Beykoz Akademi Dergisi, 1(1), s.43-58.

SELECTION OF CONTAINER PORT WITH FAHP-TOPSIS TECHNIQUE

İPEK EKER (1), AYFER ERGİN (2), GÜLER ALKAN (3)

ABSTRACT

In today's world, more than 80% of world trade is done by sea transportation. Especially in 2000's, container transportation, formerly named as unitized cargo, and has reached very high numbers. The reason for the rapid increase in container transportation, in recent years, is that it can easily be integrated to other transportation systems. With globalization the increase in sea transportation, has brought the increase with the container transportation. Hence, in order to make the transportation network more efficient the importance of the selection of container ports has been increased. The research presented in this paper applies an integrated model using both the Fuzzy Analytic Hierarchy Process (FAHP) and TOPSIS methods to reveal and analyze container port selection by global container carriers. By the FAHP model, we can obtain the importance weight of each factor influencing the decision-making of carriers' port choices. By TOPSIS technique, container ports are ranked.

Within the process of defining the criteria expert opinions in shipping line firms were taken as well as the research was made in literature among the international articles published. In application of this study, Ambarlı Port region is chosen since this area has more than 42.04 (according to maritime trade statistics 2012) percent handling ratio of container transportation in Turkey. Thus, the criteria which are important on behalf of port selection such as geographic location, the hinterland economy, and customs were eliminated. Due to the reason that the study was made in a particular region elimination of the above-mentioned criteria is intended to bring a difference within the studies had been published in the literature. In addition, the criteria like port performance, port infrastructure, cost, information systems used in ports, and port security is selected in order to emphasize the difference in this study. Finally, the most important criterion is

1 Lecturer, BeykozVocational School of Logistics, ipekeker@beykoz.edu.tr

2 Research Assistant, Dr., İstanbul University, Department of Maritime Transportation Management Engineering, ayfersan@istanbul.edu.tr

3 Professor Dr., İstanbul University, Department of Maritime Transportation Management Engineering.

determined as "cost" while the second important criterion is "port efficiency". Among the present alternative container ports, alternative port A is selected as the one which has the highest score.
Keywords: Fuzzy AHP, Port selection, TOPSIS Method
JEL Codes: C01, C02, C44, C61, R10, R40

ÖZ

Günümüzde dünya ticaretinin %90'dan fazlası denizyolu taşımacılığı ile yapılmaktadır. Birimleştirilmiş yük olarak adlandırılan konteynır taşımacılığı özellikle 2000'li yıllarda çok yüksek sayılara ulaşmıştır. Son yıllarda konteynır taşımacılığındaki hızlı artışının sebeplerinden birisi de diğer taşıma sistemlerine kolaylıkla entegre olabilmesidir. Globalleşmeyle birlikte deniz taşımacılığındaki artış, beraberinde konteynır taşımacılığında da artış getirmiştir. Bu bağlamda taşımacılık ağını daha verimli hale getirmek konteynır limanlarının seçiminin önemini artırmıştır. Bu çalışmada konteynır taşıyıcıları tarafından konteynır liman seçimini analiz etmek için yapılan uygulamada bulanık analitik hiyerarşi süreci ve TOPSİS yöntemleri birlikte kullanılmıştır. Belirlenen kriterlerin ağırlıklarının hesaplanmasında bulanık AHP yöntemi ve bu ağırlıklar kullanılarak, TOPSİS yöntemi ile alternatiflerin sıralanması gerçekleştirilmiştir.

