PressAcademia

Journal of Management, Marketing and Logistics

Year: 2017 Volume: 4 Issue: 2

THE DETERMINATION OF TURKISH CONTAINER PORTS PERFORMANCE WITH TOPSIS MULTIPLE CRITERIA DECISION MAKING METHOD

DOI: 10.17261/Pressacademia.2017.452
JMML- V.4-ISS.2-2017(1)-p.67-75

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To cite this document
Acer, A and G. Yanginlar, (2017). The determınatıon of Turkısh container ports performance with TOPSIS multiple criteria decision making method. Journal of Management, Marketing and Logistics (JMML), V.4, Iss.2, p.67-75.
Permemant link to this document: http://doi.org/10.17261/Pressacademia.2017.452

ABSTRACT

Purpose- Ports have a leading role on affecting country and regional economy with the development of international trade. With the world trading volume increasing day by day the performance of ports and terminals, which provide export, import, transit, local or regional transportation services, must be examined regularly in order for their maximum capacity to be utilized. Furthermore, due to the high costs of infrastructure and superstructure investments of container ports, long term plans and strategies are required. This study aims to evaluate the performance of 20 container ports operating in Turkey by examining the performance criteria of container ports in the world.

Methodology- For this reason, when calculating the maximum capacity utilization of the ports, the main principle is to examine the effective utilization of all the inputs using various methods. In this study, the performance of 20 container ports operating in Turkey, has been analysed with the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method, using non-financial data from 2015.

Findings- As a result of the analysis, the values that show the overall performance of the ports were converted into a single score with the help of the TOPSIS method and port performances were evaluated by comparatively examining the results obtained. Mersin port, Ambarlı Marport and Kumport derived first with the highest performance.

Conclusion- Port performance measurement has an important requirement for maritime transport. The high performance of container ports improve the productivity of the production such as labour and capital.

Keywords: Container Ports, Multiple Criteria Decision Making, Performance, TOPSİS
JEL Codes: L9, P27, R41

1. INTRODUCTION

Container terminals have a profound important role in world maritime transportation systems in parallel with the development of international trade. Besides being a starting or ending point, container ports are also connection points. It also emphasizes the transfer function of container terminals, ensuring which container is transported accurately, timely and securely among different transportation vehicles. Container ports generally provide the transfer of containers between mainline vessels and feeder vessels or land/railways. Container terminals have three main functions such as container transport, storage and container handling. Container ports draw the attention one of the important indicators in determining the economic development levels of the countries as well as the fact that they allow the transport of the increasing variety and quantities of goods by containers where loaded to the ship, evacuated from the ship and stored temporarily. The goods handling system which involves storage, transportation within port, loading and unloading activities is the heart of the activities at the ports. Container terminals are basically needed to the infrastructure and superstructure equipment's of the port such as dock, mole, approach channel for providing load handling service. Despite of container handling in the world's ports began to spread in 1965, container handling in Turkey started to appear in 1985 (Ateş, 2010). The total number of handled containers in our ports increased from 48.644.314 in 2007 to 94.928.597 in 2016. Container transportation in Turkey has seen to be in incessant development in the last decade (DTGM, 2016). The pressures, which are reducing container handling costs and growing operational efficiency on ports, are increasing gradually.

Due to the increase in the number of handled containers in Turkey, container terminals have evaluated over time transforming into logistic base where value-added logistics activities are carried out. A problematic issue has occurred in the harbour operation process which affects directly or indirectly the international sea transportation. Inefficient operation of the dock winch will cause to increase their demurrage at the vessels' berth by affecting the speed of loading and unloading operations (Esmer, 2008). Therefore, it is aimed to increase the efficiency of container ports by using automatic stacking winches providing faster, more reliable service at container ports (Gharehgozli et al., 2017). Today, port harbours need to improve their operations and ensure cost efficiency so that they can maintain their presence in the competitive market and create customer satisfaction. Therefore, the selection of the best performing ports and the determination of the factors that will increase the efficiency are the basic principles in this process.

2. LITERATURE REVIEW

This study aims to evaluate the performance of 20 container ports operating in Turkey by examining the performance criteria of container ports in the world. While examining the literature, one can easily realize that the data envelopment method is used when the performances of container ports in the world are analyzed. By examining the performance of 20 container ports in Turkey through TOPSİS method, a difference can be made. The data obtained as a result of the research can also be used as a basis for this topic research in the future. The databases of Science Direct, Taylor & Francis, Emerald Group Publishing, Ibima Publishing and Ulakbim have been examined and the articles, especially the ones regarding the performance evaluation of container ports were selected among the ones published between 1981 and 2017 with the key words “multi-criteria decision-making method”, “container ports”, “performance” and “TOPSİS”.

