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PROPOSAL OF AN OPTIMIZATION MODEL FOR DRY PORT APPLICATION FOR CONTAINER TRANSPORTATION FROM KOCAELI PORTS

KOCAELİ LİMANLARINDAN KONTEYNER TAŞIMACILIĞI İÇİN KURU LİMAN UYGULAMASINA YÖNELİK BİR OPTİMİZASYON MODELİ ÖNERİSİ

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ABSTRACT

Increased maritime transport due to global trade has a significant impact on the ports, which are the gateways of countries to trade. Ports make investment plans in order to maintain their competitiveness in the face of increasing freight traffic and also apply various measures in order to store more containers in their storage areas. In the Kocaeli region, the primary method for ports that are stuck in a narrow area is to gain space by filling the sea. However, it is thought that the dry port application, which is becoming more widespread in the world, can be a remedy for Kocaeli container terminals that might suffer from lack of space.

The benefits of a dry port application in a circumstance when the seaport has capacity constraints have been examined by developing an optimization model provided that the seaport has a railway connection and is collaborating with that dry port. As a result of this study, it has been understood that all actors involved in container transportation can benefit to a certain level. It is thought that the developed mathematical model in this study can help the decision-making process of port operators.

Keywords: Dry port, container transportation, optimization model, maritime management.

ÖZET

Küresel ticarete bağlı olarak artan denizyolu taşımacılığı, ülkelerin ticarete açılan kapıları olan limanları önemli derecede etkilemektedir. Limanlar, artan yük trafiği karşısında rekabet güçlerini muhafaza edebilmek için yatırım planları yapmakta, ayrıca istif alanlarında daha çok konteyner depolayabilmek için çeşitli tedbirlere başvurmaktadırlar. Kocaeli bölgesinde, dar alana sıkışmış durumdaki limanlar için öncelikli yöntem, denizin doldurulması yöntemiyle alan kazanılmasıdır. Bununla birlikte, dünyada yaygınlaşmakta olan kuru liman uygulamasının da, yer kısıtlaması olan Kocaeli konteyner terminalleri için bir çare olabileceği düşünülmektedir.

Bir deniz limanı açısından kapasite sorunu söz konusu olduğunda, demiryolu bağlantısına sahip olması ve bir kuru liman ile işbirliği yapması halinde, kuru liman uygulamasının sağlayacağı faydalar, bir optimizasyon modeli geliştirilerek incelenmiştir. Bu çalışmanın neticesinde, konteyner taşımacılığında rol alan tüm aktörlerin belli seviyede fayda sağlayabilecekleri anlaşılmıştır. Geliştirilen matematiksel modelin, liman operatörlerinin karar verme süreçlerinde yardımcı olabileceği düşünülmektedir.

Anahtar Kelimeler: Kuru liman, konteyner taşımacılığı, optimizasyon modeli, deniz işletmeciliği.

1. INTRODUCTION

Global seaborne trade expanded at 4% in 2017, with the fastest growth in the last five years. Among all modes of maritime transportation, container transportation was the fastest growing one by increasing 6,4% (UNCTAD, 2018). During the last decades, the global container trade has increased tremendously. According to the values in tonnage, the share of container transportation in the sum of global trade has increased to 17% at the end of 2017, whereas it was only 2,75% in 1980. Global container trade values in tonnage have increased almost 17 times during that period, from 102 million tons in 1980 to 1.834 million tons in 2017.

The container terminals certainly are very important nodes in facilitating the transportation of containerized cargoes (Notteboom and Yap, 2012). Developments in containerization and intermodal transportation have assisted to extend the hinterland reach of seaports (Berg and Langen, 2011). 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). Therefore, the hinterland connections of a seaport have become a crucial issue for the competition among the seaports (Notteboom, 2008). In other words, the ports managing to expand their hinterlands will be able to be in a more advantageous situation in such competitive environments (Hoshino, 2010).

The world's leading 40 container ports handled a total of 415.9 million TEUs in 2016, which accounts for nearly 60% of the world's total. These 40 terminals showed a 1.7% increase in total compared to the previous year (UNCTAD, 2017). In general Turkey and specially Kocaeli Ports showed a much better performance in that period in comparison with the world total and top 40s total volumes. One of the Kocaeli province's ports, YILPORT has exhibited a remarkable performance with an annual increase of 26.3% in 2017 as seen in Table-1. Between the years 2007 and 2017, the Compound Annual Growth Rate (CAGR) of Turkey's total container throughput has been 8.13% whereas it has been 25.84% for Kocaeli Ports and 22.06% for YILPORT.

