# APPLICATION OF FUZZY TOPSIS MODEL FOR CONTAINER PORT SELECTION CONSIDERING ENVIRONMENTAL FACTORS

(DOI No: 10.3940/rina.ijme.2019.a3.546)

**A Ergin,** Georgia State University, Robinson College of Business, United States and **I Eker**, Istanbul University-Cerrahpasa, Institute of Sciences, Turkey

**SUMMARY**

Container ships are the type of ships that produce the most emissions in maritime transport. In container transportation not only in navigation but also at container ports, a lot of emissions are formed. Ports are generally close by and highly interacted with the inner parts of the city, the impacts of the gas emissions are quite high on people. The study investigated port selection criteria, in terms of cost, efficiency and especially in terms of environmental impacts in order to create awareness. Container port selection problem was solved using fuzzy TOPSIS (The Technique for Order Preference by Similarity to Ideal Situation) method considering the perspective of carriers. In the study, the container port selection was carried out among the four largest container ports in Turkey.

## NOMENCLATURE

| | |
|---|---|
| TOPSIS | The Technique for Order Preference by Similarity to Ideal Situation |
| MADM | Multiple-Attribute Decision Making |
| DCM | Discrete Choice Models |
| AHP | Analytic Hierarchy Process |
| ANP | Analytical Network Process |
| ELECTRE | Elimination and Choice Translating Reality |
| DEA | Data Envelopment Analysis |
| IMO | International Maritime Organisation |

## 1. INTRODUCTION

Ports can be defined as hubs where the merchandise enter and exit for the economy. Like all over the world, most of the international trade is being done by the most economical transportation mode, sea transportation. Ports have a crucial role in the economic and environmental development of countries. All over the world, developed ports have become a strategic position. Green port project is an element of prestige and competition among the developed country ports. To overcome this competitive constraint, ports are spending money on infrastructure, operation system development, and green port project. Many port facilities in Turkey are serving in a narrow area in or near the city center. Thus, people and city life are adversely affected by the pollution caused by ship and port operations. Container transportation constitutes 17.1% of world maritime trade. Also, it is the fastest growing segment of sea transportation with 6.4% growth (Jan Hoffmann et al., 2018). It is very important to examine the container port selection criteria not only in terms of cost and efficiency but also from environmental aspects. As the container port provides fast loading/unloading, ships can depart sooner. Container ships have a certain transit time. As the time spent at ports by container ships decreased, navigation speed can be reduced. Reducing navigation speed causes to consume less fuel. This results in fewer ship emissions. Container port efficiency enables the reduction in the total amount of ship emissions. Studies have shown that 30 minutes of time reduction on the overall operation of the ships in the port provides 10% efficiency (Talay et al., 2014).

Container port selection is one of the main topics in the improvement of container transportation. Container port selection is a complicated issue because it has both quantitative and qualitative variables. In this context, the multiple attribute decision making (MADM) methods can be suitable for studying this issue. Among all MADM methods, TOPSIS is the most commonly used method for this kind of problems. In order to eliminate uncertainties inherent in decision-making problems and to eliminate the disadvantages of TOPSIS, fuzzy TOPSIS method was preferred in the study.

The expected increase in container transport has enhanced the importance of container ports further. Container ships are the ships that produce the most emissions. Although container ships have only 12.8% of the world's fleet, they realize 26% of the ship-based $CO_2$ generation and energy consumption (Smith et al., 2015, Ergin and Ergin, 2018). Thus, liner shipping companies and their supply chains want to lower carbon emissions. In this context, container port selection criteria used in the study were examined while taking into account the environmental criteria. The study aimed to take into consideration the ship-based emissions and their environmental impacts, one of the main problems of the maritime sector.

World maritime transport has reached 10.7 billion tons. About half of this trade consists of dry cargo transportation. This data indicates that container transportation and dry cargo transportation are growing very quickly. World container transportation, increased by 6.4% compared to the previous year, throughput reached 752 million TEUs volume (2018)

(Jan Hoffmann et al., 2018). Parallel to the growth in the world in 2017 container transportation in Turkey has increased from 8,023,662 TEU (2016) to 10,010,536 TEU (2017) (Turnaoglu, 2017). This increase in ports of Turkey can also be expressed as 13.1% increase. In this context, the container port selection study carried out among four container ports which have the highest capacity in Turkey. Three of the four ports included in the study are the container ports of the Marmara region which is the most populated region of the country (Turnaoglu, 2017). A selection and ranking were done by the fuzzy TOPSIS method among four container ports in Turkey.

The study was organized as follows. The literature review on container port selection and footprint in the container ports was given in section 1. Fuzzy TOPSIS method was defined in section 2. Case study and application of fuzzy TOPSIS was introduced in section 3. Lastly, results and future research suggestions were discussed in section 4.

## 1.1 LITERATURE REVIEW

The models used in port selection studies in the literature can be grouped under the titles of Multi attribute decision making (MCDM) techniques, Discrete Choice Models (DCM) and fuzzy versions of these models/techniques, statistical approaches, integrated approaches, and other mathematical models.

### 1.1 (a) Multi Attribute Decision-Making (MCDM) Techniques

The most widely used MCDM technique in port selection studies is AHP (Lirn et al., 2004, Song and Yeo, 2004, Ugboma et al., 2006, Chou, 2010a, van Dyck and Ismael, 2015, Nazemzadeh and Vanelslander, 2015, Gohomene et al., 2016, Chen et al., 2017). Onut et al. (2011) studied an evaluation among seven alternative container ports have been made for a production firm with FANP model (Onut et al., 2011). Wang et. al. (2014) in their study detects the primary factors to choose the ports for the cruise lines using a fuzzy AHP model (Wang et al., 2014). Huang and Wei (2017) utilized the ANP method to evaluate the military port location. In the study, 5 main and 27 sub-criteria were used (Huang and Wei, 2017). Ergin et al. (2015) used ELECTRE method for the first time container port selection study (Ergin et al., 2015). Pak et al. (2015) made the port selection by using fuzzy TOPSIS method among major five container ports in the Asian Pacific region. Five criteria were used in their study (Pak et al., 2015).