The criteria used for measuring the performance of container ports in the relevant literature have been identified. In his study, Ateş (2010) suggests that the port performance was reviewed in two titles: port productivity and port production. Port efficiency clarifies the relationship between the input and output of the container terminal, port production explains the technical relationship between input and output of container terminal operators. In Collison's study (1984), average waiting period, port schedule and port services capacity were selected as the selection criteria while Willingale (1981) signified the components such as cruise distance between ports, hinterland proximity, port infrastructure, tariffs and port usage. Estache et al. (2004) compared the performance of 11 container ports in Mexico between 1996 and 1999 according to port lengths and the number of employees, Alejandro and César (2009) analyzed the performance of seven container ports in Mexico according to storage area, port length, number of cranes between 2000 and 2007. Cheon et al. (2010) investigated the performance of the 98 container ports in the world between the years 1994 and 2004 based on the number of containers, the terminal area, the number of container cranes, the length of a ship's shoreline. Between the years 2003 and 2007, Yuen et al. (2013) evaluated 21 container terminals in China, South Korea and Singapore by using the variables “the number of terminal seaport” and “the length of terminal seaport”, “terminal area” and “the number of cranes”.

McCalla (1994) researched the effects of port facilities, transportation networks and container transportation routes on the efficiency of container ports. Song et al. (2014) sought out the performance of container ports in China for the period from 2006 to 2011 by means of the Malmquist productivity index. He emphasized that the main factor of increasing productivity at the ports is technological development. Additionally, the terminals in Yangtze Delta had the highest efficiency, while the southeastern coast had the lowest. Kim (2012) measured the efficiency of 19 container ports in Europe through the Promethee method. The results put forward that some precautions had to be taken for the efficient use of the cranes at the Rotterdam harbour and the working-hours of staff had to be reduced in GioiaTauro and Valencia ports. Rios et al. (2014) utilized hierarchical cluster analysis considering the criteria of container number, dock length, dock number, terminal tariffs, dock depth, average waiting time, average waiting time for cargo or unloading cargo. They determined that the Tecon terminal at Santos port is the best performing terminal. Wilmsmeier et al. (2013) measured the impact of the financial crisis on terminal efficiency by the Data Envelopment Analysis in 20 container ports in 10 countries between 2005 and 2011.

Table 1: Research Studies on Performance Criteria of Container Ports

Sequence of Number	Criteria	Total	Paper
1	Berth length	6	Rios and Sousa, (2014), Kim (2012), De Neufville and Tsunokawa (1981), Al-Eraqi et al., (2009), Guerrero and Rivera, (2009), Lozano, (2009)
2	Number of cranes	3	Rios and Sousa, (2014), Rios and Maçada (2006), Wanke et al., (2011)
3	Average wait time	2	Collison (1984), Rios and Sousa, (2014)
4	Number of equipment	3	Rios and Maçada (2006), Al-Eraqi et al., (2009), Lozano, (2009)
5	Number of yard gantries	2	Yuen et al., (2013), Wanke et al., (2011)
6	Port land area	2	Cheon et al., (2010), Yuen et al., (2013)
7	Number of cranes	10	Yuen et al., (2013), Alejandro and César (2009), Cheon et al., (2010), Rios and Maçada (2006), Kim (2012), De Neufville ve Tsunokawa (1981), Guerrero and Rivera, (2009), Lozano, (2009), Haralambides et al., (2010), Bottasso et al., (2011)
8	Length of docks	2	Estache et al., (2004), Alejandro and César (2009)
9	Number of employees	5	Estache et al., (2004), Rios and Maçada (2006), Guironnet et al., (2009), Haralambides et al., (2010), Bottasso et al., (2011)
10	Storage area	3	Alejandro and César (2009), Guerrero and Rivera, (2009), Lozano, (2009)
11	Terminal area	9	Cheon et al., (2010), Yuen et al., (2013), Mccalla (1994), Rios and Maçada (2006), Wanke et al. (2011), Kim (2012), Martin (2002), Al-Eraqi et al., (2009), Bottasso et al., (2011)

In Table 1, it is stated that the number of cranes, berth length, terminal area and the number of employees are influential in the performance criteria of the container ports in the literature. It is seen that the number of cranes is the most chosen criteria.

