AN APPLICATION OF FUZZY ANALYTIC HIERARCHY PROCESS TO OVERCAPACITY ABSORBING METHODS IN CONTAINER SHIPPING

(DOI No: 10.3940/rina.ijme.2020.a4.617)

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KEY DATES: Submitted: 20/02/2020; Final acceptance: 29/09/2020; Published: 04/12/2020

SUMMARY

The market in container shipping has been characterised as highly cyclical. In a depressed stage of the cycle, with a sharp decrease in demand, the gap between supply and demand widens significantly leading to a deepening overcapacity in the sector. In order to reduce overcapacity in the container shipping sector specific actions have been undertaken by such shipping operators. This paper describes a study which modelled certain selection criteria applied to overcapacity absorbing methods for containership companies. The relative ranking of each criterion was determined through a fuzzy-AHP method. In order to conduct the method, five main and twenty seven sub-criteria were determined. The results of this approach showed that during the times of a collapsed market the most preferred type of overcapacity absorbing method is to lay-up vessels, followed by adopting slow-steaming and thirdly, scrapping. Newbuilding contract cancellation/postponement and service suspension were found to have the least effect.

NOMENCLATURE

CCFI	China Containerized Freight Index
DEA	Data envelopment analysis
$\tilde{E}^k$	Fuzz decision matrix
$\tilde{E}^a$	Aggregated pairwise comparison matrix
$\tilde{e}_{ij}^k$	Fuzzy comparison value of criterion i to criterion j for kth decision maker
$\tilde{e}_{ij}^p$	Each decision maker's preferences
$\tilde{e}_{ij}$	Average of each decision maker's preferences
FCC	Cellular container vessels
FAHP	Fuzzy Analytical Hierarchy Process
MCDM	Multiple criteria decision making
$\mu_{\tilde{y}}(x)$	Membership function
$\tilde{r}_i$	Geometric mean of the fuzzy comparison
TEU	Twenty Equivalent Unit
TFN	Triangular fuzzy numbers
$\widetilde{w}_i$	Fuzzy weight of the *i* th criterion
$w_i^{c,sc}$	Crisp weight of the *i* th main or sub criterion
$(w_N)_i^C$	Normalized crisp weight of the *i* th main criterion
$(w_N)_i^{SC}$	Normalized crisp weight of the *i* th sub-criterion
$(w_R)_i^{SC}$	Relative crisp weight of the *i* th sub- criterion
$\tilde{y}$	A triangular fuzzy number
y_l	Lower boundary
y_m	Mean value
y_u	Upper boundary
$\tilde{z}$	A triangular fuzzy number

1. INTRODUCTION

Liner service has been maintained with different types of vessel; however, most of the services in this segment are increasingly provided with fully cellular container vessels (FCC) which dominated the liner industry with 92 % of total capacity in 2014 (Tran and Haasis, 2015). Over the course of time, container markets in the liner business have been characterized by market cycles. As pointed out by Stopford (2009), there are three different types of cycles occurring in shipping and these are long term, short term, and seasonal cycles. The first one that comes to mind among them is the short-term cycle. When there is a mention of a shipping cycle, it is generally pointing to the short cycles. Based on this, we will characterize the cycle term attributes of a short-cycle. A cycle consists of 4 different stages that are: recovery, peak, collapse, and duration of a complete cycle can be between 4 and 12 years.

The liner industry is particularly vulnerable to supply and demand matching issue, and container shipping lines are characteristically similar to firms operating as natural monopolies like public utilities (Haralambies, 2004). Some of the aspects characterizing this industry are as follows. The fixed to variable cost ratio is high, supply in the short term is fixed, and the productive capital is highly specialized. Demand is variable, however, schedules in the industry are fixed and this situation leads to container operating firms often sustaining services with surplus capacity (Fusillo, 2004). Operating with a low degree of surplus capacity is tolerated in the industry. However, due to depressive market conditions in the collapse stage of the cycle, demand decreases sharply and the gap between supply and demand widens significantly. This situation exacerbates overcapacity in the markets and that results in depressing the industry (Paul and Pillai, 2012; Ivor, 2013; Teepen, 2017).

After 2000 the container market based on charter rates, underwent a cycle of seven years between the years of 2002 and 2009, a cycle of three years between 2009- 2012, and a cycle of four years between 2012 and 2016 years (Kamal, 2019). Many research papers indicate that the container shipping industry experienced the collapse stage of the last cycle most severely in the period between the second half of 2015 and the first half of 2016 (Seatrade, 2015; Danish Ship Finance, 2016; JOC, 2016; BCG, 2016; BRS, 2017; UNCTAD, 2017). Within this period, China's Containerized Freight Index (CCFI) dropped to a 632 point level in April 2016 which was the lowest level since its inception in 1998 (Richter, 2016).

Following this period, the container shipping industry experienced one of the biggest bankruptcy in its history when Hanjin was dissolved in 2016 (Song et al., 2019). The annual global container fleet growth was about 10 % annually during the last 25 years. In 2016, the container vessel fleet expanded only by 1,5 % reaching 20.27 million TEU on the 1st of January 2017. This corresponded to the lowest annual growth rate recorded in the history of the industry. This situation was also aggravated by the opening of the new locks in the Panama Canal in June 2016, consequently, some 3.000-5.000 TEU container vessels became less attractive due to the greater capacity of the Canal (BRS, 2017).

In this specific period of the collapse stage,the absorption of overcapacity became the focus of decision-making in container shipping lines. As indicated by Fusillo (2003), excess capacity in the industry prevents the operator's ability to sustain sufficient revenues for covering the high fixed costs prevailing in liner markets. Based on this, to reduce overcapacity in the collapse stage of a cycle, some initiatives were undertaken by the liner operators. As specified by Notteboom (2012), Pillai and Paul (2012), Kalgora and Christian (2016), these initiatives were lay-up, slow-steaming, postponement, or cancellation of the newbuilding orders, scrapping, and service suspension.

However, each of these overcapacity absorbing practices implies different types of factors being taken into consideration by the decision-makers. Thus through slow-steaming options, container shipping lines can save bunker consumption as well as reducing greenhouse gas emissions, with the latter being adopted as a marketing strategy. On the other hand, slow steaming has negative effects on the supply chain of shippers/receivers, especially for time-sensitive products, while operating cost increases because of longer transit times.

Further, in a weak market condition, liner operators are not eager to absorb overcapacity by demolishing vessels, when demolishing prices are low in the collapse stage of the market.Similarly, shipyards are not keen on the cancellation and/or postponement of orders received. In the context of the laying-up of vessels, questions of where to lay-up or how long to lay-up arise. Thus there are many criteria to be taken into account by the decision-makers for each overcapacity reduction activity.