Kriterleri belirlerken öncelikle literatürde bulunan uluslararası makaleler incelenmiş ve konteynır limanı seçmek adına konteynır taşıyıcı firmalarındaki uzman kişilerin görüşleri alınmıştır. Uygulama olarak Türkiye konteynır taşımacılığının %40'tan fazlasını elleçleyen Ambarlı liman bölgesi seçilmiştir. Böylelikle liman seçimi adına önem taşıyan coğrafi lokasyon ve hinterland ekonomisi ve gümrük gibi kriterler elenerek özellikle liman performansı, altyapısı, fiyat, limanlarda kullanılan bilgi sistemleri ve liman güvenliği gibi kriterleri vurgulaması adına çalışmanın farklılık getirmesi amaçlanmıştır. Sonuçta, en önemli kriter "fiyat" olurken ikinci en yüksek değeri alan kriter "liman verimliliği" olarak belirlenmiştir. Alternatif konteynır limanları arasında yapılan uygulama sonucunda en yüksek değeri alan A alternatif liman olarak seçilmiştir.
Anahtar Kelimeler: Bulanık AHP, Liman seçimi, TOPSİS Yöntemi
JEL Kodları: C01, C02, C44, C61, R10, R40

1. Introduction

At the present time, 90% of world trade is being handled through seaports. This amount of handling ratio reflects the importance of ports in national and especially in international transportation. Container transportation referred as unitized cargo has increased since it can easily be integrated to other transportation modes, gets reduction in cargo handling time and costs, decreases the loss and damages, and presents safe and secure environment for the cargo. As a result, around 17 per cent of word seaborne trade relates specifically to container trade. The potential for container trade to continue increasing its share of dry cargo sector is therefore a real possibility. World container port throughput increased by an estimated 5.9 per cent to 572.8 million TEUs in 2011, its highest level ever (UNCTAD, 2012: 79). Parallel to world container trade Turkey's container port throughput has raised up by 6.63 per cent to 7.192,396 TEU in 2012 (DTGM, 2013: 25).

Being an interface linking sea and inland transportation, a port is an integral platform, serving as a base for logistics, production, information transfer and international trade, and as a springboard for the economic development of the hinterland (Lam and Dai, 2012: 509). Sea port choice is one of important issues in the development of international trade of the countries. Hence selection of the appropriate container port is a complex problem since it has both qualitative and quantitative variables. And it is requires an extensive evaluation process. In order to reduce the total transportation cost, and to increase the service quality, they are very important for shipping carriers to choose an optimal port for callings.

A containership involves a major capital investment, the daily operating costs e.g. the fuel cost, the crew salary, and the depreciation cost. The daily operating costs of a large containership may amount to thousands of US dollars. To select an optimal container port for containership calling could yield great potential of improving their economic performance and costs saving (Chou, 2010: 221). To choose an appropriate container port, a number of both quantitative and qualitative criteria should be considered and evaluated. Therefore port selection can be considered as a multiple criteria decision making (MCDM) problem. Since these criteria may vary in the degree of importance, analytic hierarchy process (AHP), one of the MCDM methods, is employed to identify these criteria, to define the effects of them on each other, to assess their importance and to choose a particular container port.

Recently, the port selection problem has received more attention and some studies have been reported in the literature. These studies are being mentioned in the literature review section of this study. In practice, the current mode of planning is still to a large extent undertaken manually, where considerable professional knowledge and experience is the key driver. This may not be an ideal method when time is of the essence and rapid decision-making is required to respond in competitive business conditions. A better, faster approach should be called for. There are numerous studies on freight transport choice by shippers, but they are mostly focused on modal choice and carrier selection, rather than addressing the more specific question of choice between competing ports. On the other hand, we think that the selection of port choice is an important issue in container transportation. Thus the results from this study can provide some practical information on port choice factors.

Most of the port selection methods mentioned have been developed based on the concepts of exact measurements and crisp evaluation. However most of the selection parameters cannot be given precisely and the evaluation data of the alternative ports suitability for various subjective criteria and the weights of the criteria are usually expressed in linguistic terms by the decision makers. This makes fuzzy logic a more natural approach for this kind of problems.

The remainder of this paper is organized as follows. The literature review is shown in Section 2. In Section 3 the methodology about Fuzzy AHP and TOPSIS are presented, and in Section 4 the proposed FAHP-TOPSIS methodology and the results of an application are given. Finally, some conclusions are presented in Section 5.