3. DATA AND METHODOLOGY

Multi-criteria decision-making methods are used to solve decision-making problems based on more than one criteria. The most common of these methods can be line up as Analytic Hierarchy Process (AHP), Fuzzy AHP, Topsis, Fuzzy Topsis, Electre, Point Factor Analysis (Eleren, 2007). In the literature, Data Envelopment Analysis (DEA) is mainly used to determine the performance and effectiveness of container ports and terminals. Although this study uses a method which is widely preferred in various economic researches, it differs from other studies in terms of the use of the TOPSIS method, which is not often found in national studies in assessing operational performance at container ports. The TOPSIS method, which was developed by Hwang and Yoon (1981), is a multi-criteria decision-making method (Ömürbek et al., 2015). This method is based on the assumption that the alternative solution point is the shortest distance between the positive-ideal solution and the farthest distance from the negative-ideal solution (Eleren and Karagül, 2008). The TOPSIS method is one of the multi-criteria decision-making methods that apply directly to the data and rank the alternatives by evaluating the ideal solution distance according to the specified criteria, maximum and minimum values. At the heart of the TOPSIS approach lies the idea that the most preferred alternative is not only the one nearest to the ideal positive solution but also the one farthest to the negative ideal solution (Dumanoğlu and Ergül, 2010). The TOPSIS technique includes the following steps (Kumar and Singh, 2012):

Step 1. Creating The Decision Matrix

The first step of the TOPSIS method is the creation of the decision matrix (A) which refers to m alternatives and n criteria. This decision matrix is given below;

$$A_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad i = 1, 2, 3, \cdots m, \quad j = 1.2.3.\cdots n \tag{1}$$

Step 2. Calculating The Normalized Decision Matrix

The normalized decision matrix (R), generated using the elements of decision matrix (A), is obtained through the following formula;

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1, 2, 3, \cdots m, \quad j = 1.2.3.\cdots n \tag{2}$$

$$R = \left[r_{ij} \right] \tag{3}$$

Step 3. Constructing The Weighted Normalized Decision Matrix

In this stage, the elements of the normalized decision matrix must be weighted according to the degree of importance (W_j) given to the criteria. Then, the Weighted Normalized Decision Matrix (Vi_j) is produced by multiplying the elements in the columns of R matrix with the corresponding (W_j) value.

$$V_{ij} = r_{ij} \times W_j \tag{4}$$

Step 4. Determining The Positive and Negative Ideal Solutions

The TOPSIS method assumes that each evaluation criterion has a monotone increasing or decreasing tendency. To create the ideal solution set, the largest of the weighted evaluation criteria in the V matrix, the largest column values (if the relevant evaluation factor is maximization direction, the smallest) is selected. On the other hand, the negative ideal solution set is created by selecting the weighted evaluation factors in the V matrix, the smallest (if the relevant evaluation factor is minimization direction, the biggest) of the column values (Ömürbek and Kınay; 2013). In this instance, the following formulas are used determining positive (V_j^+) and negative (V_j^-) ideal solutions.

$$V_j^+ = \left\{ (\max_j V_{ij} \mid i \in I), (\min_j V_{ij} \mid i \in j) \right\}, \tag{5}$$

$$V_j^- = \left\{ (\min_j V_{ij} \mid i \in I), (\max_j V_{ij} \mid i \in j) \right\} \tag{6}$$

Step 5. Calculating The Separation Measures

In this step, the calculation of the distance between each alternative of positive ideal (S_i^+) and negative ideal (S_i^-) solution is made using an approach of n-dimensional Euclidean distance.

The positive ideal distance measure: $S_i^+ = \sqrt{\sum (V_{ij} - V_i^+)^2}$, $i = 1, 2, 3, \cdots m$ and $j = 1.2.3.\cdots n$ (7)

The negative ideal distance measure: $S_i^- = \sqrt{\sum (V_{ij} - V_j^-)^2}$, $i = 1, 2, 3, \cdots m$ and $j = 1.2.3.\cdots n$ (8)

Step 6. Calculating The Relative Closeness to Ideal Solution

The following formula is used in the calculation of the relative proximity to reach the ideal solution;

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}; \quad 0 \leq C_i \leq 1, \quad i = 1, 2, 3, \cdots m \tag{9}$$

Step 7. Relative Ranking of Each Alternative

In the last stage, the alternatives are arranged in terms of their scores according to calculated Ci values. The alternative with the highest score indicates the most ideal alternative.

