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A DECISION MAKING SUPPORT OF THE MOST EFFICIENT STEAMING SPEED FOR THE LINER BUSINESS INDUSTRY

N.S.F. ABDUL RAHMAN (Corresponding author)
Department of Maritime Management, Faculty of Maritime Studies and Marine Science
Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia.
Tel: +609-6684252 E-mail: nsfitri@umt.edu.my

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Abstract

Due to the global economic recession, the global financial crisis, the increase of the bunker fuel prices and the issue of global climate change, many shipping companies suffered operating their vessels especially for the long-haul business services, such as the Asia-Europe trade. These global factors influence not only the movement of container volumes, but the ship expenditure costs and revenues are also affected. Selection of the most efficient steaming speed of containerships is an alternative solution for assisting shipping companies in planning a proactive business strategy and reducing the ship expenditure costs. There are four different levels of steaming speed in the liner shipping sector. Shipping companies need to make a decision as to which one of them will be the most efficient steaming speed considering the elements of technical, financial, environmental and commercial aspects. A combination method called FTOPSIS (Fuzzy-TOPSIS) method is presented in this paper. Such a method is capable of helping shipping companies in the decision making process of the liner business industry. Extra slow steaming is classified as the most efficient steaming speed.

Keywords: FTOPSIS; Shipping Business; Decision Making Process; Vessel Speed.

1. Introduction

The container shipping industry is one of the popular maritime businesses because it can carry a large volume of containers at a cheaper price compared to other transport modes. Therefore, it becomes the most preferred mode of transport among importers and exporters for doing business especially for the international trades. A number of global factors that occurred together in the past periods, such as 1) the global economic recession, 2) the financial crisis, 3) the sharp increase of bunker fuel prices and 3) the issue of global climate change have created huge impacts to the liner business industry. Due to the uncertainty of the global conditions, selection of the most efficient steaming speed of liner vessels for a specific service loop is one of the most important decisions shipping lines has to make in order to reduce the vessels' expenditure costs together with providing a good service performance to customers. The implementation of different levels of steaming speed will automatically influence the financial performance of shipping companies with other elements, such as the total days of journey time and the total number of vessels deployed. The motivation of this paper is to analyse and determine the most efficient steaming speed of liner business industry in terms of service performance, technical, commercial and also cost saving perspectives. A combination method between a fuzzy set theory and a technique for order preference by similarity to ideal solution (TOPSIS) method is applied in this study. To retrieve the feasibility of the scientific method developed, a test case that related to the current situation is studied as an applicable case of interest.

2. Literature Review

The world's gross domestic products (GDP) decreased by 2.2% in 2009, while trade dropped by 14.4% as traders and factories used up their inventories in the same year (World Bank, 2010). 2009 was the worst global economic recession in over seven decades and the sharpest decline in the volume of global merchandise trade (UNCTAD, 2010). Together with the collapse in economic growth and trade, international seaborne trade volumes contracted by 4.5% in 2009 (UNCTAD, 2010). Due to that, the world's largest containership is travelling at lower speeds today than sailing clippers such as the Cutty Sark did more than 130 years ago (Vidal, 2010). The strategy of changing the steaming speed helps shipping companies to reduce ship expenditure costs by consuming low bunker fuel consumption. Also, the implementation of different levels of steaming speed gives huge impacts to the total days of journey time, the total bunker fuel cost, the total number of vessels deployed and also the operational and voyage costs. In the shipping and shipbuilding markets report 2011 prepared by CAP-MARINE (2011) mentioned that there are four different levels of steaming speed for commercial containerships which are full steaming speed, slow steaming speed, extra slow steaming speed and super slow steaming speed. Full steaming speed is considered as the maximum speed for commercial containerships that has been designed by its engine manufacturer. Usually, the range of this speed is between 23 and 25 knots. Slow steaming speed refers to the speed lower than the maximum and it is approximately from 20 to 22 knots. Shipping companies which operate their vessels between 17 and 19 knots are considered as implementing extra slow steaming speed. However, if the vessel speed used is less than extra slow steaming speed, it is categorised as super slow steaming speed which is approximately from 14 to 16 knots.