2. Literature Review

A wide number of studies have researched the factors determining the choice of ports. There are so many factors that are considered for selection of container ports. Brian (1985: 293) utilized the following 11 factors for port selection; port security, size of port, inland freight rates, port charges, quality of customs handling, free time, congestion, port equipment, number of sailings, proximity of port, possibility of inter-modal links. Tongzon and Sawant (2007: 477) developed a model for port choice of the shipping lines based on a revealed preference approach. The empirical study is based on a survey conducted among major shipping lines operating in Singapore and Malaysia. The findings have shown port charges and wide range of port services to be the only significant factors in their port choice. Chang et al. (2008: 877) applied a survey to shipping companies. As a result of this, six factors as; local cargo volume, terminal handling charge, berth availability, port location, transshipment volume and feeder network were considered relatively important. Tongzon (2009: 186) considered the criteria for port choice from freight forwarders' perspective. Finally, four criteria are found to be important. These are, efficiency, shipping frequency, adequate infrastructure and location, respectively.

One of the most important issues in today's international container transportation is the choice of transshipment port. In this sense, the choice of the transshipment port is the critical decision to make. For reduction on operational and port costs, while choosing the efficient, fast and good service giving port. There also have been many researches made on transshipment port choice. Lirn et al. (2003: 229) used the AHP technique to identify the importance of factors that influence transshipment port selection by Taiwanese ocean container carriers. Four main criteria and sixteen sub-criteria were applied in the study.

In their study regarding the work of an international transshipment port selection, Lirn et al. (2004: 70) have implemented an AHP technique using a survey of consisting 4 main and 12 sub-criteria for both global ocean container operators and port service providers and compared the results. Chou (2007: 435, 441) proposed a new fuzzy multiple criteria decision making method for solving the transshipment container port selection problem under fuzzy environment. Chou utilized six main criteria and eighteen sub-criteria.

Many research methods for port choice have been developed and proposed. Some of these methods are Mathematical Programming Models, Strength Weakness Opportunity and Threat (SWOT) analysis method, Multi Criteria Decision-Making (MCDM) Models, Hybrid Models, and Fuzzy MCDM Models. The commonly used method is AHP model which can integrate the qualitative factors and quantitative data. Ugboma et al. (2006: 251) utilized seven criteria for the port selection decision and identified four ports. The decision problem was structured into a three-level hierarchy using the Analytic Hierarchy Process. The findings suggest that shippers place high emphasis on efficiency, frequency of ship visits and adequate infrastructure, on the other hand quick response to port users' needs was insignificant to them. Chou (2010: 221) proposed an Analytic Hierarchy Process (AHP) model for simulating the behaviors of carriers' port choice and identifying the importance weight of every influential factor influencing carriers' port choices in the multiple-ports region. Onut et al. (2011: 182-187) studied a real world problem of a production firm which has three main warehouses and seven production facilities in the Marmara Region. In this study, an evaluation among seven alternative container ports with six main criteria has been made for a production firm. Chou et al. (2010: 1080) formulated a combined fuzzy multiple criteria decision making and optimization programming model for solving the container transportation demand split problem. Shengrong and Huiyuan (2010: 488) build a combined model of Cluster and TOPSIS analysis according to the characteristics of these two methods, and they use the model to evaluate port competitiveness of ten coastal ports in China. Veldman et al. (2011: 509) used a multinomial logic model for establishing a demand choice function for the Spanish container port services. Tran (2011: 39) sets up a non-linear programming model to deal with port choice decisions. The model has been applied in real data, with cargo flows between the USA and Northern Europe. Lam and Dai (2012: 514) integrate AHP with DSS using AIMMS, an optimization system development tool, in 2012.

