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Application of axiomatic design and TOPSIS methodologies under fuzzy environment for proposing competitive strategies on Turkish container ports in maritime transportation network

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ABSTRACT

The strategic positions and geographical advantages of the Turkish container ports in the world transportation network create an excessive demand which seek urgent development strategies for managing ongoing problems in operational and administrative level. This paper proposes a hybrid approach on ensuring the competitiveness requirements for major Turkish container ports by utilizing fuzzy axiomatic design (FAD) and fuzzy technique for order performance by similarity to ideal solution (TOPSIS) methodologies to manage strategic decision-making with incomplete information. The outcomes of the quantitative models are utilized as data input for SWOT analysis that provide additional contributions for identifying the development strategies on container ports. The proposed strategies on Turkish container ports can be originally recommended as guidelines both for port administrations and new enterprises in Turkish maritime industry.

1. Introduction

Acceleration in containerization trends in maritime transportation industry has been monitored by maritime expertise and strategy analysts in recent years. Especially, the changes in cargo flows in major routes and lines within container transportation network (Hsu & Hsieh, 2007) such as trans-Pacific and Asia–Europe reach to extreme rates approximately to 12.1% and 11.2%, respectively, during 2005 (UNCTAD, 2006). Moreover, the estimations on maritime transport with container mode (Knowles, 2006) underline the potential tendencies of maritime enterprises and growing rate of container seaborne traffic (Guy, 2003; Ocean Shipping Consultants, 2003), the size and service speeds (Flynn, 2001; McLellan, 1997; O'Mahony & Porter, 2004; Wijnolst, 2000). Therefore, the rapid growths influence the demand for new building vessels, ports, terminals, and other service related infrastructures (Baird, 2006; O'Mahony, 1998). In this sense, several needs have been appeared about performing and executing continual improvement strategies on container ports which are recognized as the critical integral part of the maritime transportation network (Müller-Jentsch, 2002). The external pressures of shareholders in maritime community such as ship owners, cargo owners, and governmental organizations enforce the port and terminal authorities to execute effective development strategies for managing the competitiveness and continual improvement together in the transportation market.

The ports, channels, and inland waters of Turkey can be recognized as critical nodes in world container transportation network due to its strategic and geographical position. The globalization and liberalization processes in the region and new enterprises on several sector increase the demand and expectations especially from port and terminal authorities (Celik & Er, 2007a). Hence, this paper proposes competitive strategies with strengths, weaknesses, opportunities, and threats (SWOT) analyses on major Turkish container ports by utilizing the outcomes of fuzzy axiomatic design (FAD) and technique for order performance by similarity to ideal solution (TOPSIS) in fuzzy environment correspondingly as multiple-criteria evaluation methodologies. Both of the models are suitable for the problem characteristics due to the several common properties and assumptions such as evaluating under multiple criteria, identifying the acceptable levels and expectations in terms of defining functional requirements (FRs) and ideal solutions, respectively. On the other hand, application of two different methodologies on focusing problem is expected to increase the consistency to a desired level. The initial outcomes of FAD and TOPSIS methodologies are planned to be utilized as input data for the SWOT analysis to support strategy-making process as well. The information flow in the phases of research methodology is illustrated in Fig. 1.

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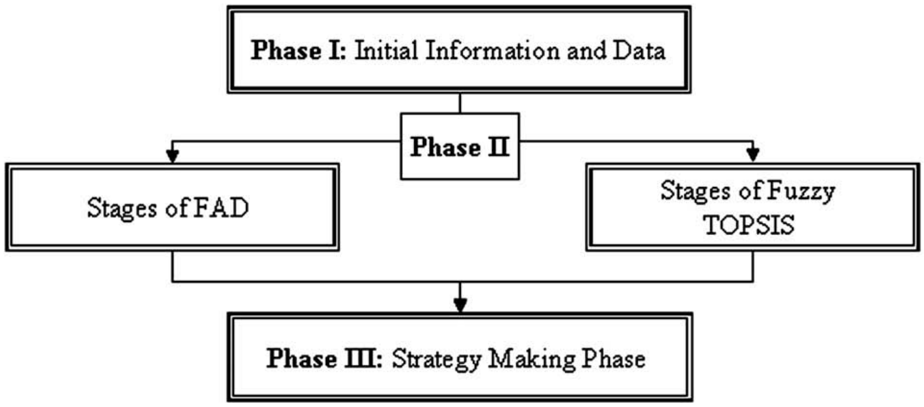

Fig. 1. Fundamental phases of research methodology.

Briefly, the remaining sections of the paper are organized as follows: Section 2 overviews the existing researches on port competitiveness and developments to identify the key assessment factors for this study. Section 3 explores the conditions of major container ports in Turkish maritime industry and structures the internal/external assessment scheme. The methodologies of FAD and fuzzy TOPSIS are performed in Sections 4 and 5, respectively. The outcomes of both models are utilized as input data for the quantified SWOT analysis in Section 6. The conclusion is drawn on expressing the utility and original contributions of this study for maritime society.

2. Literature survey on container port competitiveness in maritime industry

The external pressures of market players in regional and global perspective (Airriess, 2001) enforce the container terminal authorities to adopt new strategies (Chlomoudis & Pallis, 2002a; Chlomoudis & Pallis, 2002b; European Parliament, 1999; Juhel, 2001; Moglia & Sanguineri, 2003; Pallis, 1997, 2003) to satisfy the maritime industry expectations (Heaver, Meersman, & Van De Voorde, 2001). However, the proposed strategies within existing studies are not founded any of the analytical methodologies or strategy-making tools dramatically, instead, the industry-based reports and statistical data are utilized. The aim of this paper is to manage this shortfall by integrating the analytical methodology and strategy-making tool in fuzzy environment into the research methodology as well. As a more systematic approach, Perez-Labajos and Blanco (2004) outlined the links between the contents of future planning of port administrations and strategic actions of international logistics companies as a critical result of his research on commercial sea ports in European Union (EU). Hence, the significance of customer expectations is clearly appeared on development of ports and marine infrastructures. For managing this issue, the proposed approach in this paper takes the customer expectations into account by defining FRs and ideal solutions, respectively. On the other hand, it is one of the initial issues to identify the factors for structuring an evaluation model on port competitiveness. Generally, the existing studies on port competitiveness handle the problem as multiple criteria evaluation. According to Haezendonck and Notteboom (2002), hinterland accessibility, productivity, quality, cargo generating effect, reputation, and reliability are critical factors in enhancing a port's competitiveness while Malchow and Kanafani (2001) cited the oceanic and hinterland distances as the significant characteristics of ports. As other taxonomy, the influencing factors on port's competitiveness are categorized into six groups by Rugman and Verbeke (1993) under extensive framework as follows: factor conditions such as production, labor, infrastructure, etc., demand conditions, related and supporting industries, firm structure and rivalry, chance, and government intervention. Yap and Jasmine (2006) outlined the key factors to identify the competitive dynamics between the major container ports in East Asia. Besides the additional contributions of existing studies on structuring evaluation scheme in this research, this paper also proposes additional items in advance to be able to outline the administrative, infrastructural, and operational factors on port competitiveness as internal and external aspects properly. Therefore, an original multiple-criteria evaluation scheme is proposed in the further sections of this paper.

The second part of the literature survey is based on investigation of the existing analytical model on container port development and performance analysis. The various proposals on investigation of port efficiency with methodological approaches (Roll & Hayuth, 1993; Talley, 1994; Tongzon, 2001; Valentine & Gray, 2001) have seemed in literature. However, it is necessary to develop more complicated approaches for modeling the port competitive requirements in dynamic maritime environment. In this sense, Koh (2001) described a mathematical model which incorporates linear programming and dynamic programming for identifying an optimal container port development plan and evaluating the alternative investments in Korea. As more advance approach, Wang, Song, and Cullinane (2003) developed hybrid model with DEA and free disposal hull (FDH) on measuring container port production efficiency. As another quantitative approach, Song and Yeo (2004) performed a competitive analysis on Chinese container ports by using the traditional analytic hierarchy process (AHP) methodology. The identifiable elements of port competitiveness were defined widely within this research. On the other hand, Min and Park (2005) proposed an inter-temporal data envelopment analysis (DEA) for measuring the operational efficiency of major container terminals in South Korea for satisfying the continuous improvement of container services. In recent years, extended discussions have been continued in maritime literature about specific themes of port competitiveness such as port privatization process, technology integration, efficiency improvement, safety aspects, security procedures, etc. (Clark, Dollar, & Micco, 2004; Cullinane, Ji, & Wang, 2005; Goodchild & Daganzo, 2007; Llacer, 2006; Murty, Liu, Wan, & Linn, 2005; Peris-Mora, Orejas, Subirats, Ibanez, & Alvarez, 2005; Tongzon & Heng, 2005).

The literature survey on existing studies regarding with the ports competitiveness provided invaluable support for structuring of assessment criteria scheme in the further sections of this paper. However, the numbers of considerable shortfalls on philosophy of existing methodological approaches were monitored during literature survey. First of all, managing the competitiveness in the market mainly requires a strategic management perspective. This paper enables this problem with integrating the quantified SWOT methodology into proposed research to make strategy formulation based on strengths and weakness of container ports. It is another common issue to measure customer expectations of the market players to propose short-term or long-run strategic action plans. Various market shareholders such as ship owners, cargo owners, shipping managers, etc. are involved in the systematic evaluation process in this research to get the required feedback from maritime society as well.

3. Structuring multiple criteria evaluation model on Turkish container ports

This section structures a framework for performing multiple criteria assessment on Turkish container ports. The required information on port and terminal facilities in Turkish maritime industry and technical specifications of major container ports are determined as alternatives.

3.1. Overview on Turkish ports

The ports in Turkey can be categorized into three groups: governmental, municipal, and private ports. State Economic Enterprises operate the numbers of 10 government ports some of which are still under privatization programs. The Turkish State Railways operates the ports of HAYDARPASA, DERINCE, BANDIRMA, IZMIR, MERSIN, ISKENDERUN, and SAMSUN, all of which are connected with the railway network. The discussions have still been continued about the prioritization of the government ports. The Turkish Maritime Organization operates TRABZON and KUSADASI ports. The remaining ports are under the control of private enterprises (i.e. AMBARLı, GEMPORT, YıLPORT, BORUSAN, AKPORT, EVYAP). In general, Fig. 2 illustrates the geographical positions of Turkish ports.

3.2. Technical specifications of alternatives

The scope of this research covers the major container ports whose cargo handling capacities exceed 100 thousands TEU (20-ft equivalent units) per annum in last 5 years' statistics. Therefore, the ports of IZMIR, MERSIN, HAYDARPASA, AMBARLı, and GEMPORT are determined as alternatives. The detailed information and technical specifications of alternative ports are represented in this section (Melody Shipping Agency, 2007).

