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SELECTION OF THE MOST BENEFICIAL SHIPPING BUSINESS STRATEGY FOR CONTAINERSHIPS

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Abstract

Various shipping business strategies have been proposed to tackle the recent uncertainty of global conditions. Some strategies are designed to reduce the total amount of emissions produced by containerships and also to reduce the vessel expenditures especially the bunker fuel cost. To deal with the uncertainties, a scientific decision making model is therefore proposed using an evidential reasoning (ER) method in association with a fuzzy-link based technique and an analytical hierarchy process (AHP) approach for assisting shipping companies in selecting the most beneficial shipping business strategy. A set of qualitative data has been obtained from expert judgements. A strategy "combination of Mega Containership and Reduction of Ports of Call" is addressed as the most beneficial shipping business alternative in a dynamic operational environment.

Keywords: Shipping Business Strategy; Containerships; Fuzzy-link Based; Evidential Reasoning; Decision Making Technique.

1. Introduction

1976, 1986, 1997 and 2008/2009 were the years which possessed the bad economic histories globally (Tomas et al., 2010). The major impacts of these years were the decrease of the domestic and international business activities, ultimately increasing the price of all consumables, foods and fuels. The increase of fuel price was resulted in the increase of public and private transportation costs. Due to such impacts, the development of economic activity was dramatically slow; thus, firms decided to save money rather than invest. In the container shipping sector, many players plan a proactive business strategy in order to reduce any unexpected risks during a bad economic period. Business strategy is defined as a short or long term plan of action designed to achieve a particular goal or set of goals. Several opinions or ideas have come out from different perspectives (e.g. the engineering, operational and business point of views) in the past few years with the purpose of finding suitable long and short term solutions for achieving the business goals. The motivation of this paper is to analyse and determine the most beneficial business strategy of containerships in order to reduce any unexpected risks during the bad global economic period in the future. In addition, the elements of journey time, service costs, service quality, technical quality and market share will be taken into consideration.

1.1 The Impacts of Global Crisis to the Container Shipping Sector

The service performance of the container shipping industry depends on both the global economy and the container market demand conditions (Bendall and Stent, 2003). The period from September 2008 to April 2009 was the worst economic recession after World War 2 and in over seven decades (International Monetary Fund, 2009; UNCTAD, 2010). As a consequence, the world's gross domestic products (GDP) decreased by up to 5% in 2009 compared to the year before (World Bank, 2010). At the same year of the global economics recession, the global financial crisis occurred. The crisis originated in the United States and spread rapidly to the rest of the world in a matter of days (Samaras and Papadopoulou, 2010). The global financial crisis in September 2008 was exploded and triggered by the sudden bankruptcy of Lehman Brothers (Barry Rogliano Salles, 2009). Bad debts were revealed at most western banks and billions of dollars in value were wiped from stock markets (Barry Rogliano Salles, 2009). This phenomenon shows that almost all international businesses including the container shipping sector suffered and some of them collapsed. This crisis was the biggest global economic contraction on record, due to the reduction of global exports by 9% in 2009 (World Trade Organization, 2009). Together with the global economic recession and the global financial crisis, the bunker fuel price has extremely increased in 2008 (Barillo, 2011; Kontovas and Psaraftis, 2011). The current situation of the bunker fuel price is still under debate among the liner shipping players because it plays a major role in influencing the bunker fuel cost of containerships (Clarkson Research Services, 2010). The high bunker fuel price is leading to the increase of bunker fuel cost (Kontovas and Psaraftis, 2011). The history of bunker fuel price was fluctuated from US$142 per tonne in 1980s, US$81 in 1990s, US$265 in 2000s, spiking at US$495 in April 2008, suddenly falling to US$276 in April 2009 before increasing again at a level of US$467 in April 2010 and the price continues increased to a level of US$650 per tonne in April 2011 (Clarkson Research Services, 2012). Such an issue makes shipping companies under pressure to find a good solution in reducing the bunker fuel cost. This is because the bunker fuel cost is accounting for 60% of total voyage costs per sailing (Ben, 2009).

The downturn in the global economy and the global financial crisis has been resulted in reducing the container market demand (UNCTAD, 2010; Wiesmann, 2010; Clarkson Research Services, 2012). The international seaborne trade volumes have been decreased by up to 7% in 2009 compared to 2008 (UNCTAD, 2010). In the first half of 2009, the container volumes reduced by double digits over the full year, and global box trade faced an unprecedented collapse (Clarkson Research Services, 2009). Also, in 2009, the total liner fleet expanded by 9.6% to total 15.7 million TEUs (UNCTAD, 2010). The increase of vessel capacity in carrying containers and the decrease of container volumes occurred together in 2009 led to an imbalance between vessels' supply and the demand of container shipping (Clarkson Research Services, 2010). Such a condition was significant downwards pressure on the container shipping markets as a whole. At the same time, the new regulation of global emissions has been introduced by the International Maritime Organization (IMO) in October 2008 with the purpose of monitoring air emissions produced by containerships (IMO, 2010; Kontovas and Psaraftis, 2011; Wiesmann, 2010). The IMO adopted a number of important amendments to Annex VI of the Maritime Pollution (MARPOL) Convention which regulates air emissions. It introduced more stringent controls on Nitrogen Dioxide (NO_x) and undertook much work to gradually reduce the global limit for Sulphur Dioxide (SO_x) emissions from 4.5% to 0.5% sulphur content in fuel by 2020 (IMO, 2010). Also, the new MARPOL includes "Sulphur Emissions Control Areas" (SECA) and require vessels to run on low sulphur fuels in order to reduce emissions of sulphuric acid formed in engine exhaust pipes by the combination of water with sulphur dioxide (Barry Rogliano Salles, 2008).