Such steaming speeds have been introduced to the shipping industry in different periods of time. Slow steaming speed has been implemented in the liner shipping markets since the second half of 2008 (Cariou, 2010). According to the Edlogistics's website, extra slow steaming has gathered pace for liner operators since fuel prices reached over $350 per metric tonne in May 2009. Afterwards an announcement by COSCO's CEO, Mr Wei (SEATRADE, 2010), the alliance which also includes "K" Line, Yang Ming and Hanjing stated that they had adopted super slow steaming from November 2009. Before the global economic recession, the financial crisis and the increase of the bunker fuel prices occurred in the middle of 2008, many shipping companies enjoyed operating their ships at full steaming speed.

3. Methodology

TOPSIS method is a method to solve the Multi-Criteria Decision Making (MCDM) problems which was first developed by Hwang and Yoon in 1981 (Balli and Korukoglu, 2009; Hung and Chen, 2009; Jahanshahloo *et al.*, 2006; Mohammad *et al.*, 2010; Olson, 2004; Tsai *et al.*, 2008; Wu and Olson, 2006). Such a method is a practical and useful technique for ranking and selecting a number of alternatives through distance separation measures (Shih *et al.*, 2007). By using this method, it helps decision makers organise problems that need to be solved and then conduct the analysis comparisons. Finally, all alternatives will be ranked based on the preference order. The primary concept of the TOPSIS method is the most preferred alternative will be chosen based on not only have the shortest distance from the positive ideal solution (PIS), but also have the farthest distance from the negative ideal solution (NIS) or nadir (Balli and Korukoglu, 2009; Hung and Chen, 2009; Jahanshahloo *et al.*, 2006; Mohammad *et al.*, 2010; Tsai *et al.*, 2008; Wu and Olson, 2006).

The TOPSIS method provides a number of attributes or criteria in a systematic way (Wu and Olson, 2006). Moreover, the advantages of the TOPSIS method are 1) ability to identify the best alternative quickly (Olson, 2004), 2) simple and rationally comprehensive concept, 3) good computational efficiency, 4) ability to measure the relative performance of each alternative in a simple mathematical form (Hung and Chen, 2009; Mohammad *et al.*, 2010; Yeh, 2002), 5) large flexibility in the definition of the choice set (Mohammad *et al.*, 2010), 6) a sound logic that represents the rationale of human choice and 7) a simple computational process that can be easily programmed into a spreadsheet (Shih *et al.*, 2007). Such advantages make this technique as a relevant method to be used in this paper. According to Jahanshahloo *et al.*, (2006), the TOPSIS method can be concisely expressed in a matrix format as follows:

Table 1: A decision matrix form in TOPSIS method

	C_1	C_2	…	C_n
A_1	x_{11}	x_{12}	…	x_{1n}
A_2	x_{21}	x_{22}	…	x_{2n}
A_m	x_{m1}	x_{m2}	…	x_{mn}

where $A_1, A_2, \dots, A_m$ are the possible alternatives that shipping companies can choose; $C_1, C_2, \dots, C_n$ are the possible evaluation criteria or attributes against which an alternative performance is measured; x_{ij} is a set of values indicating the performance rating of each alternative A_i with respect to each criterion C_j (Mahmoodzadeh *et al.*, 2007). The proposed TOPSIS method procedure is defined as follows:

Step 1: Calculate the weight of the evaluation criteria

To determine the relative weight of each criterion, the fuzzy set theory and pair-wise comparison techniques are used. To conduct the pair-wise comparison matrix, firstly, it is necessary to set up n criteria in the row and column of a $n \times n$ matrix. Then, the pair-wise comparison is performed to all the criteria by applying a ratio scale assessment. The assessment scale is shown in Table 2.