Briefly, the port of IZMIR is located in the western coast by the Aegean Sea and it is very close to the business centers. The port has a vast agricultural and industrial hinterland. It is the main port for the Aegean Region's industry and agriculture and it plays a vital function in the country's export. It is one of the fast growing ports and continuously seeking to improve its facilities. The IZMIR port has 1050 m berth's length with the holding capacity of 7074 TEU in 152,000 m^2 as total area. Container operations at the quays are carried out by 6 rubber-tyred cranes and 4 reach stackers of 40 tons capacity together with 12 container forklifts of up to 42 tons capacity.

On the other hand, the port of MERSIN is located in the eastern part of the Mediterranean coast. It is the main port for the Eastern Mediterranean Region's industry and agriculture. The port's rail link and its easy access to the international highway make it an ideal transit port for trade to the Middle East. Container handling operations at the terminal are carried out by 5 quayside container gantry cranes of 40–60 tons capacity, 3 reach stackers of 40 tons capacity and 5 container forklifts of 10–42 tons capacity. There are two container freight stations of 9000 and 1309 m^2.

The port of HAYDARPASA is located on the Anatolian side of Istanbul Strait. The port serves a hinterland which is the most industrialized area of Turkey.It has a great importance being a gateway to the world as the biggest container port in Marmara Region. The space for container terminal is nearly 100,000 m^2. The holding capacity of the container terminal is 6000 TEU (both full and empty).There are two areas hired outside the port for stacking

Fig. 2. General view on geographical positions of Turkish ports.

the empty containers. A container freight station of 3600 m^2 is available behind the container quay. Another facility available at the port is the provision of reefer facilities for refrigerated containers.

The port of AMBARLI is located 34 km away from Istanbul on the North shores of the Sea of Marmara. It reaches the container handling rates up to 2000 TEU/day. As cargo handling equipment, container cranes (1×104 tons, 1×64 tons), mobile cranes (2×400 tons, 3×60 tons, 2×40 tons), container stacker (2×45 tons), trailers (52×35 tons), and 10 pieces of forklifts are serving in the 375,000 m^2 open storage area.

The port of GEMPORT is located in the southern shore of the Gulf of Gemlik. The port is connected to the hinterland by high standard roads. The port is the natural gateway to the wealthiest and most populated areas of North West of Turkey; moreover, it is strategically positioned on motorway networks that supply the best links to and from the Marmara, Anatolia, and North Eagean regions. GEMPORT has a container capacity of 250,000 TEU with the 98,000 m^2 open storage area and 850 m berth lengths in total.

3.3. Framework of the multiple criteria evaluation model on Turkish container ports

The research facilities and investigations on development of Turkish container ports are so rare in academic literature. The ongoing researches have been performed on port privatization, port infrastructural development, service quality improvement, logistic strategies, etc. by Ertuna (1998), Yetkin (1998), Deveci, Cerit, and Sigura (2001), Tuna (2002), Gunaydın (2006), Zeybek (2006), Cebi and Celik (2007), Celik and Er (2007b). The existing studies on container port competitiveness and the research outcomes on Turkish container ports guide this study to structure a multi-criteria assessment scheme over Turkish container ports which is illustrated in Table 1.

4. Theoretical background of research methodology

In this section, the mathematical concept and theoretical background of the research methodology are introduced. In this case, the theoretical framework of FAD methodology, the fundamentals of fuzzy TOPSIS, a brief overview on quantified SWOT approach, and the application phases of proposed methodology in detail are presented, respectively.

4.1. Theoretical framework of FAD methodology

In this section, the main structure and the theoretical framework of fuzzy axiomatic design (FAD) methodology are presented. FAD methodology is based on conventional axiomatic design (AD) which is put forward by Nam Pyo Suh in 1990. According to Suh (2001), the goal of AD is to establish a scientific basis to improve design activities by providing the designer with a theoretical foundation based on logical and rational thought process and tools.

AD consists of two axioms; one of them is the independence axiom and the other is information axiom. The first axiom, independent axiom, states that the independence of functional requirements (FRs) must always be maintained, where FRs are defined as the minimum set of independent requirements that characterizes the design goals (Kulak, Durmusoğlu, & Kahraman, 2005a, 2005b). Then, the other axiom, information axiom, states that the design having the smallest information content is the best design among those designs that satisfy the independence axiom (Suh, 2001). The information axiom (IA) is a conventional method and facilitates the selection of proper alternative that has minimum information content. In the literature, AD methodology is used to design products, design systems, design software, and make a decision (Albano & Suh, 1994; Babic, 1999; Brunner & Starkl, 2004; Chen, Chen, & Lin, 2001; Durmusoglu & Kulak, 2008; Hirani & Suh, 2005; Jang, Yang, Song, Yeun, & Do, 2002; Kim, Suh, & Kim, 1991; Suh, Cochran, & Paulo, 1998; Thielman, Ge, Wu, & Parme, 2005). Fig. 3 illustrates AD studies.

In the real life problem, sometimes, it is difficult to explain decision variables by conventional ways or expression of decision variables may be ill defined by crisp numbers. Hence, the conventional IA approach may not give good solution for ill defined problem. For this reason, fuzzy axiomatic design is developed by Kulak and Kahraman (2005a) to use AD under fuzzy environment. And also, the method is used as an efficient tool to solve multi-criteria decision making problems (Celik, Kahraman, Cebi, & Er, 2007; Kulak, 2005; Kulak & Kahraman, 2005a, 2005b). In this study, FAD meth-

Table 1
Multiple criteria assessment scheme over Turkish container ports

SWOT aspects and factors		Criterion code	Assessment code	Alternative ports
Internal	Infrastructural characteristics	C_1		IZMIR – MERSIN – HAYDARPASA – AMBARLI – GEMPORT (A1 – A2 – A3 – A4 – A5)
	Size of terminal area for safe operations	C_{11}	I_1	
	Available number of berths	C_{12}	I_2	
	Quantity and capacity of quay cranes	C_{13}	I_3	
	Reliability of terminal equipments and superstructures	C_{14}	I_4	
	Suitability of terminal structure for maneuvering, berthing, and shifting	C_{15}	I_5	
	Opportunities of multimodal transportation integrity	C_{16}	I_6	
	Geographical advantages of terminal location	C_{17}	I_7	
	Service level and quality	C_2		
	Loading and discharging rate	C_{21}	I_8	
	Size and quality of labor force	C_{22}	I_9	
	Duration of transshipment process	C_{23}	I_{10}	
	Quality of customs handling	C_{24}	I_{11}	
	Scope of port service coverage	C_{25}	I_{12}	
	Frequency of continuous dredging facilities	C_{26}	I_{13}	
	Preparations for catastrophic risks during terminal operations	C_{27}	I_{14}	
External	Operational principles and policy	C_3		
	Flexibility in port operations and working hours	C_{31}	E_1	
	Additional service support for maneuvering and berthing of vessels	C_{32}	E_2	
	Level of security precautions and alerts	C_{33}	E_3	
	Privilege contract opportunities to ship-owners and charterers	C_{34}	E_4	
	Payment conditions of port charges and tariffs	C_{35}	E_5	
	Lay-time period	C_{36}	E_6	
	Policies for reducing bureaucracy in administrative issues	C_{37}	E_7	

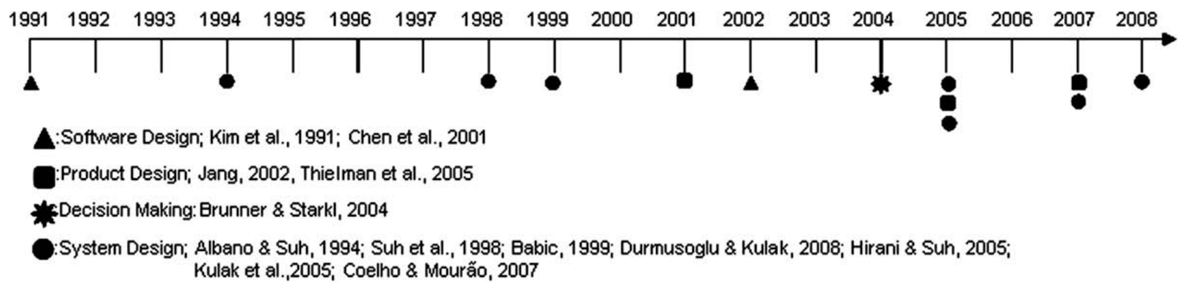

Fig. 3. AD studies.

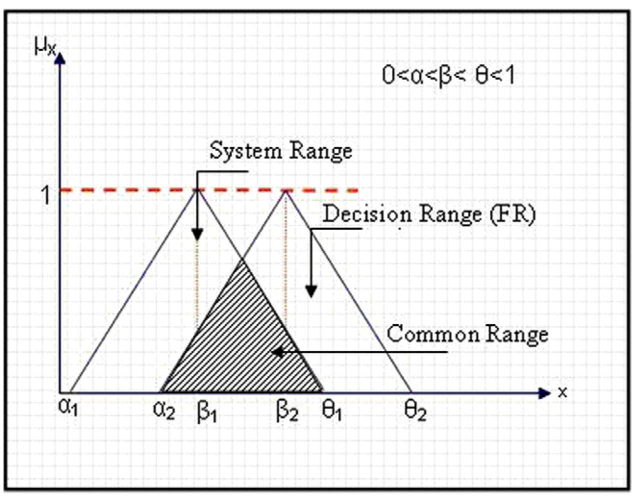

Fig. 4. Design range, system range, and common range.

odology is utilized as a tool for performing multi-criteria evaluation on Turkish container ports.

In the basis of the FAD methodology, functional requirements (FR's) that define decision goals are determined as in AD method. In the FAD, FRs must be defined for each criterion by triangular fuzzy numbers or trapezoidal fuzzy numbers. And then, each alternative is evaluated with respect to functional requirements of each criterion via fuzzy numbers (Fig. 4).

Intersection of the decision range which belongs to criterion and the system range which belongs to alternative called as common area. A ratio called as information content, I, is calculated by using common range and system range (Suh, 2001).

$$I_i = \log\left(\frac{1}{p_i}\right) \tag{1}$$

$$p_i = \frac{\text{common range}}{\text{system range}} \tag{2}$$

$$I_i = \log_2\left(\frac{\text{system range}}{\text{common range}}\right) \tag{3}$$

Eq. (3) lets us to select a suitable alternative for our decision goals. In this study, however, our aim is to evaluate the performance of the alternatives and rank them. Sometimes, FAD does not give permission to rank alternatives if the alternative never satisfies the decision goal, when the value of information content is infinitive or a common range is not occurred. If there are more than one alternative which do not satisfy the decision goal, it is not possible to compare alternatives among them.

