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Evaluation of Containerized Trade and Competitiveness among Container Ports in Black Sea Basin

Metin Daniş[1*], Avni Zafer Acar[2]

[1] Zonguldak Bülent Ecevit University, Maritime and Port Management Department, Kdz.Ereğli, Zonguldak, Turkey, e-mail: metn.danis@gmail.com; metin.danis@beun.edu.tr

[2] İstanbul Bilgi University, Faculty of Applied Sciences, Beyoğlu, İstanbul, Turkey, e-mail: a.zaferacar@gmail.com; zafer.acar@bilgi.edu.tr

* Corresponding author

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ABSTRACT

With the increase in trading volume and competitiveness in global trade, ports have become indispensable and critical rivalry zones for countries. As competitiveness among the firm increase at a global level, ports become a rivalry zone cause of being the most critical economic structures and increasing competitiveness for transnational business and trade activities. The Black Sea Basin is one of the most important waterways in the world in terms of commercial, political and strategic aspects. The devastating consequences of conflicts and tensions, especially in recent years, prove the importance of the Black Sea Basin for world maritime trade. Therefore, the ports of the Black Sea Basin are of great importance. When the existing literature is reviewed, it is seen that there are many studies on the competitiveness and efficiency issues. Since the studies in the literature are mostly conceptual, it is obvious that they do not reveal analytical results, which constitutes a deficiency in the literature. In addition, the lack of a scientific study on the efficiency of container ports in the Black Sea Basin in recent years has made this study necessary.

The aim of this study is to examine the efficiency and competitiveness of container ports in the Black Sea Basin, which has a great importance both regionally and globally. The "Data Envelopment Analysis" (DEA) of the input-oriented CCR model, which is a linear program, was used to measure the productivity of the ports, and the relative efficiency of the ports was calculated.

1 Introduction

With the effect of globalization, significant increases in the amount of trade among the countries are observed. Additionally, with the increase in international commercial activities, there has been an increase in the demand for transportation systems, particularly there is a growing need for maritime transportation.

Maritime transportation, which is the most widely used mode of transportation and the most important activity of the international logistics system, has a very important role in international trade. Maritime transportation is very important for world trade since over 90 % of world trade is carried through seaborne and it is the most convenient way to move the raw materials and mass goods. (IMO, 2023) There have been some major technological and structural changes in the transportation of goods between countries. Perhaps the most important one among them is the worldwide recognition of container transportation and the growth of the container market. With the increasing use of containers, the need for larger container ships and, consequently, more capacity container terminals have increased. (Blonigen & Wilson, 2018)

Maritime transportation is of great significance in terms of the development and sustainability of world trade. When the developments in the world are followed, it is observed that container transportation brings the door-to-door transport concept and that it is used more frequently, every day than general cargo transportation (Stubbs et al., 2017). Especially with the increasing use of e-commerce, the importance of container transportation has been rapidly increasing as it enables the small-scale yet various cargoes to be consolidated and carried Having been investigated the trend in container transportation in the last years, an increase between 4% and 6% has been observed. In 2019 around the world, the amount of load that is handled with the container is over 163 million TEU. (Unctad, 2023)

Container transport and port industry are seen as key factors for the development of countries and the globalization of the world economy. Especially international line and container operators have great investment and infrastructure opportunities and thanks to these opportunities, International large companies built huge ships to transport cargoes, and as a natural consequence of this, they needed modern ports and equipment (Wang et al., 2003). When the trend of world container trade in recent years is examined, it is seen that especially Far East ports, the USA and European ports generate a large part of the container trade in the world. (Unctad, 2023). In addition to the main trade corridors in the world, the Black Sea, which is located between Europe and Asia, is an important place for world maritime trade.

Container transportation in the Black Sea Basin is a significant component of global trade routes, connecting Europe, Asia, and the Middle East. The Black Sea serves as a crucial maritime thoroughfare, facilitating the movement of goods between various regions. The Black Sea connects to the Mediterranean Sea via the Bosporus Strait and the Aegean Sea, providing access to European and North African markets. It also connects to the Sea of Azov via the Kerch Strait, offering access to ports in southern Russia and Ukraine. These connections make it a critical link in global trade routes between Europe, Asia, and the Middle East.

The Black Sea is a transport bridge between Europe and Asia, and the Black Sea Basin is a vital area for the TRACECA[1]and OBOR[2] projects. When TRACECA and OBOR projects are taken into consideration, it is expected that the amount of container transport in this region will increase in the recent future. For this reason, the countries in this region should have the capacity to serve not only the commercial goods belonging to their export and import activities but also the transit loads. In line with all these reasons, the ports in the Black Sea Basin are important players in world trade. Container ports in the Black Sea basin are pivotal for the economic activities of countries in the region. These ports are crucial centers for import and export operations, significantly contributing to the economic development of Black Sea countries (Tokuşlu, 2022). The strategic location of these ports enables efficient transportation of goods. Ongoing infrastructure projects like the Baku-Tbilisi-Kars railway and the construction of the Anaklia Deep Sea Port are further enhancing connectivity and trade opportunities (Gigauri & Damenia, 2019). There are many container ports in the Black Sea Basin with different equipment and port capacity, and as a natural consequence, competition between these ports is inevitable. There are different parameters concerned with competition between container ports. These parameters can basically be categorized as; operational parameters, financial parameters, supporting activities, customer satisfaction, port supply chain integration and sustainable growth performance. However, among these parameters, the most used parameters for container ports are operational efficiency parameters. (Kalgora, 2019)

In this research, the selection of ports to be selected included examining the voyages of container line operators operating in the Black Sea Basin. Consequently, the study focused on the container ports that are most often frequented. This research aims to assess the effectiveness of the busiest container ports in the Black Sea Basin, which is crucial for global trade. The analysis will be conducted using the input oriented CCR DEA method. This research is significant because there is a lack of scientific studies on port competitiveness in this region.