Therefore, identification of the effects of these overcapacity absorbing practices on each other, evaluating the importance of these practices, and choosing a strategic implementation for all these measures would holistically necessitate a well-designed multi-criteria decision making (MCDM). Fuzzy Multiple Criteria Decision Making analysis has been widely employed for handling the decision-making problems involving multi-criteria selection and/or evaluation of the alternatives. The practical applications of the Fuzzy-AHP, as reported in the literature, have suggested advantages for handling qualitative criteria as well as obtaining reliable results (Hsieh et al., 2004). Hence, in this study, Fuzzy-AHP method was applied for the managerial decision-making problem of overcapacity absorbing methods in order to help managers select the most appropriate capacity-reducing measure in the liner industry. For this purpose, the criteria taken into account by liner operators consist of revising literature as well as recommendations from industrial experts.

This study is structured in six sections. After the introduction, capacity and overcapacity of the liner industry is discussed in Section 2 followed in Section 3 by consideration of the stages of the proposed approach are explained step by step. Next, the application of the Fuzzy-AHP approach on overcapacity reducing methods is analyzed in Section 4 and the results of the approach are shown in Section 5. In the concluding section, some suggestions on how to proceed are given.

2. LITERATURE REVIEW

The literature on capacity issues in the liner industry is quite expansive. In this context, Bendall and Stent (2003) use real options analysis to evaluate the additional value of flexibility in the decision of capacity expansion in a container ship company. Lun and Marlow (2011) used data envelopment analysis (DEA) to assess the impact of the liner operators' fleet capacity on their revenue and profit. Fan and Luo (2013) analysed capacity expanding decision and ship choice behaviour for liner companies. It is pointed out that most of the expansion decisions are driven by the market and that large companies expand to sustain their market shares.

Ng (2015) focuses on carriers' decisions on optimal container vessel deployment under demand uncertainty. Tran and Haasis (2015) focus on capacity expansion and ship size growth in the liner industry to see how these influence the financial performance of container shipping lines. For this purpose, multiple regression models are used and the results show that new capacity helps liner firms to obtain more revenue but at a lower level than the capacity growth. Dong et al. (2015) address dynamic container routing and joint service capacity planning in the liner industry by proposing a two-stage stochastic programming model with recourse. Also, the determination of the optimal service capacity issue is the subject of investigation.

Similarly, Rau and Spinler (2016) evaluated how to optimize capacity in the container market through cost, competitive intensity, lead times, fuel use efficiency, volatility, and a number of the liner operators. For this purpose, they developed a real options investment model under oligopolistic competition taking into account the function of endogenous lead times, effective fuel investment, endogenous price and endogenous market price formation for old vessels. The study showed that an increase in the number of operating firms in the liner industry leads to higher optimal capacities and a decrease in individual firm values. Moreover, the position of the lower variable cost causes a higher optimal capacity.

Rau and Spinler (2017) extended their studies by including a dynamic alliance formation of the liner shipping under three different investment approaches. Findings of Rau and Spinler (2017) indicate a competition-free minimum capacity existing in the container markets. Moreover, it is pointed out that the real options trigger approaches leading to the lowest average capacity and hence can help alleviate the overcapacity problem in the liner industry. Haehl and Spinler (2018) propose a real options model for capacity expansion in the container shipping in an uncertain regulatory environment.

Despite the existence of vast literature on the capacity issues in the liner industry, little research on the surplus capacity in container shipping has been conducted. Fusillo (2003) constructed an excess capacity model as a strategic entry deterrent, and the results of the study suggest that a strategic entry deterrent is a part of the excess capacity in the liner industry, at the top four-carrier grouping through saturating the market. Sjostrom (2004) reveals that in a natural monopoly industry like the liner industry, operating firms should expand their cooperation to avoid overcapacity depressing the industry.

Fusillo (2009) indicates that changes in technology and demand along with entry and expansion of existing firms in the liner industry may contribute to the creation of excess capacity. It is specified that excess capacity leads to destabilization of the competitive environment and makes consolidation in the industry more alluring.

Previous studies regarding overcapacity in liner shipping either provide measures to be taken by operators to absorb overcapacity (UNCTAD, 2009; Pillai and Paul, 2012; Notteboom, 2012; Alizadeh et al, 2016; Kalgora and Christian, 2016) or they focus on each overcapacity absorbing measures from different perspectives. For instance, some studies take slow steaming into consideration for cost optimization, emission reduction, or effect on the supply chain (Notteboom and Vernimmen, 2009; Maloni et al. 2013; Notteboom and Cariou, 2013; Psaraftis and Contovas, 2013; Zanne et al. , 2013; Elzarka and Morsi 2014; Kim et al, 2014; Tran and Haasis, 2015; Carson et al., 2015; Huang et al., 2015). There are also some studies carried out in an attempt to analyse the underlying reasons for the occurrence of overcapacity in liner business (Zerby and Conlon, 1978; Fusillo, 2003; Fusillo, 2004; Kou and Lou, 2015; Teepen, 2017).

The existing literature gives a variety of reasons for the implications of the excess capacity in the industry. However, there is no research indicating holistically what criteria and sub-criteria are taken into account to select an overcapacity absorbing practice or how these criteria are ranked by the liner operators under depressive market conditions. Therefore, this paper aims to model rational selection criteria for overcapacity absorbing methods in the liner industry during the collapsed stage of a cycle.

3. BUCKLEY'S FUZZY AHP APPROACH

In this study, the Fuzzy Analytical Hierarchy Process (FAHP) method proposed by Buckley (1985) was employed for the application of overcapacity reduction methods. The AHP method was first developed by Saaty in the 1970s. Since then, it has become a very popular way to solve multiple criteria decision-making problems and has been used extensively by many researchers (Yilmaz, 2017). However, researchers criticized it for the lack of reflecting human-style thinking. In the AHP method, exact numbers are used for pairwise formulation. However, in many cases, decision-makers generally fail to identify their preferences precisely because of the vagueness of the decision-making problems handled.

To cope with the uncertainty problems as to the subjective perception of a decision-maker, Zadeh (1965) suggested a fuzzy set theory. It fuzzifies the decision-maker's perceived value by taking into account that the exact values cannot always be perceived by human beings. Based on this, some scholars combined fuzzy logic with AHP, and this allowed them to obtain decision-makers' thorough judgements (Balci et al., 2018). In this way, decision problems' uncertainty can be overcome more easily. With the advantages of fuzzy logic, the shortcomings of the AHP method are overcome by this approach.

The Fuzzy AHP method is applied in many different areas including shipping (Celik et al., 2009; Uğurlu, 2015; Beşikçi et al., 2016; Balci et al., 2018; Celik and Akyuz, 2018; Özdemir et al., 2018; Chang et al., 2019). However, in the literature, there are no reports that employ the Fuzzy AHP method in capacity issues in the container shipping industry.

It can be seen that many different Fuzzy AHP methods have been developed in the literature. However, in this study, Fuzzy AHP proposed by Buckley (1985) is utilized since it is easy to extend decision-making problems into the fuzzy environment in this method. Also, the steps in Buckley's approach are relatively easier to be conducted as well as guaranteeing a unique solution to the reciprocal comparison matrix, as compared to other FAHP methods, despite its inclusion of additional steps (Celik et al., 2009). Furthermore, there are some limitations in other methods. For instance, all information on fuzzy comparison matrices cannot be fully used in the extent analysis method. The extent analysis method can cause an irrational zero weight to the selection criteria (Chan and Wang, 2013).

