşkın	10.3.2019 00:22	EVYAP Port
85	Ministry of Customs	Ümit Yaşar Yılmaz	11.3.2019 11:41	Ünsped Customs Brokerage
86	Researcher/Scholar	Aykut Arslan	18.3.2019 11:49	Piri Reis Univertsity
87	Port Sector	Sinan Şener	18.4.2019 11:55	TCEEGE Terminal
88	Ministry of Environment	Filiz Çetin	22.5.2019 16:59	Yalçın Metal Ltd.
89	Industry	Selçuk Ayyıldız	23.5.2019 07:41	Torun Döküm San.
90	Industry	Mukaddes Gülcü	23.5.2019 08:36	İstanbul Anadolu OSB Dir.
91	Industry	Burcu Yanık	23.5.2019 08:49	Mutlu Plastik
92	Industry	Akın Öztürk	23.5.2019 09:23	Anadolu Kompozit San.
93	Industry	Serkan Erdem	23.5.2019 14:46	CUMMİNS TURKEY
94	Industry	Birol Temel	10.6.2019 11:27	ABB Elektrik A.Ş.

(Prepared by the author)

APPENDIX C: LIST OF OIZ WITHIN THE HINTERLAND OF KOCAELI PORTS

Nu.	Name of the OIZ	Size of the OIZ (m^2)	City	Export in 2018 (1000 USD)	Ratio of Export in Turkey's Total (%)
1	İstanbul İkitelli OIZ	N/A	IST	85.060.132	50,64
2	İstanbul Anadolu Yakası OIZ	665.855			
3	İstanbul Deri OIZ	3.710.264			
4	Birlik OIZ	N/A			
5	İstanbul-Tuzla Kimya Sanayicileri OIZ	637.244			
6	İstanbul Dudullu OIZ	N/A			
7	İstanbul Tuzla OIZ	474.152			
8	İstanbul Beylikdüzü OIZ	N/A			
9	Gebze OIZ	4.743.174	KOC	8.904.222	5,30
10	TOIZ Otomotiv Yan Sanayi İhtisas OIZ	1.153.077			
11	Kocaeli Gebze Plastikçiler OIZ	1.450.895			
12	Kocaeli Gebze Güzeller OIZ	1.106.728			
13	Kocaeli-Gebze VI.(İMES) Makina İhtisas OIZ	2.153.473			
14	Makine İhtisas OIZ	3.823.193			
15	Kocaeli Gebze V. (Kimya) İhtisas OIZ	1.893.397			
16	Kocaeli Gebze Dilovası OIZ	2.558.942			
17	Kocaeli Arslanbey OIZ	883.066			
18	Asım Kibar OIZ	2.126.391			
19	Kocaeli Gebze Kömürcüler İhtisas OIZ	647.093			
20	Kocaeli-Alikahya OIZ	920.763			
21	Kandıra Gıda İhtisas OIZ	N/A			
22	Kocaeli Dilovası (Köseler) Islah OIZ	N/A			
23	Sakarya II. OIZ	3.006.053	SAK	5.639.445	3,36
24	Sakarya III. OIZ	1.512.648			
25	Sakarya I.OIZ	1.486.732			
26	Karasu OIZ	246.340			
27	Ferizli OIZ	741.439			
28	Kaynarca Mobilya İhtisas OIZ	62.815			
29	Sakarya Kaynarca D.Mar.Mak.İm.İht. OIZ	N/A			
30	Düzce OIZ	1.112.102	DUZ	107.068	0,06
31	Düzce 2. OIZ	462.162			
32	Çilimli OIZ	N/A			
33	Düzce Gümüşova OIZ	N/A			
34	Akçakoca Demir Çelik İhtisas OIZ	N/A			

Nu.	Name of the OIZ	Size of the OIZ (m^2)	City	Export in 2018 (1000 USD)	Ratio of Export in Turkey's Total (%)
35	Bolu Karma ve Tekstil İhtisas OIZ	987.940	BOL	143.073	0,09
36	Bolu-Gerede OIZ	1.539.721			
37	Gerede Deri İhtisas OIZ	1.632.881			
38	Yeniçağa OIZ	N/A			
39	Zonguldak Çaycuma OIZ	1.180.284	ZON	504.469	0,30
40	Zonguldak Alaplı OIZ	N/A			
41	Zonguldak-Ereğli OIZ	1.148.962			
42	TAİOIZ - Taşıt Araçları Yan Sanayi İht. OIZ	N/A			
43	Bartın Merkez I.OIZ	444.261	BAR	33.584	0,02
44	Yalova Kalıp İmalatı İhtisas OIZ	N/A	YAL	312.172	0,19
45	Yalova Gemi İhtisas OIZ	N/A			
46	Yalova Kompozit ve Kimya İhtisas OIZ	17.303			
47	Yalova İMES Makina İhtisas OIZ	N/A			
48	Yalova Avrasya Giyim İhtisas OIZ	N/A			
49	İnegöl OIZ	2.263.140	BUR	11.149.894	6,64
50	Nilüfer OIZ	1.618.875			
51	Bursa OIZ	4.798.997			
52	Uludağ OIZ	186.895			
53	DEMİRTAŞ OIZ	14.932.715			
54	Mustafakemalpaşa OIZ	1.593.675			
55	Mustafakemalpaşa Mermerciler OIZ	N/A			
56	Kestel OIZ	N/A			
57	Bursa İhtisas Deri OIZ	1.808.841			
58	Yenişehir OIZ	N/A			
59	Hasanağa OIZ	1.029.615			
60	TOSAB-Bursa Tekstil Boyahaneleri İht. OIZ	1.873.404			
61	inegöl Mobilya Ağaç İşleri İhtisas OIZ	5.292.036			
62	KAYAPA ISLAH OIZ	N/A			
63	Yenice OIZ	N/A			
64	Barakfakih Islah OIZ (BOSAB)	1.000			
65	Akçalar Islah	N/A			
66	Bursa Teknoloji OIZ	N/A			
67	Bandırma OIZ	7.030.872	BAL	608.814	0,36
68	Balıkesir OIZ	4.669.199			
69	Balıkesir II. OIZ	475.160			
70	Gönen Deri ihtisas ve Karma OIZ	2.641.575			
71	Zeytin ve Zeytin Ürünleri İşleme İhtisas OIZ	N/A			
72	Balıkesir Dursunbey OIZ	N/A			