2 Port Competition and Efficiency

Port competitiveness is one of the most important issues that has been studied within the maritime field. Regarding the literature in the field, port competitiveness has been discussed through various approaches in many studies. When dividing the studies on port competitiveness into two categories, the first one includes the empirical studies that employ qualitative methods (Yap & Notteboom, 2011; Ju & Liu, 2015). The second category includes the studies that investigate the port performance and employ methods such as time series analysis, analytical hierarchy process and dea (Munisamy & Jun, 2013; Bichou, 2011; Wu & Goh, 2010; Tetteh et al., 2016).

In competitive market conditions, customers will benefit from selecting among more than one supplier or product since the suppliers will have the opportunity to improve quality and reduce prices. Similarly, as suppliers are making the market more active, it is inevitable for them to benefit from competition, which requires more innovative management, strategic thinking and marketing techniques. For years, competition strategies applied in different ways in industrial activities are inevitable within ports. The port line has radically

[1] "TRACECA (The Europe-Caucasus-Asia Transport Corridor); The Europe-Caucasus-Asia Transport Corridor (TRACECA) is an EU program, began in 1993, to advance a carrying trade corridor from Europe to China, via the Black Sea, the Caucasus and the Caspian Sea".

[2] "OBOR (One Belt One Road), also known as the Belt and Road Initiative (BRI) Its aim is to set up trade ways between China and the countries in Central Asia, Europe, and Indo-Pacific littoral countries".

Table 1 Literature Review on Port Efficiency of Ports

Authors	Year	Title of Study	Methodology	Input/ Research Area	Output/Main Contributions
Roll & Hayuth	1993	Port performance comparison applying data envelopment analysis	Data envelopment analysis (DEA)	➢ Shipping Features ➢ Labor ➢ Investment capital	➢ Number of visiting ships ➢ Shipowner satisfaction ➢ Quality of service provided
Tongzon	1995	Determinants of port performance and efficiency	Data envelopment analysis (DEA)	➢ Length of berth ➢ Number of cranes at the berth	➢ Number of containers handled
Heaver	1995	The implications of increased competition among ports for port policy and management	Conceptual	➢ Economy of ports ➢ Port capacity	➢ Competitiveness of Ports /Monopoly power
Notteboom	1997	Concentration and load centre development in the European container port system	Herfindahl Hirschman Index (HHI), Gini Coefficient	➢ Analysis of container terminal systems in Europe between 1980-1994	➢ The effect of the container on port competition could not be verified.
Martinez-Budria et al	1999	A Study of the efficiency of Spanish port authorities using data envelopment analysis	Data envelopment analysis (DEA)	➢ 26 ports using 5 observations for each port ➢ Amortization fee ➢ Other costs ➢ Labor expenditure	➢ Total freight transfer between berths ➢ Rental revenues of port facilities
Tongzon	2001	Efficiency Measurement of Selected Australian and Other İnternational Ports Using Data Envelopment Analysis	DEA-CCR	➢ Number of berths ➢ Number of cranes ➢ Number of Tugboats ➢ Number of Employees ➢ Standby time	➢ Container Handled Amount (TEU) ➢ Ship Operation Speed
Wang et al.	2003	Container Port Production Efficiency: A Comparative Study of DEA and FDH Approaches	Data envelopment analysis (DEA)	➢ Dock Length ➢ Terminal Area ➢ Number of dock cranes ➢ Number of field Cranes ➢ Number of SC	➢ Container Handled Amount (TEU)
Estache et al.	2004	Efficiency Gains in Port Reform: A DEA Decomposition of a Malmquist TFP İndex for Mexico	Data envelopment analysis (DEA)	➢ Dock Length ➢ Number of Employees	➢ Container Handled Amount (TEU)
Bonilla et al.	2004	An efficiency analysis with the tolerance of the Spanish port system	Data envelopment analysis (DEA)	➢ Measurement of activities of Spanish ports	➢ Correlation among existing port equipment and cargo traffic
Cullinane & Wang	2006	Efficiency gains from port reform and the potential for yardstick competition: lessons from Mexico	Data envelopment analysis (DEA)	➢ Dock Length ➢ Terminal Area ➢ Number of Dock Cranes ➢ Number of Field Cranes ➢ Number of Straddle Carrier	➢ Container Throughput