Table-1: Container Handling Values (1000 TEU)

Year	Turkey Total		Kocaeli Ports Total		YILPORT	
	Value	**Change**	**Value**	**Change**	**Value**	**Change**
2007	4.582		132		68	
2008	5.091	11.1%	252	90.9%	135	98.5%
2009	4.404	-13.5%	280	11.1%	133	-1.4%
2010	5.743	30.4%	415	48.2%	184	38.3%
2011	6.523	13.6%	507	22.1%	230	25.0%
2012	7.192	10.3%	630	24.2%	230	0.0%
2013	7.899	9.8%	807	28.1%	305	32.6%
2014	8.351	5.7%	899	11.4%	354	16.0%
2015	8.146	-2.5%	988	9.9%	375	5.9%
2016	8.761	7.6%	1.143	15.6%	395	5.33%
2017	**10.010**	**14.3%**	**1.315**	**15.0%**	**499**	**26.3%**

Source: Statistics of "Ministry of Transportation, Maritime and Communication", and "YILPORT".

Container transportation is expected to grow increasingly. Lloyd's List Intelligence (LLI) projects 3,1% annual growth rate for seaborne trade and 4,6% annual growth rate for containerized trade between 2017 and 2026, whereas UNCTAD (UN Conference on Trade and Development) projects 3,8% annual growth rate for seaborne trade and 6,0% annual growth rate for containerized trade between 2018 and 2023 (UNCTAD, 2018). These estimations being accepted as the average rates, three different scenarios are predicted for the transaction volumes of Turkey's and Kocaeli ports (see Table-2) that may be acquired in the future. Pessimistic scenario indicates lower rates than LLI and UNCTAD predict, whereas the optimistic scenario foresees that Turkey's ports will be able to maintain a rate close to the increase they have shown over the last period.

Table-2: Projections for Future Throughput Values of Turkey's Ports.

		Year	Turkey Total		Kocaeli Ports		YILPORT	
			Value (1000 TEU)	CAGR %	Value (1000 TEU)	CAGR %	Value (1000 TEU)	CAGR %
Recent Throughput Value		2018	10.843		1.597		**552**	
Projected Throughput Values in Scenarios	Scenario-I (Pessimistic)	2023	12.570	3,0	1.851	3,0	640	3,0
		2029	15.009	3,0	2,210	3,0	764	3,0
		2035	17.922	3,0	2.639	3,0	912	3,0
	Scenario-II (Average)	2023	14.510	6,0	2.137	6,0	739	6,0
		2029	20.583	6,0	3.032	6,0	1.048	6,0
		2035	29.198	6,0	4.301	6,0	1.487	6,0
	Scenario-III (Optimistic)	2023	15.567	7,5	3.212	15,0	1.110	15,0
		2029	24.025	7,5	5.690	10,0	1.966	10,0
		2035	34.080	6,0	8.072	6,0	2.790	6,0

Source: Prepared by the Authors.

YILPORT is located on the northern bank of the Kocaeli Gulf in the area of 206.000 m^2. It has a land terminal at a distance of 7 km established on an area of 90,000 m^2. It is mainly used to store empty containers but does not have dry port characteristics. Including this terminal, YILPORT has a total of 13.400 TEU stacking capacity. Although the railways just pass through the borderline of the port there is no junction to it. The transportation from and to the hinterland is only ensured by trucks which sometimes causes congestion on roads of the city.

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). The main reason to face such difficulty is derived from lack of space. Another problem is the inadequate network for transportation. 97.6% of the cargo carried between ports and cities is transported by road and 2.4% by rail (MIT, 2015). The intensive use of the highway in transportation brings in many risk factors.

Strengthening the highway connections of the ports and ensuring the railway connections are of the top priority of the port industry, especially in the Kocaeli region. This requirement has found its place among Turkey's 2023 and 2035 targets. Integrating the ports with logistics villages by means of railways and highways, fostering the intermodal transportation and increasing the share of railway transportation of goods from 5% to 20% are of the targets indicated in this vision (MIT, 2018). Increasing the share of eco-friendly rail and sea passenger-freight transport in order to reduce greenhouse gas emissions and establishing and strengthening dry ports for the development of logistics has been adopted within the national transport master plan (Milliyet, 2018). Dry ports are seen as a means of increasing logistics solutions to increase the transaction volumes of ports experiencing capacity problems and to reduce the congestion and the resulting energy consumption and harmful gas emissions, especially in port cities (Notteboom and Rodrigue, 2009).