Due to the uncertain atmospheres described above, the total revenue of the container shipping sector fell by 45% in 2009 compared to the year before (Clarkson Research Services, 2010), which was more than US$15 billion (Raoust, 2010). For example, A.P. Moller Maersk Group, who lost approximately US$1 billion in 2009 (Siyu, 2011).

1.2 Shipping Business Strategy

The uncertainty of the global factors affects the service performance of shipping companies in total. Therefore, most shipping companies are now looking for the most beneficial business strategy in operating their vessels for a long term period. Several business strategies have come out from different perspectives (e.g. the engineering, operational and business point of views) in the past few years with the purpose of reducing the vessels expenditures costs, emissions produced by containerships and increasing the profit margin of the shipping business. There are four shipping business strategies that have been mostly discussed by researchers, namely 1) Mega Containership (MC) (Lim, 1998; Gilman, 1999; Cullinane and Khanna, 2000; Ircha, 2001; Damas, 2001; Wijnolst and Wergeland, 2009; Imai *et al.*, 2006;), 2) Reduction of Ports of Call (RPoC) (Palsson, 1998; Wang, 2008; Imai *et al.*, 2009; Wilmsmeier and Notteboom, 2009; Gelareh *et al.*, 2010; Fremont, 2007), 3) Business Sharing (BS) (Ding and Liang, 2005; Solesvik and Westhead, 2010; Das, 2011; Midoro and Pitto, 2000) and 4) a combination of Mega Containership and Reduction of Ports of Call (MC & RPoC) (Epaminondas, 2007; Payer, 1999). These authors have discussed the advantages and disadvantages of each shipping business strategy in their findings. Nevertheless, no one has conducted an analysis to discover which one of the shipping business strategies described is the most beneficial to the shipping companies in operating their vessels, although the importance of such researches has been highlighted.

2. Methods

Three types of decision making technique will be used in this paper, namely 1) analytical hierarchy process (*AHP*) method and 2) evidential reasoning (*ER*) method and a fuzzy-link based technique. The reasons of choosing these methods are:

i) It is suitable for analysing both qualitative and quantitative decision making criteria.

ii) It enables to take a large quantity of criteria into consideration.
iii) It enables to facilitate the construction of a flexible hierarchy to address the decision making problem.
iv) As a hierarchical evaluation process, it is capable of offering a rational and reproducible methodology to aggregate the data assessed.
v) It is capable of handling incomplete and complete data.
vi) It is capable of accommodating uncertainty and risk that is inherent in the decision analysis.
vii) It is capable of obtaining the assessment output using mature computing software, called the Intelligent Decision System (*IDS*).

2.1 An Analytical Hierarchy Process (AHP) Approach

The *AHP* approach is a structured technique for organising and analysing complex decisions using the mathematical structure of consistent matrices for determining the weight values (Merkin, 1979; Saaty, 1980 and 1994). Also, it enables comparison of criteria with respect to a criterion in the nature of the pair-wise comparison mode. Such a comparison, using a fundamental scale of absolute numbers, is obtained from Saaty (1980). The fundamental scale has been shown to be one that captures individual preferences with respect to quantitative and qualitative attributes (Saaty, 1980 and 1994). The *AHP* approach has been widely applied in several areas, such as strategic decision making (Bhushan and Kanwal, 2004), engineering education (Drake, 1998) and risk analysis (Dey, 2003). The qualified judgements on pairs of attribute A_i and A_j are represented by a $n \times n$ matrix *A* as shown in Eq. 1.

$$A = (a_{ij}) = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ ^{a}/_{a_{12}} & 1 & \cdots & a_{2n} \\ . & . & \cdots & . \\ ^{1}/_{a_{1n}} & ^{1}/_{a_{2n}} & \cdots & 1 \end{bmatrix} \quad \text{(Eq. 1)}$$

where $i, j = 1, 2, 3, \ldots, n$ and each a_{ij} is the relative importance of attribute A_i to attribute A_j. The weight vector indicates the priority of each element in the pair-wise comparison matrix in terms of its overall contribution to the decision making process. Such a weight value can be calculated using the following Eq. 2.

$$w_k = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}}\right) \qquad (k = 1, 2, 3, \ldots, n) \quad \text{(Eq. 2)}$$

where a_{ij} stands for the entry of row *i* and column *j* in a comparison matrix of order *n*. Next, the consistency of the pair-wise comparison needs to be evaluated. Such a consistency process can be done using a consistency ratio (*CR*). *CR* is designed in such a way that a value greater than 0.10 indicates an inconsistency in pair-wise comparison. If *CR* is 0.10 or less, the consistency of the pair-wise comparisons is considered reasonable. Further detail of the calculation process can be referred to Anderson *et al.*, (2003).