Authors	Year	Title of Study	Methodology	Input/ Research Area	Output/Main Contributions
Panayides et al.	2008	Measuring Seaport Economic Efficiency: A Comperative DEA Study	Data Envelopment Analysis (DEA)	➢ Terminal Length ➢ Terminal Area ➢ Crane Capacity	➢ Container Throughput
Tongzon vd.	2008	Efficiency Measurement of Selected Korean and Other International Ports Using Stepwise Data Envelopment Analysis (DEA)	Data Envelopment Analysis (DEA)	➢ Number of Port Employees ➢ Container Cranes ➢ Number of Berths ➢ Berthing Place Length ➢ Terminal Area ➢ Berthing Place Depth	➢ Number of Ships ➢ Container Handled Amount (TEU)
Wu & Goh	2010	Container Port Efficiency in Emerging and More Advanced Markets	Data Envelopment Analysis	➢ Terminal Area - Length of Berth ➢ Number of Equipment	➢ Container Handled Amount (TEU)
Hung et al.	2010	Benchmarking The Operating Efficiency of Asia Container Ports	Data Envelopment Analysis	➢ Terminal Area ➢ SSC Crane Number ➢ Container Berthing Place ➢ Terminal Length	➢ Container Throughput
Yuen et al.	2013	Foreign Participation and Competition: A Way to İmprove The Container Port Efficiency in China	Data Envelopment Analysis	➢ Berthing Place Length ➢ Total Length ➢ Harbor Land Area ➢ Number of Rim Crane ➢ Field Gantry Cranes	➢ Container Throughput
Schoyen & Odeck	2013	The Technical Efficiency of Norwegian Container Ports: A Comparison to Some Nordic and UK Container Ports Using Data Envelopment Analysis (DEA)	Data Envelopment Analysis	➢ Berthing Place Length ➢ Terminal Area - ➢ Number of Field Cranes ➢ Number of SC ➢ Number of Tugboats	➢ Container Handled Amount (TEU)
Ateş & Esmer	2014	Calculatıon of contaıner port effıcıency ın Turkey wıth different methods	Free Disposable Hull (FDH), Data Envelopment Analysis (DEA)	➢ Dock Length ➢ Draft ➢ Total number of cranes ➢ Storage space ➢ Stowage equipment	➢ It is observed that capacity utilization rates of Turkish container ports are low.
Tetteh et al.	2016	Container ports throughput analysis: a comparative evaluation of China and five west African Countries' seaports efficiencies	Data Envelopment Analysis (DEA)	➢ Number of Berths, ➢ Number of Cranes, ➢ Length of Quay (meters), ➢ Vessel Calls	➢ Port Throughput ➢ Theoretical Capacity
Kalgora	2019	Strategic Container Ports Competitiveness Analysis in West Africa Using Data Envelopment Analysis (DEA) Model	Data Envelopment Analysis (DEA)	➢ Quay Length ➢ Terminal Area ➢ Quayside Cranes ➢ Yard Gantry Cranes ➢ Reach Stackers	➢ Container Throughput Limit ➢ Container Throughput

Source: Authors

changed over the past two centuries. During the 19th century and first part of the 20th-century ports became major instruments of governments and colonial powers. Port entries and exits were considered as a means of controlling markets. Rivalry among ports was lowest and costs of concerning about terminal activities were relatively unimportant in comparing to the high cost of maritime transport and interior transport. (Stophord, 2009) Consequently, there was little motivation to develop port efficiency. Due to this reason, world economy and international trade system have changed and improved accordingly. Today, most of the ports have considerably increased their productivity in deep-ocean transport and have been globally competing with each other over the last decades (Notteboom, 2012).

To analyze the elements that have an impact on port competition the problems will be evaluated from several angles. Competition in container ports are not only dependent on economic conditions. There are many factors affecting competition in this maritime basin. Among these factors, economic, political and geographical conditions directly affect the competition of the ports. As Jacobs (2007, p. 10) states, "economic activity cannot be solely understood by the rational behavior of agents operating on free markets. Instead, markets and individual behavior are structured by all kinds of social, economic and political rules, procedures and conventions".

Port efficiency is a critical factor in determining the competitiveness of ports. It is a quantitative indicator that reflects the effective allocation of port resources (Wang and Chen, 2023). Studies have shown that port efficiency plays a significant role in trade flows, with evidence suggesting that more efficient ports lead to increased trade activities. (Blonigen & Wilson, 2018)

Efficiency is not only essential for competitiveness but also for sustainability. Ports worldwide are increasingly focusing on improving efficiency to reduce emissions and operate in an environmentally friendly manner (Huang et al., 2019). Moreover, the impact of efficiency on transport costs has been studied, highlighting the importance of efficient port operations in reducing overall logistics expenses (Dappe et al., 2021). Efficiency in ports is often measured through indicators like port productivity, which reflects the relative competitiveness of ports (Moon & Woo, 2014). Data envelopment analysis (DEA) is a commonly used method to assess port efficiency, allowing for comparisons among ports and identifying areas for improvement (Kalgora, 2019; Dyck, 2015). The intense competition among ports, especially in regions like West Africa, has led to a growing interest in efficiency analysis by both port operators and users (Dyck, 2015). Efficiency assessments using methods like DEA have been applied globally, from Chinese ports to Norwegian and UK container ports, providing insights into the relative efficiency of different port systems (Ablanedo-Rosas et al., 2010; Schøyen & Odeck, 2017). The size of ports has also been found to impact efficiency, with smaller ports often demonstrating higher efficiency levels compared to larger ports (Rajasekar & Deo, 2012). In conclusion, port efficiency is a multifaceted aspect that influences port competitiveness, trade flows, environmental sustainability, and overall operational costs.

Present literature and studies on port performance evaluation have primarily concentrated on the efficiency and profitability of core port services. Several scopes have been used in this research to analyze efficiency analogies, engineering, and economic optimization. Previous studies focused on the level of competitiveness and efficiency at ports. Furthermore, the literature has numerous research on port competition and productivity. Table 1 presents a comprehensive examination of the existing body of research on the effectiveness and competitiveness of ports.

3 Port Competitiveness from Porter's Theoretical Perspective

''Competitive strategy provides managers with the raw material to think about how to change the rules of the marketplace in their favor'' (Porter, 1980, p. 31).

Choosing from more than one supplier or product will benefit customers as suppliers will have the opportunity to improve quality and reduce prices. Similarly, as suppliers have been making the market more active, it is certain that they will take advantage of competition in which innovative management, marketing techniques and strategic thinking are necessary. Furthermore, dealers can benchmark products, staff, and customers. Therefore, every company rivalry in a production industry has a competitive strategy, which might have been advanced by an accurately detailed strategic process or by being sensitive to others when competing.

Porter's Five Forces Model, which is one of the most important models made to understand the competitive strategies for businesses, is an analysis model that helps to describe why various companies can maintain different levels of profitability. With this model, Porter aims to analyze the structure and corporate strategy of a company (Grundy, 2006).