Container terminals located in the Gulf of Kocaeli have no expansion opportunities to increase their capacity. The dry port application may be an effective measure against the capacity problems that may occur in the future for the container terminals. This practice is quite new to Turkey. Turkish Republic State Railways (TCDD), knowing the importance of the port and railway connection related to the dry port concept, is leading this subject. Koseköy Logistics Center (KLC) is one of the nine logistics centers put into service by TCDD and it is feasible to be a close dry port for the ports in the Gulf of Kocaeli. Although in service it is still undergoing the second phase of a project. It is aimed to reach a capacity of 1.5 million tons at the end of the project on a land of 360,000 m^2 (Saka and Çetin, 2017).

Taking into account the average and optimistic projections indicated in Table-2, it may be anticipated for YILPORT that a capacity constraint may arise around the 2020s. A Public-Private Partnership (PPP) model with KLC may be very beneficial to overcome such a problem and also to increase the transaction volumes and the income for both partners provided that a good transportation network is established.

2. FORMULATING AN OPTIMIZATION MODEL

In order to solve the capacity problems at sea terminal and maximize profit, an LP (Linear Programming) model has been developed. The description, assumptions, indices, parameters, decision variables and constraints of the problem are described below.

2.1. Problem Description

A seaport that might have difficulties to meet the future demands due to the capacity constraints collaborates with a dry port to welcome the surplus amount and not to lose the customers. It is assumed that the seaport has the overall authority to either stack the boxes (containers) in its terminal or to send them to dry port to provide room for the coming surplus amount. However, the issue of how many to stack in the terminal and how many to send to the dry port will be revealed by solving an LP problem.

2.2. Assumptions

- A 30 days period is considered at or after 2023.

- Only import boxes are being handled in the seaport.

- Transporting the boxes out of the seaport is carried out through trucks.

- Average Dwell Time (DT) in the seaport is 6 days. Each arriving box leaves the port after 6 days.

- The railway connection between the seaport and the dry port enables 12 train shuttles to be executed in a day. Each shuttle must contain 25 cars, and each 60 feet length railway car must carry 2 boxes, one 20 feet, and the other 40 feet. Train shuttles are operated by TCDD; railway transportation and dry port warehouse costs are based on TCDD's tariff.

- Each box, either 20 or 40 feet, weighs between 18 and 26 tons.

- The aggregate cost of a truck carrying any type of box is 0.8 €/km.

- Seaport earns 50 €/box as Terminal Handling Cost (THC), 12 €/day for each 20 feet box and 20 €/day for each 40 feet box as warehouse fees. Seaport also earns the same price through boxes transported to dry port, but the transportation cost belongs to the seaport.

- Dry port earns 3 €/day for warehousing any type of box.

- Seaport authority manages a team in dry port to load/unload boxes to/from cars/land by operating reach stackers. Each operation by a reach stacker will cost 4 €.

2.3. Sets

$$D= \{1\ldots|D|\} \text{ set of days - indexed by d.} \quad (1)$$

$$V= \{1\ldots|V|\} \text{ set of container size - indexed by v.} \quad (2)$$

2.4. Parameters

A: Number of containers **arriving** at 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 the seaport in terms of TEU,

F: Container stock at the beginning of **first** day in terms of TEU,

Box_v: Container (**box**) size of type v (Box_{v1}: 1 TEU, Box_{v2}: 2 TEU),

I_v: Income through a **container with size v stacked** at sea terminal,

I_r: Income through one **railway car** carrying 2 boxes (60 feet in total).

2.5. Decision Variables

Y_d: Total number TEUs being stocked at sea terminal's **yard**, $d \in D$

$S_{v,d}$: Number of **stacked** containers size in that day, $v \in V$, $d \in D$

J_d: Number of railway **journey** to dry port, $d \in D$

$R_{v,d}$: Number of **railway** cars including containers' size in that day, $v \in V$, $d \in D$

2.6. Objective Function

$$Z_{max} = \sum_v \sum_d (I_v * S_{v,d}) + \sum_d (I_r * 25 * J_d)$$

The objective function maximizes the total income of seaport. I_v includes THC and warehouse fees in seaport. I_r indicates the income through 2 boxes after subtracting the expenses of transportation on railway, warehouse fee and reach stacker operations.