Table 2: The ratio scale of pair-wise comparison

Numerical Assessment	Linguistic meaning
1	Equally important
3	A little important
5	Important
7	Very important
9	Extremely important
2, 4, 6, 8	Intermediate values of important

Numerical Assessment	Linguistic meaning
1	Equally important
1/3	A little unimportant
1/5	Unimportant
1/7	Very unimportant
1/9	Extremely unimportant
1/2, 1/4, 1/6, 1/8	Intermediate values of unimportant

Such a table contains two parts which describe the numerical assessment together with the linguistic meaning of each number. The first part is on the left hand side of the table explains "IMPORTANT", while the right hand side is the second part describes "UNIMPORTANT" (Aghajani *et al.,* 2008; Wu 2007). For a matrix of order n, $(n \times (n-1)/2)$ comparisons are required. The weighting vector of such a matrix can be computed using the geometric mean technique in association with the fuzzy set algorithm as follows:

$$f_j^{\sim} = (a_{j,1}^{\sim} \times a_{j,2}^{\sim} \times \dots a_{j,i}^{\sim} \dots \times a_{j,n}^{\sim})^{\frac{1}{n}} = \left(\left(a_{j,1}^{\sim l} \times a_{j,2}^{\sim l} \times \dots \times a_{j,n}^{\sim l}\right)^{\frac{1}{n}}, \left(a_{j,1}^{\sim m} \times a_{j,2}^{\sim m} \times \dots \times a_{j,n}^{\sim m}\right)^{\frac{1}{n}}, \left(a_{j,1}^{\sim u} \times a_{j,2}^{\sim u} \times \dots \times a_{j,n}^{\sim u}\right)^{\frac{1}{n}} \right)$$

(Eq. 1)

$(a_{j,i}^{\sim l}, a_{j,i}^{\sim m}, a_{j,i}^{\sim u})$ presents the lower bound (*l*), median (*m*) and upper bound (*u*) values of $a_{j,i}^{\sim}$.

$$W_j^{\sim} = \frac{f_j^{\sim}}{f_1^{\sim} + f_2^{\sim} + \dots f_j^{\sim} \dots + f_n^{\sim}} = (\sigma, \beta, \delta)$$

(Eq. 2)

where $f_j^{\sim}$ is the geometric mean of the *j*th row in the fuzzy pair-wise comparison matrix and $W_j^{\sim}$ is the fuzzy weight vector of the *j*th attribute. The defuzzification technique is applied in order to convert a triangular fuzzy weight value into the corresponding crisp weight value. The defuzzification approach (Mikhailov, 2004) is defined as follows:

$$DFW_j^{\sim} = \frac{1}{3}(\sigma + \beta + \delta)$$

(Eq. 3)

where $DFW_j^{\sim}$ is the defuzzified mean value of a fuzzy weight factor. The weighting vector value of attribute *j*(W_j) can then be calculated using Eq. 4.

$$W_j = \frac{DFW_j^{\sim}}{\sum_{j=1}^{n} DFW_j^{\sim}}$$

(Eq. 4)

Step 2: Construct the normalised decision matrix, R_{ij}

To convert the various attributes dimensions into non-dimensional attributes, Eq. 5 is applied. This is a useful tool to help decision makers to make a choice between complex alternatives with respect to all criteria.

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2{}_{ij}}} \quad , i = 1,2, \dots \dots , m; \quad j = 1,2, \dots \dots , n$$

(Eq. 5)

Step 3: Calculate the weighted normalised decision matrix, V_{ij}

The weighted normalised decision matrix is obtained by multiplying the weights of all the criteria in Step 1 with the normalised decision matrix in Step 2 (Eq. 6). Once all the weights of criteria have been determined, this process helps to sort them in their relative priority.

$$V_{ij} = W_j \times R_{ij}, \quad i = 1,2,\ldots\ldots,m; \quad j = 1,2,\ldots\ldots,n$$

(Eq. 6)

where W_j represents the weight of the j^{th} attribute or criterion (Mahmoodzadeh *et al.,* 2007; Yoon and Hwang, 1995).

Step 4: Determine the positive ideal solution (PIS), V^+ and negative ideal solution (NIS), V^-

According to Yoon and Hwang (1995), an ideal solution is defined as a collection of ideal levels (or ratings) in all criteria considered. It is to be as close as possible to such an ideal solution based on the rationale of human choice. PIS and NIS are determined respectively as follows:

$$V^+ = \{V^+{}_1, V^+{}_2, V^+{}_3, \ldots\ldots, V^+{}_n\} = \{(max_j V_{ij} \mid j \in J)\}, \{(min_j V_{ij} \mid j \in J')\}$$

(Eq. 7)

$$V^- = \{V^-{}_1, V^-{}_2, V^-{}_3, \ldots\ldots, V^-{}_n\} = \{(min_j V_{ij} \mid j \in J)\}, \{(max_j V_{ij} \mid j \in J')\}$$

(Eq. 8)

where J is associated with the benefit criteria and J' is associated with the cost criteria (Mahmoodzadeh *et al.,* 2007).