As Porter points out, knowing and being aware of these five forces will help the company understand the industry it is in, as well as showing how it can be more profitable and resilient to attacks. Porter defined five incontestable forces that play a role in shaping all markets and businesses in the world. Porter's five forces model is used to estimate the competitiveness of a business and the market, the competitive state of the market, and the profitability of businesses. (Porter, 1996). Global competition and changes in market conditions have affected port competition as in all industries. The port line has dramatically changed over the past two centuries. During the 19th century and first part of the 20th-century ports, became the major instruments of governments and colonial powers. Port entries and exits were considered as a means of controlling markets. Rivalry among ports was the lowest and port-related costs were relatively unimportant compared to the high cost of sea-ocean transport and interior transport. Since ports are involved in the business industry, Porter's model can be used to assess the competitive position of the ports. In this context, Porter's five forces model has been adapted to the ports and given below.

Competition in the industry: When companies in a particular market compete, as a natural consequence of this, business profits begin to decline. For this reason, companies that have been active in the sector for a long time must create certain conditions in order to prevent new entries. These conditions are as follows; number of competitors, diversity of competitors, switching cost, brand loyalty, are industry growth (Porter, 1996). As in all other industries, the businesses in the port industry become aggressive towards a rival that will be new in the market. The ports in the market will have position based on the size of the port making new investments to the region, amount of the investment as well as the target customer profile. Port competitiveness is affected by the consumers in other words the special requests from the port users, specific production factors, supporting industries that directly or indirectly affect the port operations, and the capacities and effectiveness of the port operators and other ports that have the same target market within the same region (Tongzon & Heng, 2005).

The Threat of New Entrants: This power defines how simple (or not) it is to insert a specific industry. If a sector is profitable and there are few borders and barriers to enter, as a natural consequence, competition intensifies soon. When more companies are in competition or the same market share, profits begin to decrease (Porter, 1996). With the positive impact of globalization and liberalization facts on international trade, demand for freight shipment has increased. As a natural consequence of this, there have been an increase in the number of ships and ports. According to the European Sea Ports Organization, 90% of goods trade takes place in about 1200 small and large ports of the 23 countries that have a coast on the European Union (ESPO, 2019). These ports have different strategies and facilities according to the hinterland marketing and geographical locations. Therefore, there will be difficulties for the ports that will enter the market within such an intensely competitive marketplace. As a result of increasing port investments in recent years near the Black Sea Region, many port builts have been made in the sector. Asyaport, which was built by MSC in Tekirdağ Region, and DP World and Yılport ports, one of the major port investments in the İzmit Bay, became one of the most important competitors of the competition in the region (TCS, 2022).

Bargaining Force of Suppliers: In this case, suppliers can sell high priced and low-quality goods to buyers. This directly affects the buyer since the buyer will have to pay more money for better quality raw material, as a consequence, the cost of the product will naturally increase. Suppliers have a powerful bargaining force when they are the number and size of suppliers or supplier's, inevitableness of supplier's product, cost of changing, your ability to substitute (Porter, 2008).

Ports have a complex structure. Therefore, it is quite difficult for all business processes in ports to be carried out by the port. Ports receive services from stevedoring companies for the handling of ships. Stevedoring companies are one of the most important suppliers of ports. Moreover, since the bunker companies and logistics companies are one of the biggest suppliers of ports, the service cost that is provided by the suppliers is highly important for the ports. (Stopford, 2009)

Bargaining Force of Buyers: When buyers have this force, they have the force to demand high-quality products from raw material manufacturers at lower prices. In this case, while the manufacturers make less profit, the buyers not only increase the quality of the product but also get a better service and product for more a convenient price. Buyers apply strong bargaining power in the following situations: seller's (supplier) switching costs, differentiation of products, how efficiently the recipient can use the information, in sectors with higher fixed costs, leverage of bargain, network effects (Porter, 2008). Since the main aim of the establishment of ports is to serve ships, the most important buyers are the ships and their owners. Therefore, it is a matter of fact that there is a rivalry between the ports that are in a close relationship with ship owners at the pricing and bargaining stages.

The Substitute Products or Services Threat: With this force, buyers can find replacement products at more affordable prices, and if the main product substitution is available, it is a threat for businesses to switch to low-cost replacement products (Porter, 2008). Even though maritime transport, which is the most widely used mode of transportation in the world trade, has many advantages, any adverse developments in terms of increasing costs, speed and timely delivery may negatively affect the sector. As a result, customers may prefer other transportation modes of substitution. They can also prefer Iron Silk Road and Airway Transportation over time. Therefore, there is a need to follow the recent developments and changes in other modes of transportation as well as innovative studies in the maritime industry. According to Porter (2008), the activities of a business can be classified into two dimensions to create a competitive advantage: core activities and supporting activities. However, it is very difficult to apply Porter's value chain to the port sector, because, unlike the general production, the port sector is a multidimensional case as it is made by different organizations and enterprises.

Table 2 Operational Port Performance Param*eters*

Operational Parameters	**Throughput**	Output growing (TEUs/year)
		Vessel call size (TEU/number of vessels)
	Productivity	Dock usage (throughput/dock length)
		Dock exposure time (ship time at berth/terminal operation time)
		Dock occupancy (ship time at berth/terminal operation time)
		Crane productivity (lift/hr)
		Container stowage yard utilization (output/area of container area)
		Berth productivity
		Personal productivity (TEU/workers)
	Delivery Period	Ship return (average ship stay time at the terminal (hour)
		Container staying time (container staying time at port (day)

Source: Authors

4 Parameters of Port Performance

There are various parameters to evaluate ports in terms of rivalry and efficiency perspectives. These parameters can be classified under six categories: operational parameters, financial parameters, supporting activities, customer satisfaction, port supply chain integration, and sustainable growth performance.