2.2 A Fuzzy-Link Based Technique

A fuzzy-link based transformation technique is developed using the concept of evaluation rules, considering that different grades in different criteria may be used to describe equivalent standards (Figure 1) (Yang *et al.*, 2009). For example, let "*I*" (e.g. Trip Time) be an upper level qualitative criterion (*ULC*) and "*J*" (e.g. Time at Road) be a lower level qualitative criterion. "L_i" stands for the lower level linguistic term (e.g. L_1 stands for "*Fast*", L_2 stands for "*Reasonably Fast*", L_3 stands for "*Average*", L_4 stands for "*Reasonably Slow*" and L_5 stands for "*Slow*") and "l^i" represents the fuzzy inputs of "L_i". "U_j" stands for the upper level linguistic term (e.g. U_1 stands for "*Short*", U_2 stands for "*Reasonably Short*", U_3 stands for "*Average*", U_4 stands for "*Reasonably Long*" and U_5 stands for "*Long*") and "u^j" represents the fuzzy outputs of "U_j".

$$u^j = \sum_{i=1}^{5} l^i \beta_i^j \quad \text{(Eq. 3)}$$

$$\sum_{i=1}^{5} l^i \leq 1 \quad \text{(Eq. 4)}$$

$$\sum_{j=1}^{5} \beta_1^j = 1, \sum_{j=1}^{5} \beta_2^j = 1, \sum_{j=1}^{5} \beta_3^j = 1, \sum_{j=1}^{5} \beta_4^j = 1, \sum_{j=1}^{5} \beta_5^j = 1 \quad \text{(Eq. 5)}$$

where β_i^j stands for the belief degrees that are assigned by experts. The relationships between fuzzy inputs and fuzzy outputs can be calculated using Eqs. 3 and 4. Note that the sum of the belief values from one linguistic variable has to be equal to one (Eq. 5). Such a technique has been widely used in the research fields including maritime security assessment (Yang *et al.*, 2009) and risk operation in supply chain (Riahi, 2010).

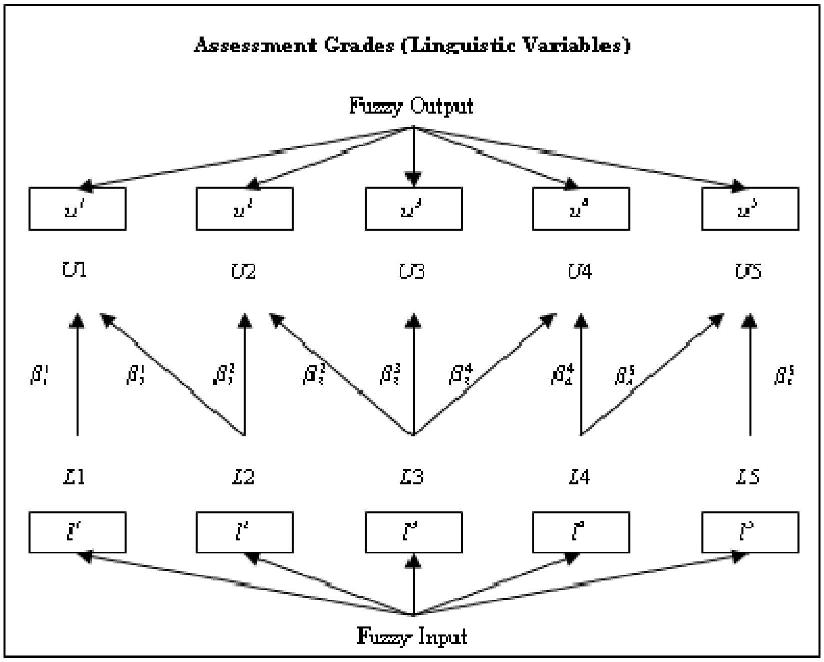

Figure 1: A fuzzy-link based for transforming fuzzy input values to fuzzy output values

2.3 An Evidential Reasoning (ER) Approach

The *ER* approach was developed in 1994 by Yang and Singh, later updated by Yang in 2001 and further modified by Yang and Xu in 2002 (Lee, 2008; Riahi, 2010). It is particularly useful for dealing with both qualitative and quantitative criteria under uncertainty utilising individuals' knowledge, expertise and experience in the forms of belief functions (Riahi, 2010). The *ER* approach has been successfully applied in several areas, such as offshore design, system evaluation, container line security assessment, crude oil tanker selection, safety analysis in Yang and Sen (1997), Riahi (2010), Lee (2008) and Wang *et al.*, (1995 and 1996). Given a simple two-level hierarchy of attributes with a general attribute at the top level and a number of basic attributes at the bottom level as an example.