The steps of Buckley's Fuzzy AHP approach are given below:

Step 1: Qualifying criteria were established by decision-makers.

Step 2: Fuzzy numbers and linguistic scale employed in this study were obtained from the literature.

Step 3: Decision-makers' assessments for the degree of importance of each main and sub-criterion were collected through a survey (see Appendix). A Fuzzy decision matrix is shown in equation (1) below;

$$\tilde{E}^k = \begin{pmatrix} \tilde{e}_{11}^k & \cdots & \tilde{e}_{1n}^k \\ \vdots & \ddots & \vdots \\ \tilde{e}_{n1}^k & \cdots & \tilde{e}_{nn}^k \end{pmatrix} \quad (1)$$

$$e_{ij}^k = \begin{cases} \begin{matrix} \textit{If the criterion in the row} \\ \textit{is more important than ,} \\ \textit{the criterion in the column} \end{matrix} & \begin{cases} \textit{row abso. imprtnt col.} \\ \textit{row strong imprtnt col.} \\ \textit{row fairly imprtnt col.} \\ \textit{row weakly imprtnt col.} \end{cases} \\ \begin{matrix} \textit{If the criterion in the row is} \\ \textit{of the same importance as,} \\ \textit{the criterion in the column} \end{matrix} & \{\textit{row} - \textit{col equal imprtnt}\} \\ \begin{matrix} \textit{If the criterion in the column} \\ \textit{is more important than,} \\ \textit{the criterion in the row} \end{matrix} & \begin{cases} \textit{col.weak. imprtnt.row} \\ \textit{col.fair. imprtnt.row} \\ \textit{col.strong. imprtnt.row} \\ \textit{col.abso. imprtnt.row} \end{cases} \end{cases} \quad (2)$$

$\tilde{E}^k$ is a fuzz decision matrix given by the kth decision-maker for the degree of importance of each criterion, k=1,2,3,….p, p is the number of decision-makers, $\tilde{e}_{ij}^k$ is the fuzzy comparison value of criterion i to criterion j for kth decision-maker, i,j=1,2,3,…n. Here n points to the number of criteria compared. In equation (2), abbreviations are given and explained as follows: 'abso.' is the short version of 'absolutely', 'imprtnt' is the short version of 'important', 'col.' is the short version of 'column'. 'Row abso. imprtnt col.' is the abbreviation for ' the criterion in the row is absolutely more important than the criterion in the column' (All the expansion of abbreviations is given in the Appendix).

Step 4: In this step, collected data is transformed into triangular fuzzy numbers. Since mathematical operations cannot be conducted on verbal judgements, linguistic assessments must be transformed into triangular fuzzy numbers (TFN). As pointed out by Kafalı and Özkök (2015), a fuzzy set is represented by a membership function, $\mu_{\tilde{y}}(x)$ identifies elements' membership degree in the range [0,1]. In Equation (3) below, triangular fuzzy numbers' description is given:

$$\mu_{\tilde{y}}(x) = \begin{cases} \textit{if } y_{1 \le x \le y_m}, & (x - y_1)/(y_m - y_1) \\ \textit{if } y_m \le x \le y_u, & (y_u - x)/(y_u - y_m) \\ \textit{if } x > y_u \textit{ or } x < y_1, & 0 \end{cases} \quad (3)$$

Given in the equation above, $\mu_{\tilde{y}}(x)$ is the function of membership, y_u is the upper boundary, y_l is the lower boundary, and y_m is the mean value. An example of triangular fuzzy numbers can be seen in Figure 1.

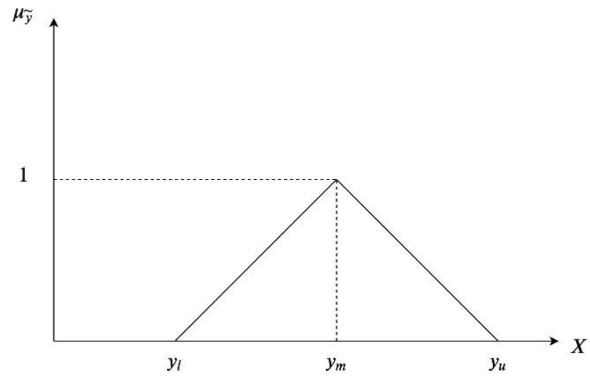

Figure 1. $\tilde{y} = (\tilde{y}_l, \tilde{y}_m, \tilde{y}_u)$ TFN

Let $\tilde{y} = (y_l, y_m, y_u)$ and $\tilde{z} = (z_l, z_m, z_u)$ be two TFN and below summarization of the algebraic operations is as follows (Chen and Hwang, 1992):

$$\tilde{y} \oplus \tilde{z} = (y_1 + z_1,\ y_m + z_m,\ y_u + z_u), \quad (4)$$
$$\tilde{y} \ominus \tilde{z} = (y_l - z_u,\ y_m\ z_m,\ y_u - z_l) \quad (5)$$
$$\tilde{y} \otimes \tilde{z} = (y_l \times z_l,\ y_m \times z_m,\ y_u \times z_u),\ \tilde{y} > 0,\ \tilde{z} > 0 \quad (6)$$
$$\tilde{y} \oslash \tilde{z} = (y_l \div z_u,\ y_m \div z_m,\ y_u \div z_u),\ \tilde{y} > 0,\ \tilde{z} > 0 \quad (7)$$
$$\tilde{y}^{-1} = (1 \div y_u,\ 1 \div y_m,\ 1 \div y_l). \quad (8)$$

A positive fuzzy number, $\tilde{y}$, is defined as, $\mu_{\tilde{y}}(x) = 0,\ \forall_x < 0$ (Zimmerman, 2001)

Step 5: In this stage, the preferences of decision-makers are aggregated. If there is more than one decision-maker assessment, these assessments of experts' preferences need to be combined through the aggregation process. To obtain an aggregated pairwise comparison matrix, each decision maker's preferences ($\tilde{e}_{ij}^p$) are averaged and ($\tilde{e}_{ij}$) calculated as in equation 10.

$$\tilde{E}^a = \begin{pmatrix} \tilde{e}_{11}^a & \cdots & \tilde{e}_{1n}^a \\ \vdots & \ddots & \vdots \\ \tilde{e}_{n1}^a & \cdots & \tilde{e}_{nn}^a \end{pmatrix} \quad (9)$$

$$\tilde{e}_{ij} = \frac{\sum_{p=1}^{P} \tilde{e}_{ij}^p}{P} \quad (10)$$

where $\tilde{E}^a$ is the comparison matrix of aggregated pairwise for importance degree of each criterion, $\tilde{e}_{ij}^a$ is the aggregated fuzzy comparison value of criterion *i* to criterion *j* , *p* is the number of decision-makers, *I,j* = 1, 2,…,*n* and *n* is the number of compared criteria.