4.2. Theoretical framework of fuzzy TOPSIS

It is the first time that TOPSIS method proposed for ranking performance technique based on similarity to ideal solution by Hwang and Yoon (1981). The main goal of the method is to select alternative which has both the shortest distance from the positive ideal reference point, and have the longest distance from the negative ideal reference point. And then, Lai, Liu, and Hwang (1994) extended TOPSIS method to solve a multiple objective decision making problem under fuzzy environment. In their paper, membership functions of fuzzy set theory are used to represent the satisfaction level. After that, TOPSIS Method is extended for group decision-making under fuzzy environment by Chen (2000). Now, a Hierarchical TOPSIS method is presented by Kahraman, Buyukozkan, and Ates (2007). Fuzzy TOPSIS is an effective and also simple method to measure the distance between two triangular fuzzy numbers, when the assessment of alternatives with respect to criteria and the importance weight are suitable to use the linguistic variables instead of numerical values in decision-making process. Up to now, fuzzy TOPSIS method is used to solve decision making and performance evaluation problem under different domains recently (Abo-Sinna, Amer, & Ibrahim, 2008 Abo-Sinna & Abou-El-Enien, 2006; Benítez, Martín, & Román, 2007; Chen, Lin, & Huang, 2006; Kahraman, Buyukozkan, et al., 2007; Kahraman, Cevik, Ates, & Gulbay, 2007; Kuo, Tzeng, & Huang, 2007; Lin & Chang, 2008 Onut & Soner, in press; Wang & Chang, 2007; Wang & Elhag, 2006; Wang & Lee, 2007; Wang, Luo, & Hua, 2007; Yang & Hung, 2007; Yang, Chen, & Hung, 2007).

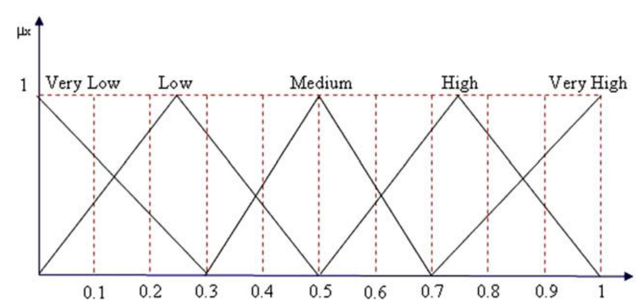

Fig. 5. TFNs for tangible criteria.

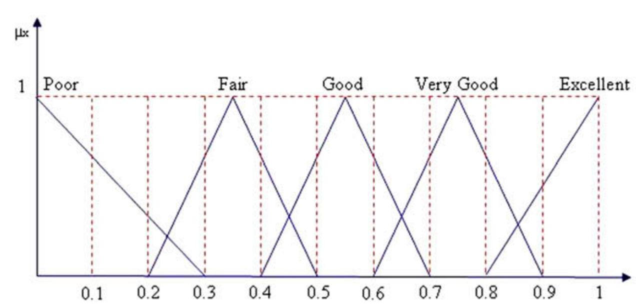

Fig. 6. TFNs for intangible criteria.

4.3. Brief overview on quantified SWOT approach

The quantified SWOT analysis is relatively a new approach in strategy-making. The quantified SWOT approach satisfies the needs of decision-makers in effective strategy formulation in practice (Chang & Huang, 2006). The philosophy of this methodology is based on utilizing of the analytical decision-making models such as AHP, analytical network process (ANP), etc. in quantification process of SWOT analysis. Recently, the wide range of applications have been seemed in literature on various industrial disciplines (Dyson, 2004; Hill & Westbrook, 1997; Kajanus, Kangas, & Kurttila, 2004; Kurttila, Pesonen, Kangas, & Kajanus, 2000; Leskinen, Leskinen, Kurttila, Kangas, & Kajanus, 2006; Pesonen, Kurttila, Kangas, Kajanus, & Heinonen, 2000; Shrestha, Alavalapati, & Kalmbacher,

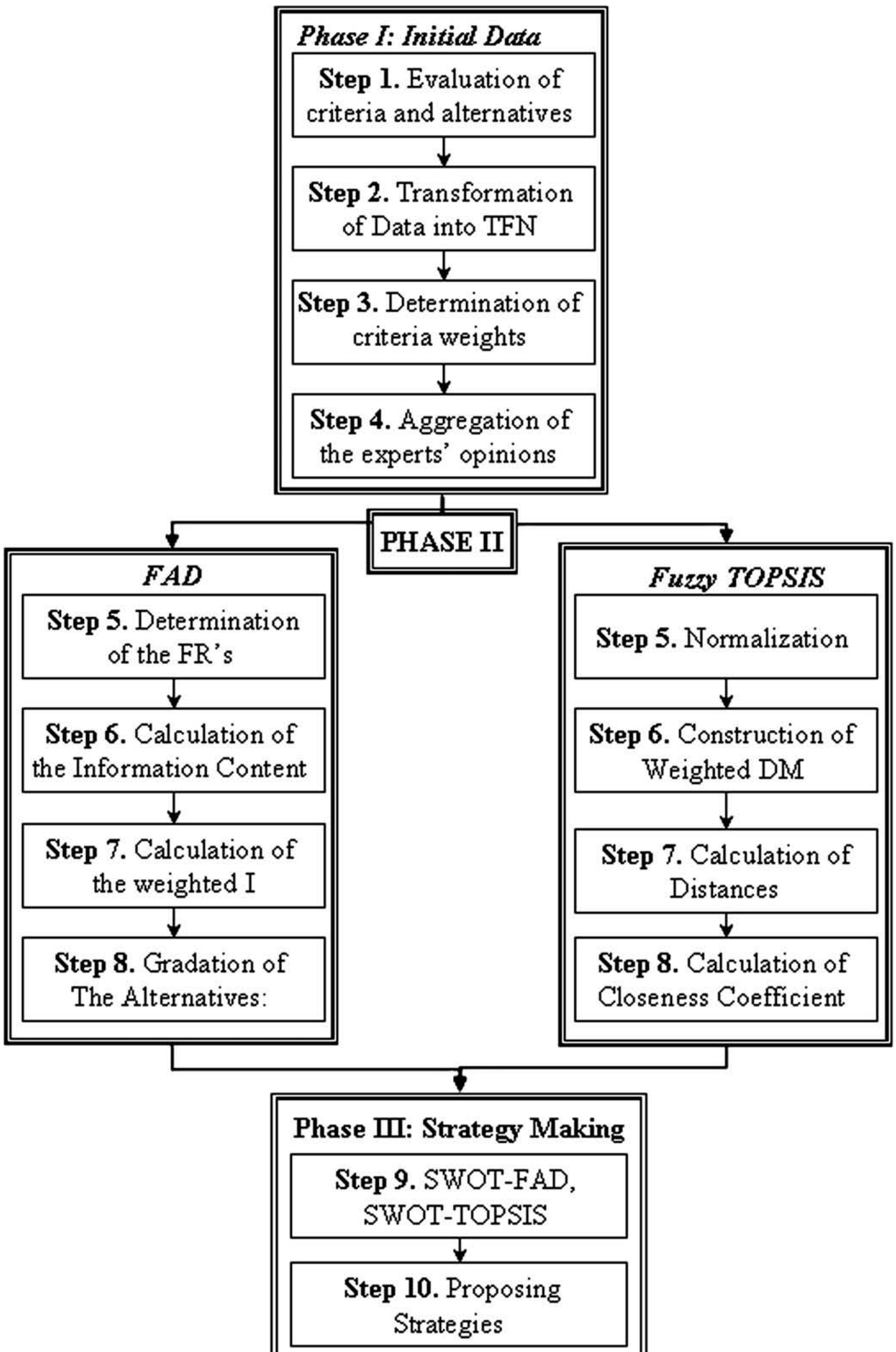

Fig. 7. Detailed structure of the proposed methodology.

2004; Yuksel & Dagdeviren, 2007). In this study, the outcomes of the FAD and TOPSIS methodologies are utilized as input data for the quantified SWOT analysis to propose development strategies over Turkish container ports.

4.4. Information flow for proposed methodology

In this section, the stages of the research methodology and the information flow during problem solution are expressed, respectively.

4.4.1. Phase I: initial information and data

Phase I expresses the required information and initial data for defining the boundaries of case analysis.

Step 1. *Evaluation of criteria and alternatives*: Experts evaluate the alternatives with respect to the defined criteria and thus, the weights of the criteria are determined. Fuzzy decision matrix $\widetilde{D}$ and fuzzy weight matrix $\widetilde{W}$ are as follows:

$$\widetilde{D} = \begin{bmatrix} \tilde{d}_{11} & \tilde{d}_{12} & \cdots & \tilde{d}_{1n} \\ \tilde{d}_{21} & \tilde{d}_{22} & \cdots & \tilde{d}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{d}_{m1} & \tilde{d}_{m2} & \cdots & \tilde{d}_{mn} \end{bmatrix} \tag{4}$$

$$\widetilde{W}^K = [\tilde{w}_1 \quad \tilde{w}_2 \quad \cdots \quad \tilde{w}_n] \quad K = 1, 2, \ldots \tag{5}$$

where K is the number of decision makers.

Step 2. *Transformation of data into triangular fuzzy numbers (TFN)*: There can be crisp or fuzzy numbers or linguistic variables in a decision process. Since linguistic terms are not mathematically operable, they must be first transformed into numbers by using an appropriate method. In this study two different scales are used for tangible and intangible criteria (Figs. 5 and 6).

Step 3. *Determination of criteria weights*: It is possible to determine weights of criteria by pairwise comparisons or any other methodology. In this study, the weights of the criteria are assumed to be equal. Since the experts informed that the importance of all the criteria were almost equal.