### 1.1 (b) Discrete Choice Model

In literature, discrete choice models have been implemented for the port selection problem (Tiwari et al., 2003, Garcia-Alonso and Sanchez-Soriano, 2009). Nir et al. (2003) made surveys among a group of Taiwanese shippers to realize the effect of transportation cost, transit time and frequency of weekly departures on port choice (Nir et al., 2003). Malchow and Kanafani (2004) presented this model for the allocation of shipments to vessels/ports to measure amount eight ports (Malchow and Kanafani, 2004). Steven and Corsi (2012) used this model to investigate the port selection by focusing on the importers of US (Steven and Corsi, 2012). Onwuegbuchunam (2013) applied the DCM to estimate utility function of the shipper' in Nigeria (Onwuegbuchunam, 2013). Wu et al. (2014) carried out a port selection by using DCM between South China ports (Wu et al., 2014). Magala and Sammons (2015) took into account shippers' perspective in port selection. They suggested a new approach using the model (Magala and Sammons, 2015).

### 1.1 (c) Fuzzy Methods

Lirn et al. (2003) utilized fuzzy model for transshipment port selection for the behavior of Taiwanese shipping liners' (Lirn et al., 2003). Transshipment container port choice using FMCDM was presented by Chou (2007). The case study applied in the three most important ports of Taiwan (Chou, 2007). The research of Wiegmans et al. (2008) emphasized that a differentiation should be investigated between port selection and container terminal problem choice from carriers' perspective (Wiegmans et al., 2008). The container port demand split problem in Taiwan using an integrated FMCDM and optimization programming model was formulated by Chou et al. (2010) (Chou et al., 2010). Chou (2010) implemented the model for solving container transshipment ports problem Southeastern Asia (Chou, 2010b). Yeo et al. (2014) presented fuzzy evidential reasoning (FER) method by using carriers' behavior. The study used seven major container ports in Northeast Asia (Yeo et al., 2014).

### 1.1 (d) Statistical Approaches

In the statistical studies on port selection, there are many studies that take into account the views of the carriers (Ng, 2006, Tongzon and Sawant, 2007, Chang et al., 2008, Yeo et al., 2008, Sanchez et al., 2011, Kavirathna et al., 2018). Slack (1985) investigated port selection criteria between the North American Midwest and Western European ports using shippers' and freight forwarders' views. (Slack, 1985). Murphy and Daley (1992) Murphy and Daley (1992) stressed the significance of port selection criteria in inbound transportation. The surveys were conducted by consignees in their study (Murphy et al., 1992). This paper of Tongzon (2009) was analyzed for port selection using freight forwarders' view (Tongzon, 2009). Ng et al. (2013) have taken into consideration the views of both shippers and carriers in port selection studies in Austria. In this study, the differences between the two groups were examined (Ng et al., 2013).

 

### 1.1 (e) Integrated Approaches

Container selection problem, has been integrated in many different models such as: a novel Network-based Integrated Choice Evaluation (NICE) (Tang et al., 2011), AHP with DSS using AIMMS, an optimization system development tool (Lam and Dai, 2012), AHP and TOPSIS (Eker et al., 2013), (Sayareh and Alizmini, 2014), AHP with DSS using AIMMS, an optimization system development tool (Zavadskas et al., 2015), Gray matter fieldalysis (GRA) and AHP (Yang and Chen, 2016), fuzzy AHP and ELECTRE III (Gao et al., 2018), in the literature.

### 1.1 (f) Data Envelopment Analysis (DEA)

Tongzon (2001) utilized DEA to find out an efficiency measurement among sixteen container ports. In the study, four Australian ports were used (Tongzon, 2001). Cullinane et al. (2006) determined the efficiency of European ports by DEA model (Cullinane and Wang, 2006). Ng et al. (2010) defined the factors that affect the competitiveness of a container port using DEA model (Ng et al., 2010). Barros and Athanassiou (2015) utilized the model for efficiency in European ports (Barros and Athanassiou, 2015). Park and De (2015) implemented to performance measurement and provided port efficiency measurement with this model (Park and De, 2015).

### 1.1 (g) Other Mathematical Models

Different mathematical models were applied other than the classified methods mentioned above for solving port selection problems (Tran, 2011, Tavasszy et al., 2011, Anderson et al., 2009, Wu and Peng, 2013). Guy and Urli (2006) took into account shippers' perspective in the selection of Montreal and New York ports (Guy and Urli, 2006). Talley and Ng (2013) developed a mathematical model considering the perspectives of carriers' and shippers'(Talley and Ng, 2013).

Table 1: Summary of Literature Review on Port Selection

| Method | Number | Rate(%) |
|---|---|---|
| Multi Attribute Decision Making Techniques | 13 | 0.24 |
| Discrete Choice Model | 8 | 0.14 |
| Statistical Approaches | 10 | 0.18 |
| Fuzzy Methods | 6 | 0.11 |
| Other Mathematical Models | 6 | 0.11 |
| Data Envelopment Analysis | 5 | 0.09 |
| Integrated Approaches | 7 | 0.13 |
| Total | 55 | 1.00 |

The 55 articles analyzed showed that Multi attribute decision making techniques are the most commonly used methods with 24%. This can be clearly observed from Table 1. These methods were followed by statistical approaches with a share of 18%. In the third row, the Discrete choice model methods are seen with 14%. Then integrated approaches are in the fourth row with 13%, fuzzy methods and other mathematical models are in the fifth row with 11%, and finally, Data Envelopment Analysis method is in the sixth row with 0.09%.