The port sector is a large initial investment, an intense capital, and a cost-oriented industry. The first capital expenditure used for superstructure equipment and the latest system of technology products is a requirement for ports. This capital is generally derived from financial institutions, banks, and investors. Therefore, the financial situation is one of the most important issues for the port investor, thus this indicator has been often used in port performance evaluation research studies. (PWC, 2010). There are different indicators for measuring the financial efficiency of ports. United Nations introduced that financial efficiency, income and cost expenditures, labor costs, equipment costs, and capital costs were categorized and studied at Unctad 1992.

Brooks (2006) examined 42 ports in different parts of the world. He examined the most common income and cost parameters used by port operators. PWC (2010) introduced the performance criteria of the international maritime and port industry. Supporting activities in port efficiency is crucial to develop the organization of the company (Porter, 2008b). For this reason, inner sources continued successfully to reach joint organizational objectives. The success of supporting activities such as human capital, organization capital, and information capital is important, as they are for-profit enterprises in their ports. In addition to these, customer satisfaction, port supply chain integration, and sustainable growth performance parameters have also been used in studies on port efficiency in the literature. The efficiency of a container port is part of a process that includes maritime, terminal, and hinterland operations. These dimensions are related since inefficiencies in one dimension are probably to affect the others. Therefore, it is important that port operations are carried out flawlessly. Operational activities, which are the most important parameters of port competitiveness, mainly consist of three sub-indicators. The Table 2 shows the Operational Port Performance Parameters.

5 Methodology

The method used in the study is DEA which is used to measure the effectiveness of decision-making units according to the specified inputs and outputs (Charnes et al., 1978). This method was first used Farrell (1957a) and Charnes et al. (1978) and developed by analysis has become a method used in many studies. The purpose of the method is to determine how resources are used by the decision-making unit to produce specific outputs (Ramanathan, 2003). To be used within the research, the inputs consisted of length (m), depth (m), crane capacity (tons), storage area (m^2), and total area (m^2) whereas the outputs involved total load amount that was handled by means of TEU in the seaports which were referred in the research by the year of 2021.

Through the calculations, it was analyzed whether the same output could have been obtained by using less resources. In this regard, with an aim to find out if the present seaports used much more resources than needed to obtain the existing output, input oriented CCR model of DEA was used in this study. The analysis was calculated using the “DEAOS” analysis program.

In the previous studies that had used this method, the researchers focused on two questions. The first one was the effect of the ownership structure of the ports on the port efficiency and the other one was the analysis of the port efficiency after the port privatizations (Stewart, 1996). In this context, the findings of Liu (1995) for the UK ports show that there is no connection between ownership structure and port efficiency forecast. Tongzon (2001) found that in the study on Australian container terminals, the ownership structure is not a determinant of port efficiency. Similarly, (Notteboom et al., 2000) found no evidence of the impact of private sector participation in the effectiveness of ports in Europe and Asia. Valentine & Gray (2001), which analyzed the world's largest hundred container ports according to 1998 data, used DEA for their analysis. The study shows that ownership structure has no significant impact on productivity and organizational structure is much more effective.In a similar study examining 19 port samples in North America and Europe (Valentine and Gray, 2002), it was revealed that ownership structure has no significant effect on port efficiency. Barros (2003) applies DEA for the Portuguese port industry and examines the efficiency of Portugal ports. Barros and Athanassiou (2015) used DEA to the evaluation of the relative efficiency of Portuguese and Greek seaports. The authors examined the economic benefits of benchmarking in the ports of Greece and Portugal DEA method is used to measure the relative performances of the businesses in which they operate and to determine the performance between different units of the same enterprise, to give ideas to managers, to identify errors and deficiencies and to take necessary measures (Simar, 1996). Since the early 2000s, DEA has been applied in many studies to the assessment of port efficiency. One of the most important reasons for using DEA adequacy levels of the ports to use their existing capacities and the efficiency levels of the ports after private sector participation (Demirel et al., 2012). DEA has been used to analyze port production. Cross-checked with conventional approaches, DEA has the superiority that consideration can be used to multiple outputs and inputs. This is in accordance with the characteristics of port production, so it can provide an overall assessment of port performance. Therefore, the most suitable method for analyzing the competitiveness and efficiency of container ports in the Black Sea Basin is considered to be DEA. (Demirel et al., 2012)

5.1 Data Envelopment Analysis

DEA is a relatively new "data-focused" approach for assessing the efficiency and productivity of a set of peer entities named Decision Making Units (DMUs) which transform multiple inputs into multiple outputs (Cooper et al., 2011). In an article that symbolizes the origin of DEA, Farrell (1957b) was encouraged by the necessity for advancing better methods and models to measure productivity. DEA is a nonparametric technique in management analysis and economics for the forecast of production frontiers. (Sickles & Zelenyuk, 2019). It is used to empirically evaluate the reproductive efficiency of decision-making units. DEA, firstly offered by (Charnes et al., 1978), is applied to evaluate the relative performance of a number of entities using a common set of appropriate inputs to compose a common set of appropriate outputs. The analysis provides for multiple inputs to, and multiple outputs from, the DMU. It is achieved by creating a sole "virtual" output that is designed into a sole "virtual" input, without reference to a default manufacture function (Martić et al., 2009). The efficiency evaluation statement is formulated as a task of rational programming, but the DEA practice process consists of unfastening the linear programming (LP) works of each of the unit assessments (Cooper et al., 2005). As a non-parametric method DEA, has been commonly used in measuring the effectiveness of organizations such as schools, insurance companies, universities, and hospitals. In recent years, it is also widely used in determining the effectiveness of container terminals.