4. FINDINGS AND DISCUSSIONS

The classifications in the literature and professional opinions are employed for the determination of decision variables which is effective in measuring the performance of container ports operating in Turkey.

4.1. Identifying the Problem

With multi-criteria decision making methods it is possible to evaluate the performances of ports with different structures by comparing them according to independent criteria using mathematical modeling. In this paper, the performance of container ports operating in Turkey was evaluated using the TOPSİS model according to the criteria specified.

4.2. Determination of Criteria and Alternatives

In determining the decision variables that are effective in performance measurement, the classifications in the literature and expert opinions were used. Seven decision variables that are container throughput, the number of containers, terminal handling capacity, the number of quay, quay length, terminal area and maximum draft were used for the year 2015. As the alternatives, there are 20 container ports operating in Turkey.

4.3. Obtaining Data

The data used in the study were obtained from TURKLIM, the related ports and sector reports. The measurement units and explanations of the criteria are given in Table 2.

Table 2: Performance Criteria for Container Terminals

Criteria	Explanation	Unit
Annual Container Throughput	20 foot(1 TEU)	TE/ Annual
Number of Container	20 and 40 foot container	Unit
Terminal Capacity of Handling	For 20 foot Container	TE/Annual
Number of Quay	Container Terminal Quay Number	Unit
Quay Length	Container Terminal Quay length	Kilometer
Terminal Area	-	Square meters
Maximum Draft	-	Meter

The decision matrix with a data set including the twenty container ports used as the alternative and seven criteria is shown in Table 3.

Table 3: Initial Decision Matrix

	Container Throughput (TE)	Number of Container	Handling Capacity	Number of Quay/Berth	Container Terminal Quay Length	Terminal Area	Maximum Draft
	x_1	x_2	x_3	x_4	x_5	x_6	x_7
ASSAN	91203	58059	250000	1	340	69350	24
BORUSAN	225718	154510	400000	4	560	120000	14,5
ÇELEBİ BANDIRMA	18613	18458	40000	5	824	215569	11,5
ASYA PORT	129297	74986	250000	4	1330	300000	18
EGE GÜBRE	330252	217065	400000	5	697	155000	20
EVYAP	605385	393690	855000	4	1171	265000	16
GEMPORT	380511	253766	600000	8	1016	680000	36
KUMPORT	1170000	731250	2500000	5	2174	469000	16,5
ALPORT	18417	16779	350000	2	870	90000	12
LİMAK İSKENDERUN	144657	85502	1300000	4	920	900000	15,50
LİMAŞ	26622	13928	200000	2	240	60000	19
MARDAŞ	335576	208679	1300000	3	915	330000	16,5
MARPORT	1585419	1048447	2000000	7	1800	440000	16,5
MERSİN	1466199	923506	1800000	6	1475	1100000	14
NEMPORT	254311	170678	450000	6	820	140000	21,5
RODAPORT	91749	54821	180000	3	400	100000	12,3
SAMSUNPORT	56713	47764	184730	2	400	320000	10,5
YILPORT	374544	241831	600000	2	525	200000	25
TCDD ALSANCAK	656410	467344	1164917	4	933	635000	13
TCDD HAYDARPAŞA	121641	75511	654637	4	650	322503	12
GENERAL AVERAGE	404161,85	262828,7	773964,2	4,05	903	345571,1	17,22

4.4. Calculating the Criterion Weights

In practice, the weights of the selection criteria are given equal weights which is one of the decision-making methods in case of uncertainty for all criteria

4.5. The Positive (V^+_j) and Negative (V^-_j) Ideal Solutions Set

In Step 1, each value in the decision matrix is divided by the square root of the sum of the squares of the values in its column and thus the normalized decision matrix is obtained. The weighted standard decision matrix is established by multiplying this matrix with the weights of each criteria. At this stage, the maximum and minimum values in the column are selected for the positive ideal and the negative ideal solution sets. The solution sets obtained is given in Table 4.

Tablo 4: The Positive (V^+_j) and Negative (V^-_j) Ideal Solutions

V^+_j	0,0826	0,0843	0,0780	0,0578	0,0678	0,0791	0,0988
V^-_j	0,0010	0,0011	0,0012	0,0072	0,0075	0,0043	0,0222

4.6. Ranking of Alternatives by Ideal Solving

In this step, the positive and negative ideal solution distance values are determined by subtracting the positive ideal and the negative ideal values from the values in each column. The results obtained using the formulas in Step 5 and Step 6 are given in Table 5.