3. Methodology

a. Fuzzy analytic hierarchy process

In application, Chang's method is used. Let X = {x1, x2, ..., xn} be an object set, and U = {u1,u2, ..., un} be a goal set. According to the method of Chang's (1992: 352) extent analysis, each object is taken and extent analysis for each goal, gi; is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^{1}, M_{gi}^{2}, \ldots\ldots\ldots M_{gi}^{m}, \qquad i=1,2,\ldots n \qquad (1)$$

Where all the M_{gi}^{j} (j=1, 2,...m) are TFNs. The steps of Chang's extent analysis can be given as in the following:

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} \qquad (2)$$

To obtain $\sum_{j=1}^{m} M_{g_i}^{j}$ perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \qquad (3)$$

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{G_i}^{j}\right]^{-1}$ perform the fuzzy addition operation of, M_{gi}^{j} (j=1,2,..., m) values such that:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_j, \sum_{i=1}^{n} m_j, \sum_{i=1}^{n} u_j \right) \qquad (4)$$

And then compute the inverse of the vector such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \qquad (5)$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left\lfloor \min \mu_{M_1}(x), \mu_{M_2}(y) \right\rfloor \qquad (6)$$

And can be equivalently expressed as follows:

$$V(M_2 \geq M_1) hgt(M_1 \cap M_2) = \mu_{M_2}(d) \begin{cases} 1, & if \quad m_2 \geq m_1 \\ 0, & if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & else \end{cases} \quad (7)$$

Where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}.

To compare M_1 and, M_2 we need both the values of, $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$

Step 3: The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1,2,....., k)$ can be defined by:

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1) ve (M \geq M_2) ve.....ve (M \geq M_k)]$$
$$= \min V(M \geq M_i), \quad i = 1,2,......, k \quad (8)$$

Assume that:

$$k = 1,2,......., n; k \neq i$$
$$d'(A_i) = \min V(S_i \geq S_k), \quad (9)$$

Then the weight vector is given by:

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \quad (10)$$

Where A_i (i = 1, 2, ..., n) are n elements.

Step 4: Via normalization, the normalized weight vectors are:

$$W = (d(A_1), (A_2), ... d(A_n))^T \quad (11)$$

Where W is a non-fuzzy number (Chang, 1992: 352; 1996: 649-651).

b. TOPSIS Methodology

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), firstly introduced by Hwang and Yoon, is a multi-criteria decision making (MCDM) methodology based on the assumption that the best alternative should be as close as possible to the ideal solution and the farthest from the negative-ideal solution (Hwang and Yoon, 1981: 38-41).

The principle of compromise (of TOPSIS) for MCDM is that the chosen solution should have the shortest distance from the positive ideal solution as well as the longest distance from the negative ideal solution.

TOPSIS defines an index called similarity to the positive- ideal solution by combining the proximity to the positive-ideal solution and remoteness from the negative-ideal solution. Then the method chooses an alternative with the maximum similarity to the positive-ideal solution. The method is presented as a series of successive steps:

Step 1: Calculate Normalized Ratings: The vector normalization is used for computing , which is given as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \quad \mathrm{i = 1,...,m \ ve \ j = 1,...,n} \tag{1}$$

Step 2: Calculate Weighted Normalized Ratings: The weighted normalized value is calculated as:

$$v_{ij} = w_j * r_{ij} \quad \mathrm{i = 1,...,m; \ j = 1,...,n} \tag{2}$$

Where w_j is the weight of the j. attribute.

Step 3: Identify positive-ideal and negative-ideal solutions: The A^* and A^- are defined in terms of the weighted normalized values:

$$A^* = \{v_1^*, v_2^*, ..., v_j^*, ..., v_n^*\} = \{(\max v_{ij} | j \in J_1), (\min v_{ij} | j \in J_2) | \mathrm{i = 1,...,m}\}, \tag{3}$$

$$A^- = \{v_1^-, v_2^-, ..., v_j^-, ..., v_n^-\} = \{(\min v_{ij} | j \in J_1), (\max v_{ij} | j \in J_2) | \mathrm{i = 1,...,m}\} \tag{4}$$

Where J_1 is a set of benefit attributes and J_2 is a set of cost attributes.