2.7. Constraints

$$S_{v,d} + R_{v,d} = A \qquad \forall\, v,d \qquad (1)$$

$$Y_d \leq Cap \qquad \forall\, d \qquad (2)$$

$$Y_1 = F + \sum_v Box_d * (S_{v1} - T_{v1}) \qquad (3)$$

$$Y_d = Y_{d-1} + \sum_v Box_v * (S_{v,d} - T_{v,d}) \qquad \forall\, d \in \{2\ldots6\} \qquad (4)$$

$$Y_d = Y_{d-1} + \sum_v Box_v * (S_{v,d} - S_{v,d-6}) \qquad \forall\, d \in \{7\ldots D\} \qquad (5)$$

$$\sum_v Box_v * T_{v,d} = S_{v,d-6} \qquad \forall\, d \in \{1\ldots6\} \qquad (6)$$

$$J_d \leq 12 \qquad \forall\, d \qquad (7)$$

$$R_{v,d} = 25 * J_d \qquad \forall\, v,d \qquad (8)$$

$$Y_d, S_{v,d}, J_d, R_{v,d}, \in Z^+ \qquad (9)$$

Constraint (1) indicates that the amount of freight arriving at the port will be equal to the sum of the TEU-denominated amounts that are stacked in the terminal and sent to the dry port within that day. Constraint (2) ensures that the amount of boxes waiting in the terminal cannot be more than the capacity. Constraint sets (3), (4) and (5) explains that the difference between the amount stacked at the terminal's yard and the amount withdrawn through the trucks will be added to the previous day's amount to find the final waiting value at the yard. After the first six days, the amount withdrawn through the trucks will be equal to the amount stacked at the terminal's yard six days ago. Similarly, the amount withdrawn in the first six days will be equal to the amount stacked six days ago as indicated in constraint (6). Constraint sets (7) and (8) ensures that the number of freight journeys on the railway cannot be more than 12 times in a day; each shuttle must involve 25 cars and each car must be carrying 2 boxes. Constraint (9) shows that all decision variables will be natural and positive numbers.

3. A CASE STUDY: YILPORT AND KLC

YILPORT is a seaport whose transaction volume constantly increases and that might experience capacity problems in the years of 2020s whereas Kosekoy Logistics Center (KLC) is a close dry port candidate that can support Kocaeli ports with the completion of the project. A case has been designed assuming that KLC will have the ability to support seaports through a well-established rail and road network and that YILPORT will meet a demand as projected in Table-2. The optimization model will be used to solve the problem related to this case study. The additional assumptions and parameters for this case study are described below.

- Currently (at the beginning of day "d1") there are 12.000 TEUs (1) stacked in YILPORT. Each day over the next six days, one in six of those (2) will depart from the terminal by trucks to be delivered to the users through roads and highways.

- Beginning from "d1" until the end of "d30", YILPORT will meet one vessel with 3.000 TEUs (3) (1.000x20 feet and 1.000x40 feet) every day provided that it has adequate capacity. The stacking capacity is 13.800 TEUs (4). In each party; half of it will be distributed in Istanbul and Kocaeli; 10 % will be transported to Ankara, 400 km away from YILPORT by road, and 40% to other locations in eastern and southern directions from KLC.

- The income of YILPORT based on THC (Terminal Handling Cost) and warehouse fees for every 20 feet and 40 feet boxes will be 122 € and 170 € respectively (5).

- The cost of a train car carrying 2 boxes (60 feet in total) from YILPORT to KLC is 92 € related to the tariff of TCDD. This expense will belong to YILPORT authority. The income of YILPORT for a pair of boxes carried on a car will be 148 € (6) after subtracting the expenses resulting from rail transportation, warehouse fee in KLC and unloading/loading operations in KLC.

- On the other side, the carrier will have the chance to carry on through the railway towards Hasanbey Logistics Center (HLC) for the goods to be carried to Ankara. It will cost 126 €/car from KLC to HLC for the expense belonging to the carrier. This route will necessitate an extra 240 km road transportation from HLC to Ankara which will cost 190 €/box.

- The equations explained in this section are as follows:

$$F = 12.000 \tag{1}$$

$$S_{v,d-6} = 2.000;\ \forall\ D \in \{1\ldots6\} \tag{2}$$

$$A = 3.000 \tag{3}$$

$$Cap = 13.800 \tag{4}$$

$$I_{v1} = THC + (DT*12);\ I_{v2} = THC + (DT*20);\ (THC: 50\ €;\ DT: 6\ days) \tag{5}$$

$$I_r = (\ I_{v1} +\ I_{v2}) - [92 + 2*(DT*3) + 2*(2*4)] \tag{6}$$

4. NUMERICAL EXPERIMENT

The experimental studies are carried out via IBM ILOG CPLEX 12.6 on a computer of Intel(R) Core(TM) i5-4210U CPU 2.40 GHz processor - 4 GB RAM. IBM ILOG CPLEX 12.6 is a commercial optimization solver based on the Simplex Algorithm.

The decision variables for each day are seen in Table-3. "Y_d" gives the value of total waiting boxes in TEU at the end of the day. "S_d" explains the value in TEU of the boxes that should be stacked in that day. "J_d" indicates the total railway journeys on that day. In total **280 railway journeys** to dry port throughout the 30 days period is proposed on the solution.