Suppose there are *L* basic attributes $e_i (i = 1, 2, \dots, L)$ associated with a general attribute y. Define a set of *L* basic attributes as follows: $E = \{e_1, \dots, e_i, \dots, e_L\}$. Given weights $w_i (i = 1, 2, \dots, L)$ of the basic attributes, where w_i is the relative weight of the ith basic attribute (e_i) with $0 \le w_i \le 1$. Such weight values can be established through a pair-wise comparison involving the *AHP* approach as described in Section 2.1. A given assessment for $e_i (i = 1, 2, \dots, L)$ can be mathematically represented as shown in Eq. 6 (Yang and Xu, 2002).

$$S(e_i) = \{(H_n, \beta_{n,i}),\ n = 1, 2, \dots, N\},\quad (i = 1, 2, \dots, L) \qquad \text{(Eq. 6)}$$

where H_n is the nth evaluation grade. $\beta_{n,i}$ denotes a degree of belief satisfying $\beta_{n,i} \ge 0$ and $\sum_{n=1}^{N} \beta_{n,i} \le 1$. An assessment $S(e_i)$ is called complete (relatively, incomplete) if $\sum_{n=1}^{N}\beta_{n,i}=1$ (respectively, $\sum_{n=1}^{N}\beta_{n,i}\leq 1$). Next, let $m_{n,i}$ be a basic probability mass representing the degree to which the ith basic attribute e_i supports the hypothesis that the general attribute y is assessed to the nth grade H_n. $m_{n,i}$ is calculated as follows (Yang and Xu, 2002):

$$m_{n,i}=w_i\beta_{n,i}\quad (n=1,2,\ldots,N;\ i=1,2,\ldots,L) \tag{Eq. 7}$$

where w_i need to be normalised. $m_{H,i}$ is given by

$$m_{H,i}=1-\sum_{n=1}^{N}m_{n,i}\ (i=1,2,\ldots,L) \tag{Eq. 8}$$

The remaining probability mass $m_{H,i}$ is split into two parts, $\bar{m}_{H,i}$ and $\tilde{m}_{H,i}$, and is calculated using the following equations (Yang and Xu, 2002):

$$\bar{m}_{H,i}=1-w_i\quad (i=1,2,\ldots,L) \tag{Eq. 9}$$
$$\tilde{m}_{H,i}=w_i\left(1-\sum_{n=1}^{N}\beta_{n,i}\right)\quad (i=1,2,\ldots,L) \tag{Eq. 10}$$

where $m_{H,i}=\bar{m}_{H,i}+\tilde{m}_{H,i}$. $\bar{m}_{H,i}$ is a basic probability mass representing the belief degree of the basic attributes e_i, while $\tilde{m}_{H,i}$ is the incompleteness of the belief degree assessment. The recursive evidential reasoning algorithm can be summarised as follows (Yang and Xu, 2002):

$$m_n=K\left[m_{n,i}m_{n+1,i}+m_{n,i}m_{H,i+1}+m_{H,i}m_{n+1,i}\right]\ (n=1,2,\ldots,N) \tag{Eq. 11}$$
$$\tilde{m}_H=K\left[\tilde{m}_{H,i}\tilde{m}_{H,i+1}+\bar{m}_{H,i}\tilde{m}_{H,i+1}+\tilde{m}_{H,i}\bar{m}_{H,i+1}\right] \tag{Eq. 12}$$
$$K=\left[1-\sum_{t=1}^{N}\sum_{\substack{j=1\\ j\neq t}}^{N}m_{t,i}m_{j,i+1}\right]\quad (i=1,2,\ldots,L-1) \tag{Eq. 13}$$

where K is a normalising factor so that $\sum_{n=1}^{N}m_n+\tilde{m}_H=1$. Note that the attributes in E are numbered arbitrarily. The results of m_n and $\tilde{m}_H$ do not depend on the other in which the basic attributes are aggregated. The normalisation of the probability $\bar{m}_H$ can be computed using Eq. 14.

$$\bar{m}_H=K[\bar{m}_{H,i}\bar{m}_{H,i+1}] \tag{Eq. 14}$$

In the *ER* approach, the combined degree of belief β_n is directly given by (Yang and Xu, 2002):

$$\beta_n=\frac{m_n}{1-\bar{m}_H}\quad (n=1,2,\ldots,N) \tag{Eq. 15}$$

where β_n be a degree of belief to which the general attribute y is assessed to the grade H_n. β_H is the degree of belief unassigned to any individual evaluation grade after all the *L* basic attributes have been assessed. It denotes the degree of incompleteness in the overall assessment.

3. Selection of the Most Beneficial Shipping Business Strategy

Step 1: Set up a goal

Four shipping business strategies have been described in Section 1.2. Therefore, the goal of this study is to analyse and aggregate the attributes in a model with the purpose of selecting the most beneficial shipping business strategy for containerships.