Step 4: Calculate Separation Measures: The separation between alternatives can be measured by the n-dimensional Euclidean distance. The separation of each alternative from the positive-ideal solution A^*, is then given by:

$$s_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, i = 1,..., m. \tag{5}$$

Similarly, the separation from the negative-ideal solution, A^- is given by

$$s_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \ i = 1,..., m. \tag{6}$$

Step 5: Calculate Similarities to Positive-Ideal Solution:

$$C_i^* = \frac{S_i^-}{\left(S_i^* + S_i^-\right)} \quad i = 1,\ldots,m. \quad 0 \leq C_i^* \leq 1. \tag{7}$$

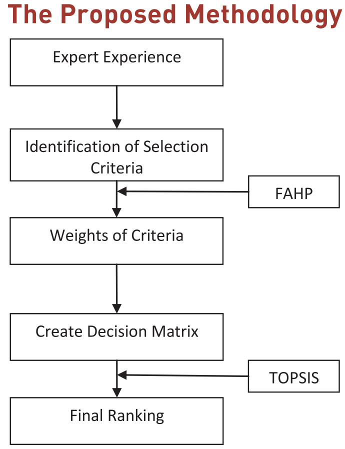
Step 6: Rank Preference Order: Choose an alternative with the maximum C_i^* or rank alternatives in descending order.

4. Case Study: A FAHP-TOPSIS Methodology for Container Port Selection

There are four main criteria and ten sub-criteria to select convenient container port in Ambarlı region. According to 2011 Chamber of Shipping statistics, Ambarlı Port region is the port administrative that does the maximum container handling with the 2,624,711 TEU and 40.23% share. Ambarlı Port administrative is followed by Mersin and Gemlik with the shares %17 and %11.6, respectively (DTGM, 2012: 29).

As alternatives three container ports are chosen, the names of these three ports are kept anonymous and are referred to as A, B, and C according to principle of competition. These three ports are considered as alternatives according to their container handling area, handling capacity, length of berth and draft depth. These ports are located in the same area. Thus, the criteria which are important on behalf of port selection such as geographic location, the hinterland economy, and customs were eliminated. As these ports address the same geographic location and the hinterland economy it is aimed to emphasize the importance of competitiveness. In addition, the criteria like port performance, port infrastructure, cost, information systems used in ports, and port security is selected for evaluation of the model.

Figure 1:
The Proposed Methodology



Firstly criteria for the evaluation are determined according to the DM's experience. When the evaluation criteria are identified then the FAHP method is applied to determine the weights of the criteria. Decision matrix is created. Each alternative is assessed via main and sub-criteria. TOPSIS technique is used to find the final ranking of the alternatives. The proposed methodology is summarized in Figure 1.

For determining the criteria expert opinions in shipping line firms were taken. Also there has been a literature review among the international articles. The four main criteria and the ten sub-criteria retained for the survey of global ocean carriers are given in Table 1.

Table 1:
Main criteria and sub-criteria for port selection

MAIN CRITERIA	SUB-CRITERIA	WEIGHT
C1 Port Physical (PP)	C11: Infrastructure condition (IC)	0.50
	C12: Port facilities and equipment (PFE)	0.50
C2 Port Efficiency (PE)	C21: Port berthing time length (PBTL)	0.24
	C22: Container handling efficiency (CHE)	0.45
	C23: Container yard efficiency (CYE)	0.31
C3 Cost (C)	C31: Port charge (PC)	0.41
	C32: Cargo charge (PC)	0.59
C4 Other conditions (OC)	C41: EDI computer system (EDI)	0.20
	C42: Good reputation related to damage and delays (GRDD)	0.41
	C43: Personnel Quality (PQ)	0.39

Explanations for each criteria and sub-criteria can be presented as follows:

Port Physical (PP); including sub-criteria, Infrastructure Condition (IC), and Port Facilities and Equipment (PFE). Infrastructure Condition includes water access for the basic infrastructure of the port. Depth is the one of the major constraints which prevents the use of larger vessels to which carriers have been turning to recent years. Port Facilities and Equipment: Ports require special handling equipment (for instance reefer container services and hazardous container services) and adequate equipment capacity.