Step 5: Calculate the distance separation measure for PIS, $D^+{}_i$ and NIS, $D^-{}_i$

Distance separation is considered as a degree or amount of separation between two points of the study. All the alternatives with their PIS and NIS can be measured using the Euclidean distance technique as shown in Eqs. 9 and 10.

$$D^+{}_i = \sqrt{\sum_{j=1}^{n}(V_{ij} - V^+{}_j)^2}, \; i = 1,2,\ldots\ldots,m$$

(Eq. 9)

$$D^-{}_i = \sqrt{\sum_{j=1}^{n}(V_{ij} - V^-{}_j)^2}, \; i = 1,2,\ldots\ldots,m$$

(Eq. 10)

The detailed information of the Euclidean distance technique can be referred to such literatures as Dattorro (2001), Gower (1982) and Gutierrez and Garcia-Palomares (2008).

Step 6: Calculate the relative closeness to the ideal solution, RC_i^+

A closeness coefficient is defined to determine the ranking order of all alternatives once the $D^+{}_i$ and $D^-{}_i$ of each alternative A_i has been calculated. The relative closeness (RC_i^+) to the ideal solution can be computed using Eq. 11 as follows:

$$RC_i^+ = \frac{D_i^-}{D^+{}_i + D_i^-} \quad i = 1,2,\ldots\ldots,m$$

(Eq. 11)

Step 7: Rank the preference order of alternatives

Based on the relative closeness to the ideal solution in Step 6, the larger is the RC_i^+ value; the better is the performance of the alternative A_i (Devi *et al.*, 2009; Mahmoodzadeh *et al.*, 2007).

4. Selection Of The Most Efficient Steaming Speed For The Liner Business Industry

A test case is created based on the current situation faced by shipping companies. Firstly, it starts with identifying the issue faced by shipping companies and sets up a goal that needs to be achieved. Secondly, the main body of the test case contains of 1) identifying criteria, 2) identifying alternatives, 3) a model development process and 4) data collection process of all the criteria and sub-criteria. Finally, it concludes with 1) performing the weighting vector calculation process using a fuzzy set theory and 2) ranking the preference order of all the alternatives using the TOPSIS method.

4.1 Identify the problem matter and determine a goal

The discussion technique with the selected experts has been used to determine an appropriate goal that needs to be achieved based on the current situation faced by many shipping companies regarding the steaming speed. Such experts are selected based on their experiences of about 10 to 20 years in the shipping industry including knowledge, skills and also ability to judge on certain issues that are closely related to the container shipping sector. Due to the global factors described in Section 1, all players in the liner business industry looked for a new formula on how to reduce bunker fuel costs and gas emissions by adjusting the vessel speed as part of a business strategy. Therefore, the goal of this paper is to select the most efficient steaming speed of the liner business industry when dealing with uncertainties in the global situations.

4.2 Identify the evaluation criteria and sub-criteria

A discussion technique with the selected experts has been used in this study for identifying the evaluation criteria and sub-criteria. The main criteria can be grouped into four categories which are 1) Technical and Operational Aspect (TOA), 2) Financial Aspect (FA), 3) Environmental Aspect (EA) and 4) Commercial and Trade Aspect (CTA). Each group of criteria has its associated sub-criteria as listed in Table 3. All the criteria and sub-criteria will assist the FTOPSIS method to achieve the goal described in Section 4.1. In this paper, there are two possible goals for each sub-criterion which are either "Benefit" or "Cost" goal. The goal "Benefit" is related to a positive solution, while the goal "Cost" is associated with a negative solution in determining the PIS and NIS.