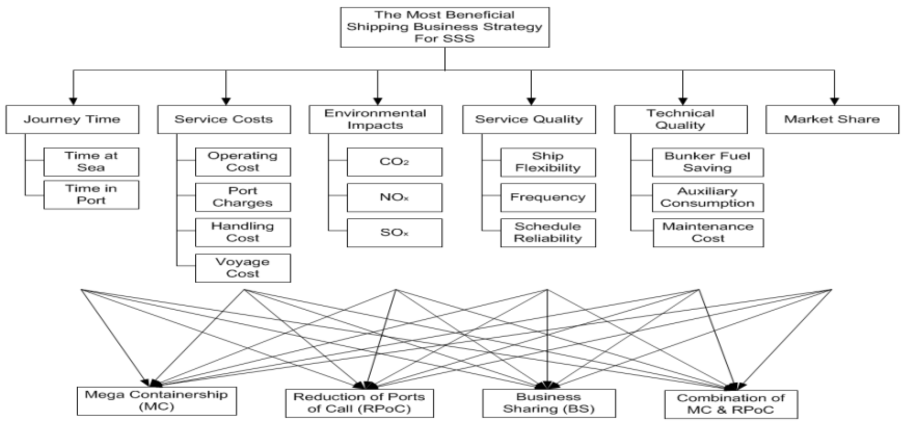

Figure 2: The model of selection the most beneficial shipping business strategy

Step 2: Identification of decision making criteria

A brainstorming technique incorporating the selected experts and literature surveys described in Section 1 are used in this process. As a result, all evaluation parameters are divided into main criteria (Level 1) and sub-criteria (Level 2) as shown in Figure 2.

Step 3: Identification of shipping business strategies

Four shipping business strategies have been discussed in Section 1.2. They are 1) Mega Containership (MC), 2) Reduction of Ports of Call (RPoC), 3) Business Sharing (BS) and 4) a combination of Mega Containership and Reduction of Ports of Call (MC & RPoC). Such strategies will be evaluated incorporating a number of criteria and sub-criteria described in Figure 2.

Step 4: Data collection process

A qualitative data set used in this study and is obtained from expert judgements. The experts are selected based on their knowledge, expertise and experiences in the maritime industry of 20 years. All experts contribute their opinions in developing a scientific model, determining the parameters and answering a set of questionnaires using the pair-wise comparison technique. Given the six main criteria as an example, a 6×6 pair-wise comparison matrix is developed for obtaining the weight of each of them. $A(JS_C ES_Q TM)$ is a matrix expressing the qualified judgement with regard to the relative priority of the JT (J), SC (S_C), EI (E), SQ (S_Q), TQ (T) and MS (M). By using Eq. 1, the pair-wise comparison matrix for the main criteria is obtained as shown in Table 1. Given the importance/priority of the criterion "JT" to the criterion "EI" as an example in determining the average ratio rate of the pair-wise comparison, the expert A ticked number two, while the expert B ticked number three and the expert C ticked number four in order to articulate the importance of the two criteria. Consequently, the total ratio rate is 2.00 (expert A) + 3.00 (expert B) + 4.00 (expert C) = 9.00. The average ratio value of the importance of the criterion "JT" to the criterion "EI" is 3.00 (9.00÷3) (Table 1). The same calculation technique of the average ratio value is applied to all main criteria and sub-criteria. Next, the pair-wise comparison matrix is used for calculating the weight vector.

Table 1: Pair-wise comparison matrix for the main criteria

$A(JS_CES_QTM)$=

	JT	SC	EI	SQ	TQ	MS
JT	1	2	3	3	4	2
SC	1/2	1	3	2	3	1
EI	1/3	1/3	1	1/2	2	2
SQ	1/3	1/2	2	1	2	2
TQ	1/4	1/3	1/2	1/2	1	1/2
MS	1/2	1	1/2	1/2	2	1
SUM	**2.9170**	**5.1670**	**10.0000**	**7.5000**	**14.0000**	**8.5000**

Step 5: Establishment of weight value for each criterion using the AHP approach

The weight value of the matrix in Step 4 is determined using Eq. 2. The $\frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$ values of $A(JS_CES_QTM)$ are calculated and summarised in Table 2.

Table 2: The values in each column of the pair-wise comparison

JT	1 ÷ 2.917 = 0.3430	2 ÷ 5.167 = 0.3870	3 ÷ 10.000 = 0.3000	3 ÷ 7.500 = 0.4000	4 ÷ 14.000 = 0.2860	2 ÷ 8.500 = 0.2350
SC	1/2 ÷ 2.917 = 0.1710	1 ÷ 5.167 = 0.1940	3 ÷ 10.000 = 0.3000	2 ÷ 7.500 = 0.2670	3 ÷ 14.000 = 0.2140	1 ÷ 8.500 = 0.1180
EI	0.1140	0.0650	0.1000	0.0670	0.1430	0.2350
SQ	0.1140	0.0970	0.2000	0.1330	0.1430	0.2350
TQ	0.0860	0.0650	0.0500	0.0670	0.0710	0.0590
MS	0.1710	0.1940	0.0500	0.0670	0.1430	0.1180