Step 4. *Aggregation of the experts' opinions*: The method presented by Chen is used for aggregation of expert opinions in the aggregation state of the presented study (Chen, 1998; Olcer & Odabasi, 2005). The steps of the method are as follows;

1. Calculate the degree of agreement $S_{uv}(W_u, W_v)$ of the opinions between each pair of experts E_u and E_v, where $S_{uv}(W_u, W_v) \in [0, 1]$; $1 \leqslant u \leqslant M$; $1 \leqslant v \leqslant M$ and $u \neq v$. Let A and B be two standardized trapezoidal fuzzy numbers $A = (a_1, a_2, a_3, a_4)$, $B = (b_1, b_2, b_3, b_4)$ where $0 \leqslant a_1 \leqslant a_2 \leqslant a_3 \leqslant a_4 \leqslant 1$ and $0 \leqslant b_1 \leqslant b_2 \leqslant b_3 \leqslant b_4 \leqslant 1$. Then the degree of similarity between the standardized trapezoidal fuzzy numbers A and B can be measured by the similarity function

$$S(A, B) = 1 - \frac{|a_1 - b_1| + |a_2 - b_2| + |a_3 - b_3| + |a_4 - b_4|}{4} \tag{6}$$

where $S(A, B) \in [0, 1]$. The larger the value of $S(A, B)$ the greater the similarity between the standardized trapezoidal fuzzy numbers A and B. The following equation is valid for the degree of similarity.

$$S(A, B) = S(B, A) \tag{7}$$

2. Calculate the average degree of agreement $\mathrm{AA}(E_u)$ of expert E_u $(u = 1, 2, \ldots, M)$

$$\mathrm{AA}(E_u) = \frac{1}{M-1} \sum_{\substack{v=1 \\ v \neq u}}^{M} S(W_u, W_v) \tag{8}$$

3. Calculate the relative degree of agreement $\mathrm{RA}(E_u)$ of expert E_u $(u = 1, 2, \ldots, M)$, where

$$\mathrm{RA}(E_u) = \frac{\mathrm{AA}(E_u)}{\sum_{u=1}^{M} \mathrm{AA}(E_u)} \tag{9}$$

4. Calculate the consensus degree coefficient $\mathrm{CC}(E_u)$ of expert E_u $(u = 1, 2, \ldots, M)$, where

$$\mathrm{CC}(E_u) = \beta \times we_u + (1 - \beta) \times \mathrm{RA}(E_u) \tag{10}$$

where β $(0 \leqslant \beta \leqslant 1)$ is a relaxation factor of the method and we_u is degree of importance of expert (Chen, 1998). It shows the importance of the we_u over $\mathrm{RA}(E_u)$. The consensus degree coefficient of each expert is a good measure for evaluating the relative worthiness of each expert's opinion.

5. Finally, the aggregation result of the fuzzy opinions is

$$W_{AG} = CC(E_1) \otimes R_1 \oplus CC(E_2) \otimes R_2 \oplus \cdots \oplus CC(E_M) \otimes R_M \tag{11}$$

where operators $\otimes$ and $\oplus$ are the fuzzy multiplication operator and the fuzzy addition operator, respectively. The method

Table 2
Expert judgments

	Alternatives	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}
E1																						
1	IZMIR	M	M	L	F	F	G	P	L	M	M	F	P	M	F	F	F	F	F	F	L	F
2	MERSIN	M	M	M	F	F	G	G	H	M	H	F	F	L	F	F	G	F	F	F	M	F
3	HAYDARPASA	L	L	M	F	F	P	F	L	M	L	F	F	L	F	F	F	F	F	F	M	F
4	AMBARLI	M	M	L	G	F	P	G	H	M	M	F	G	L	F	F	F	G	F	G	M	F
5	GEMPORT	M	M	M	G	F	P	G	M	M	M	F	G	L	F	F	F	F	F	F	M	G
E2																						
1	IZMIR	L	VL	L	F	F	F	P	L	M	M	P	P	VL	P	F	F	P	F	F	L	P
2	MERSIN	M	M	M	F	F	F	F	L	M	M	P	P	VL	P	F	F	F	F	F	L	P
3	HAYDARPASA	VL	L	L	F	P	P	P	L	L	L	P	F	VL	P	F	F	P	F	F	L	P
4	AMBARLI	M	M	M	M	F	P	G	H	H	H	P	G	L	F	F	F	G	F	F	M	F
5	GEMPORT	M	M	M	G	F	P	G	M	H	M	P	G	L	F	F	F	G	F	F	M	F
E3																						
1	IZMIR	M	L	L	F	F	F	P	L	M	M	F	F	M	P	F	F	F	F	F	L	P
2	MERSIN	M	M	M	F	F	G	G	M	M	M	F	P	L	P	F	F	G	F	F	M	F
3	HAYDARPASA	L	L	M	F	P	P	F	L	M	L	F	F	VL	P	F	F	F	F	P	L	F
4	AMBARLI	M	M	M	G	G	P	VG	H	H	M	F	G	L	F	F	F	G	F	G	M	F
5	GEMPORT	M	M	M	M	F	P	G	M	M	M	F	G	L	P	F	F	G	F	F	M	G

Table 3
TFNs for expert judgments

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{21}	C_{22}	C_{23}	C_{24}
E1											
1	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
2	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.4, 0.55, 0.7)	(0.5, 0.75, 1.0)	(0.3, 0.5, 0.7)	(0.5, 0.75, 1.0)	(0.2, 0.35, 0.5)
3	(0.0, 0.25, 0.5)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)
4	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.0, 0.25, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.4, 0.55, 0.7)	(0.5, 0.75, 1.0)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
5	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.4, 0.55, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
E2											
1	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.0, 0.0, 0.3)
2	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.0, 0.0, 0.3)
3	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.0, 0.25, 0.5)	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)
4	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.4, 0.55, 0.7)	(0.5, 0.75, 1.0)	(0.5, 0.75, 1.0)	(0.5, 0.75, 1.0)	(0.0, 0.0, 0.3)
5	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.4, 0.55, 0.7)	(0.3, 0.5, 0.7)	(0.5, 0.75, 1.0)	(0.3, 0.5, 0.7)	(0.0, 0.0, 0.3)
E3											
1	(0.3, 0.5, 0.7)	(0.0, 0.25, 0.5)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
2	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.4, 0.55, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
3	(0.0, 0.25, 0.5)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.3, 0.5, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)
4	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.4, 0.55, 0.7)	(0.4, 0.55, 0.7)	(0.0, 0.0, 0.3)	(0.6, 0.75, 0.9)	(0.5, 0.75, 1.0)	(0.5, 0.75, 1.0)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
5	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.4, 0.55, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)

	C_{25}	C_{26}	C_{27}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}
E1										
1	(0.0, 0.0, 0.3)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)
2	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
3	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
4	(0.4, 0.55, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
5	(0.4, 0.55, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.4, 0.55, 0.7)
E2										
1	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)
2	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)
3	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)
4	(0.4, 0.55, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
5	(0.4, 0.55, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
E3										
1	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)
2	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
3	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.0, 0.0, 0.3)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)
4	(0.4, 0.55, 0.7)	(0.0, 0.25, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.3, 0.5, 0.7)	(0.2, 0.35, 0.5)
5	(0.4, 0.55, 0.7)	(0.0, 0.25, 0.5)	(0.0, 0.0, 0.3)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.4, 0.55, 0.7)	(0.2, 0.35, 0.5)	(0.2, 0.35, 0.5)	(0.3, 0.5, 0.7)	(0.4, 0.55, 0.7)

is independent of the type of membership functions being used. Some other membership functions, for example triangular membership functions, are also applicable (Chen, 1998).

4.4.2. Phase II: stages of FAD

Step 5. *Determination of the functional requirements*: The minimum sets of independent requirements that characterize the design goals called Functional Requirements (FRs) are decided. FRs are also determined by more than one expert. Yet, in the literature, FRs do not need to be determined by a group or more than one expert. However, in this study, FRs are determined by an expert group originally.

Step 6. *Calculation of the information content*: For each FR_i the Information Content is calculated by Eq. (3). Following equations are derived from Eq. (3).

For benefit attributes:

$$I = \begin{cases} 0, & \text{if } A_{ici}^{L} > C_i^{U} \\ \text{infinitive}, & \text{if } A_{ici}^{U} < C_i^{L} \\ \log_2 \frac{\text{TFN System Design}}{\text{Common Area}}, & \text{otherwise} \end{cases} \tag{12}$$

For cost attributes;

$$I = \begin{cases} 0, & \text{if } A_{ici}^{U} < C_i^{L} \\ \text{infinitive}, & \text{if } A_{ici}^{L} > C_i^{U} \\ \log_2 \frac{\text{TFN System Design}}{\text{Common Area}}, & \text{otherwise} \end{cases} \tag{13}$$

Table 6
Aggregation decision making for FRs

	National	International	Overall
C_{11}	(0.234, 1.000, 1.000)	(0.366, 1.000, 1.000)	(0.300, 1.000, 1.000)
C_{12}	(0.234, 1.000, 1.000)	(0.435, 1.000, 1.000)	(0.334, 1.000, 1.000)
C_{13}	(0.234, 1.000, 1.000)	(0.566, 1.000, 1.000)	(0.400, 1.000, 1.000)
C_{14}	(0.303, 1.000, 1.000)	(0.400, 1.000, 1.000)	(0.351, 1.000, 1.000)
C_{15}	(0.197, 1.000, 1.000)	(0.466, 1.000, 1.000)	(0.331, 1.000, 1.000)
C_{16}	(0.100, 1.000, 1.000)	(0.400, 1.000, 1.000)	(0.250, 1.000, 1.000)
C_{17}	(0.100, 1.000, 1.000)	(0.466, 1.000, 1.000)	(0.283, 1.000, 1.000)
C_{21}	(0.234, 1.000, 1.000)	(0.566, 1.000, 1.000)	(0.400, 1.000, 1.000)
C_{22}	(0.300, 1.000, 1.000)	(0.500, 1.000, 1.000)	(0.400, 1.000, 1.000)
C_{23}	(0.000, 0.000, 0.700)	(0.000, 0.000, 0.434)	(0.000, 0.000, 0.567)
C_{24}	(0.197, 1.000, 1.000)	(0.400, 1.000, 1.000)	(0.299, 1.000, 1.000)
C_{25}	(0.303, 1.000, 1.000)	(0.197, 1.000, 1.000)	(0.250, 1.000, 1.000)
C_{26}	(0.067, 1.000, 1.000)	(0.565, 1.000, 1.000)	(0.316, 1.000, 1.000)
C_{27}	(0.303, 1.000, 1.000)	(0.400, 1.000, 1.000)	(0.351, 1.000, 1.000)
C_{31}	(0.303, 1.000, 1.000)	(0.400, 1.000, 1.000)	(0.351, 1.000, 1.000)
C_{32}	(0.303, 1.000, 1.000)	(0.600, 1.000, 1.000)	(0.451, 1.000, 1.000)
C_{33}	(0.303, 1.000, 1.000)	(0.466, 1.000, 1.000)	(0.384, 1.000, 1.000)
C_{34}	(0.197, 1.000, 1.000)	(0.303, 1.000, 1.000)	(0.250, 1.000, 1.000)
C_{35}	(0.303, 1.000, 1.000)	(0.197, 1.000, 1.000)	(0.250, 1.000, 1.000)
C_{36}	(0.000, 0.000, 0.566)	(0.000, 0.000, 0.366)	(0.000, 0.000, 0.466)
C_{37}	(0.197, 1.000, 1.000)	(0.600, 1.000, 1.000)	(0.399, 1.000, 1.000)