Table 3: The list of criteria and sub-criteria associated with the goal

Level 1 (Main Criteria)	**Level 2 (Sub-criteria)**	**Goal**
Technical and Operational Aspect (TOA)	Maintenance Cost (MC)	Cost
	Auxiliary Consumption (AC)	Cost
	Propulsion Power (PP)	Benefit
	Service Performance (SP)	Benefit
Financial Aspect (FA)	Bunker Fuel Cost (BFC)	Cost
	Operational Cost excluded MC (OC)	Cost
	Additional Vessel Cost (AVC)	Cost
	Ship Revenue (SR)	Benefit
Environmental Aspect (EA)	Carbon Dioxide (CO_2)	Cost
	Nitrogen Dioxide (NO_x)	Cost
	Sulphur Dioxide (SO_x)	Cost
Commercial and Trade Aspect (CTA)	Journey Time (JT)	Cost

4.3 Identify the possible alternatives solution

As described in Section 2, there are four different levels of steaming speed. All of them have to be considered for assisting shipping companies in the decision making process for reducing the ship's expenditure costs, while providing an excellent service performance to customers.

4.4 Data collection process

Quantitative and qualitative data collections are involved in this process. The quantitative data of three sub-criteria are obtained using published mathematical algorithms which are 1) journey time (Notteboom and Vernimmen, 2009), 2) bunker fuel cost (Magelssen, 2010) and 3) carbon dioxide (Corbett, Wang and Winebrake, 2009). The propulsion power data of the selected containership is obtained from Man B&W (2010), while the ship's operational cost data is obtained from the Institute of Chartered Shipbrokers (2009). The qualitative data of MC, AC, SP, AVC, SR, NO_x and SO_x are obtained from the selected experts, who are originally from a shipping background, by using a set of questionnaires consisting of a rating scale ranging from 1 to 10. All the feedbacks received from them are calculated using Eq. 12 for determining the average rating value.

$$Average\ Rating\ Value = \frac{\text{Total rate given by all the experts for the same criterion}}{\text{Total number of experts}}$$

(Eq. 12)

All the quantitative and qualitative data are aggregated in Table 4 with respect to all the alternatives.

Table 4: The data of all the evaluation criteria

	MC	AC	PP (kW) (×10^3)	SP	BFC ($) ('000)	OC ($) ('000)	AVC	SR	CO_2 (kg) (×10^3)	NO_X	SO_X	JT (days)
FS	2.67	8.33	65.53	9.67	4,363	1,482	0.00	6.00	39.87	10.00	10.00	56.00
SS	3.67	7.00	59.96	7.00	3,379	1,630	4.33	6.00	23.17	7.67	7.67	61.33
ESS	4.67	5.00	51.40	4.67	2,520	1,826	7.00	6.33	13.23	5.67	5.67	68.35
SSS	6.33	3.00	44.54	3.33	1,787	2,094	10.00	6.67	7.77	4.00	4.00	77.99
	17.34	**23.33**	**221.43**	**24.67**	**12,049**	**7,032**	**21.33**	**25.00**	**84,04**	**27.34**	**27.34**	**263.67**

4.5 Perform calculation and rank all the alternatives

Step 1: Estimate the weight of each criterion. The weight estimation process of all the criteria in Table 3 is conducted using the pair-wise comparison technique. The implementation of this technique is associated with a number of selected expert judgements for analysing the priority of each criterion to another by incorporating the ratio scale of pair-wise comparison in Table 2. Given the four main criteria as an example, a 4×4 pair-wise comparison matrix is developed for obtaining the weight of each of them. *A(TFEC)* is a matrix expressing the qualified judgement with regard to the relative priority of TOA (*T*), FA (*F*), EA (*E*) and CTA (*C*).

$$A(TFEC) = \begin{array}{c} \\ T \\ F \\ E \\ C \end{array} \begin{bmatrix} T & F & E & C \\ (1,1,1) & (3,3,4) & (\frac{1}{6},\frac{1}{4},\frac{1}{5}) & (3,4,3) \\ (\frac{1}{3},\frac{1}{3},\frac{1}{4}) & (1,1,1) & (2,3,2) & (2,2,2) \\ (6,4,5) & (\frac{1}{2},\frac{1}{3},\frac{1}{2}) & (1,1,1) & (\frac{1}{4},\frac{1}{5},\frac{1}{5}) \\ (\frac{1}{3},\frac{1}{4},\frac{1}{3}) & (\frac{1}{2},\frac{1}{2},\frac{1}{2}) & (4,5,5) & (1,1,1) \end{bmatrix}$$