Nu.	Name of the OIZ	Size of the OIZ (m^2)	City	Export in 2018 (1000 USD)	Ratio of Export in Turkey's Total (%)
73	Biga OIZ	476.838	CAN	152.730	0,09
74	Çanakkale OIZ	562.851			
75	Ezine Gıda İhtisas OIZ	N/A			
76	Bilecik 1. OIZ	1.382.052	BIL	101.448	0,06
77	Bilecik 2. OIZ	3.260.410			
78	Bozüyük OIZ	4.216.067			
79	Osmaneli OIZ	660.694			
80	Pazaryeri OIZ	1.042.820			
81	Söğüt OIZ	629.650			
82	Eskişehir Sanayi Odası OIZ	N/A	ESK	1.060.819	0,63
83	Sivrihisar OIZ	N/A			
84	Ostim OIZ	1.552.043	ANK	7.613.120	4,53
85	Ankara-İvedik OIZ	66.153			
86	Ankara Sanayi Odası I. Sincan OIZ	3.393.889			
87	Ankara Anadolu OIZ - AOIZ	2.307.334			
88	Ankara Polatlı OIZ	2.241.030			
89	Başkent OIZ	3.592.369			
90	Ankara Sanayi Odası 2. ve 3. OIZ	4.295.721			
91	Şereflikoçhisar OIZ	351.000			
92	Ankara Polatlı Ticaret Odası OIZ	N/A			
93	Ankara Uzay ve Havacılık İhtisas OIZ	N/A			
94	Elmadağ Mobilyacılar İhtisas OIZ	N/A			
95	Kütahya OIZ	1.518.338	KUT	217.542	0,13
96	Kütahya Merkez İkinci OIZ	436.653			
97	Gediz OIZ	1.620.152			
98	Simav OIZ	N/A			
99	Kütahya Tavşanlı OIZ	859.663			
100	Kütahya Altıntaş Zafer OIZ	N/A			
101	Uşak OIZ	4.790.859	USA	245.506	0,15
102	Uşak Deri (Karma) OIZ	1.754.255			
103	Uşak Karahallı OIZ	528.302			

Nu.	Name of the OIZ	Size of the OIZ (m^2)	City	Export in 2018 (1000 USD)	Ratio of Export in Turkey's Total (%)
104	Afyonkarahisar OIZ	3.389.404	AFY	341.752	0,20
105	Afyonkarahisar Bolvadin OIZ	324.103			
106	Afyonkarahisar Dinar OIZ	380.488			
107	Afyonkarahisar Emirdağ	938.762			
108	İscehisar Mermer İhtisas OIZ	1.038.892			
109	Sandıklı OIZ	342.463			
110	Afyonkarahisar Dazkırı Dokuma ve Konf. OIZ	3.862.454			
111	Afyonkarahisar Şuhut OIZ	1.987.036			
112	Afyonkarahisar Merkez 2 OIZ	N/A			
113	Konya OIZ	N/A	KON	1.785.166	1,06
114	Konya 1. OIZ	6.741.470			
115	Konya Ereğli OIZ	1.784.345			
116	Beyşehir OIZ	780.539			
117	Akşehir OIZ	847.266			
118	Seydişehir OIZ	2.643.613			
119	Kulu OIZ	N/A			
120	Çumra OIZ	N/A			
121	Karapınar OIZ	2.259.912			

(**Source:** Ministry of Industry and Technology of Turkish Republic, OIZ Information Portal. <https://osbbs.sanayi.gov.tr/default.aspx>, Accessed 14.04.2019).