Table 4
Aggregation decision matrix

	A1	A2	A3	A4	A5
C_{11}	(0.210, 0.425, 0.640)	(0.300, 0.500, 0.700)	(0.000, 0.172, 0.438)	(0.300, 0.500, 0.700)	(0.300, 0.500, 0.700)
C_{12}	(0.092, 0.246, 0.497)	(0.300, 0.500, 0.700)	(0.000, 0.250, 0.500)	(0.300, 0.500, 0.700)	(0.300, 0.500, 0.700)
C_{13}	(0.000, 0.250, 0.500)	(0.300, 0.500, 0.700)	(0.210, 0.425, 0.640)	(0.210, 0.425, 0.640)	(0.300, 0.500, 0.700)
C_{14}	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.367, 0.534, 0.700)	(0.367, 0.534, 0.700)
C_{15}	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.030, 0.105, 0.360)	(0.191, 0.411, 0.561)	(0.100, 0.350, 0.500)
C_{16}	(0.191, 0.411, 0.561)	(0.307, 0.488, 0.638)	(0.000, 0.000, 0.300)	(0.000, 0.000, 0.300)	(0.000, 0.000, 0.300)
C_{17}	(0.000, 0.000, 0.300)	(0.307, 0.488, 0.638)	(0.070, 0.245, 0.440)	(0.462, 0.612, 0.762)	(0.400, 0.550, 0.700)
C_{21}	(0.000, 0.250, 0.500)	(0.269, 0.501, 0.733)	(0.000, 0.250, 0.500)	(0.500, 0.750, 1.000)	(0.300, 0.500, 0.700)
C_{22}	(0.300, 0.500, 0.700)	(0.300, 0.500, 0.700)	(0.210, 0.425, 0.640)	(0.440, 0.675, 0.910)	(0.360, 0.575, 0.790)
C_{23}	(0.300, 0.500, 0.700)	(0.362, 0.578, 0.793)	(0.000, 0.250, 0.500)	(0.360, 0.575, 0.790)	(0.300, 0.500, 0.700)
C_{24}	(0.070, 0.245, 0.440)	(0.069, 0.242, 0.438)	(0.070, 0.245, 0.440)	(0.070, 0.245, 0.440)	(0.070, 0.245, 0.440)
C_{25}	(0.030, 0.105, 0.360)	(0.031, 0.108, 0.361)	(0.100, 0.350, 0.500)	(0.400, 0.550, 0.700)	(0.400, 0.550, 0.700)
C_{26}	(0.220, 0.366, 0.593)	(0.000, 0.170, 0.436)	(0.000, 0.078, 0.362)	(0.000, 0.250, 0.500)	(0.000, 0.250, 0.500)
C_{27}	(0.030, 0.105, 0.360)	(0.031, 0.108, 0.361)	(0.030, 0.105, 0.360)	(0.100, 0.350, 0.500)	(0.070, 0.245, 0.440)
C_{31}	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)
C_{32}	(0.100, 0.350, 0.500)	(0.193, 0.412, 0.562)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)
C_{33}	(0.100, 0.350, 0.500)	(0.193, 0.412, 0.562)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)
C_{34}	(0.070, 0.245, 0.440)	(0.193, 0.412, 0.562)	(0.070, 0.245, 0.440)	(0.400, 0.550, 0.700)	(0.309, 0.489, 0.639)
C_{35}	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)
C_{36}	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.070, 0.245, 0.440)	(0.309, 0.489, 0.639)	(0.100, 0.350, 0.500)
C_{37}	(0.000, 0.250, 0.500)	(0.208, 0.423, 0.638)	(0.090, 0.325, 0.560)	(0.300, 0.500, 0.700)	(0.300, 0.500, 0.700)

Table 5
Expectation levels – acceptable levels for evaluation process for Containership Management Companies

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}
National level																					
SMC – 1	M	M	L	G	F	P	F	M	M	M	F	G	L	G	G	G	G	G	G	L	F
SMC – 2	M	L	M	F	F	F	F	M	H	M	G	F	VL	G	G	F	F	P	F	M	F
SMC – 3	L	M	M	G	G	P	P	L	L	M	F	G	L	F	F	G	G	F	G	L	G
International level																					
Expert – 1	M	H	H	G	G	G	G	H	H	L	G	G	H	G	G	VG	VG	F	F	L	E
Expert – 2	H	H	VH	G	G	G	VG	H	H	VL	G	F	H	G	G	E	G	G	F	VL	G
Expert – 3	M	M	H	G	VG	G	G	VH	H	L	G	F	VH	G	G	G	G	G	G	VL	VG

Table 7
Information contents for national expectations

	C_{11} I_1	C_{12} I_2	C_{13} I_3	C_{14} I_4	C_{15} I_5	C_{16} I_6	C_{17} I_7	C_{21} I_8	C_{22} I_9	C_{23} I_{10}	C_{24} I_{11}	C_{25} I_{12}	C_{26} I_{13}	C_{27} I_{14}	C_{31} E_1	C_{32} E_2	C_{33} E_3	C_{34} E_4	C_{35} E_5	C_{36} E_6	C_{37} E_7
A1	2.573	3.883	3.844	3.121	2.861	0.960	3.170	2.848	1.170	2.700	2.648	6.577	0.837	6.577	3.121	3.121	3.121	2.648	3.121	1.453	2.523
A2	2.204	2.204	2.204	3.121	2.861	0.616	0.616	0.909	1.170	3.213	2.666	6.505	1.939	6.505	3.121	2.214	2.214	1.401	3.121	1.453	1.174
A3	4.635	3.844	2.573	3.121	4.801	3.170	1.809	2.848	1.767	1.437	2.648	3.121	2.338	6.577	3.121	3.121	3.121	2.648	3.121	1.275	1.891
A4	2.204	2.204	2.573	0.864	2.334	3.170	0.307	0.669	0.402	3.193	2.648	0.828	1.657	3.121	3.121	3.121	3.121	0.569	3.121	2.982	0.770
A5	2.204	2.204	2.204	0.864	2.861	3.170	0.429	1.683	0.754	2.700	2.648	0.828	1.657	4.129	3.121	3.121	3.121	0.837	3.121	1.453	0.770

Table 8
Information contents for international expectations

	C_{11} I_1	C_{12} I_2	C_{13} I_3	C_{14} I_4	C_{15} I_5	C_{16} I_6	C_{17} I_7	C_{21} I_8	C_{22} I_9	C_{23} I_{10}	C_{24} I_{11}	C_{25} I_{12}	C_{26} I_{13}	C_{27} I_{14}	C_{31} E_1	C_{32} E_2	C_{33} E_3	C_{34} E_4	C_{35} E_5	C_{36} E_6	C_{37} E_7
A1	3.499	7.752	Inf.	5.714	8.694	4.823	Inf.	Inf.	4.129	5.351	7.191	3.099	8.166	Inf.	5.714	Inf.	8.911	5.292	2.861	2.607	Inf.
A2	2.902	3.445	5.142	5.714	8.694	3.695	4.500	4.578	4.129	7.186	8.030	3.072	Inf.	Inf.	5.714	Inf.	5.929	3.377	2.861	2.607	8.463
A3	7.450	7.592	6.899	5.714	Inf.	Inf.	Inf.	Inf.	5.189	2.069	7.191	1.16	Inf.	Inf.	5.714	Inf.	8.911	5.292	2.861	2.112	Inf.
A4	2.902	3.445	6.899	2.575	5.736	Inf.	2.933	1.864	2.128	7.098	7.191	0.089	Inf.	4.013	5.714	Inf.	8.911	2.287	2.861	6.87	5.666
A5	2.902	3.445	5.142	2.575	8.694	Inf.	3.607	5.146	3.088	5.351	7.191	0.089	Inf.	6.741	5.714	Inf.	8.911	2.628	2.861	2.607	5.666

Table 9
Distribution of information contents over attributes

	C_{11} I_1	C_{12} I_2	C_{13} I_3	C_{14} I_4	C_{15} I_5	C_{16} I_6	C_{17} I_7	C_{21} I_8	C_{22} I_9	C_{23} I_{10}	C_{24} I_{11}	C_{25} I_{12}	C_{26} I_{13}	C_{27} I_{14}	C_{31} E_1	C_{32} E_2	C_{33} E_3	C_{34} E_4	C_{35} E_5	C_{36} E_6	C_{37} E_7
A1	2.985	5.118	6.409	4.655	4.327	3.184	11.757	6.413	3.152	3.363	4.448	4.160	2.016	11.230	4.655	7.907	5.552	4.432	3.333	1.904	6.141
A2	2.492	2.693	3.152	4.655	4.327	2.595	2.759	2.909	3.152	4.430	4.483	4.119	4.483	10.787	4.655	5.542	4.313	2.928	3.333	1.904	3.591
A3	5.669	5.055	3.823	4.655	9.587	8.678	5.173	6.413	3.823	1.607	4.448	1.632	7.269	11.230	4.655	7.907	5.552	4.432	3.333	1.531	4.770
A4	2.492	2.693	3.823	2.228	3.441	8.678	2.230	1.344	1.703	4.398	4.448	0.199	3.233	2.953	4.655	7.907	5.552	2.137	3.333	4.195	2.903
A5	2.492	2.693	3.152	2.228	4.327	8.678	2.467	3.156	2.442	3.363	4.448	0.199	3.233	4.519	4.655	7.907	5.552	2.345	3.333	1.904	2.903

Table 10
Ranking for national expectations

	$\sum I$	Ranking
A1	62.877	4
A2	51.431	3
A3	62.987	5
A4	42.979	1
A5	43.879	2

Table 11
Ranking for overall expectations

	$\sum I$	Ranking
A1	107.141	4
A2	83.302	3
A3	111.242	5
A4	74.545	1
A5	75.996	2

where A^L_{ici} and A^U_{ici} are the lower and upper values of the alternative A_i under the criterion C_i, respectively, and C^L_i and C^U_i are the lower and upper values of FR_i.

Step 7. *Calculation of the weighted information content*: Weighted information content is calculated by Eq. (14) (Kulak & Kahraman, 2005b).

$$I_{ij} = \begin{Bmatrix} \left[\log_2\left(\frac{1}{p_{ij}}\right)\right]^{\frac{1}{w_j}}, & 0 \leqslant I_{ij} < 1 \\ \left[\log_2\left(\frac{1}{p_{ij}}\right)\right]^{\frac{1}{w_j}}, & I_{ij} > 1 \\ w_j, & I_{ij=1} \end{Bmatrix} \tag{14}$$

Step 8. *Ranking of the alternatives*: The alternative which has the minimum Information Content Value is the best alternative. Hence, the alternatives are ranked from best to worst.