The weighting vector of the *A(TFEC)* matrix is calculated using the geometric mean in association with the fuzzy set and defuzzification techniques as described in Eqs. 1 to 4. The weighting vector values of all the main criteria are computed as follows:

$$f_{TOA} = \left[(1,1,1) \times (3,3,4) \times \left(\frac{1}{6},\frac{1}{4},\frac{1}{5}\right) \times (3,4,3)\right]^{\frac{1}{4}}$$

$$= (1 \times 3 \times \frac{1}{6} \times 3)^{\frac{1}{4}}, (1 \times 3 \times \frac{1}{4} \times 4)^{\frac{1}{4}}, (1 \times 4 \times \frac{1}{5} \times 3)^{\frac{1}{4}}$$

$$= \underline{(0.3750, 0.7500, 0.6000)}$$

$f_{FA} = (0.3333, 0.5000, 0.2500)$, $f_{EA} = (0.1875, 0.0667, 0.1250)$

$f_{CTA} = (0.1667, 0.1563, 0.2083)$

Total geometric mean $(f_{TOA} + f_{FA} + f_{EA} + f_{CTA})$ = $\underline{(1.0625, 1.4730, 1.1833)}$

The fuzzy weight vector values of all the main criteria are calculated by using Eq. 2 as follows:

$$W_{TOA} = \frac{(0.3750, 0.7500, 0.6000)}{(1.0625, 1.4730, 1.1833)} = \left(\frac{0.3750}{1.1833}, \frac{0.7500}{1.4730}, \frac{0.6000}{1.0625}\right) = (0.3169, 0.5092, 0.5647)$$

$W_{FA} = (0.2817, 0.3394, 0.2353)$, $W_{EA} = (0.1584, 0.0453, 0.1176)$

$W_{CTA} = (0.1409, 0.1061, 0.1960)$

The above estimates are triangular fuzzy weight vectors. Therefore, defuzzification is applied in order to convert the triangular fuzzy weight vector values into the corresponding crisp weight vector values (Eq. 3). The weight vector value of each criterion is computed using Eq. 4 as shown in Table 5.

Table 5: The weighting vector values of all the main criteria

Fuzzy Weight Vectors	Defuzzification	Weighting Vector Value
$W_{TOA} = (0.3169, 0.5092, 0.5647)$	0.4636	0.4618
$W_{FA} = (0.2817, 0.3394, 0.2353)$	0.2855	0.2844
$W_{EA} = (0.1584, 0.0453, 0.1176)$	0.1071	0.1067
$W_{CTA} = (0.1409, 0.1061, 0.1960)$	0.1477	0.1471
	1.0039	**1.0000**

According to the weighting vector values described in Table 5, TOA is 46.18% of priority compared to others, which is almost half of the total priority. It is highlighted as the most important element influencing shipping companies to select the most efficient steaming speed of the selected containership. The second important element influencing shipping companies to achieve the main goal is FA, 28.44% of priority and followed by CTA, 14.71% of priority at the third place. Finally, EA is the least considered element with 10.67% of priority respectively.

The same calculation process of the weighting vector described previously is applied to determine the priority of each sub-criterion compared to others in the same criterion's group at Level 2. There are 11 sub-criteria under the three groups of main criteria, which are 1) TOA, 2) FA and 3) EA that need to be evaluated. The weighting vector value of the sub-criterion "JT" is 0.1471, which is same as the weighting vector value of the main criterion "CTA" because it is the only variable in this group.

The weighting vector values of all the twelve sub-criteria in Level 2 are summarised as follows: $W_{MC} = 0.0473$, $W_{AC} = 0.0004$, $W_{PP} = 0.9499$, $W_{SP} = 0.0024$, $W_{BFC} = 0.$ 9082, $W_{OC} = 0.0721$, $W_{AVC} = 0.0096$, $W_{SR} = 0.0101$, $W_{CO_2} = 0.2865$, $W_{NO_X} = 0.4269$, $W_{SO_X} = 0.2865$, $W_{JT} = 0.1471$.