Step 6: In this step, criteria weights are calculated. In this study, Fuzzy AHP proposed by Buckley (1985) is used for the calculation of fuzzy weights. The summary of the method is given below.

After the aggregated pairwise comparison matrix, $\tilde{E}^a$ is obtained, and the calculation of the fuzzy weight matrix is conducted as given below.

$$\tilde{r}_i = (\tilde{e}_{i1}^a \otimes \tilde{e}_{i2}^a \otimes ....\tilde{e}_{in}^a)^{1/n} \quad (11)$$

$$\widetilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus ...... \oplus \tilde{r}_n)^{-1} \quad (12)$$

Where $\tilde{r}_i$ is the geometric mean of the fuzzy comparison value of criterion *i* to each criterion, $\widetilde{w}_i$ is the fuzzy weight of the *i*th criterion, *i*=1,2,…,*n;* where *n* is the number of compared criteria.

Step 7: In this stage, defuzzification and normalization procedure for the fuzzy weights is carried out. To transform the fuzzy weights into crisp values (traditional values or non-fuzzy values), the centroid method, which generates a crisp value based on the centre of the gravity, is applied.

$$w_i^{c,sc} = \frac{w_1 + w_2 + w_3}{3} \quad (13)$$

Where $w_i^{c,sc}$ is the crisp weight of the *i*th main or sub-criterion, w_l is the lower boundary, w_u is the upper boundary, w_m is the mean value of the fuzzy weight of the *i*th criterion.

The crisp values should be normalized to obtain much more comprehensive results as given below (Ding, 2011):

$$(w_N)_{\mathrm{i}}^C = \frac{w_{\mathrm{i}}^C}{\sum_{\mathrm{i}=1}^{b} w_i^c} \quad (14)$$

Where $(w_N)_{\mathrm{i}}^C$ is the normalized crisp weight of the *i*th main criterion, w_i^c is the crisp weight of the *i*th main criterion calculated by Equation (13), and *b* is the number of the main criteria.

For sub-criteria, the following equation is used:

$$(w_N)_{\mathrm{i}}^{SC} = \frac{w_i^{SC}}{\sum_{i=1}^{g} w_i^{SC}} \quad (15)$$

Where $(w_N)_i^{SC}$ is the normalized crisp weight of the *i*th sub-criterion, w_i^{sc} is the crisp weight of the *i*th sub-criterion calculated by Equation (13), and *g* is the number of sub-criteria under the germane main criterion.

Step 8: In this step, relative crisp weights are calculated in order to better analyse the sub-criteria among themselves. For comparing sub-criteria among themselves, the calculation of relative crisp weights is as follows:

$$(W_R)_i^{SC} = (W_N)^C \times (W_N)_i^{SC} \quad (16)$$

where $(w_R)_{\mathrm{i}}^{SC}$ is the relative crisp weight of the *i*th sub-criterion, $(W_N)^C$ is the normalized crisp weight of the main criterion which includes the germane sub-criterion, $(w_N)_{\mathrm{i}}^{SC}$ is the normalized crisp weight of the *i*th sub-criterion , *i*=1,2….*h* and *h* is the number of sub-criteria under the germane main criterion (Kafalı & Özkök, 2015).

4. APPLICATION OF FUZZY-AHP

In this paper, the preferences of 13 decision-makers from 6 different container operating companies are collected. These 13 decision-makers comprise 1 shipowner, 2 general managers, 4 deputy general managers, 1 commercial director, 3 operation managers, 1 sales manager, and 1 logistics manager. Sale and logistics managers also have deep knowledge of the capacity issues, and each of the respondents has at least 10 years of market experience. Also, some decision-makers have varying experience between 15 and 20 years.

In the first round for model construction, we attempted to prepare a draft of the selection criteria comprised of main and sub-criteria for absorbing overcapacity through literature review when it was available. For example, there was enough literature for slow steaming, scrapping, and lay-up; however, it was not available for newbuilding contract cancellation and/or postponement and service suspension. Besides, we received the support of one experienced maritime lawyer who had newbuilding contract experience.

Similarly, for the sub-criteria of service suspension, we asked the respondents questions via email. After the formation of the main criteria and sub-criteria for overcapacity absorbing selection (Figure. 2), we transferred this frame into an excel form that included descriptions of the criteria chosen (Table 1) besides a survey for evaluating the importance of each main and sub-criterion through pairwise comparisons (Figure A-1). In the second round, this excel draft including an explanation of how to fill in the form was sent to the decision-makers. Overall, 13 returns from decision-makers were obtained.

Step 1: In this study, the model built consists of 5 main criteria and 27 sub-criteria. These criteria are formed through a combination of both literature review and recommendations from the managers of liner firms. The main criteria are lay-up, scrapping, slow-steaming, contract cancelling/postponement, and service suspension. Sub-criteria are explained in Table 1 and depicted in Figure 2.

Table 1. Explanations of sub-criteria used in overcapacity reducing method selection process.

MAIN CRITERIA	SUB CRITERIA	EXPLANATIONS
Vessel Lay-up		
	Lay-up Period	Duration of lay-up period
	Reactivation Period	Time period passing to reactivate a laid-up vessel
	Vessel Capacity	Which vessel will be laid up? The capacity of a vessel to be laid-up
	Lay-up Region	In which region will the vessel be laid up?/ Closeness to the trade routes
	Situation of Crew	Approach of liner operator towards crew/ whether to keep them within the company with different positions or to leave them unemployment
	Age of Vessel	Age of vessel to be laid up
	Cost Saving	Technical and commercial cost savings
Scrapping		
	Country of Scrapping	In which country will a vessel be scrapped?
	Scrap Price	Vessel scrap prices in demolishing markets
	Vessel Age	The age of vessel to be scrapped
	Vessel Type	Segment-capacity of the vessel to be demolished
	Demand for Scrap Steel	Demand for scrap steel in steel markets
Slow-steaming		
	Fuel Saving	Fuel savings through slow steaming
	Extra Vessel Cost	Cost of adding an extra vessel to the service cycle due to slow steaming to fullfill a service commitment
	Emission Reduction	Reduction in harmful emissions / Environmental benefits
	Reaction of Customer	Reaction of consignor/consignee whose supply chain will be affected
	Service-Schedule Reliability	Thanks to adding an extra vessel to the service cycle due to slow steaming, delays are eliminated and thus leading to the betterment of schedule reliability
Contract Cancelling/ Order Postponement		
	Jurisdiction/Arbitration	The jurisdiction/arbitration to be applied in the case of order cancelling or delivery postponement
	Country of Shipyard	Country of the shipyard
	Compensation Payment	If an ongoing construction project is cancelled or the delivery date is postponed by the shipowning company then compensation payment issue including down and stage payments can arise
	Refund Guarantee	Possibility of recovering payments made to the shipyard under a refund guarantee
	Second-Hand Market	Vessel prices in second-hand markets / If the sum of payments made to the shipyard and price of the same type second-hand vessel in depressed markets are lower than the vessel order value then it is better to cancel the order and to buy a cheap second-hand vessel
Service Suspension		
	Reaction of Consignor & Consignee	The reaction of consignor/consignee who book slots before and impact of service suspension on the supply chain of consignor/consignee.
	Brand Value	When suspending a service, the brand value of a liner company is affected negatively.
	Competition Power	Position of a liner operator firm when competing with other liner operator firms.
	Financial Power of Operator	Financial durability of a liner operator to sustain a service rather than suspending.
	Profitability	Situation of profitability of a service / Even if an operator reaches full capacity in a service and freight rates are not in a desired level that is to say if it is not profitable then that service can be suspended.