Given the criterion "JT" as an example, the weight value is computed as follows:

$$w_{JT} = \frac{0.3430 + 0.3870 + 0.3000 + 0.4000 + 0.2860 + 0.2350}{6} = 0.3250$$

where the weight value of the criterion "JT" is known to be 0.3250. In a similar way, the weight calculation algorithm is applied to all other main criteria. Table 3 summarises all the output values of the weight calculation. The same calculation process is applied to compute the weight values of all the sub-criteria and they are summarised as follows: 0.8333 (TS), 0.1667 (TP), 0.4884 (OC), 0.1034 (PC), 0.1575 (CHC), 0.2507 (VC), 0.5936 (CO_2), 0.2493 (NO_x), 0.1571 (SO_x), 0.1172 (SF), 0.2684 (F), 0.6144 (SR), 0.6144 (BFS), 0.1172 (AC) and 0.2684 (MC).

Table 3: The weight value of evaluation criteria

							Weight Values
JT	0.3430	0.3870	0.3000	0.4000	0.2860	0.2350	**0.3250**
SC	0.1710	0.1940	0.3000	0.2670	0.2140	0.1180	**0.2110**
EI	0.1140	0.0650	0.1000	0.0670	0.1430	0.2350	**0.1210**
SQ	0.1140	0.0970	0.2000	0.1330	0.1430	0.2350	**0.1540**
TQ	0.0860	0.0650	0.0500	0.0670	0.0710	0.0590	**0.0660**
MS	0.1710	0.1940	0.0500	0.0670	0.1430	0.1180	**0.1240**

Step 6: Conversion of lower level criteria (LLC) to upper level criteria (ULC) using the fuzzy-link based theory

Firstly, a set of assessment grades of the *ULC* and *LLC* have to be determined. A technique incorporating expert opinions through a brainstorming process is used. For example, Table 4 shows the assessment grades of all the main criteria that will be used in this study.

Table 4: Assessment grades of main criteria (*ULC*)

Upper Level Criteria	**Assessment Grades**				
JT	Short	Reasonably Short	Average	Reasonably Long	Long
SC	Low	Reasonably Low	Average	Reasonably High	High
EI	Less Contribution	Reasonably Less Contribution	Average	Reasonably More Contribution	More Contribution
SQ	Excellent	Good	Average	Poor	Worst
TQ	High	Reasonably High	Average	Reasonably Low	Low
MS	Increase	Reasonably Increase	Average	Reasonably Decrease	Decrease

Secondly, the corresponding fuzzy input as described in Section 3.2 is obtained from the expert opinions. Given the sub-criterion "Time at Sea" (*LLC*) as an example with respect to the alternative "Mega Containership", the fuzzy input values are {(*Short, 0.0*), (*Reasonably Short, 0.0*), (*Average, 0.6*), (*Reasonably Long, 0.3*), (*Long, 0.1*)}. After obtaining the fuzzy input values, the mapping process of transforming fuzzy input values (*LLC*) to fuzzy output values (*ULC*) is conducted as shown in Figure 3. The belief degree values are also obtained through the discussion process with the experts. A subjective fuzzy rule-based with the belief degree concept is applied using Eq. 5 in order to describe the mapping process. The fuzzy output values for the assessment grades of the criterion "Journey Time" (*ULC*) are obtained using Eqs. 3 and 4 as follows:

Short = $(0.0 \times 1.0) + (0.0 \times 0.2) = 0.0000$

Reasonably Short = $(0.0 \times 0.8) + (0.6 \times 0.2) = 0.1200$

Average = $(0.6 \times 0.6) = 0.3600$

Reasonably Long = $(0.3 \times 0.8) + (0.6 \times 0.2) = 0.3600$

Long = $(0.1 \times 1.0) + (0.3 \times 0.2) = 0.1600$

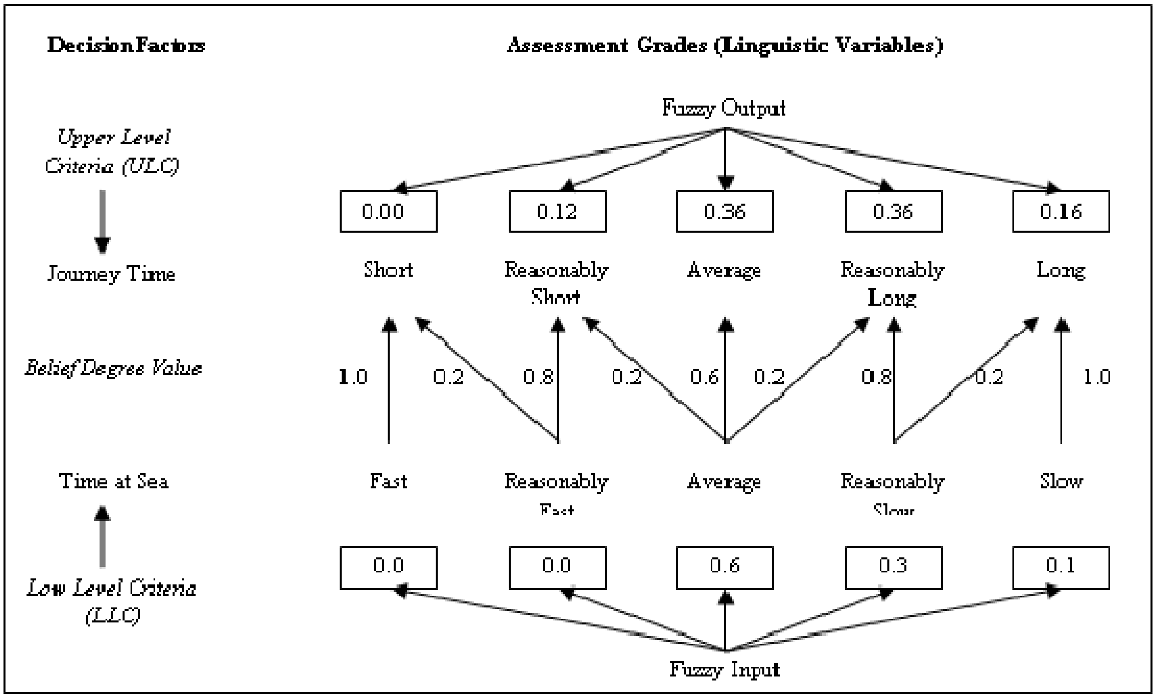

Figure 3: The mapping process of transforming fuzzy input values to fuzzy output values

A subjective fuzzy rule-based with the belief degree concept is applied using Eq. 5 in order to describe the mapping process. The fuzzy output values for the assessment grades of the criterion "Journey Time" (*ULC*) are obtained using Eqs. 3 and 4 as follows:

Short	=	$(0.0 \times 1.0) + (0.0 \times 0.2)$	= 0.0000
Reasonably Short	=	$(0.0 \times 0.8) + (0.6 \times 0.2)$	= 0.1200
Average	=	(0.6×0.6)	= 0.3600
Reasonably Long	=	$(0.3 \times 0.8) + (0.6 \times 0.2)$	= 0.3600
Long	=	$(0.1 \times 1.0) + (0.3 \times 0.2)$	= 0.1600

The fuzzy output values of the assessment grades of the criterion "Journey Time" by applying the rule-based principle are {(*Short, 0.0000*), (*Reasonably Short, 0.1200*), (*Average, 0.3600*), (*Reasonably Long, 0.3600*), (*Long, 0.1600*)} respectively. The same technique is applied for transforming all the fuzzy input values of the sub-criteria (*LLC*) to the fuzzy output values of the correspondence main criterion (*ULC*).

Step 7: Conduction of calculation process for all decision options using the Evidential Reasoning approach and the IDS software package

After the transformation process in Step 6, the fuzzy output values for the assessment grades of all criteria are obtained. For example, the belief degree values of the criterion "Journey Time" with respect to the alternative "Mega Containership" are shown in Table 5.

Table 5: The belief degree values of the criterion "Journey Time" with respect to the alternative "Mega containership"

Belief Degree (β)		**Assessment Grades**				
		Short	**Reasonably Short**	**Average**	**Reasonably Long**	**Long**
Journey Time	*TS*		0.1200	0.3600	0.3600	0.1600
	TP				0.5600	0.4400

By using Eq. 6, the belief degree values of TS and TP are formed as follows:

S(*TS*) = {(*Short,0.0000*), (*Reasonably Short, 0.1200*), (*Average, 0.3600*), (*Reasonably Long, 0.3600*), (*Long, 0.1600*)}.

S(*TP*) = {(*Short,0.0000*), (*Reasonably Short, 0.0000*), (*Average, 0.0000*), (*Reasonably Long, 0.5600*), (*Long, 0.4400*)}.

The weight values of TS and TP are 0.8333 and 0.1667 which have been obtained in Step 6. By using the information given in Table 5 and the weight values, the basic probability masses $m_{n,i}$ are calculated using Eq. 7 as follows:

$m_{1,1} = 0.8333 \times 0.0 = 0.0000$, $m_{1,2} = 0.8333 \times 0.12 = 0.1000$, $m_{1,3} = 0.3000$, $m_{1,4} = 0.3000$, $m_{1,5} = 0.1333$.

$m_{2,1} = 0.1667 \times 0.0 = 0.0000$, $m_{2,2} = 0.1667 \times 0.00 = 0.0000$, $m_{2,3} = 0.0000$, $m_{2,4} = 0.0934$, $m_{2,5} = 0.0733$.