## 1.2 FOOTPRINT IN CONTAINER PORTS

Increasing competition and globalization force companies to reduce the production costs. These efforts increased the importance of the ports in maritime transportation. The majority of world trade is carried by maritime transportation. In this context, ports, being the starting and finishing points of the maritime transports, affects a number of sectors by providing services to freights. Ports are businesses that have an environmental impact on land and seaside due to the processes performed in the coastal areas. The impact of the processes carried out on ports is highly sensitive against pollution and environmental degradation. World’s 2.5% of greenhouse gas emissions are caused by ships (Smith et al., 2015). According to Third IMO Greenhouse Gas Study data, ships causing maximum emission are, respectively, container, bulk carrier, and oil tankers. Despite the fact that Container ships have 12.8% of World maritime fleet, they are responsible only for 26% of the total ship emissions (Smith et al., 2015, Ergin and Ergin, 2018).

Container ports need a very high amount of energy consumption because of the diversity of its operations and its highly dynamic structure. The amount of emissions generated by the ships consists of three parts. These parts are navigating, maneuvering and port process. The emissions occurring in the port is the total amount of emissions emitted during the period until the ship left the quay berthing docks. Exhaust gas emissions are generated by the generator within the time spent at the port. Exhaust gas emissions are taken into account during the stay of each ship at the port. In this context, in container ports efficiency is very important.

## 2. MATERIALS AND METHODS

Multi criteria decision making (MCDM) methods are used in most and in the presence of conflicting criteria. TOPSIS is one of the most widely utilized multi criteria decision making methods. The method was presented by Hwang and Yoon in 1981 (Hwang and Yoon, 1981). TOPSIS can be utilized to assess a number of criteria selected among multiple alternatives. As an optimal solution is the one with nearest to the Positive Ideal Solution (FPIS) and farthest from the Negative Ideal Solution (FNIS). On the other hand, many real-life decision problems are not sufficient to model linguistic or qualitative variables. Therefore, fuzzy TOPSIS method was utilized to obtain more meaningful results from the study.

Fuzzy TOPSIS method, has been applied in many different areas such as: supply selection (Chen et al., 2006, Boran et al., 2009, Junior et al., 2014, Yayla et al., 2012), green supplier selection for a Brazilian electronics firm (Kannan et al., 2014), system analysis for the software company engineer selection (Chen, 2000), robot selection (Chu and Lin, 2003), bridge risk assessment (Wang and Elhag, 2006), service provider selection (Bottani and Rizzi, 2006), factory layout design problems (Yang and Hung, 2007) and facility location selection (Ertuğrul and Karakaşoğlu, 2008), warehouse selection (Ashrafzadeh et al., 2012), network selection for energy efficiency (Chamodrakas and Martakos, 2012), web service selection (Lo et al., 2010), energy technology selection (Kaya and Kahraman, 2011), shopping websites selection (Sun and Lin, 2009), renewable energy sources in Turkey (Şengül et al., 2015) in the literature.

Fuzzy TOPSIS method developed by Chen (2000) (Chen, 2000) and Chen (2006) et al. (Chen et al., 2006) was used in the study. The description of the model is as follows.

1. A group of decision-makers is formed. In a decision commission that has K members; fuzzy rating of each member $D_k = (k = 1,2,...,K)$ is characterized as triangular fuzzy number $\widetilde{R}_k = (k = 1,2,...,K)$ with membership function $\mu_{\widetilde{R}_k}(x)$.
2. The assessment criteria are decided.
3. The linguistic variables for assessing the alternatives and criteria are selected.
4. The criteria weights are collected. If the fuzzy ratings of all decision-makers are defined as triangular fuzzy numbers $\widetilde{R}_k = (a_k, b_k, c_k), k = 1,2,...K$ after the collected fuzzy rating is decided as:

$$\widetilde{R} = (a,b,c), k = 1,2,..K \tag{1}$$

Here;

$$a = \min_k \{a_k\} \tag{2}$$

$$b = \frac{1}{K}\sum_{k=1}^{K} b_k \tag{3}$$

$$c = \max_k \{c_k\} \tag{4}$$

5. The assessment criteria are decided.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{5}$$

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n] \tag{6}$$

where

$(\widetilde{x}_{ij}) = (a_{ij}, b_{ij}, c_{ij})$ and $\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$; $i = 1,2,...,m$, $j = 1,2,...,n$ can be approached by positive triangular fuzzy numbers.

6. The decision matrix is normalized.
7. The weighted normalized decision matrix is calculated.
8. The fuzzy positive ideal solution $(FPIS, A^*)$ and fuzzy negative ideal solution $(FNIS, A^-)$ are decided as follows [68]:

$$A^* = (\widetilde{v}_1^*, \widetilde{v}_2^*, \ldots, \widetilde{v}_n^*), \tag{7}$$

$$A^- = (\widetilde{v}_1^-, \widetilde{v}_2^-, \ldots, \widetilde{v}_n^-), \tag{8}$$

where

$\widetilde{v}_j^* = \max_i \{v_{ij3}\}$ and $\widetilde{v}_j^- = \min_i \{v_{ij1}\}$ $i = 1,2,...,m$, $j = 1,2,...,n$.