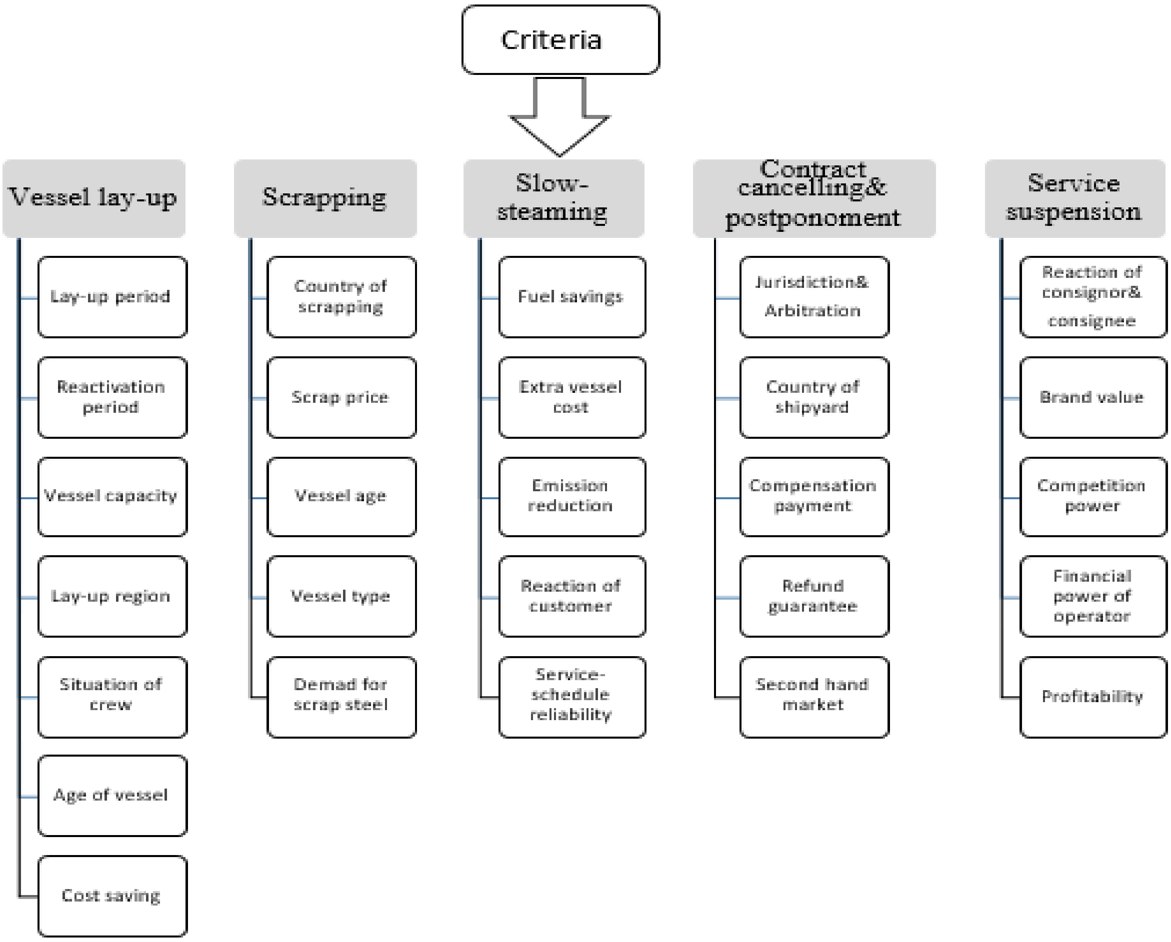

Figure 2. All main criteria and sub-criteria taken into account in this study.

Step 2: Linguistic terms and corresponding triangular fuzzy numbers and the inverse of them are provided in Table 2 (Erensal et al, 2006 and Yilmaz, 2017).

Step 3: Decision-makers' preferences for the degree of importance of each main and sub-criterion are collected using a questionnaire prepared in Excel format (see the Appendix). For example, preferences of the decision-maker 1 for main criteria can be seen in Table 3.

Table 2. Linguistic scale and corresponding fuzzy numbers

Fuzzy Preference Scale	Corresponding triangular fuzzy numbers	The inverse of the corresponding triangular fuzzy numbers
Equally important	(1,1,1)	(1,1,1)
Weakly important	(1,3,5)	(1/5, 1/3, 1)
Fairly important	(3,5,7)	(1/7, 1/5, 1/3)
Strongly important	(5,7,9)	(1/9, 1/7, 1/5)
Absolutely important	(7,9,11)	(1/11, 1/9, 1/7)

Table 3. Pairwise comparison for main criteria of decision maker 1.

	Vessel Lay-up (LU)	Scrapping (SC)	Slow-steaming (ST)	Contract Cancelling & Order Postponoment(CCP)	Service Suspension(SS)
LU	-	col. fair. imprtnt row	row abso. imprtnt col.	row abso. imprtnt col.	row abso. imprtnt col.
SC	row fairly imprtnt col.	-	row weakly imprtnt col.	row weakly imprtnt col.	row weakly imprtnt col.
ST	col. abso. imprtnt row	col.weak.imprtnt. row	-	row-col equal imprtnt	row fairly imprtnt col.
CCP	col. abso. imprtnt row	col.weak.imprtnt. row	row-col. equal imprtnt	-	row fairly imprtnt col.
SS	col. abso. imprtnt row	col.weak.imprtnt. row	col. fair. imprtnt row	col. fair. imprtnt row	-

Table 4. Aggregated pairwise comparisons for the main criteria.