5.2 Selection of Parameters

While choosing the parameters to be used in the study, analyzed studies examining the efficiency and performance of the ports. The following Table 3 shows the inputs, outputs used in these studies.

Table 3 Selection Parameters of DEA to Measure Port Efficiency

Authors	Year	Study	Methodology	Inputs	Outputs
Tongzon	1995	Determinants of port performance and efficiency	Data envelopment analysis	➢ Length of berth ➢ Number of cranes at the berth	➢ Number of containers handled
Tongzon	2001	Efficiency measurement of selected Australian ports using data envelopment analysis	Data envelopment analysis	➢ Number of winches ➢ Number of docks ➢ Terminal area ➢ Number of tugboats	➢ Number of containers handled
Cullinane & Wang	2006	The efficiency of European container ports: A cross-sectional data envelopment analysis	Data envelopment analysis (DEA)	➢ Crane capacity ➢ Total dock length ➢ Number of stackers ➢ Terminal area	➢ Container Throughput
Wu &Goh	2010	Container Port Efficiency in Emerging and More Advanced Markets	Data Envelopment Analysis	➢ Terminal Area ➢ Length of Berth ➢ Number of Equipment	➢ Container Handled Amount (TEU)
Hung et al	2010	Benchmarking The Operating Efficiency of Asia Container Ports	Data Envelopment Analysis	➢ Terminal Area ➢ SSC Crane Number ➢ Container Berthing Place ➢ Terminal Length	➢ Container Throughput
Yuen et al.	2013	Foreign Participation and Competition: A Way to İmprove The Container Port Efficiency in China	Data Envelopment Analysis	➢ Berthing Place Length ➢ Total Length ➢ Harbor Land Area ➢ Number of Rim Crane ➢ Field Gantry Cranes	➢ Container Throughput
Schoyen &Odeck	2013	The Technical Efficiency of Norwegian Container Ports: A Comparison to Some Nordic and UK Container Ports Using Data Envelopment Analysis	Data Envelopment Analysis	➢ Berthing Place Length ➢ Terminal Area ➢ Number of Field Cranes ➢ Number of SC	➢ Container Handled Amount (TEU)
Tetteh et al.	2016	Container ports throughput analysis: a comparative evaluation of China and five west African Countries' seaports efficiencies	Data Envelopment Analysis (DEA)	➢ Number of Berths, ➢ Number of Cranes, ➢ Length of Quay (meters) ➢ Vessel Calls	➢ Port Throughput ➢ Theoretical Capacity

Source: Created by the author

5.3 Selection of Ports

The world's largest container line companies are operated in the Black Sea Basin. Container companies with regular container voyages from Black Sea Basin to different zones of the world, contribute to the increase of regional trade. Major shipping lines operate container services in the Black Sea, connecting the region to global trade networks. These lines offer regular container shipping services to and from ports in the Black Sea Basin, facilitating the movement of goods and fostering international trade. The following Table 4 illustrates the routes (service rotation), average voyage times and ship capacities of the major container lines in the Black Sea Basin.

When the liner container voyages in the Black Sea Basin are examined, in terms of shipping within this basin the busiest ports of the countries that have a coast on Black Sea (Turkey, Russia, Bulgaria, Ukraine, Georgia, Romania) are included in the current study.

Table 4 Routes, Voyage Duration and Ship Capacities of the Major Container Lines in The Black Sea Basin.

Line Operator	Service Name/ Type of service	Service Rotation (Routes)	Voyage Duration (Days)	Number / Capacity of Ships (nominal)
MAERSK[3]	ME 3/Direct	Pipavar – Hazira – Nehru – Jebel Ali – Port Said – Damietta – Ambarlı – Chornomorsk – Constanta	30 days	5 vessels / 34.084 TEU
	Z 39/Feeder	Marport – Kumport – Burgas – Varna	5 days	1 vessel / 1.155 TEU
	ECUMED/Direct	Novorrosiyk – Yuzhny – Ambarlı – Algerias – Manzanillo – Buenaventura – Guayequil	38 days	5 vessels / 15.384 TEU
	Z 20 Emes/Feeder	Ambarlı – Gemlik – Poti – Constanta	10 days	2 vessels / 2.421 TEU
	Z-05/Feeder	Marport – Bosporus – Burgas – Varna	3 days	1 vessel / 1.600 TEU
MSC[4]	Black Sea/Feeder	Gioia Tauro – Piraeus – Batumi – Odessa – Constanta – Burgas	6 days	3 vessels / 5.960 TEU
ZIM[5]	WBS/Feeder	Piraeus – Ambarlı – Varna – Constanta	6 days	4 vessels / 5.600 TEU
	ZMP/Direct	Pusan – Qingdao – Ningho – Shangai – Da Chan Bay – Suez – Ashdod – Haifa – İstanbul – Novorrosiyk – Odessa	40 days	11 vessels / 51.750 TEU
	BME/Feeder	Piraeus – Ambarlı – Constanta	7 days	2 vessels / 3.470 TEU
	BSX/Feeder	Piraeus – Novorrosiyk – Poti	8 days	2 vessels / 3300 TEU
	TBX/Feeder	Haifa – Ashdod – Yarımca – Novorrosiyk – Odessa – Ambarlı – Gemlik – Piraeus	12 days	3 vessels / 8300 TEU
	ZBX/Feeder	Alexandria – Ashdod – Novorrosiyk	8 days	2 vessels / 3400 TEU
ARKAS LINE[6]	BMX/Feeder	Odessa – Constanza – Marport – Piraeus	8 days	2 vessels / 3400 TEU
	BSX/Feeder	Poti – Novorrosiyk – Piraeus	8 days	2 vessels / 3300 TEU
	IBX/Feeder	Constanza – Odessa – Ambarlı	4 days	1 vessel / 1800 TEU
	TBS/Feeder	Burgas – Varna – Marport	4 days	1 vessel / 1600 TEU
	TPS/Feeder	Poti – Samsun – Ambarlı – Novorossiysk	6 days	2 vessels / 3200 TEU
	WBS/Feeder	Tangier – Piraeus – Gemlik – Marport – Constanza – Varna – Ambarlı	14 days	4 vessels / 5700 TEU
	REX/Feeder	Ashdod – El Dekhelia – Novorrosiyk	6 days	3 vessels / 7800 TEU
CMA CGM[7]	SSLMED/Feeder	Piraeus – Poti – Varna	5 days	2 vessels / 2000 TEU
	3PF SSLMED3 /Feeder	Piraeus – Ambarlı – Poti – Novorrosiyk	4 days	2 vessels / 3300 TEU
	3PF SSLMED4/Feeder	Piraeus – Ambarlı – Constanta – Odessa	6 days	2 vessels / 3400 TEU
	IST. BL.SEA EXPRESS/ Feeder	Ambarlı – Novorossiysk	2 days	2 vessels / 1700 TEU
	WEST BS EXPRESS/Feeder	Piraeus – Haydarpasa – Novorossiysk – Constanta – Varna	12 days	2 vessels / 3200 TEU
	WEST BS EXPRESS2/Feeder	Malta – Haydarpasa – Odessa – Constanta	7 days	2 vessels / 1450 TEU
	PPN SERVICE/Feder	Piraeus – İstanbul – Poti – Novorossiysk	12 days	2 vessels / 3100 TEU