9. The distance of each alternative from FPIS and FNIS is computed as:

$$d_i^* = \sum_{j=1}^{n} d_v(\widetilde{v}_{ij}, \widetilde{v}_j^*), i = 1,2,...,m \tag{9}$$

$$d_i^- = \sum_{j=1}^{n} d_v(\widetilde{v}_{ij}, \widetilde{v}_j^-),\ i = 1,2,...,m \tag{10}$$

10. Closeness coefficient $(CC_i)$ of each alternative is computed as [68]:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}\ ,\ i = 1,2,...,m \tag{11}$$

## 3. RESULTS AND DISCUSSION

The Marmara region in Turkey is where nearly 62% of container handling is produced. Three of the four ports included in the study are the container ports of the Marmara region which is the most populated region of the country (Turnaoglu, 2017). In this context, the present study deals with the port selection problem among four private ports with the highest container handling ratio in Turkey. According to the competition policy ports are referred as $A_1$, $A_2$, $A_3$, $A_4$. Besides, the two selected ports are located in Istanbul and the other is close to Istanbul. With more than 15 million inhabitants Istanbul is Turkey's most populous city. Gas emissions have serious negative effects on global warming, acid rain and human health. In this context, the container port facilities are required to take some precautions to produce lower emissions. Therefore, the criteria used are described in terms of efficiency, cost, and environmental impact. The criteria used in the study have been determined by analyzing the studies in the literature (Slack, 1985, Ugboma et al., 2006, Lirn et al., 2004, Chang et al., 2008) and also created as a result of negotiations with the carriers. A total number of sixteen criteria were used. Figure 1 presents the hierarchical structure for container port selection as well as the criteria names.

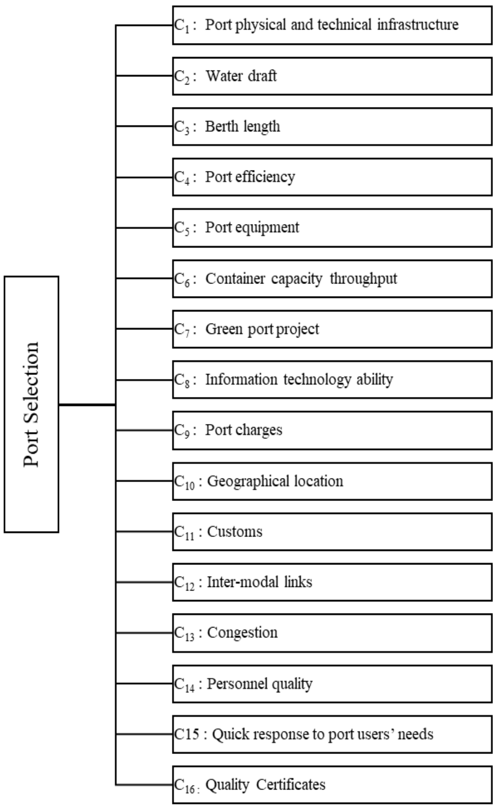


Figure 1: Hierarchical structure for container port selection.

Port selection criteria explained as follows:

$C_1$: Ports should have sufficient work area (terminal, CFS, etc.) to provide fast and high-quality service to ships and cargoes.

$C_2$: Water draft has become increasingly important for mega-container ships due to maximum ship length and tidal windows.

$C_3$: Berth length has an effect on ship waiting time. The longer the berth length the less the waiting time.

$C_4$: Port efficiency includes port return time for ships, terminal and operational efficiency for cargoes.

$C_5$: The container port needs special handling equipment (crane, container stacking machine, etc.) and sufficient equipment capacity.

$C_6$: It is maximum handling capacity in the port.

$C_7$: Green port project aims to take administrative and technical cautions in order to reduce the environmental impact of ship and port operations with an effective, comprehensive and coordinated approach of port facilities. It contains protecting water quality and animals, reducing harmful air emissions and other environmental problems from port activities.

$C_8$: Information technology has the ability to bring values such as speed, accuracy, and easiness to monitor the process.

$C_9$: Port charges include the cost of services given to the ship and the cargo.

$C_{10}$: Geographical location is the distance from port to production and trade centers.

$C_{11}$: Customs provides a clear, straightforward and quick load handling.

$C_{12}$: Inter-modal links provide access to other transport modes.

$C_{13}$: Congestion is the difficulties in container handling and delivery caused by the increased volumes at the ports.

$C_{14}$: Personnel- quality is the knowledge and competence of employees during port management and operation processes.

$C_{15}$: It means that willingness to prompt response to port users' needs

$C_{16}$: Port should have ISO and other quality certificates to give quality services.

The evaluations made with linguistic variables are converted into triangular fuzzy numbers using the data in Table 2 and Table 3.

Table 2: Linguistic Variables for Importance Weight of Each Criterion.

| Linguistic variables | Triangular fuzzy numbers | | |
|---|---|---|---|
| Very high (VH) | 0.9 | 1.0 | 1.0 |
| High (H) | 0.7 | 0.9 | 1.0 |
| Medium high (MH) | 0.5 | 0.7 | 0.9 |
| Medium (M) | 0.3 | 0.5 | 0.7 |
| Medium low (ML) | 0.1 | 0.3 | 0.5 |
| Medium low (ML) | 0 | 0.1 | 0.3 |
| Very low (VL) | 0 | 0 | 0.1 |

Table 3: Importance Weight of Criteria from Eight Decision Makers.