4.4.3. Phase II: stages of fuzzy TOPSIS

Step 5. *Normalization*: In this step, evaluation values are normalized because of two different scales. To avoid the complicated normalization formula used in classical TOPSIS, the linear scale transformation is used to obtain normalized fuzzy decision matrix denoted by $\widetilde{R}$

$$\widetilde{R} = [\tilde{r}_{ij}]_{mxn} \Rightarrow \tilde{r}_{ij} = \left(\frac{a_{ij}}{c^*_j}, \frac{b_{ij}}{c^*_j}, \frac{c_{ij}}{c^*_j}\right) \tag{15}$$

where $c^*_j = \max_i c_{ij}$ if $j\varepsilon$ benefit criteria. If the criterion is cost, the following equation is used

$$\tilde{r}_{ij} = \left(\frac{a^-_j}{c_{ij}}, \frac{a^-_j}{b_{ij}}, \frac{a^-_j}{a_{ij}}\right) \quad \text{where } a^-_j = \min_i a_{ij} \tag{16}$$

Step 6. *Construction of weighted decision matrix*: The weighted normalized fuzzy decision matrix is constructed

$$\begin{aligned} &\widetilde{V} = [\tilde{v}_{ij}]_{mxn} \quad i = 1, 2, \ldots, m \;\; j = 1, 2, \ldots, n \\ &\tilde{v}_{ij} = \tilde{r}_{ij} \cdot \tilde{w}_j \end{aligned} \tag{17}$$

Step 7. *Calculation of distances*: Then, the distances (d^*_i, d^-_i) of each alternative from fuzzy positive-ideal solution (FPIS, A^*) and fuzzy negative-ideal solution (FNIS, A^-) are calculated, respectively

Table 12
Normalization matrix

	A1	A2	A3	A4	A5
C_{11}	(0.300, 0.607, 0.914)	(0.429, 0.714, 1.000)	(0.000, 0.246, 0.625)	(0.429, 0.714, 1.000)	(0.429, 0.714, 1.000)
C_{12}	(0.132, 0.351, 0.709)	(0.429, 0.714, 1.000)	(0.000, 0.357, 0.714)	(0.429, 0.714, 1.000)	(0.429, 0.714, 1.000)
C_{13}	(0.000, 0.357, 0.714)	(0.429, 0.714, 1.000)	(0.300, 0.607, 0.914)	(0.300, 0.607, 0.914)	(0.429, 0.714, 1.000)
C_{14}	(0.143, 0.500, 0.714)	(0.143, 0.500, 0.714)	(0.143, 0.500, 0.714)	(0.525, 0.762, 1.000)	(0.525, 0.762, 1.000)
C_{15}	(0.178, 0.624, 0.891)	(0.178, 0.624, 0.891)	(0.053, 0.187, 0.642)	(0.341, 0.732, 1.000)	(0.178, 0.624, 0.891)
C_{16}	(0.300, 0.644, 0.879)	(0.480, 0.764, 1.000)	(0.000, 0.000, 0.470)	(0.000, 0.000, 0.470)	(0.000, 0.000, 0.470)
C_{17}	(0.000, 0.000, 0.394)	(0.403, 0.640, 0.837)	(0.092, 0.322, 0.578)	(0.606, 0.803, 1.000)	(0.525, 0.722, 0.919)
C_{21}	(0.000, 0.250, 0.500)	(0.269, 0.501, 0.733)	(0.000, 0.250, 0.500)	(0.500, 0.750, 1.000)	(0.300, 0.500, 0.700)
C_{22}	(0.330, 0.549, 0.769)	(0.330, 0.549, 0.769)	(0.231, 0.467, 0.703)	(0.484, 0.742, 1.000)	(0.396, 0.632, 0.868)
C_{23}	(0.300, 0.500, 0.700)	(0.362, 0.578, 0.793)	(0.000, 0.250, 0.500)	(0.360, 0.575, 0.790)	(0.300, 0.500, 0.700)
C_{24}	(0.159, 0.557, 1.000)	(0.157, 0.551, 0.996)	(0.159, 0.557, 1.000)	(0.159, 0.557, 1.000)	(0.159, 0.557, 1.000)
C_{25}	(0.043, 0.150, 0.514)	(0.044, 0.154, 0.516)	(0.143, 0.500, 0.714)	(0.571, 0.786, 1.000)	(0.571, 0.786, 1.000)
C_{26}	(0.371, 0.618, 1.000)	(0.000, 0.287, 0.736)	(0.000, 0.131, 0.611)	(0.000, 0.422, 0.843)	(0.000, 0.422, 0.843)
C_{27}	(0.060, 0.210, 0.720)	(0.061, 0.215, 0.723)	(0.060, 0.210, 0.720)	(0.200, 0.700, 1.000)	(0.140, 0.490, 0.880)
C_{31}	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)
C_{32}	(0.178, 0.623, 0.889)	(0.344, 0.733, 1.000)	(0.178, 0.623, 0.889)	(0.178, 0.623, 0.889)	(0.178, 0.623, 0.889)
C_{33}	(0.178, 0.623, 0.889)	(0.344, 0.733, 1.000)	(0.178, 0.623, 0.889)	(0.178, 0.623, 0.889)	(0.178, 0.623, 0.889)
C_{34}	(0.100, 0.350, 0.629)	(0.276, 0.589, 0.803)	(0.100, 0.350, 0.629)	(0.571, 0.786, 1.000)	(0.441, 0.699, 0.913)
C_{35}	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)	(0.200, 0.700, 1.000)
C_{36}	(0.100, 0.350, 0.500)	(0.100, 0.350, 0.500)	(0.070, 0.245, 0.440)	(0.309, 0.489, 0.639)	(0.100, 0.350, 0.500)
C_{37}	(0.000, 0.357, 0.714)	(0.297, 0.604, 0.912)	(0.129, 0.464, 0.800)	(0.429, 0.714, 1.000)	(0.429, 0.714, 1.000)

Table 13
Distances to FPIS

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}
A1	0.466	0.648	0.706	0.596	0.526	0.459	0.888	0.777	0.485	0.526	0.549	0.790	0.425	0.727	0.493	0.526	0.526	0.676	0.493	0.357	0.706
A2	0.369	0.369	0.369	0.596	0.526	0.329	0.413	0.533	0.485	0.604	0.551	0.788	0.725	0.724	0.493	0.409	0.409	0.494	0.493	0.357	0.469
A3	0.755	0.706	0.466	0.596	0.749	0.872	0.698	0.777	0.567	0.323	0.549	0.596	0.797	0.727	0.493	0.526	0.526	0.676	0.493	0.294	0.602
A4	0.369	0.369	0.466	0.307	0.411	0.872	0.254	0.323	0.333	0.601	0.549	0.277	0.673	0.493	0.493	0.526	0.526	0.277	0.493	0.498	0.369
A5	0.369	0.369	0.369	0.307	0.526	0.872	0.321	0.526	0.416	0.526	0.549	0.277	0.673	0.581	0.493	0.526	0.526	0.370	0.493	0.357	0.369

Table 14
Distances to FNIS

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}
A1	0.657	0.463	0.461	0.510	0.636	0.652	0.227	0.323	0.578	0.526	0.667	0.310	0.712	0.434	0.714	0.635	0.635	0.419	0.714	0.703	0.461
A2	0.751	0.751	0.751	0.510	0.636	0.778	0.651	0.536	0.578	0.457	0.663	0.312	0.456	0.437	0.714	0.743	0.743	0.597	0.714	0.703	0.654
A3	0.388	0.461	0.657	0.510	0.387	0.271	0.385	0.323	0.505	0.777	0.667	0.510	0.361	0.434	0.714	0.635	0.635	0.419	0.714	0.763	0.539
A4	0.751	0.751	0.657	0.787	0.742	0.271	0.819	0.777	0.771	0.460	0.667	0.805	0.544	0.714	0.714	0.635	0.635	0.805	0.714	0.538	0.751
A5	0.751	0.751	0.751	0.787	0.636	0.271	0.740	0.526	0.661	0.526	0.667	0.805	0.544	0.587	0.714	0.635	0.635	0.711	0.714	0.703	0.751

Table 15
Closeness coefficients

	CC	Ranking
A1	0.481	4
A2	0.556	3
A3	0.464	5
A4	0.602	1
A5	0.586	2

$$A^* = (v_1^*, v_2^*, \ldots, v_n^*) \quad \text{where } v_j^* = (1,1,1) \tag{18}$$

$$A^- = (v_1^-, v_2^-, \ldots, v_n^-) \quad \text{where } v_j^- = (0,0,0)$$

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*) \quad i = 1,2,\ldots,m$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \quad i = 1,2,\ldots,m \tag{19}$$

Step 8. *Calculation of* closeness coefficient: A closeness coefficient (CC_i) is calculated by using d_i^* and d_i^-

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad i = 1,2,\ldots,m \tag{20}$$

Obviously, if an alternative A_i is closer to the FPIS (A^*) and farther from FNIS (A^-), CC_i approaches to 1. Hence, the alternatives are ranked via CC_i. The alternative has the biggest CC_i value is the best in all for our goal.

4.4.4. Phase IV: strategy-making phase

Step 9. *Application of SWOT–FAD and SWOT–TOPSIS*: In this step, the SWOT analysis is performed on both the outcomes of FAD and TOPSIS methodologies.

Step 10. *Proposing competitive strategies* on alternatives: The strategy proposals are expressed based on the information contents in FAD methodology and closeness coefficient in TOPSIS methodology correspondingly. The selection of proposed strategies towards internal/external assessment factors are determined by considering the intersecting points of graphical illustrations on SWOT–FAD and SWOT–TOPSIS methodologies.

Up to now, main phases including all steps of the methodology have been given; and now, the phases of the research methodology are given by the flow diagram in Fig. 7. The figure illustrates all phases of the research methodology so as to make it easy to be conceived by readers. Hereafter, the real case application of the research methodology and tables of results will be presented.

5. Results and findings of fuzzy TOPSIS methodology

5.1. The outcomes of phase I

Step 1. *Evaluation of criteria and alternatives*: During analysis process, a market-based survey is performed to get the considerations of maritime professionals. In this case, it is contacted with the three expert groups: technical, commercial, and operational managers from container shipping firms. Table 2 illustrates the expert judgments on alternatives.

Step 2. *Transformation of data* into *triangular fuzzy numbers (TFN)*: Because of linguistic variables in a decision process as it is seen in Table 2, values in Figs. 4 and 5 are used to transform linguistic terms into fuzzy triangular numbers. Table 3 includes TFNs for expert judgments.

Step 3. *Determination of criteria weights*: In this study, the weights of the criteria and experts are assumed to be equal to investigate the value of each alternative under related criterion.