Table-3: The Solution of the Problem by Simplex Algorithm.

D	Y_d	S_d	J_d	D	Y_d	S_d	J_d	D	Y_d	S_d	J_d	D	Y_d	S_d	J_d
1	12400	2400	8	9	13800	3000	0	17	13800	2100	12	25	13800	2100	12
2	12500	2100	12	10	13800	2100	12	18	13800	2100	12	26	13800	2100	12
3	13500	3000	0	11	13800	2100	12	19	13800	2100	12	27	13200	2400	8
4	13600	2100	12	12	13800	2100	12	20	13500	2100	12	28	13800	3000	0
5	13700	2100	12	13	13500	2100	12	21	13500	3000	0	29	13800	2100	12
6	13800	2100	12	14	13800	2400	8	22	13800	2400	8	30	13800	2100	12
7	13800	2400	8	15	13800	3000	0	23	13800	2100	12				
8	13800	2100	12	16	13800	2100	12	24	13800	2100	12		**Total:**	**69000**	**280**

Source: Prepared by the Authors.

According to the solution; 21.000 TEUs (280*25*3) should be sent to KLC and 69.000 TEUs should be stacked in the terminal to **maximize the income** of YILPORT. This solution will result in a total of **"7.752.000 €"** income.

TCDD will get an extra "644.000 € (280*25*92€)" income arising from transportation and KLC will get "252.000 € (280*25*2*18€)" extra income arising from warehousing.

Carriers will save "560.000 € (280*25*2*0,8 €*50 km)" in total since the road way of 14.000 containers will be diminished by about 50 km (distance between YILPORT and KLC).

If there were no possibility to make use of a dry port system, YILPORT would have to cancel the arrival of 10 vessels which means a loss for handling 30.000 TEUs. This time the total income of YILPORT would come down to **"5.840.000 €".**

The solution of the optimization model demonstrates that YILPORT may **boost its income 32.7% up** if the circumstances assumed in the scenario are encountered in the future.

The scenario also assumes that an average of 200 containers per day will be directed to Ankara. For this job, the carriers may use 100 railway cars to transfer the containers to HLC (Hasanbey Logistics Center) with a total cost of 12.600 € and then transport them to Ankara by truck with a total cost of 19.400 €. Excluding the expenses given to seaport, the carriers will spend 32.000 € per day for the goods to be transported to Ankara. If the carriers were to use roads and highways instead of railway, one container would cost 320 € (400 km*0,8 €/km). Carriers would have to spend 64.000 € for 200 containers. It means that carriers may have a chance to reduce the half of the expenses on roads from YILPORT to Ankara.

5. CONCLUSIONS

In this study, an optimization model has been designed to test the possible contributions of a dry port system. The case study was designed assuming that YILPORT and KLC will have a well-established railway connection in addition to the option of road transportation. Experimental results in relation to this model and the case study show that all actors in the scenario may have benefits through the application of dry port. To sum up these benefits;

- **YILPORT** will be able to handle more than its real capacity can embrace. It will head off the risk of losing customers and **handle 34.7% more** than it can which brings in **32.7% extra income** related to the case study.

- **TCDD** will gain an extra income that it was not used to earlier.

- **KLC** will also get an extra income in collaboration with a new partner.

- **Carriers of the close region** will be able to save since the road way of 14.000 containers from YILPORT to KLC will be accomplished by rail transportation, as the expense belonging to YILPORT authority. **Carriers to Ankara** will also be able to **reduce the transportation cost almost to half** since the majority of the route is taken on railways.

- **The environmental benefit** will also be acquired since the duration of trucks on the roads and consequently, the **CO_2 emissions will be reduced.**

The decision variables acquired in the solution might affect the decision-makers of seaports to take some steps such as sending more boxes to dry port at the expense of losing some warehouse fees to open more rooms for the next days' arriving boxes.

A seaport may increase its competitiveness through a dry port system provided that it has a perfect transportation network involving both the railway and highway infrastructure. Since the railway is a very important tool in this system the railway operators may have an active role to develop the system. Investment in the logistics sector is very demanding, but it may reach success more easily if a PPP is established. Turkish official Railway Company (TCDD), already having seven active dry ports, may lead the sector to constitute some PPP models to enhance the current and prospective dry ports in Turkey.

The development of ports and the establishment of dry ports to support the growth of the economy is an important component of the countries' maritime strategies. It is believed that the optimization model presented in this paper may be developed to test other scenarios related to similar circumstances in anywhere of the world which necessitates some logistics solutions.

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