| | $DM_1$ | $DM_2$ | $DM_3$ | $DM_4$ | $DM_5$ | $DM_6$ | $DM_7$ | $DM_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | MH | M | H | MH | M | M | MH | M |
| $C_2$ | M | ML | M | M | M | ML | ML | ML |
| $C_3$ | M | M | MH | M | MH | MH | M | ML |
| $C_4$ | H | VH | H | MH | H | VH | H | MH |
| $C_5$ | MH | M | MH | M | MH | M | M | ML |
| $C_6$ | ML | M | MH | ML | M | ML | ML | ML |
| $C_7$ | H | M | MH | M | H | MH | M | M |
| $C_8$ | MH | M | ML | M | M | MH | MH | ML |
| $C_9$ | VH | VH | H | MH | MH | H | VH | H |
| $C_{10}$ | H | MH | H | MH | MH | MH | M | MH |
| $C_{11}$ | MH | M | M | MH | MH | M | MH | M |
| $C_{12}$ | MH | M | MH | M | ML | M | ML | M |
| $C_{13}$ | MH | M | M | ML | M | ML | M | ML |
| $C_{14}$ | MH | M | MH | M | M | MH | MH | M |
| $C_{15}$ | MH | M | H | M | M | M | M | ML |
| $C_{16}$ | MH | M | MH | M | M | M | ML | ML |

After the normalized fuzzy decision matrix is formed, by using criteria weights the weighted normalized fuzzy decision matrix is formed as in Table 4.

Table 4: Weighted Normalized Fuzzy Decision Matrix.

| Criteria/ Alternative | $A_1$ | $A_2$ | $A_3$ | $A_4$ |
|---|---|---|---|---|
| $C_1$ | 0.24 0.49 0.81 | 0.14 0.35 0.63 | 0.24 0.49 0.81 | 0.24 0.49 0.81 |
| $C_2$ | 0.06 0.20 0.42 | 0.06 0.20 0.42 | 0.14 0.36 0.60 | 0.02 0.12 0.30 |
| $C_3$ | 0.04 0.17 0.38 | 0.18 0.39 0.68 | 0.11 0.28 0.53 | 0.32 0.55 0.75 |
| $C_4$ | 0.39 0.68 0.98 | 0.23 0.49 0.76 | 0.23 0.49 0.76 | 0.23 0.49 0.76 |
| $C_5$ | 0.12 0.31 0.58 | 0.12 0.31 0.58 | 0.12 0.31 0.58 | 0.19 0.43 0.75 |
| $C_6$ | 0.06 0.20 0.42 | 0.02 0.12 0.30 | 0.10 0.28 0.54 | 0.14 0.36 0.60 |
| $C_7$ | 0.41 0.65 0.83 | 0.32 0.59 0.83 | 0.32 0.59 0.83 | - - 0.08 |
| $C_8$ | 0.23 0.47 0.73 | 0.10 0.26 0.51 | 0.16 0.37 0.65 | 0.16 0.37 0.65 |
| $C_9$ | 0.73 1.24 1.76 | 1.02 1.60 1.95 | 0.73 1.24 1.76 | 0.73 1.24 1.76 |
| $C_{10}$ | 0.47 0.73 0.90 | 0.47 0.73 0.90 | 0.26 0.51 0.81 | 0.37 0.65 0.90 |
| $C_{11}$ | 0.13 0.33 0.62 | 0.04 0.20 0.44 | 0.22 0.47 0.80 | 0.22 0.47 0.80 |
| $C_{12}$ | 0.03 0.15 0.35 | 0.03 0.15 0.35 | 0.09 0.25 0.49 | 0.27 0.50 0.70 |
| $C_{13}$ | 0.03 0.15 0.36 | - 0.05 0.22 | 0.14 0.35 0.65 | 0.14 0.35 0.65 |
| $C_{14}$ | 0.28 0.54 0.80 | 0.12 0.30 0.56 | 0.12 0.30 0.56 | 0.12 0.30 0.56 |
| $C_{15}$ | 0.25 0.50 0.74 | 0.18 0.39 0.66 | 0.11 0.28 0.52 | 0.18 0.39 0.66 |
| $C_{16}$ | 0.21 0.45 0.70 | 0.09 0.25 0.49 | 0.03 0.15 0.35 | 0.03 0.15 0.35 |

Then, fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) are found as:

$$A^* = \begin{bmatrix} (1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1), \\ (0,0,0),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1) \end{bmatrix} \quad (12)$$

$$A^- = \begin{bmatrix} (0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0), \\ (1,1,1),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0) \end{bmatrix} \quad (13)$$

Then the distance of each alternative from FPIS and FNIS with respect to each criterion are computed by using vertex method.

The results are summarized in Table 5. In the study, $A_1$, which has the highest closeness, was determined as the best alternative.

Table 5: Distances from FPIS and FNIS and Ranking.

| | $d_i^*$ | $d_i^-$ | $CC_i$ | Rank |
|---|---|---|---|---|
| $A_1$ | 9.204657 | 6.277163 | 0.405 | 1 |
| $A_2$ | 10.30099 | 5.483134 | 0.347 | 4 |
| $A_3$ | 9.554362 | 5.973202 | 0.385 | 3 |
| $A_4$ | 9.480756 | 5.985304 | 0.387 | 2 |

## 4. CONCLUSION

Ports, which are the last point of transportation, are highly effective in accessing international markets and also on the economic, social, environmental and commercial - structure - of - the - country. The studies on port selection are very important when considering the factors in building new ports and factors related to increasing port efficiency. Ports are businesses that have an environmental impact on land and seaside due to the processes performed in the coastal areas. The impact of the processes carried out on ports is highly sensitive against pollution and environmental degradation. In this context, there are some issues to be considered, such as the development of projects for reduction of greenhouse gas emissions, the creation of carbon sinks, the development of technology, cost reduction, also the preference for sustainable and environmentally-friendly business machines.