Port Efficiency (PE); including sub-criteria, Port berthing time length (PBTL), Container Handling Efficiency (CHE) Container Yard Efficiency (CYE). Port Berthing Time Length: The longer the length the faster to dock the ship and it can start loading and discharging as soon as possible. Thus, this faster loading and unloading brings the time advantage to ship owners and cargo owners. This time advantage reduces the time spent at port and also reduces the cost. And the most important thing the time advantage causes is the availability of the voyage. This also reduces the ordering costs, and loading the cargo faster for cargo owners. Container Handling Efficiency provides reduced waiting time for a ship at the port without changing the port infrastructure. Especially at ports that does not have an opportunity of enlargement the available capacity need to be used efficiently. For this type of ports this is the only way to increase the efficiency. To improve the container handling efficiency maximum usage of equipment and labor force is required. Container Yard Efficiency: In case of loading or discharging the LCL or FCL cargo at port the loading or discharging process occurs at Container Freight Station (CFS). The size and efficiency of CFS is important in a way that it brings time and cost advantage to import or export customers.

Cost (C); including sub-criteria as; Port Charge (PC) and Cargo Cost (CC). Port Charge includes the costs like water, oil, pilotage service etc. that the global ocean carrier pays other than the charge paid for the occupation of port. Cargo Charge consists of loading or discharging costs, temporary admission, and demurrage are some of cargo related costs. Demurrage refers to charge paid daily per a container after the period normally allowed to load and discharge cargo. The demurrage sometimes causes a loss to the seller as it increases cost of the total freight.

Other Conditions (OC); including as sub-criteria EDI Computer System (EDI), Good Reputation Related to Damage and Delays (GRDD) and Personnel Quality (PQ). EDI Computer System is an improved computer system that speeds up works, makes it easier and faster to monitor the process which means reduce cost. Good Reputation Related to Damage and Delays: Good reputation related to damage and delays; A port which damages will damage and delays transportations will not be chosen by decision makers whatever the port charges are, because delays and damages will damage the business image (Onut et al., 2011: 182-187). Personnel Quality: By personnel quality it is meant more educated workers (for example, cranes and IT-systems operators) are needed. Increased workforce will affect the operation cost and time. As the education level increases the processes at the management level will increase. Furthermore, high labor quality will attract more multinational corporations and shipping companies.

In this study there are four main criteria and ten sub-criteria. Here, three alternative container ports are considered to be evaluated as A, B, and C. The first step in the solution of the problem is comparison of the weight with criteria and alternatives. These comparisons are made according to triangle fuzzy numbers given in Table 2.

Table 2:
Scale for FAHP Preference

Intensity of importance	Definition	Explanation
(1,1,1)	Equal importance	Two activities contribute equally to the objective
(2/3,1,3/2)	Moderate importance	Experience and judgement slightly favour one over another
(3/2,2,5/2)	Strong importance	Experience and judgment strongly favour one over another
(5/2,3,7/2)	Very strong importance	Activity is strongly favoured and its dominance is demonstrated in practice
(7/2,4,9/2)	Absolute importance	Importance of one over another affirmed on the highest possible order

These comparisons can be determined according to experts' opinions or with surveys. In this study, the data is obtained by interviewing approximately 20 percent of the shipping line firms in Turkey. Comparisons and determination of weights are done by;

- Evaluation of four main criteria according to aim,
- Evaluation of sub-criteria for each main criteria,

Table 3:
Fuzzy Evaluation Matrix of Main Criteria

	PP			PE			C			OC		
PP	1	1	1	0.51	0.63	0.82	0.47	0.63	0.87	0.56	0.79	1.14
PE	1.22	1.59	1.97	1	1	1	0.76	1.00	1.31	1.00	1.41	1.94
C	1.14	1.59	2.11	0.76	1.00	1.31	1	1	1	1.31	1.78	2.30
OC	0.80	1.26	1.78	0.52	0.71	1.00	0.44	0.56	0.76	1	1	1