Source: Own elaboration by author

[3] Maersk Schedules / https://www.maersk.com/schedules

[4] MSC Schedules / https://www.msc.com

[5] ZIM Schedules / https://www.zim.com/schedules/point-to-point

[6] Arkas Line Schedules / http://www.arkasline.com.tr/hatlar_ve_programlar.html

[7] CMA CGM Schedules / https://www.cma-cgm.com/ebusiness/schedules

Table 5 Inputs and Outputs of Selected Ports

	OUTPUT	INPUTS				
	THROUGHPUT (2021) (TEU)	Length (m)	Depth (m)	Crane carrying Capacity (tons)	Storage Area (m^2)	Total Area (m^2)
Odessa	521.519	330	12	495	34.000	395.000
Constanta	439.046	1490	14,5	406	65.000	730.000
Varna	104.300	838	11	100,5	62.630	443.000
Poti	237.715	460	9,5	360	16.250	150.000
Novorrossiyk (Nutep)	426.918	574	13	284	62.200	1.309.000
Samsun	100.881	776	10	35	50.000	445.000

Source: Informall, 2022

5.4 Application in the Research Area

The ports examined in this study are the most important ports of the Black Sea Basin. In order to measure the efficiency of the ports and their efficiency relative to each other, port data were collected and formulated to be used in the research. For the 6 container ports that are the subject of the research, 1 output and 5 input data were selected. The model presented below is applied for Odesa Port. It is also applied for all the other ports included in the present study and the efficiency scores of each port are revealed accordingly.

Optimization Model of Odesa Port

Objective Function

max $z = 521519\, y_1$

Decision Variables

x_1,; *an implicit price per unit of each input*

x_2,; *an implicit price per unit of each input*

x_3,; *an implicit price per unit of each input*

x_4,; *an implicit price per unit of each input*

x_5,; *an implicit price per unit of each input*

y_1; *an implicit price per unit of the output*

Constraints

❖ → $\frac{\text{value of output}}{\text{value of input}} \leq 1$

Converting this to standard linear form,

❖ → value of the port's outputs ≤ value of the port's inputs

✓ → $521519y_1 \leq 330x_1 + 12x_2 + 495x_3 + 34000x_4 + 395000x_5$

✓ → $439046y_1 \leq 1490x_1 + 14.5x_2 + 406x_3 + 65000x_4 + 730000x_5$

✓ → $104300y_1 \leq 838x_1 + 11x_2 + 100.5x_3 + 62630x_4 + 443000x_5$

✓ → $237715y_1 \leq 460x_1 + 9.5x_2 + 360x_3 + 16250x_4 + 150000x_5$

✓ → $426918y_1 \leq 574x_1 + 13x_2 + 284x_3 + 62200x_4 + 1309000x_5$

✓ → $100881y_1 \leq 776x_1 + 10x_2 + 35x_3 + 50000x_4 + 445000x_5$

$330x_1 + 12x_2 + 495x_3 + 34000x_4 + 395000x_5 = 1$

$x_1, x_2, x_3, x_4, x_5, y_1 \geq 0$ (Non-Negativity)

The input-oriented DEA results and efficiency score of each port in accordance with the optimization model with the help of "DEAOS (Data Envelopment Analysis On Line)" are calculated and illustrated in the Table 5.

When expert opinions and literature are examined, the operational inputs that have the most impact on the efficiency of ports have been determined accordingly. Due to the spirit of data envelopment analysis, it is used for the evaluation of more regional and similar features ports in inter-port performance and efficiency evaluation.

In this study, the container seaports that are significantly large in the Black Sea Basin were investigated as local research. The efficiency of the seaports that were included within the study, Varna, Novorossiysk, Samsun, Constanta, Poti and Odessa, was analyzed through DEA. As can be seen in Table 5, the inputs used in the efficiency analysis were length (m), depth (m), crane capacity (tons), storage area (m^2) and total area (m^2). The total amount of cargo handled in this study was taken into account as the output of the analysis.