The study suggested the Fuzzy TOPSIS method for solving the container port selection problem. The case study was analyzed among four container ports considering the perspectives of the carriers in Turkey. With the highest value of 0.405 port $A_1$ has been identified as the most suitable port. Three other alternatives $A_2$, $A_3$ and $A_4$ have been ranked respectively with the values 0.347, 0.385, and 0.387. In the study, the most important criterion was found “port cost”, this is followed by “port efficiency”, and then “geographical location” “container handling efficiency” while the least important criterion was “capacity container throughput”. One of the most important criteria is the green port project.

In future studies, for transshipment port selection or container port selection, different MCDM methods can be utilized. Most of the studies made for the port selection have taken into account the carriers' perspectives. This is followed by the studies which take into account shippers' perspectives. There are only a few numbers of studies that take into account both perspectives. And also very few numbers of studies have been conducted from the view of freight forwarders. A study can be carried out with regard to the perspective of the carriers, shippers, consignees, and freight forwarders about the port selection. In the study, a comprehensive literature study has been carried out on port selection. This study seeks to provide a significant contribution for faster and more accurate decision making for the researchers who will be working on this specific issue, the port selection problem.

## 5. REFERENCES

1. ANDERSON, C. M., OPALUCH, J. J. & GRIGALUNAS, T. A. 2009. *The demand for import services at US container ports*. Maritime Economics & Logistics, 11, 156-185.

 

2. ASHRAFZADEH, M., RAFIEI, F. M., ISFAHANI, N. M. & ZARE, Z. 2012. *Application of fuzzy TOPSIS method for the selection of warehouse location: a case study*. Interdisciplinary Journal of Contemporary Research in Business, 3, 655-671.
3. BARROS, C. P. & ATHANASSIOU, M. 2015. *Efficiency in European seaports with DEA: evidence from Greece and Portugal*. Port Management. Springer.
4. BORAN, F. E., GENÇ, S., KURT, M. & AKAY, D. 2009. *A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method*. Expert Systems with Applications, 36, 11363-11368.
5. BOTTANI, E. & RIZZI, A. 2006. *A fuzzy TOPSIS methodology to support outsourcing of logistics services*. Supply Chain Management: An International Journal, 11, 294-308.
6. CHAMODRAKAS, I. & MARTAKOS, D. 2012. *A utility-based fuzzy TOPSIS method for energy efficient network selection in heterogeneous wireless networks*. Applied Soft Computing, 12, 1929-1938.
7. CHANG, Y.-T., LEE, S.-Y. & TONGZON, J. L. 2008. *Port selection factors by shipping lines: Different perspectives between trunk liners and feeder service providers*. Marine Policy, 32, 877-885.
8. CHEN, C.-T. 2000. *Extensions of the TOPSIS for group decision-making under fuzzy environment*. Fuzzy sets and systems, 114, 1-9.
9. CHEN, C.-T., LIN, C.-T. & HUANG, S.-F. 2006. *A fuzzy approach for supplier evaluation and selection in supply chain management*. International journal of production economics, 102, 289-301.
10. CHEN, G., CHEUNG, W., CHU, S.-C. & XU, L. 2017. *Transshipment hub selection from a shipper's and freight forwarder's perspective*. Expert Systems with Applications, 83, 396-404.
11. CHOU, C.-C. 2007. *A fuzzy MCDM method for solving marine transshipment container port selection problems*. Applied Mathematics and Computation, 186, 435-444.
12. CHOU, C.-C. 2010a. *AHP model for the container port choice in the multiple-ports region.* Journal of Marine Science and Technology, 18, 221-232.
13. CHOU, C.-C. 2010b. *Application of FMCDM model to selecting the hub location in the marine transportation: A case study in southeastern Asia*. Mathematical and Computer Modelling, 51, 791-801.
14. CHOU, C.-C., KUO, F.-T., GOU, R.-H., TSAI, C.-L., WONG, C.-P. & TSOU, M.-C. 2010. *Application of a combined fuzzy multiple criteria decision making and optimization programming model to the container transportation demand split*. Applied Soft Computing, 10, 1080-1086.
15. CHU, T.-C. & LIN, Y.-C. 2003. *A fuzzy TOPSIS method for robot selection*. The International Journal of Advanced Manufacturing Technology, 21, 284-290.
16. CULLINANE, K. P. & WANG, T.-F. 2006. *The efficiency of European container ports: A cross-sectional data envelopment analysis*. International Journal of Logistics: Research and Applications, 9, 19-31.
17. EKER, İ., ERGIN, A. & ALKAN, G. 2013. *Selection of container port with fahp-topsis technique*. 1, 1, 43-58.
18. ERGIN, A., EKER, I. & ALKAN, G. 2015. *Selection of container port using electre technique*. Management, 4, 268-275.
19. ERGIN, A. & ERGIN, M. F. 2018. *Reduction of Ship Based CO2 Emissions from Container Transportation*. International Journal of Computational and Experimental Science and Engineering, 4, 1-4.
20. ERTUĞRUL, İ. & KARAKAŞOĞLU, N. 2008. *Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection*. The International Journal of Advanced Manufacturing Technology, 39, 783-795.
21. GAO, T., NA, S., DANG, X. & ZHANG, Y. 2018. *Study of the Competitiveness of Quanzhou Port on the Belt and Road in China Based on a Fuzzy-AHP and ELECTRE III Model*. Sustainability, 10, 1253.
22. GARCIA-ALONSO, L. & SANCHEZ-SORIANO, J. 2009. *Port selection from a hinterland perspective*. Maritime Economics & Logistics, 11, 260-269.
23. GOHOMENE, D. A., YANG, Z. L., BONSAL, S., MAISTRALIS, E., WANG, J. & LI, K. X. 2016. *The Attractiveness of Ports in West Africa: Some Lessons from Shipping Lines' Port Selection*. Growth and Change, 47, 416-426.
24. GUY, E. & URLI, B. 2006. *Port selection and multicriteria analysis: An application to the Montreal-New York alternative*. Maritime Economics & Logistics, 8, 169-186.
25. HUANG, B. & WEI, Z. B. A *Bayesian-ANP-based expert group decision-making method to evaluate the location of military port.* Computer and Communications (ICCC), 2017 3rd IEEE International Conference on, 2017. IEEE, 1004-1008.
26. HWANG, C.-L. & YOON, K. 1981. *Methods for multiple attribute decision making.* Multiple attribute decision making. Springer.
27. HOFFMANN, J., JUAN, W., SIRIMANNE., S. N., ASARIOTIS, R., ASSAF, M., BENAMARA, H., HOFFMANN, J., PREMTI, A., RODRÍGUEZ, WELLER, L., M. & YOUSSEF, F. 2018. *Review of Maritime Transport 2018* [Online]. United Nations