APPENDIX D: CPLEX CODES FOR THE OPTIMIZATION MODEL

```
//Indices

int D=...;
range Day=1..D;
int V=...;
range Volume=1..V;

//Parameters

float U[Volume][Day]=...;//Number of containers unloaded at the seaport
float T[Volume][Day]=...;// Number of containers leaving the seaport by trucks
float Cap=...;//TEU capacitiy of the terminal
float B=...;//Container stock at the beginning of the period
float C[Volume]=...;//Container size
float E[Volume]=...;//Earning through the type of container

//Decision Variables

dvar int+ Y[Day];//Total Number of containers stocked at terminal
dvar int+ W[Volume][Day];//Number of containers warehoused on that day
dvar int+ R[Volume][Day];// Number of train cars sent to the dry port
dvar int+ V[Day];//Number of train voyages in a day

//Objective function

maximize
sum(v in Volume,d in Day)(E[v]*W[v][d])+sum(d in Day)(6006*V[d]);

subject to {

//Constraint for capacity allocation

forall(v in Volume,d in Day)
W[v][d]+R[v][d]==U[v][d];

forall(d in 1..D)
Y[d]<=Cap;

Y[1]==B+sum(v in Volume)C[v]*(W[v][1]-T[v][1]);

forall (d in 1..6)
  sum(v in Volume)C[v]*T[v][d]==1950;

forall(d in 2..6)
Y[d]==Y[d-1]+sum(v in Volume)C[v]*(W[v][d]-T[v][d]);
```

```
forall(d in 7..D)
Y[d]==Y[d-1]+sum(v in Volume)Cx[v]*(W[v][d]-W[v][d-6]);

//Railway capacity

  forall(d in Day)
    J[d]<=16;

    forall(d in Day,v in Volume)
    R[v][d]==26*J[d];

 }
```

APPENDIX E: DATA SET FOR THE OPTIMIZATION MODEL

```
D=60;
V=2;
T=[[650,650,650,650,650,650],[650,650,650,650,650,650]];
Cap=14400;
B=11700;
C=[1,2];
I=[130,178];

//Container unloaded

        //Option-I

U=[[1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050],

[1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050,
1050,1050,1050,1050,1050,1050,1050,1050,1050,1050]];

        // Option-II

U=[[1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100],

[1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100]];
```

```
// Option-III

U=[[950,950,950,950,950,950,950,950,950,950,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1150,1150,1150,1150,1150,1150,1150,1150,1150,1150],

[950,950,950,950,950,950,950,950,950,950,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1150,1150,1150,1150,1150,1150,1150,1150,1150,1150]];

// Option-IV

U=[[900,900,900,900,900,900,900,900,900,900,
950,950,950,950,950,950,950,950,950,950,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1150,1150,1150,1150,1150,1150,1150,1150,1150,1150,
1200,1200,1200,1200,1200,1200,1200,1200,1200,1200],

[900,900,900,900,900,900,900,900,900,900,
950,950,950,950,950,950,950,950,950,950,
1000,1000,1000,1000,1000,1000,1000,1000,1000,1000,
1100,1100,1100,1100,1100,1100,1100,1100,1100,1100,
1150,1150,1150,1150,1150,1150,1150,1150,1150,1150,
1200,1200,1200,1200,1200,1200,1200,1200,1200,1200]];
```

BRIEF CURRICULUM VITAE

Murat Saka graduated from Naval Academy, Electronics Engineering Department in 1986. He completed his master's degree in International Relations at the Naval War College in 1998. He served as the commanding officer (shipmaster) of three vessels in total five years between 1994 and 2002. He served as Tokyo Military Attaché in Japan between 2006 and 2008, thereafter as the Chief of Staff of Karamürselbey Training Center and the Regiment Commander of Turkish Vocational Petty officers High School between 2008 and 2011.

He started his Ph.D. studies at the Pîrî Reis University in 2014 and defended his thesis titled "A Dry Port Model for Kocaeli Container Terminals" on 03rd of January, 2020. Murat Saka is currently working as a full-time lecturer at the Pîrî Reis University.

PUBLICATIONS/PRESENTATIONS ON THE THESIS

1. Saka, M. and Çetin, O. (2017). Konteyner taşımacılığı için yeni bir model önerisi: Köseköy kuru limanı (A new model suggestion for container transportation: Kosekoy Dry Port). III. National Port Congress. DOI: 10.18872/DEU.df.ULK.2017.011.

Verbal presentation was made in the III. National Port Congress.

2. Saka, M. and Çetin, O. (2018). An Optimization Model Suggestion for Dry Ports (OPMOPORT). 19th Annual General Assembly – AGA 2018 / IAMU Student International Association of Maritime Universities (IAMU).

Verbal presentation was made in the AGA 2018 / IAMU Student Conference.

3. Saka, M. and Çetin, O. (2019a). Proposal of an optimization model for dry port application for container transportation from Kocaeli ports. Journal of Social and Humanities Sciences Research, 6(38) 1547-1554. DOI: http://dx.doi.org/10.26450/jshsr.1235.

4. Saka, M. and Çetin, O. (2019b). Research of a dry port which can support container transportation from Kocaeli ports in terms of possibilities and capabilities. International Journal of Engineering and Innovative Research, 1(1) 35-48.

5. Saka, M. and Çetin, O. (2019c). Determination of Dry Port Location within the Hinterland of Kocaeli Ports by Applying AHP.

Verbal presentation was made in the AGA 2019 / IAMU Conference.