It is obtained;

$$S_{PP} = (2.54, 3.05, 3.83) \otimes (1/21.31, 1/16.95, 1/13.58) = (0.12, 0.18, 0.28)$$

$$S_{PE} = (3.99, 5.00, 6.22) \otimes (1/21.31, 1/16.95, 1/13.58) = (0.19, 0.30, 0.46)$$

$$S_{C} = (4.22, 5.37, 6.71) \otimes (1/21.31, 1/16.95, 1/13.58) = (0.20, 0.32, 0.49)$$

$$S_{OC} = (2.83, 3.53, 4.54) \otimes (1/21.31, 1/16.95, 1/13.58) = (0.13, 0.21, 0.33)$$

Using these vectors,

$V(S_{PP} \geq S_{PE}) = 0.45$, $V(S_{PP} \geq S_C) = 0.38$, $V(S_{PP} \geq S_{OC}) = 0.84$, $V(S_{PE} \geq S_{PP}) = 1$, $V(S_{PE} \geq S_C) = 0.92$, $V(S_{PE} \geq S_{OC}) = 1$, $V(S_C \geq S_{PP}) = 1$, $V(S_C \geq S_{PE}) = 1$, $V(S_C \geq S_{OC}) = 1$, $V(S_{OC} \geq S_{PP}) = 1$, $V(S_{OC} \geq S_{PE}) = 0.63$, $V(S_{OC} \geq S_C) = 0.56$ weight vector is calculated as $W_{PS} = (0.13 \quad 0.32 \quad 0.35 \quad 0.19)^T$.

From the criteria weights obtained by using the AHP method the weighted normalized matrix is computed as in Table 4.

Table 4:
Weighted Normalized Decision Matrix

	IC	PFE	PBTL	CHE	CYE	PC	CC	EDI	GRDD	PQ
PORT A	0.29967	0.35969	0.13204	0.29413	0.21747	0.21492	0.29325	0.14030	0.26852	0.26963
PORT B	0.24355	0.26168	0.18485	0.25406	0.16069	0.25289	0.37184	0.09781	0.22617	0.20569
PORT C	0.31762	0.22836	0.07744	0.22681	0.15161	0.24074	0.35190	0.10367	0.21177	0.19259

The results of TOPSIS analysis using FAHP weights are summarized in Table 5. Based on values, the ranking of the alternatives in descending order are Port A, B and C. According to the last step, the best alternative is selected as Port A with the highest rank of all. The final ranking for all ports are presented in Table5.

Table 5:
Final Ranking

	S*	S^-	C*
A	0.10359	0.20491	**0.664**
B	0.17809	0.11998	0.403
C	0.21944	0.11474	0.343

5. Results

In this study, we proposed an integrated FAHP-TOPSIS methodology for container port selection problem. This model is applied in Ambarlı Port region for three container ports. With the highest value of 0.664 Port A is ranked as the first alternative to be selected. Other two alternatives are ranked as Port B and Port C having the scores of 0.403 and 0.343, respectively. The reason for Port A to be ranked as the first port among other alternatives is this port especially gets high evaluation from the criteria, like port efficiency; on the other side it has low performance on cost. Since these results coincide with the real data this integrated FAHP-TOPSIS methodology is compromising.

The results may be taken into consideration by port managers and government departments of marine transportation. Based on these results, port managers can further develop useful operational strategies and government departments of marine transportation also can make some significant port policies to improve the competence among ports.

In future studies, other decision-making methods can also be included in the methodology to ensure more integrated and/or comparative study. Different alternative methodologies such as ANP, TOPSIS, ELECTRE, Fuzzy ANP, fuzzy TOPSIS and fuzzy ELECTRE can be implicated. Also, another study can be done by using the same selection criteria between ports in different region of Turkey but serve the same hinterland. In addition, by changing a portion of the selection criteria used in this study a selection for appropriate transshipment port can be done. In addition, a different research can be done by creating separate working groups with ship owners, freight forwarders, and cargo owners to understand what they care about most on behalf of port selection.

REFERENCES

Alonsoz, Lorena, Jose Angel Vallejo and Veldman Simme (2011) "Determinants of Container Port Choice in Spain", *Maritime Policy and Management*, 38(5), p.509-522.