Conference on Trade and Development. Available: https://www.alphaliner.com/.

28. JUNIOR, F. R. L., OSIRO, L. & CARPINETTI, L. C. R. 2014. *A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection*. Applied Soft Computing, 21, 194-209.

29. KANNAN, D., DE SOUSA JABBOUR, A. B. L. & JABBOUR, C. J. C. 2014. *Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company*. European Journal of Operational Research, 233, 432-447.

30. KAVIRATHNA, C., KAWASAKI, T., HANAOKA, S. & MATSUDA, T. 2018. *Transshipment hub port selection criteria by shipping lines: the case of hub ports around the Bay of Bengal*. Journal of Shipping and Trade, 3, 4.

31. KAYA, T. & KAHRAMAN, C. 2011. *Multicriteria decision making in energy planning using a modified fuzzy TOPSIS methodology*. Expert Systems with Applications, 38, 6577-6585.

32. LAM, J. S. L. & DAI, J. 2012. *A decision support system for port selection.* Transportation Planning and Technology, 35, 509-524.

33. LIRN, T.-C., THANOPOULOU, H. A. & BERESFORD, A. K. 2003. *Transhipment port selection and decision-making behaviour: analysing the Taiwanese case*. International Journal of Logistics: Research and Applications, 6, 229-244.

34. LIRN, T., THANOPOULOU, H., BEYNON, M. J. & BERESFORD, A. K. C. 2004. *An application of AHP on transhipment port selection: a global perspective*. Maritime Economics & Logistics, 6, 70-91.

35. LO, C.-C., CHEN, D.-Y., TSAI, C.-F. & CHAO, K.-M. *Service selection based on fuzzy TOPSIS method*. Advanced Information Networking and Applications Workshops (WAINA), 2010 IEEE 24th International Conference on, 2010. IEEE, 367-372.

36. MAGALA, M. & SAMMONS, A. 2015. *A new approach to port choice modelling.* Port Management. Springer.

37. MALCHOW, M. B. & KANAFANI, A. 2004. *A disaggregate analysis of port selection.* Transportation Research Part E: Logistics and Transportation Review, 40, 317-337.

38. MURPHY, P. R., DALEY, J. M. & DALENBERG, D. R. 1992. *Port selection criteria: an application of a transportation*. Logistics and transportation review, 28, 237.

39. NAZEMZADEH, M. & VANELSLANDER, T. 2015. *The container transport system: Selection criteria and business attractiveness for North-European ports*. Maritime Economics & Logistics, 17, 221-245.

40. NG, A. S.-F., LIM, A. L. C., LEONG, C. H. & CHENG, C. H. 2010. *A competitiveness measurement framework for regional container hub ports: A case study in East Asia*. International Journal of Logistics Systems and Management, 7, 368-392.

41. NG, A. S.-F., SUN, D. & BHATTACHARJYA, J. 2013. *Port choice of shipping lines and shippers in Australia*. Asian Geographer, 30, 143-168.

42. NG, K. Y. 2006. *Assessing the attractiveness of ports in the North European container transhipment market: an agenda for future research in port competition*. Maritime Economics & Logistics, 8, 234-250.

43. NIR, A.-S., LIN, K. & LIANG, G.-S. 2003. *Port choice behaviour--from the perspective of the shipper*. Maritime Policy & Management, 30, 165-173.

44. ONUT, S., TUZKAYA, U. R. & TORUN, E. 2011. *Selecting container port via a fuzzy ANP-based approach: A case study in the Marmara Region, Turkey*. Transport Policy, 18, 182-193.

45. ONWUEGBUCHUNAM, D. E. 2013. *Port selection criteria by shippers in Nigeria: a discrete choice analysis*. International Journal of Shipping and Transport Logistics, 5, 532-550.

46. PAK, J. Y., THAI, V. V. & YEO, G. T. 2015. *Fuzzy MCDM approach for evaluating intangible resources affecting port service quality*. The Asian Journal of Shipping and Logistics, 31, 459-468.

47. PARK, R.-K. & DE, P. 2015. *An alternative approach to efficiency measurement of seaports*. Port Management. Springer.

48. SANCHEZ, R. J., NG, A. K. & GARCIA-ALONSO, L. 2011. *Port selection factors and attractiveness: The service providers' perspective*. Transportation journal, 50, 141-161.

49. SAYAREH, J. & ALIZMINI, H. R. 2014. *A hybrid decision-making model for selecting container seaport in the Persian Gulf*. The Asian Journal of Shipping and Logistics, 30, 75-95.

50. ŞENGÜL, Ü., EREN, M., SHIRAZ, S. E., GEZDER, V. & ŞENGÜL, A. B. 2015. *Fuzzy TOPSIS method for ranking renewable energy supply systems in Turkey*. Renewable Energy, 75, 617-625.