Tablo 5: Ranking of Alternatives

CONTAINER PORTS	S^+	S^-	C_i	RANKING
ASSAN	0,178	0,022	0,109	20
BORUSAN	0,167	0,031	0,158	15
ÇELEBİ BANDIRMA	0,178	0,036	0,168	14
ASYAPORT	0,161	0,047	0,225	13
EGE GÜBRE	0,154	0,045	0,228	12
EVYAP	0,133	0,065	0,326	8
GEMPORT	0,120	0,094	0,440	5
KUMPORT	0,086	0,136	0,611	3
ALPORT	0,179	0,024	0,118	19
LİMAK İSKENDERUN	0,139	0,080	0,366	7
LİMAŞ	0,180	0,027	0,130	18
MARDAŞ	0,139	0,059	0,298	9
MARPORT	0,074	0,151	0,672	2
MERSİN	0,069	0,151	0,687	1
NEMPORT	0,148	0,062	0,294	10
RODAPORT	0,174	0,028	0,140	17
SAMSUNPORT	0,172	0,028	0,140	16
YILPORT	0,143	0,084	0,371	6
TCDD İZMİR ALSANCAK	0,103	0,091	0,469	4
TCDD HAYDARPAŞA	0,150	0,060	0,287	11

As a result of ranking, Mersin port comes in first place with the highest score (0,687), Ambarlı Marport comes second (0,672) and Kumport comes third (0,611). This order is followed by the following container ports; İzmir Alsancak (0,469), Gemport (0,440) Yılport (0,371), Limak İskenderun (0,366), Evyap (0,326), Mardaş (0,298), Nemport (0,294), Haydarpaşa (0,287), Ege Gübre (0,228), Asyaport (0,225), Çelebi Bandırma (0,168), Borusan (0,158), Samsunport (0,140), Rodaport (0,140), Limaş (0,130), Alport (0,118) and Assan (0,109).

5. CONCLUSION

In maritime transport, container ports play an important role in the development of both national and international trade. With increasing trade volume, performance evaluation based on various mathematical methods is required for harbours in order to make optimum use of all inputs and to make long-term plans. The performance evaluation of a port can determine whether the functions of the port such as physical infrastructure, area, handling capacity, number of berths and length are being successfully used as well as its ability to become a competitive port by increasing the quality of its services. Port performance measurement is an important requirement for maritime transport. The low performance of container ports reduces the productivity of the basic factors of production such as labour and capital and thus causes the loss of customers and capital. Container terminal efficiency aims to use port inputs such as labour, equipment, ship, load and field effectively. And terminal efficiency measurement is the calculation of the efficiency of these resources.

This study evaluates the performance of container ports operating in Turkey using the TOPSIS method, which is one of the multi-criteria decision making methods. In the study, 20 container ports were selected as alternatives. Seven criteria were considered as the decision making variables: the number of the TEUs handled in 2015, the number of the containers handled, the handling capacity of container terminals, the number and length of container docks, terminal area and the maximum draft. When the results were evaluated using the TOPSİS method, Mersin port came first with the highest performance. Mersin port, located in the south-east of Turkey with more than one hundred international ports, is an important gateway to the eastern Mediterranean. It plays an effective role in the South, Southeast and Eastern Anatolia economies and Turkish trade, as well as the domestic transit market of neighboring countries. Furthermore, the harbour has a wealth of possibilities and through these possibilities provides freight services for shipments such as containers, general, project, ro-ro, dry bulk and liquid bulk; loading and unloading services can also be provided to nearly 30 ships at the same time in the harbour which has a total of 21 berths. In second and third place are Ambarlı Marport and Kumport harbours, respectively. By increasing its port site and berth capacity the Marport container port has been transformed into a terminal where large container vessels that need deep water can be serviced and has thus become a terminal that offers efficient and effective port services. The ports of Limaş, Alport and Assan were the ports with the lowest performances. On the basis of this study, it is possible to evaluate the performance of the ports by taking into consideration other multi-criteria decision making methods and varied criteria.

ACKNOWLEDGEMENT

The authors wish to acknowledge TURKLIM and the aforementioned ports for their contribution by providing the data sets to support the research reported in this paper.

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