Beresford , Anthony K.C., Taih-Cherng Lirn and Helen Thanopoulou (2003) "Transshipment Port Selection and Decision Making Behavior: Analyzing the Taiwanese Case", *International Journal of Logistics*, 6(4), p.229-244.

Beresford , Anthony K.C., Malcolm James Beynon, Taih-Cherng Lirn, and Helen Thanopoulou (2004) "An Application of AHP on Transshipment Port Selection: A Global Perspective", *Maritime Economics & Logistics*, 6(1),p.70-91.

Brian, Slack (1985) "Containerization: Inter-Port Competition And Port Selection", *Maritime Policy and Management*, 12(4), p.293-303.

Chang, Da Yong (1992) "Extent Analysis and Synthetic Decision", in *Optimization Techniques and Applications Vol. 1*, Singapore: World Scientific, p. 352.

Chang, Da Yong (1996) "Applications of the Extent Analysis Method on Fuzzy AHP", *European Journal of Operational Research*, 95(3), p.649-655.

Chang, Young-Tae, Sang-Yoon Lee and Jose L. Tongzon (2008) "Port Selection Factors by Shipping Lines: Different Perspectives Between Trunk Liners and Feeder Service Providers", *Marine Policy*, 32(6), p.877-885.

Chou, Chien-Chang (2007) "A Fuzzy MCDM method for Solving Marine Transshipment Container Port Selection Problems", *Applied Mathematics and Computation*, 186(1), p.435-444.

Chou, Chien-Chang (2010) "AHP Model for the Container Port Choice in the Multiple-Ports Region", *Journal of Marine Science and Technology*, 18(2), p.221-232.

Chou, Chien-Chang, Fu-Tsuan Kuo, Rong-Hua Gou, Chaur-Luh Tsai, Chun-Pong Wong and Ming-Cheng Tsou (2010) "Application of a Combined Fuzzy Multiple Criteria Decision Making and Optimization Programming Model on the Container Transportation Demand Split", *Applied Soft Computing*, 10, p.1080-1086.

Dai, Jing, and Jasmine Siu Lee Lam (2012) "A Decision Support System for Port Selection", *Transportation Planning and Technology*, 35(4), p.509-524.

Deniz Ticareti Genel Müdürlüğü (2013) *Deniz Ticareti İstatistikleri*, Ankara.

Huiyuan, Jiang, Lu Shengrong and Liu Yao (2010) "Port Competitiveness Evaluation Research Based on Combined Model of Cluster and TOPSIS Analysis", paper presented in *International Conference on Environmental Science and Information Application Technology (ESIAT)*, 17-18 July 2010, Wuhan, China.

Hwang, Ching Lai, and Paul Yoon (1981) *Multiple Attribute Decision Making Methods and Applications*, New York: Springer-Verlag.

Onut, Semih, Umut R. Tuzkaya, and Erçin Torun(2011) "Selecting Container Port via a Fuzzy ANP-Based Approach: A Case Study in the Marmara Region Turkey", *Transport Policy*, c(s), p.182-193.

Sawant, Lavina and Jose L. Tongzon (2007) "Port Choice in a Competitive Environment: From the Shipping Lines' Perspective", *Applied Economics*, 39(4-6), p.477-492.

Tongzon, Jose, L. (2009) "Port Choice and Freight Forwarders", *Transportation Research Part E-Logistics and Transportation Review*, 45(1), p.186-195.

Tran, Nguyen Khoi (2011) "Studying Port Selection on Liner Routes: An Approach from Logistics Perspective", *Research In Transportation Economics*, 32(2011), p.39-53.

Ugboma, Chinonye, Ogochukwu Ugboma and Innocent C. Ogwude (2006) "An Analytic Hierarchy Process (AHP) Approach to Port Selection Decisions – Empirical Evidence from Nigerian Ports", *Maritime Economics & Logistics*, 8, p.251-266.

United Nations Conference on Trade and Development (2012) *Review of Maritime Transport*.