There are more than two sub-criteria of each criterion except the criterion "CTA". Therefore, the normalised weighting vector value of each sub-criterion needs to be determined by multiplying the weighting vector value of the sub-criterion with the weighting vector value of the corresponding main criterion. Given the TOA's group as an example, the normalised weighting vector $(W(NMAPS))$ values of all the sub-criteria in this group are obtained as follows:

$$W(MAPS) = \begin{matrix} M \\ A \\ P \\ S \end{matrix}\begin{bmatrix} 0.0473 \\ 0.0004 \\ 0.9499 \\ 0.0024 \end{bmatrix} \left(W(NMAPS)\right) = W(MAPS) \times 0.4618 = \begin{matrix} M \\ A \\ P \\ S \end{matrix}\begin{bmatrix} 0.0218 \\ 0.0002 \\ 0.4387 \\ 0.0011 \end{bmatrix}$$

where *M*, *A*, *P* and *S* stand for MC, AC, PP and SP respectively. In a similar way, the normalised weighting vector values of all other sub-criteria are obtained as shown in Table 6.

Table 6: The normalised weighting vector values of all the criteria

	MC	AC	PP	SP	BFC	OC	AVC	SR	CO_2	NO_X	SO_X	JT
Weight (W_j)	0.0218	0.0002	0.4387	0.0011	0.2583	0.0205	0.0027	0.0029	0.0306	0.0455	0.0306	0.1471

Step 2: Construct the normalised decision matrix, R_{ij}. The normalised decision matrix of the test case is computed using Eq. 5 as described in Section 3 in association with a set of data in Table 4. The calculation technique is applied

to all alternatives with respect to all attributes and Table 7 summarises the normalised decision matrix values.

Table 7: The normalised decision matrix

	MC	AC	PP	SP	BFC	OC	AVC	SR	CO_2	NO_X	SO_X	JT
FS	0.2940	0.6748	0.5858	0.7301	0.6899	0.4180	0.0000	0.4795	0.8204	0.6949	0.6949	0.4215
SS	0.4041	0.5670	0.5360	0.5285	0.5343	0.4597	0.3343	0.4795	0.4767	0.5330	0.5330	0.4616
ESS	0.5142	0.4050	0.4595	0.3526	0.3985	0.5150	0.5405	0.5059	0.2722	0.3940	0.3940	0.5144
SSS	0.6970	0.2430	0.3981	0.2514	0.2826	0.5906	0.7721	0.5331	0.1599	0.2780	0.2780	0.5870

Step 3: Calculate the weighted normalised decision matrix, V_{ij}. Referring to the normalised weighting vector value of each criterion in Table 6 and the normalised decision matrix values in Table 7, the weighted normalised decision matrix of this test case is calculated using Eq. 6. The calculation process is applied to all alternatives with respect to all criteria and Table 8 summarises the output of the calculation.

Table 8: The weighted normalised decision matrix

	MC	AC	PP	SP	BFC	OC	AVC	SR	CO_2	NO_X	SO_X	JT
FS	0.0064	0.0001	0.2570	0.0008	0.1782	0.0086	0.0000	0.0014	0.0251	0.0316	0.0212	0.0620
SS	0.0088	0.0001	0.2351	0.0006	0.1380	0.0094	0.0009	0.0014	0.0146	0.0243	0.0163	0.0679
ESS	0.0112	0.0001	0.2016	0.0004	0.1029	0.0106	0.0015	0.0014	0.0083	0.0179	0.0120	0.0757
SSS	0.0152	0.0000	0.1746	0.0003	0.0730	0.0121	0.0021	0.0015	0.0049	0.0126	0.0085	0.0863

Step 4: Determine the positive ideal solution (PIS), V^+ *and negative ideal solution (NIS),* V^-. Referring to Table 8 in association with the goal of each sub-criterion described in Table 3, the positive and negative ideal solutions are determined using Eqs. 7 and 8. The output values of PIS are summarised in Table 9.