Table 6 CCR Efficiency Values of Ports for Input and Output

Ports	Input-oriented CCR efficiency score
Odessa	100
Constanta	91,3153
Varna	64,5573
Poti	100
Novorrossiyk	100
Samsun	100

Source: Created by authors

Today, as in every period, the concept of effectiveness and efficiency must go beyond discourse and be oriented towards practice. Data envelopment analysis is the most effective method for situations with various inputs and outputs with varying measurement units, as it is based on the principle that improvement is only possible when something can be quantified.

As seen in Table 6, Odessa, Poti, Novorossiysk, and Samsun ports with efficiency score 100 are efficient ports. Constanta and Varna ports with efficiency scores <100 are not effective.

6 Conclusion and Suggestions

As a result of the analysis, the efficiency of the ports which are the subject of research has been determined. Previous studies in the literature have been examined and analyzed. (Cullinane & Wang, 2006; Hung et al., 2010; Yuen et al., 2013). According to this, the inputs and outputs used in the studies were evaluated and the data that would yield the most optimum results were included in the analysis. When the DEA studies conducted in the literature are examined, generally it is discovered that the ports of a country are evaluated, and efficiency analysis is performed between these ports. For example, In 1999, a study was conducted to evaluate the efficiency of Spanish ports. (Martinez-Budria et al., 1999) In 2001, Tongzon assessed the efficiency and performance of Australian ports (Tongzon, 2001). In 2007, Carvalho made a performance assessment of the Portuguese ports (Carvalho, 2007). In the analysis conducted by Cullinane and Wang for European ports in 2006, crane capacity, total berths length, terminal area constitute the input of the research, and container throughput forms the output of the research (Cullinane & Wang, 2006). When expert opinions and literature are examined, the operational inputs that have the most impact on the efficiency of ports have been determined accordingly. Due to the spirit of data envelopment analysis, it is used for the evaluation of more regional and similar features ports in inter-port performance and efficiency evaluation.

In this study, the container seaports that are significantly large in the Black Sea Basin were investigated as local research. The efficiency of the seaports that were included within the study, Varna, Novorossiysk, Samsun, Constanta, Poti and Odessa, was analyzed through DEA. As can be seen in Table 5, the inputs used in the efficiency analysis were length (m), depth (m), crane capacity (tons), storage area (m^2) and total area (m^2). The total amount of cargo handled in this study was taken into account as the output of the analysis. The result of the research clearly shows that; it is not enough for a port to have the longest berth or to have the most modern equipment. As the ports are highly complex structures, multiple factors must be in harmony with one another so that a port can function effectively.

According to the findings, Odessa, Poti, and Novorossiysk and Samsun are more effective ports than others; that is, they use their resources more efficiently to reach the current throughput. On the other hand, the ports of Constanta, and Varna have low activity scores compared to the others. It is surprising that Constanta Port has low efficiency scores although it has long berths and extremely high-capacity quay cranes. Varna Port is one of the best-located ports in the Black Sea Basin. Though it is very convenient for the European market, the port of Varna has a relatively low activity score. In addition, although the port of Varna has longer and deeper berths than the Port of Poti, higher capacity cranes and a wider terminal area, the Port of Poti handled more than 2 times the containers of the Port of Varna. Poti Port is operated by the international container line operator, while the operation of the port of Varna by a more local authority is thought to affect the efficiency of the ports.

The container annual throughput data used as the basis for the analysis belongs to 2021. The main reason for this is that the political and military tensions that have been ongoing between Russia and Ukraine since 2014 turned into a military intervention in February 2022, which also affected global maritime trade activities. This being the case, the fact that an efficiency analysis on the Black Sea Basin ports was conducted before the military conflict makes the study important.

The Russia-Ukraine war significantly impacted container ports, particularly in Ukraine. Cargo shipping activity from Ukrainian ports ceased entirely between March and June. Furthermore, the war and subsequent sanctions against Russia severely disrupted transportation, affecting supply chains and logistics networks, including container ports.

As a result of the analysis, Constanta and Varna ports, whose efficiency was found to be lower than other ports, are expected to take a larger share in the Black Sea container market in the coming periods, as it is predicted that they will experience a serious decline due to the military blockade of Ukrainian container ports during the Russia-Ukraine war. In particular, the fact that the Constanta port is operated by an international port operating operator has a serious potential for the cargo that will shift from Russian and Ukrainian ports in the Black Sea container market in the near future.

6.1 Suggestion for Future Research and Professionals

The ports analyzed in this study are large-scale ports of the Black Sea Basin. The scope of the research can be expanded by increasing the number of ports in future studies.

With the increase in the number of ports examined, a conclusion can be made by evaluating the ports' performance using Free Disposable Hull (FDH), Herfindahl Hirshman Index (HHI) or regression analysis. DEA is generally used in the analysis of small-scale ports, between the analysis of similar features ports and regional ports. By expanding the scope of the research and increasing the number of data, a separate assessment can be made for each port to analyze how different inputs affect the performance of the same port. As a result of the analysis, it can be concluded which operational capability of the port is strong. However before starting the research, it should be remembered that the ports have a complex structure and how difficult it is to access the port data.

6.2 Limitations of the Research

It can be affirmed that; the researchers experience several difficulties throughout the data collection procedure. Ports are companies with extremely complex structures. Each port calculates and maintains a set of data to be used by its professionals. Some ports choose to share this data with researchers, while some ports prefer not to share data and statistics. Finding the data of the ports was one of the biggest constraints of the study. Furthermore, the fact that some of the port data is not in English is another constraint that makes it difficult to understand and interpret the data.

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