Table 16
Closeness coefficients under each criterion

	C_{11} I_1	C_{12} I_2	C_{13} I_3	C_{14} I_4	C_{15} I_5	C_{16} I_6	C_{17} I_7	C_{21} I_8	C_{22} I_9	C_{23} I_{10}	C_{24} I_{11}	C_{25} I_{12}	C_{26} I_{13}	C_{27} I_{14}	C_{31} E_1	C_{32} E_2	C_{33} E_3	C_{34} E_4	C_{35} E_5	C_{36} E_6	C_{37} E_7
A1	0.585	0.417	0.395	0.461	0.548	0.587	0.204	0.293	0.544	0.500	0.549	0.282	0.626	0.374	0.591	0.547	0.547	0.383	0.591	0.663	0.395
A2	0.671	0.671	0.671	0.461	0.548	0.702	0.612	0.501	0.544	0.431	0.546	0.284	0.386	0.376	0.591	0.645	0.645	0.547	0.591	0.663	0.583
A3	0.340	0.395	0.585	0.461	0.341	0.237	0.356	0.293	0.471	0.707	0.549	0.461	0.312	0.374	0.591	0.547	0.547	0.383	0.591	0.722	0.473
A4	0.671	0.671	0.585	0.719	0.644	0.237	0.763	0.707	0.698	0.433	0.549	0.744	0.447	0.591	0.591	0.547	0.547	0.744	0.591	0.519	0.671
A5	0.671	0.671	0.671	0.719	0.548	0.237	0.697	0.500	0.614	0.500	0.549	0.744	0.447	0.502	0.591	0.547	0.547	0.658	0.591	0.663	0.671

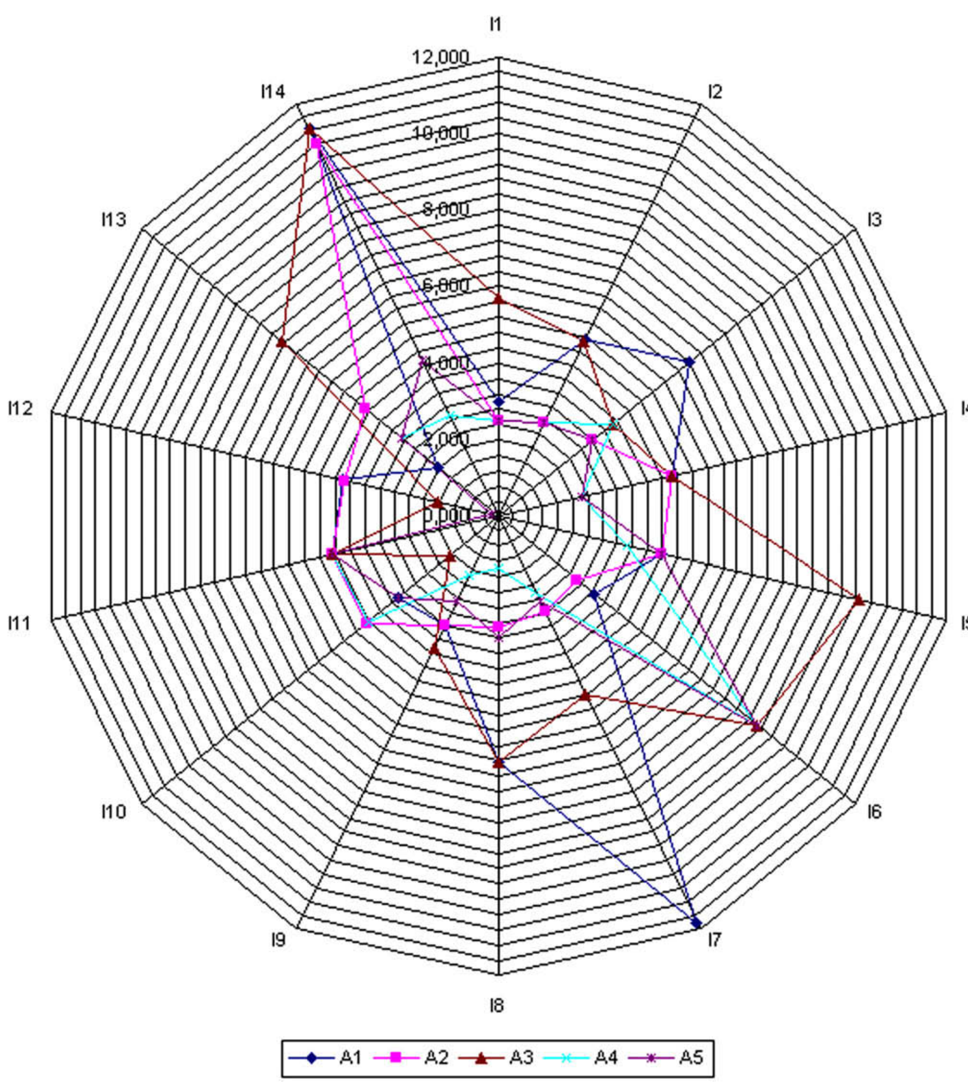

Fig. 8. Illustration of SWOT–FAD analysis over internal assessment criterion.

Step 4. *Aggregation of the experts' opinions*: The aggregation decision matrix is given in Table 4.

5.2. The outcomes of phase II: FAD

Step 5. *Determination of the functional requirements*: Functional requirements (FRs) are decided by more than one expert (see Tables 5 and 6).

Step 6. *Calculation of the information content*: The information contents of alternatives with respect to related FRs are calculated by Eq. (3) and they are presented for national and international expectation in Tables 7 and 8, respectively. Table 9 gives overall information content which will be used in phase III.

Step 7. *Calculation of the weighted information content*: Weighted information content is not calculated because all criteria have the same weight.

Step 8. *Ranking of the alternatives*: The alternative which has the minimum information content value is the best alternative. So the alternatives are ranked from best to worst in Tables 10 and 11, respectively. According to the results, the port of AMBARLI is selected as the most suitable alternatives for ship owners and cargo owners in total performance.

5.3. The outcomes of phase II: fuzzy TOPSIS

Step 5. *Normalization*: TOPSIS Method needs normalization process owing to the fact that two type scales are used in the evaluation procedure of alternatives. Normalization matrix is given in Table 12.

Step 6. *Construction of weighted decision matrix*: As the comparative evaluation is performed based on each criterion, it is not necessary to assign priority weights on attributes.

Step 7. *Calculation of distances*: After performing the proposed stages in research methodology, the distances of each alternative from FPIS and FNIS with respect to relevant criterion are calculated. Tables 13 and 14 illustrate the distances to FPIS and FNIS, respectively.

Step 8. *Calculation of closeness coefficient*: In this stage, two type of closeness coefficients are calculated. Firstly, we calculate closeness coefficient classically in TOPSIS method by using Eq. (19); and then, we rank the alternatives. After that, we compute closeness coefficient belonging to each criterion for each alternative by using the same formula with a view to use in strategy making phase. Closeness coefficient and closeness coefficient for each criterion are given Tables 15 and 16, respectively.

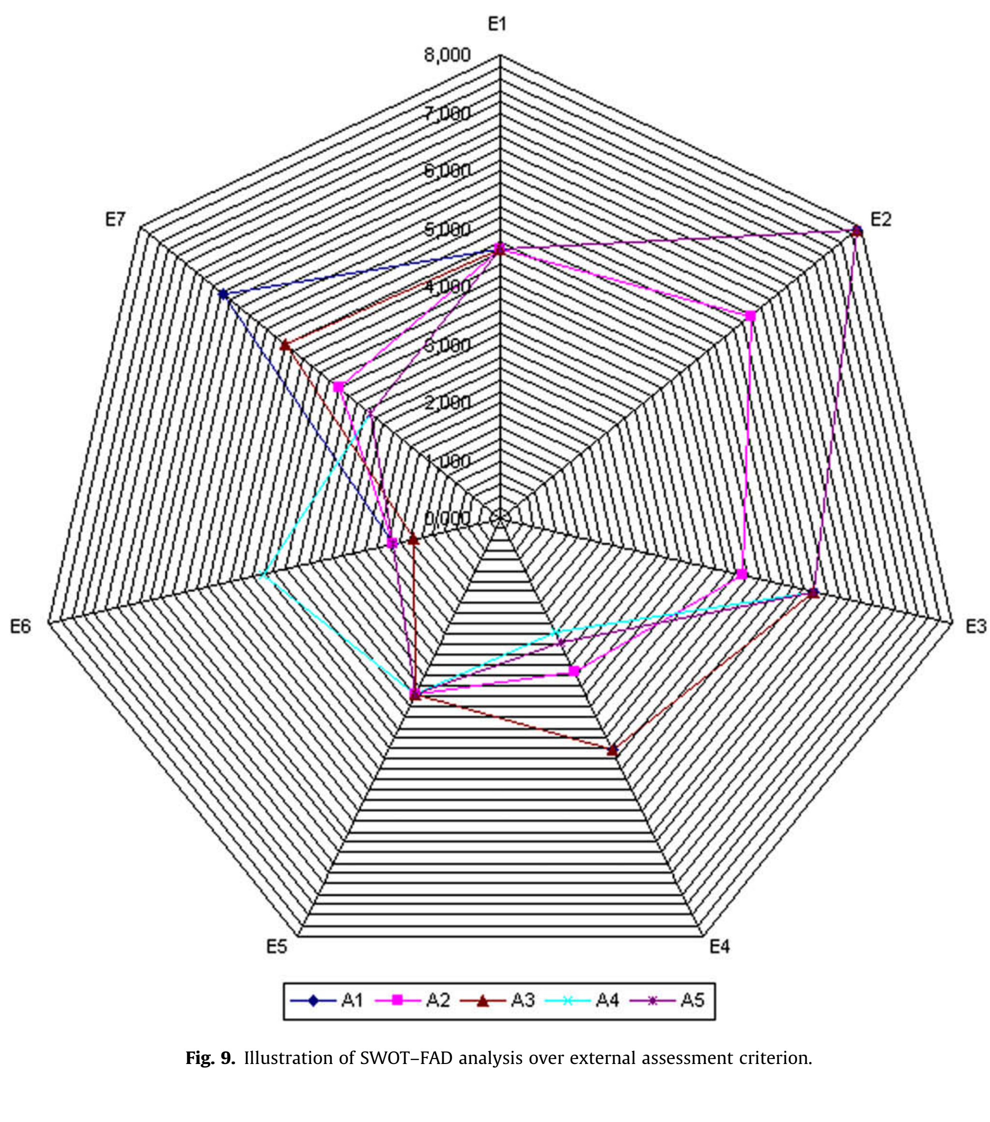

Fig. 9. Illustration of SWOT–FAD analysis over external assessment criterion.

5.4. Strategy making on Turkish container ports

Step 9. Application results of *SWOT–FAD and SWOT–TOPSIS*: Finally, this section illustrates the results graphically to make a comparative evaluation on alternatives with respect to internal/external assessment criterion. Figs. 8–11 illustrate the graphical illustrations of SWOT–FAD analysis over internal assessment criterion, SWOT–FAD analysis over external assessment criterion, TOPSIS–FAD analysis over internal assessment criterion, and TOPSIS–FAD analysis over external assessment criterion, respectively.