	Vessel Lay-up (LU)	Scrapping (SC)	Slow-steaming (ST)	Contract Cancelling & Order Postponoment (CCP)	Service Suspension (SS)
LU	(1.000,1.000,1.000)	(3.323 , 5.019, 6.718)	(2.459, 3.112, 3.871)	(2.211 ,3.163, 4.206)	(3.413,4.653,5.902)
SC	(0.149 , 0.199, 0.301)	(1.000,1.000, 1.000)	(1.635, 2.293, 3.057)	(1.020,1.523, 2.134)	(1.232,2.032,2.893)
ST	(0.258, 0.321, 0.407)	(0.327, 0.436, 0.612)	(1.000,1.000, 1.000)	(2.868, 4.415 ,5.974)	(2.958,4.360,5.810)
CCP	(0.238, 0.316, 0.452)	(0.469, 0.657, 0.980)	(0.167, 0.226, 0.349)	(1.000,1.000,1.000)	(1.907,3.016,4.220)
SS	(0.169, 0.215, 0.293)	(0.346, 0.492, 0.812)	(0.172, 0.229, 0.338)	(1.907, 3.016, 4.220)	(1.000,1.000,1.000)

Step 4. Linguistic terms were transformed into triangular fuzzy numbers per under the scale given in Table 2. For example, *row abso. imprtnt col.* is transformed into (7, 9,11) and *col. fair. imprtnt row* as (1/7, 1/5, 1/3)

Step 5. If the number of decision-makers is more than one, then each decision-maker's preferences are averaged.

In this study, 13 decision-makers are taken into account, and each decision-maker is considered to carry the same weight for the final decision. Based on this aggregated fuzzy decision, matrices are calculated via eq. (10) and the aggregated fuzzy decision matrices for the main criteria are provided in Table 4.

Step 6: Based on Buckley's Fuzzy AHP, the geometric mean of fuzzy comparison value for each criterion is calculated using eq. 11. Following that, each criterion's fuzzy weights are found using eq. 12. In Tables 5 and 6, the geometric mean of the main criteria and fuzzy weights of the main criteria are provided.

For example, $\tilde{r}_1 = (\tilde{e}^a_{11} \otimes \tilde{e}^a_{12} \otimes \tilde{e}^a_{13} \otimes \tilde{e}^a_{14} \otimes \tilde{e}^a_{15})^{1/5}$

$\tilde{r}_{LU}$=((1.000,1.000,1.000)⊗(3.323,5.019,6.718)⊗(2.459,3.112,3.871) ⊗(2.211,3.163,4.206) ⊗ (3.413,4.653,5.902))$^{1/5}$
= (2.280, 2.967, 3.647) and $\tilde{w}_1 = \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3 \oplus \tilde{r}_4 \oplus \tilde{r}_5)^{-1}$

$\tilde{w}_{LU}$ = (2.280, 2.967, 3.647) ⊗((2.280, 2.967, 3.647) ⊕ (0.789, 1.071, 1.415) ⊕(0.935, 1.219 , 1.539) ⊕ (0.514 , 0.676 , 0.918) ⊕ (0.453, 0.592 , 0.805)) $^{-1}$
= (0. 274, 0.454, 0.733)

Table 5. The geometric mean of the main criteria.

$\tilde{r}_{LU}$	$\tilde{r}_{SC}$	$\tilde{r}_{ST}$	$\tilde{r}_{CCP}$	$\tilde{r}_{SS}$
(2.280, 2.967, 3.647)	(0.789, 1.071, 1.415)	(0.935, 1.219, 1.539)	(0.514, 0.676, 0.918)	(0.453, 0.592, 0.805)

Table 6. Fuzzy weights of the main criteria

$\tilde{W}_{LU}$	$\tilde{W}_{SC}$	$\tilde{W}_{ST}$	$\tilde{W}_{CCP}$	$\tilde{W}_{SS}$
(0.274, 0.454, 0.733)	(0.095, 0.164, 0.284)	(0.112, 0.187, 0.309)	(0.062, 0.103, 0.185)	(0.054, 0.091, 0.162)

Step 7. To obtain crisp weights, fuzzy weights are defuzzified by using eq. 13. Then, to calculate normalized crisp criteria weights, eq. 14 and 15 are used. The main criteria's defuzzification and normalization procedure is given as an example only for lay-up and calculated crisp weights and normalized crisp weights of the main criteria and normalized crisp weights of lay-up sub-criteria can be seen in Table 7-9, respectively.

$$w^C_{LU} = \frac{(0.274,\ 0.454,\ 0.733)}{3} = 0{,}487$$

$$(w_n)^c_i = \frac{w^c_i}{\sum^b_{i=1} w^c_i}$$

and

$$\sum^5_{i=1} w^c_i = 0{,}487 + 0.181 + 0{,}203 + 0{,}117 + 0{,}102 = 1{,}090$$

$$(W_N)^c_{LU} = \frac{0{,}487}{1{,}090} = 0{,}447$$

Table 7. Crisp weights of the main criteria.

W_{LU}	W_{SC}	W_{ST}	W_{CCP}	W_{SS}
(0,487)	(0,181)	(0,203)	(0,117)	(0,102)

Table 8. Normalized crisp weights of the main criteria.

(0,447)	(0,166)	(0,186)	(0,107)	(0,094)

Table 9. Normalized crisp weights of sub-criteria of lay-up

w^N_{LU1}	w^N_{LU2}	w^N_{LU3}	w^N_{LU4}	w^N_{LU5}	w^N_{LU6}	w^N_{LU7}
(0,369)	(0,152)	(0,148)	(0,090)	(0,074)	(0,082)	(0,084)

Step 8. To better analyse sub-criteria among themselves, relative crisp weights are calculated using eq. 16. For example, the relative crisp weight of lay-up period sub-criterion (LU1) is calculated as in the following:

$(w_R)^{SC}_{LU\,1} = 0{,}447 \times 0{,}369 = 0{,}165$ and values of all relative crisp weights of sub-criteria can be seen in Table 10.

Table 10. Relative crisp weights

Lay-up (LU)		Slow-steaming (ST)	
Lay-up period (LU1)	0,165	Fuel Saving (ST1)	0,078
Reactivation Period (LU2)	0,068	Extra Vessel Cost (ST2)	0,053
Vessel Capacity (LU3)	0,066	Emission Reduction (ST3)	0,016
Lay-up Region (LU4)	0,040	Reaction of Customer (ST4)	0,022
Situation of Crew (LU5)	0,033	Service-Schedule Reliability	0,017
Age of Vessel (GSD6)	0,037		
Cost Saving (LU7)	0,038		

Scrapping (SC)		Contract Cancelling/ Order Postponoment CCP)	
Country of Scrapping	0,047	Jurisdiction/Arbitration (CCP1)	0,039
Scrap Price (SC2)	0,056	Country of Shipyard (CCP2)	0,020
Vessel Age (SC3)	0,035	Compensation Payment (CCP3)	0,022
Vessel Type (SC4)	0,017	Refund Guarantee (CCP4)	0,014
Demand for Scrap Steel	0,011	Second Hand Market (CCP5)	0,011

Service Suspension (SS)	
Reaction of Consignor/Consignee (SS1)	0,011
Brand Value (SS2)	0,068
Competition Power (SS3)	0,006
Financial Power of Operator (SS4)	0,005
Profitability (SS5)	0,005

Lastly, the main criteria through their normalized crisp weights and sub-criteria through their relative crisp weights were transformed into Figures (3-9) reflecting their share of percentage. For instance, it can be seen from Table 8 that aggregation of the normalized crisp weights of main criteria equals to 1 and a value of the lay-up with 0,447 corresponds to 44.7 %. Similarly, each sub-criteria can be compared among themselves in terms of percentage via relative crisp weights.