51. SLACK, B. 1985. *Containerization, inter-port competition, and port selection*. Maritime policy and management, 12, 293-303.

52. SMITH, T., JALKANEN, J., ANDERSON, B., CORBETT, J., FABER, J., HANAYAMA, S., O'KEEFFE, E., PARKER, S., JOHANASSON, L. & ALDOUS, L. 2015. Third IMO GHG Study.

53. SONG, D.-W. & YEO, K.-T. 2004. *A competitive analysis of Chinese container ports*


 

*using the analytic hierarchy process*. Maritime Economics & Logistics, 6, 34-52.
54. STEVEN, A. B. & CORSI, T. M. 2012. *Choosing a port: An analysis of containerized imports into the US*. Transportation Research Part E: Logistics and Transportation Review, 48, 881-895.
55. SUN, C.-C. & LIN, G. T. 2009. *Using fuzzy TOPSIS method for evaluating the competitive advantages of shopping websites*. Expert Systems with Applications, 36, 11764-11771.
56. TALAY, A. A., DENIZ, C. & DURMUŞOĞLU, Y. 2014. *Gemilerde verimi arttırmak için uygulanan yöntemlerin CO2 emisyonlarını azaltmaya yönelik etkilerinin analizi.* Journal of ETA Maritime Science, 2, 61-74.
57. TALLEY, W. K. & NG, M. 2013. *Maritime transport chain choice by carriers, ports and shippers*. International Journal of Production Economics, 142, 311-316.
58. TANG, L. C., LOW, J. M. & LAM, S. W. 2011. *Understanding port choice behaviour – a network perspective*. Networks and Spatial Economics, 11, 65-82.
59. TAVASSZY, L., MINDERHOUD, M., PERRIN, J.-F. & NOTTEBOOM, T. 2011. *A strategic network choice model for global container flows: specification, estimation and application*. Journal of Transport Geography, 19, 1163-1172.
60. TIWARI, P., ITOH, H. & DOI, M. 2003. *Shippers' port and carrier selection behaviour in China: a discrete choice analysis*. Maritime Economics & Logistics, 5, 23-39.
61. TONGZON, J. 2001. *Efficiency measurement of selected Australian and other international ports using data envelopment analysis*. Transportation Research Part A: Policy and Practice, 35, 107-122.
62. TONGZON, J. L. 2009. *Port choice and freight forwarders*. Transportation Research Part E: Logistics and Transportation Review, 45, 186-195.
63. TONGZON, J. L. & SAWANT, L. 2007. *Port choice in a competitive environment: from the shipping lines' perspective*. Applied Economics, 39, 477-492.
64. TRAN, N. K. 2011. *Studying port selection on liner routes: An approach from logistics perspective*. Research in Transportation Economics, 32, 39-53.
65. TURNAOGLU, B. 2017. *The Formation of Turkish Republicanism*, Turkish Chamber of Shipping.
66. UGBOMA, C., UGBOMA, O. & OGWUDE, I. C. 2006. *An analytic hierarchy process (AHP) approach to port selection decisions – empirical evidence from Nigerian ports*. Maritime Economics & Logistics, 8, 251-266.
67. VAN DYCK, G. K. & ISMAEL, H. M. 2015. *Multi-criteria evaluation of port competitiveness in West Africa using analytic hierarchy process (AHP)*. American Journal of Industrial and Business Management, 5, 432.
68. WANG, Y.-M. & ELHAG, T. M. 2006. *Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment.* Expert systems with applications, 31, 309-319.
69. WANG, Y., JUNG, K.-A., YEO, G.-T. & CHOU, C.-C. 2014. *Selecting a cruise port of call location using the fuzzy-AHP method: A case study in East Asia.* Tourism Management, 42, 262-270.
70. WIEGMANS, B. W., HOEST, A. V. D. & NOTTEBOOM, T. E. 2008. *Port and terminal selection by deep-sea container operators*. Maritime Policy & Management, 35, 517-534.
71. WU, Y., LIU, J. & PENG, C. *Analysis of port and inland transport mode selection*. Service Systems and Service Management (ICSSSM), 2014 11th International Conference on, 2014. IEEE, 1-6.
72. WU, Y. & PENG, C. 2013. RETRACTED: *A Container Port Choice Model for Pearl River Delta Region in South China*. Elsevier.
73. YANG, T. & HUNG, C.-C. 2007. *Multiple-attribute decision making methods for plant layout design problem*. Robotics and computer-integrated manufacturing, 23, 126-137.
74. YANG, Y.-C. & CHEN, S.-L. 2016. *Determinants of global logistics hub ports: Comparison of the port development policies of Taiwan, Korea, and Japan*. Transport Policy, 45, 179-189.
75. YAYLA, A. Y., YILDIZ, A. & OZBEK, A. 2012. *Fuzzy TOPSIS method in supplier selection and application in the garment industry*. Fibres & Textiles in Eastern Europe.
76. YEO, G.-T., NG, A. K., LEE, P. T.-W. & YANG, Z. 2014. *Modelling port choice in an uncertain environment*. Maritime Policy & Management, 41, 251-267.
77. YEO, G.-T., ROE, M. & DINWOODIE, J. 2008. *Evaluating the competitiveness of container ports in Korea and China*. Transportation Research Part A: Policy and Practice, 42, 910-921.
78. ZAVADSKAS, E. K., TURSKIS, Z. & BAGOČIUS, V. 2015. *Multi-criteria selection of a deep-water port in the Eastern Baltic Sea*. Applied Soft Computing, 26, 180-192.