Step 10. Proposing competitive strategies on alternatives: According the graphical illustrations, the following strategies can be proposed on developing competitive strategies over Turkish container ports:

1. Flexibility in port operations and payment conditions of port charges and tariffs can be addressed as common external threads for all of the port alternatives which require executing urgent solution plans in practice.
2. The port of IZMIR requires urgent investments on increasing quantity and capacity of quay cranes, shifting of terminal location and due to the closeness to city centers and traffic density, enhancing the quality of custom service and scope of coverage, preparing an effective execution plan towards catastrophic risks for managing internal weaknesses. On the other hand, availability of dragging facilities in short periods can be recognized as internal strength for this port. Moreover, the proposed results illustrate that high level of bureaucracy, security level, shortage of additional service support for berthing and privilege contact options are the potential external threads for the port of IZMIR.
3. The port of MERSIN has shortfalls in reliability of superstructures, duration of transshipment process, quality of custom handlings as internal weaknesses. Availability of additional service support for maneuvering and berthing of vessels can be recognized as possible challenges for the port of MERSIN in competitive transportation market. Moreover, apart form the common threads on Turkish container ports (E1, E5), there is no additional external threads that have been monitored for this alternative.
4. The port of HAYDARPASA has a very critical problem with the size of terminal area for safe operations. Moreover, the port also has internal weakness about equipment reliability, design specifications of terminal structure for maneuvering operations, opportunities for multimodal transportation integrity,

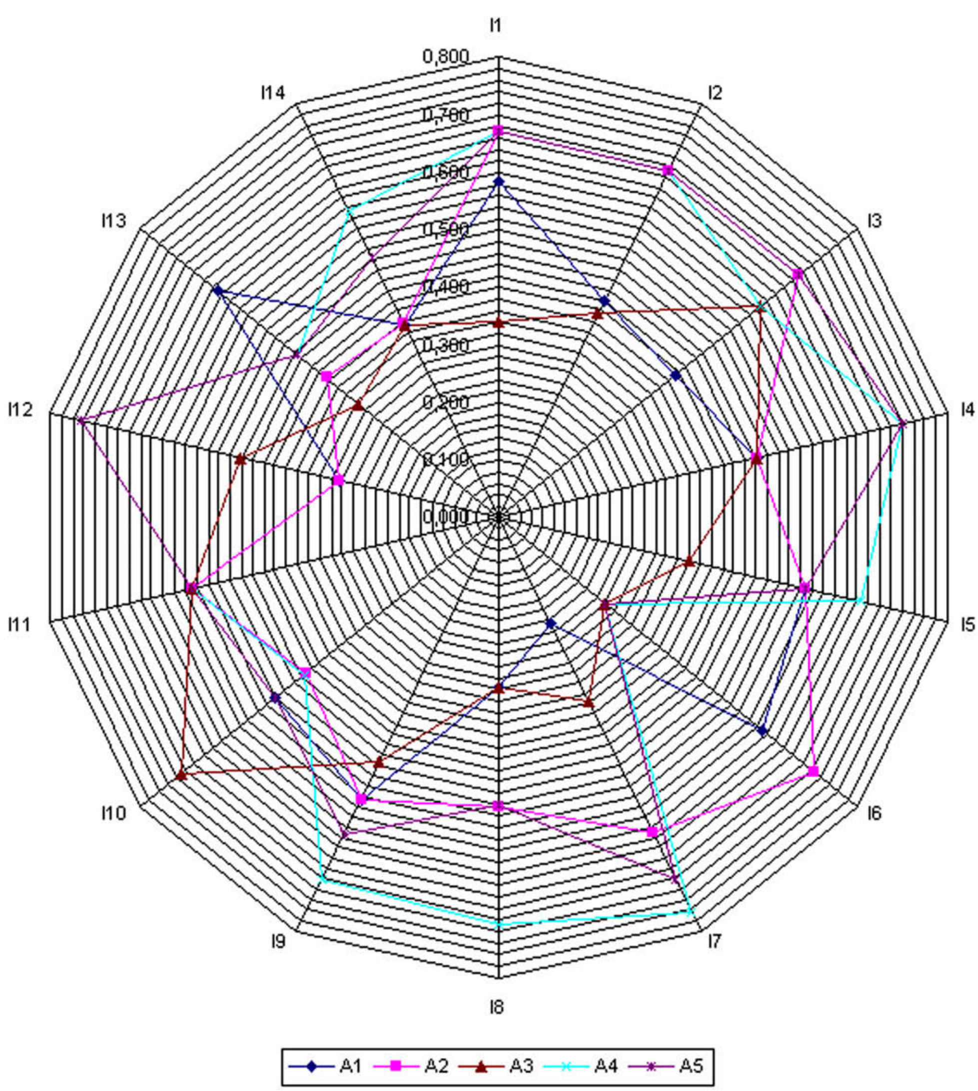

Fig. 10. Illustration of SWOT–TOPSIS analysis over internal assessment criterion.

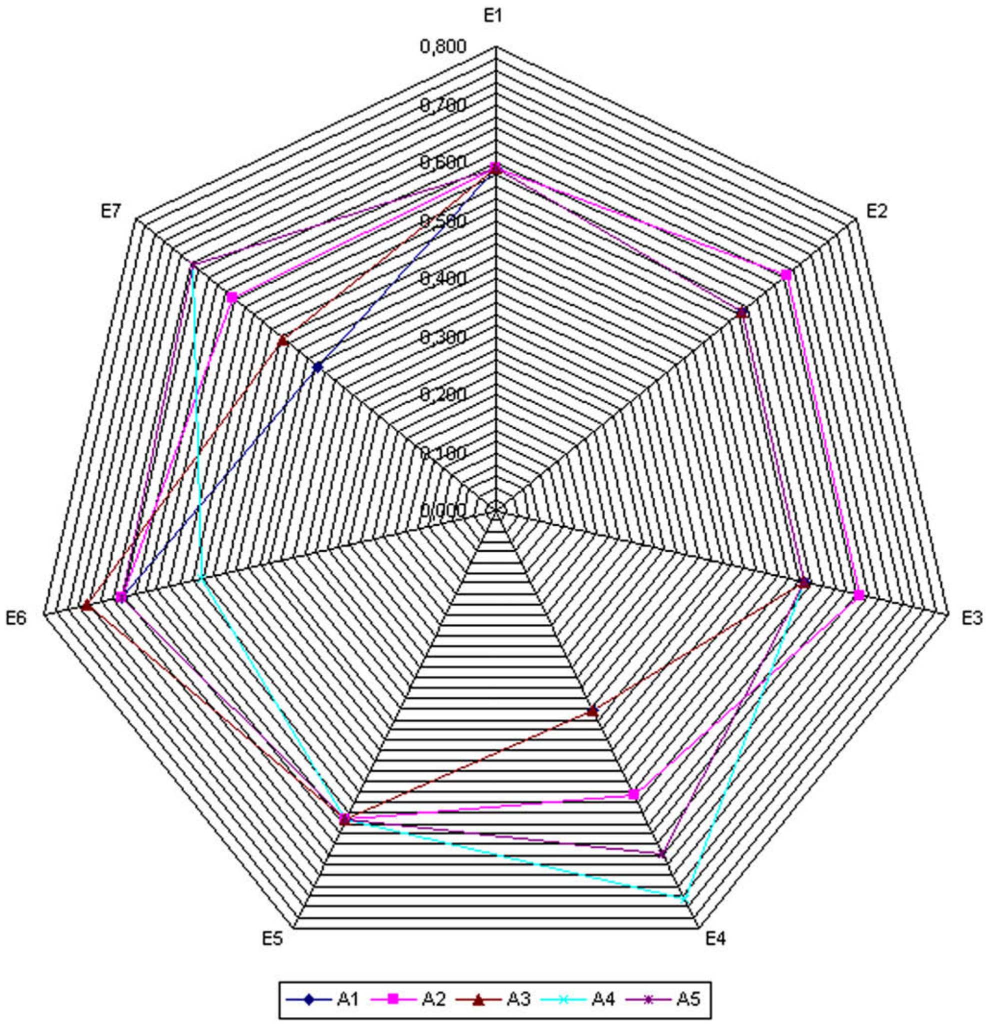

Fig. 11. Illustration of SWOT–TOPSIS analysis over external assessment criterion.

loading and discharging rates, shortage of labor force, probability of catastrophic risks due to the closeness to the urban life, and frequency of dredging facilities due to environmental concerns and geographical problems. On the other hand, incomplete of privilege contract procedures, security precautions, maneuvering and berthing service are the external threads for this alternative.

5. The port of AMBARLI has been provided the most effective service facilities for ship owners and cargo owners according to the model outcomes and finding of this research. The development opportunities for managing multimodal transportation integration can be recognized as a weakness about infrastructural characteristics. As an external thread, the high level of lay-time period due to the excessive vessel traffic can be outlined. As one of the advantages of operational principles, ensuring the privilege contract opportunities to ship owners and chatterers is a challenge for increasing the reputation and popularity in international level.
6. The port of GEMPORT has internal weaknesses in opportunities for multimodal transportation integration. Although the relevant factors on infrastructural characteristics and service level quality satisfy the expectations in the national level up to the limited capacity, there is a need for additional strategies on operational principles and policies. The threads have been monitored about maneuvering and berthing process and security plans and precautions. The opportunities on reducing administrative bureaucracy can be a challenge to extend the customer profile especially in international manner.

6. Conclusion and discussion on further issues

This paper represents the maritime industry based application of FAD and fuzzy TOPSIS methodologies in order to manage port competitiveness in the market. In this study, evaluation of alternatives is made in linguistic form owing to the fact that it is impossible to convey the value of alternative under the related criterion via crisp numbers. The underlying power of fuzzy set theory is that it uses linguistic variables, rather than quantitative variables to represent incomplete information. Since the fuzzy set theory provides a means for representing uncertainties, we choose fuzzy modeling methods which are FAD and fuzzy TOPSIS as decision making tools. The FAD and TOPSIS methodologies manage the requirements of incomplete information during the multi-criteria analysis while the quantified SWOT analysis contributes the strategy formulation over Turkish container ports. Considering of the outcomes of both methodologies is expected to increase the consistency of proposed strategies.

The outcomes of both methodologies and proposed strategies in consequence can originally be utilized as decision aid by the related governmental authorities and private sector representatives. Furthermore, the findings of detailed analyses also encourage the new enterprises in port and terminal management. Further motivations on port competitiveness can be directed to perform a benchmarking study on the container ports in EU countries and Turkish container ports to extend the scope of research.

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