5. DISCUSSION

The results of the study show that lay-up practice with 45 % is seen to be the most preferred overcapacity absorbing practice in the container markets. This is followed by slow-steaming with 19 %, scrapping with 16 % and contract cancelling and/or order postponement with 11 %. As can be seen from Figure 3, service suspension is the least preferred practice when reacting to the overcapacity issue by liner operators.

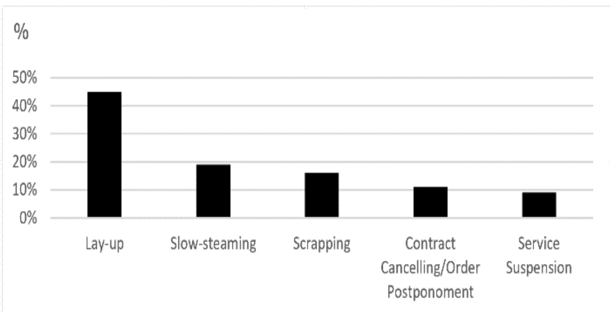

Figure 3. The degrees of importance for the main criteria of overcapacity absorbing methods.

The sub-criteria of the lay-up option is depicted in Figure 4. Thus, when carrying out lay-up practice, the most important criterion taken into account by the liner operators is the period of lay-up with 37 %. This is followed by the reactivation period and vessel capacity with each having a 15 % preference.

The least important criterion considered by operators is the situation of the crew. However, Grovdal and Tomren (2016) pointed out that when a decision was made about lay-up, the approach of some Norwegian offshore supply ship owners regarding personnel employment contract became temporary layoff or they gave them a job in the office so that when the market improved they could need them again. Nevertheless, the results of this study imply that this is not valid for container operators.

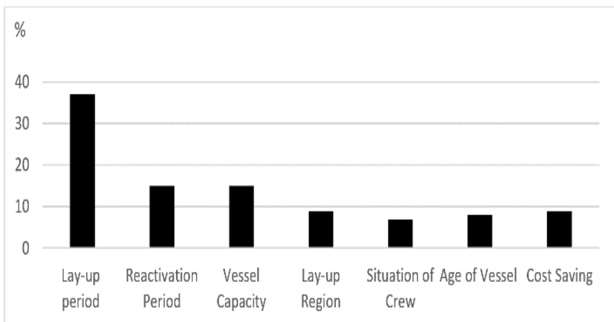

Figure 4. The degrees of importance for the sub-criteria of lay-up

In Figure 5, the sub-criteria of scrapping are examined, and it is shown that the most important criterion taken into consideration by liner operators is the scrap price. It is followed by scrap country and vessel age criteria. The least important criterion for the scrapping decision process is the demand for scrap steel with a weight of 7 %.

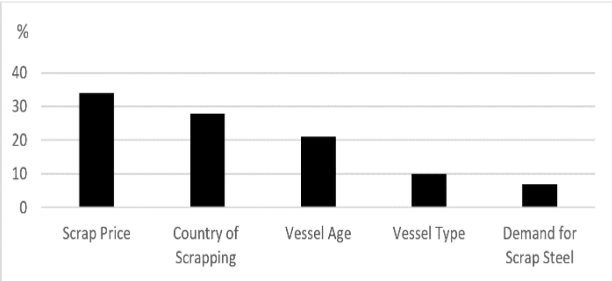

Figure 5. The degrees of importance for the sub-criteria of scrapping

When it comes to the sub-criteria of slow-steaming, Figure 6 shows that the fuel-saving criterion is the most important for operators when deciding the slow-steaming option. The slow-steaming practice has become a norm in the liner industry particularly after the 2008 financial crisis as well as rising fuel prices. When upgrading the vessel size from 15.000 TEU design to 19,000 TEU design and using average main engine fuel prices of 600 $, it can be said that the amount between 55 and 63 percent of the savings per TEU can be attributable to the layout for lower operation speeds (OECD, 2015).

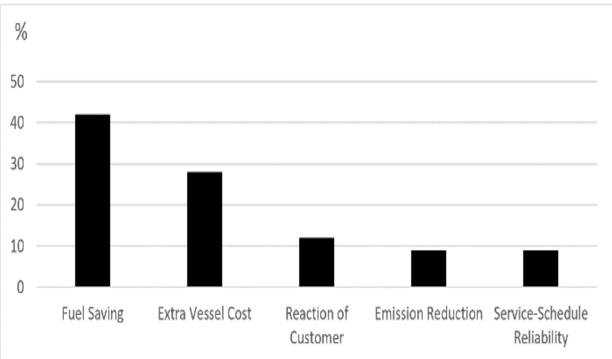

Figure 6. The degrees of importance for the sub-criteria of slow-steaming

Due to slow-steaming practice, it was noted that the advantages of a bulbous bow containership have waned in the last decade. In line with this, CMA-CGM liner company has ordered nine 22.500 TEU LNG-powered container vessels which will be the first to feature a vertical stem design for their bulbless bow as CMA-CGM has been committing its future to slow-steaming strategy (Seanews, 2018).

After fuel saving, the criterion that is taken into consideration by operators is the cost of extra vessel which should be deployed to the service string to fulfil service commitment. It is seen that operators give less importance to the reaction of customers by whom the supply chain is being affected negatively. In the slow-steaming decision process, the least important criteria are the service-schedule reliability and emission reduction.

Figure 7 indicates the sub-criteria of contract cancelling & order postponement practice. In this practice, the most important criterion taken into account by operators is the jurisdiction/arbitration which implies that there is hope for firms to recover payments made to the shipyards. It is followed by compensation payments. The situation of second-hand markets is the least important criterion when cancelling and/or postponing a contract.

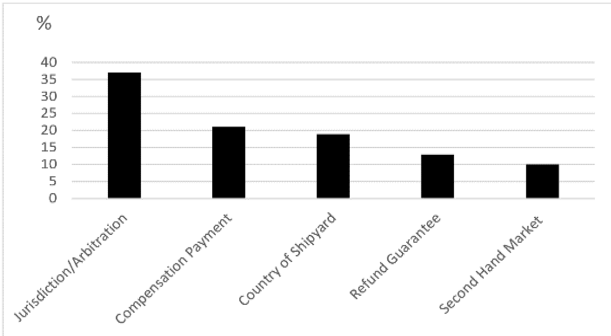

Figure 7. The degrees of importance for the sub-criteria of contract cancelling& order postponement

As can be seen from Figure 8, among service suspension sub-criteria, operators paid the most attention to the brand value criterion in overcapacity absorbing decision process with a weight of 72 %. The least important criterion for them is the financial power of the operator.