Table 9: The positive ideal solution, V^+

	Cost	**Cost**	**Benefit**	**Benefit**	**Cost**	**Cost**	**Cost**	**Benefit**	**Cost**	**Cost**	**Cost**	**Cost**
	MC	**AC**	**PP**	**SP**	**BFC**	**OC**	**AVC**	**SR**	CO_2	NO_X	SO_X	**JT**
FS	0.0064	0.0001	0.2570	0.0008	0.1782	0.0086	0.0000	0.0014	0.0251	0.0316	0.0212	0.0620
SS	0.0088	0.0001	0.2351	0.0006	0.1380	0.0094	0.0009	0.0014	0.0146	0.0243	0.0163	0.0679
ESS	0.0112	0.0001	0.2016	0.0004	0.1029	0.0106	0.0015	0.0014	0.0083	0.0179	0.0120	0.0757
SSS	0.0152	0.0000	0.1746	0.0003	0.0730	0.0121	0.0021	0.0015	0.0049	0.0126	0.0085	0.0863

The goal of each criterion in the NIS changes to the opposite way from the PIS, for instance, from “Benefit” to “Cost” and the other way around. Table 10 shows the output values of NIS.

Table 10: The negative ideal solution, V^-

	Benefit	Benefit	Cost	Cost	Benefit	Benefit	Benefit	Cost	Benefit	Benefit	Benefit	Benefit
	MC	AC	PP	SP	BFC	OC	AVC	SR	CO_2	NO_X	SO_X	JT
FS	0.0064	0.0001	0.2570	0.0008	0.1782	0.0086	0.0000	0.0014	0.0251	0.0316	0.0212	0.0620
SS	0.0088	0.0001	0.2351	0.0006	0.1380	0.0094	0.0009	0.0014	0.0146	0.0243	0.0163	0.0679
ESS	0.0112	0.0001	0.2016	0.0004	0.1029	0.0106	0.0015	0.0014	0.0083	0.0179	0.0120	0.0757
SSS	0.0152	0.0000	0.1746	0.0003	0.0730	0.0121	0.0021	0.0015	0.0049	0.0126	0.0085	0.0863

Step 5: Calculate the distance separation measures for PIS, D^+_i and NIS, D^-_i. Based on the explanation in Step 5 of Section 3, the Euclidean distance technique is applied in this step. The D^+_i is computed using Eq. 9, while the D^-_i is calculated using Eq. 10. The calculation technique is applied to all alternatives with respect to all the criteria. Table 11 summarises the values of the distance separation measure of each alternative from the PIS and NIS.

Table 11: The distance separation measure values of each alternative

	D^+	D^-
FS	0.1095	0.0866
SS	0.0707	0.0762
ESS	0.0648	0.0843
SSS	0.0866	0.1095

Step 6: Calculate the relative closeness to the ideal solution, RC_i^+. The best alternative of the steaming speed will be chosen by shipping companies based on the RC_i^+ value closest to one which has the shortest distance from the PIS point and the farthest distance from the NIS point (Eq. 11). The calculation technique is applied to all alternatives in order to compute the relative closeness values to the ideal solution. As a result, the RC_i^+ values of all the steaming speeds are shown in Table 12.

Step 7: Rank the preference alternatives. Table 12 shows the different RC_i^+ values of all the alternatives. The alternative "ESS" is ranked as the top of the alternatives list. It can be concluded that such an alternative is the most efficient steaming speed of liner business industry for the Asia-Europe route service taking into consideration all criteria described in Table 3. The full ranking of all alternatives is as follows: 1) ESS > 2) SSS > 3) SS > 4) FS.

Table 12: The relative closeness to the ideal solution

	RC_i^+
FS	0.4416
SS	0.5187
ESS	0.5654
SSS	0.5584

5. Conclusions

A steaming speed of containerships is the most important factor affecting the liner business industry including the ship expenditure costs and also service performance. By selecting the most efficient steaming speed, it could help shipping companies to manage its finances in order to minimise the ship expenditure costs, while providing a reasonable journey time for a selected route service. The FTOPSIS method is fully applied in this paper because it is capable of dealing with both qualitative and quantitative dataset. By developing a generic model, shipping companies can make a rational decision for choosing the most efficient steaming speed based on the multiple criteria requirement for a specific loop. The selection of evaluation criteria and sub-criteria can be improved from time to time based on various situations faced by shipping companies.

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Dr. Noorul Shaiful Fitri Abdul Rahman is currently affiliating with Faculty of Maritime Studies and Marine Science, Universiti Malaysia Terengganu, Terengganu, Malaysia. His research interests include steaming speed of containerships, decision making techniques in the maritime sector, shipping economics and finance, and uncertainty treatment in the maritime sector.