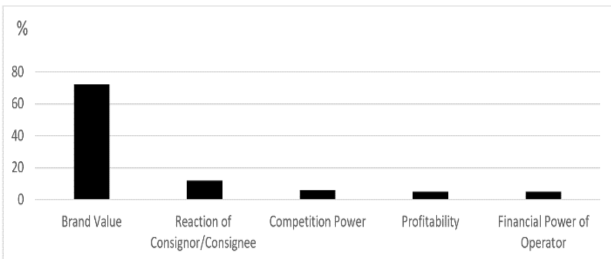

Figure 8. The degrees of importance for the sub-criteria of service suspension

If all sub-criteria are taken into account together, it can be seen in Figure 9 that the lay-up period is the most important criterion for the liner operators, and it is followed by fuel saving. Fuel-saving is followed by brand value and reactivation period with equal importance.

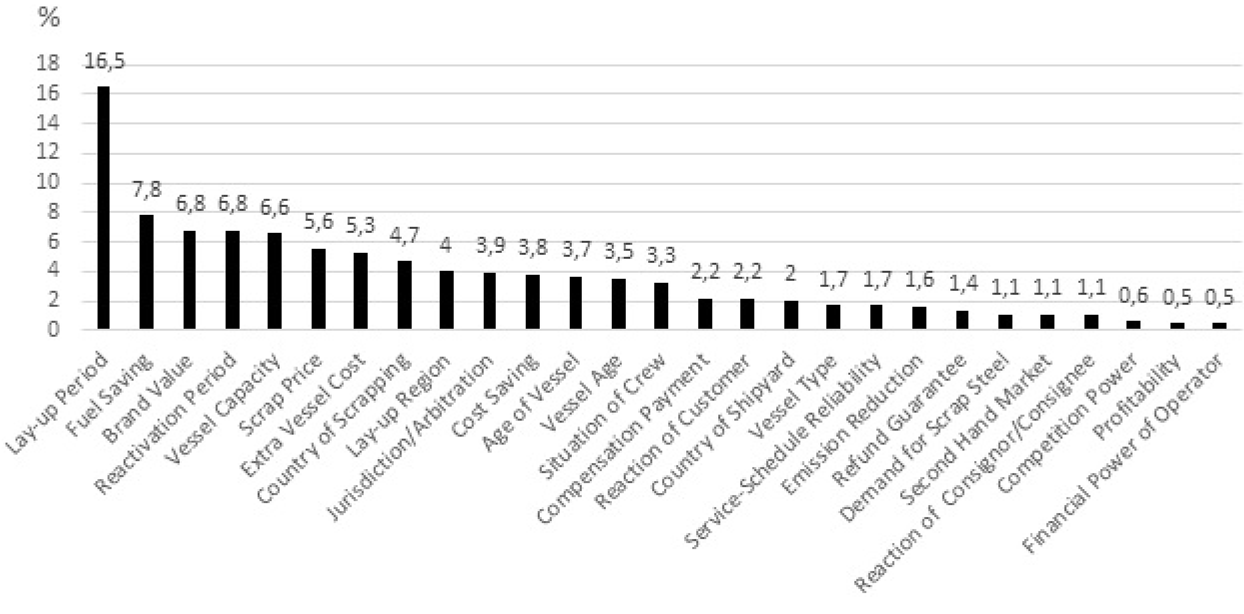

Figure 9. The degrees of importance for all sub-criteria.

6. CONCLUSION

In this study, overcapacity absorbing methods are ascertained to determine the degree of importance of each method. Managers in the decision-making positions in liner companies have difficulties as to which overcapacity reducing method to be focused on during the collapse stage of the market cycle since each overcapacity absorbing method contains different decision-making criteria inside. The reduction of overcapacity requisites 27 sub-criteria and 5 main criteria that were determined through the combination of both literature review and recommendations from the managers of liner firms.

In order to discover the importance weights of the overcapacity reducing methods, fuzzy AHP was employed. Fuzzy AHP is an efficient method to reflect the uncertainty of human thinking. Based on this it was found that during the times of a collapsed market the most preferred type of overcapacity absorbing activity is laying-up vessels with 45 %, followed by initiating slow-steaming with 19 % and, scrapping with 16 %. Newbuilding contract cancellation and/or postponement and service suspension options were found to have the least effect with 11 % and 9 %, respectively.

Depending on the results of this study, it is suggested for liner operators to revise their chartering policy in terms of the period if they require extra tonnage. Also, operators should conduct a full risk assessment before the laying-up of a vessel and it is suggested that operators work closely with stakeholders such as flag states, port authorities, ship finance and insurance providers so that their interests are considered. Regarding slow-steaming practice, operating firms are suggested to diversify some of their services especially for time-sensitive customers.

The findings of this study can provide decision-makers with a strategic approach to see how operators react to overcapacity when there is a severe collapse in the market and help them to develop strategies to better manage fleet capacity. Other multi-criteria decision-making methods, such as Fuzzy TOPSIS or other types of Fuzzy-AHP methods, could be applied to this issue.

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APPENDIX

EXPLANATION OF THE SURVEY

In order to evaluate the degree of importance for each main and sub-criterion through pairwise comparisons, a survey was formed in Excel sheet and a section for the evaluation of main criteria was given in Figure 10. Black-coloured cells are not to be filled and only white-coloured cells are filled according to the procedure explained below. The decision makers select the degree of importance indicated in each white cell through comparing a criterion with another criterion as to how important one criterion is over another one. When each white cell is clicked on, abbreviations of preferences of verbal judgements show up as given in Table A-1.

To explain, for example when comparing scrapping lying in the row and slow-steaming lying in the column, if the decision maker thinks that scrapping is absolutely more important than slow-steaming in order to absorb overcapacity, then row abso. imprtnt col. should be clicked and if the decision maker considers that slow-steaming is weakly more important than scrapping, then abbreviation of col.weak.imprtnt. row should be clicked. If the decision maker considers that two criteria are equally important then abbreviation of row-col equal imprtnt should be clicked.

Table A-1. Explanations of the abbreviations

Abbreviations of preferences	Expansions of these abbreviations
row abso. imprtnt col.	Row is absolutely important to column
row strong imprtnt col.	Row is strongly important to column
row fairly imprtnt col.	Row is fairly important to column
row weakly imprtnt col.	Row is weakly important to column
row-col equal imprtnt	Row and column is equally important
col. abso. imprtnt row	Column is absolutely important to row
col. strong. İmprtnt row	Column is strongly important to row
col. fair. İmprtnt row	Column is fairly important to row
col.weak.imprtnt. row	Column is weakly important to row

EVALUATION OF MAIN CRITERIA	Vessel Lay-up	Scrapping	Slow-steaming	Contract Cancelling/Order Postponoment	Service Suspension
Vessel Lay-up		col. fair. İmprtnt row	row abso. imprtnt col.	row abso. imprtnt col.	row abso. imprtnt col.
Scrapping			row weakly imprtnt col.	row weakly imprtnt col.	row weakly imprtnt col.
Slow-steaming				row-col equal imprtnt	row fairly imprtnt col.
Contract Cancelling/Order Postponoment					row fairly imprtnt col.
Service Suspension					

Figure A-1. A section of the survey