The $m_{H,i}$ values for both $m_{H,1}$ and $m_{H,2}$ are calculated using Eq. 8. $\bar{m}_{H,i}$ can be calculated using Eq. 9, while $\tilde{m}_{H,i}$ can be computed using Eq. 10. Further calculations of these equations are shown as follows:

$$\bar{m}_{H,1} = 1 - 0.8333 = 0.1667$$

$$\tilde{m}_{H,1} = 0.8333\big(1 - (0.12 + 0.36 + 0.36 + 0.16)\big) = 0.0000$$

$$m_{H,1} = 1 - (0.10 + 0.30 + 0.30 + 0.1333) = 0.1667$$

$$\bar{m}_{H,2} = 1 - 0.1667 = 0.8333$$

$$\tilde{m}_{H,2} = 0.1667\big(1 - (0.56 + 0.44)\big) = 0.0000$$

$$m_{H,2} = 1 - (0.0934 + 0.0733) = 0.8333$$

To calculate the normalised factor (K), Eq. 13 is applied. This equation can be further expressed as follows:

$$K = \left\{ 1 - \begin{pmatrix} m_{1,1}m_{2,2} + m_{1,1}m_{2,3} + m_{1,1}m_{2,4} + m_{1,1}m_{2,5} \\ m_{1,2}m_{2,1} + m_{1,2}m_{2,3} + m_{1,2}m_{2,4} + m_{1,2}m_{2,5} \\ m_{1,3}m_{2,1} + m_{1,3}m_{2,2} + m_{1,3}m_{2,4} + m_{1,3}m_{2,5} \\ m_{1,4}m_{2,1} + m_{1,4}m_{2,2} + m_{1,4}m_{2,3} + m_{1,4}m_{2,5} \\ m_{1,5}m_{2,1} + m_{1,5}m_{2,2} + m_{1,5}m_{2,3} + m_{1,5}m_{2,4} \end{pmatrix} \right\}^{-1}$$

$$K = \left\{ 1 - \begin{pmatrix} 0+0+0+0 \\ +0+0+0.00934+0.00733 \\ +0+0+0.02802+0.02199 \\ +0+0+0+0.02199 \\ +0+0+0+0.01245 \end{pmatrix} \right\}^{-1} = \{1-0.10112\}^{-1} = 1.1125$$

The normalisation factor (K) can be further calculated using Eq. 11 as follows:

$$m_1 = K(m_{1,1}m_{2,1} + m_{1,1}m_{H,2} + m_{H,1}m_{2,1}) = 1.1125(0+0+0) = 0.0000$$

$$m_2 = K(m_{1,2}m_{2,2} + m_{1,2}m_{H,2} + m_{H,1}m_{2,2}) = 1.1125(0+0.08333+0) = 0.0927$$

$$m_3 = 0.2781,\ m_4 = 0.3266,\ m_5 = 0.1481$$

The normalisation of the probability $\tilde{m}_H$ is calculated using Eq. 12 as follows:

$$\tilde{m}_H = K(\tilde{m}_{H,1}\tilde{m}_{H,2} + \bar{m}_{H,1}\tilde{m}_{H,2} + \tilde{m}_{H,1}\bar{m}_{H,2}) = 1.1125(0+0+0) = 0.0000$$

The normalisation of the probability $\bar{m}_H$ is calculated using Eq. 14 as follows:

$$\bar{m}_H = K(\bar{m}_{H,1}\bar{m}_{H,2}) = 1.1125(0.1389) = 0.1545$$

The combined degrees of belief values are calculated using Eq. 15 as follows:

$$(Short)\,\beta_1 = \frac{m_1}{1-\bar{m}_H} = \frac{0}{1-0.1545} = 0.0000$$

$$(Reasonably\ Short)\,\beta_2 = \frac{m_2}{1-\bar{m}_H} = \frac{0.0927}{1-0.1545} = 0.1096$$

$$(Average)\beta_3 = 0.3289,\ (Reasonably\ Long)\beta_4 = 0.3863,\ (Long)\beta_5 = 0.1752$$

The aggregated assessment for the criterion "Journey Time" with respect to the alternative "Mega Containership" is therefore given by the following distribution:

$$S(Journey\ Time) = S(TS \oplus TP)$$

$$= \{(Short, 0.0000), (Reasonably\ Short, 0.1096), (Average, 0.3289), (Reasonably\ Long, 0.3863), (Long, 0.1752)\}$$

Such aggregated assessment values can also be calculated using the Intelligent Decision System (*IDS*) software tool as shown in Figure 4.

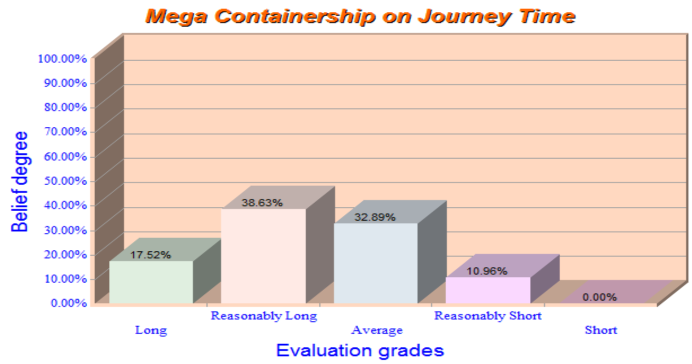

Figure 4: The belief degree of evaluation grades of the criterion "Journey Time" with respect to the alternative "Mega Containership"

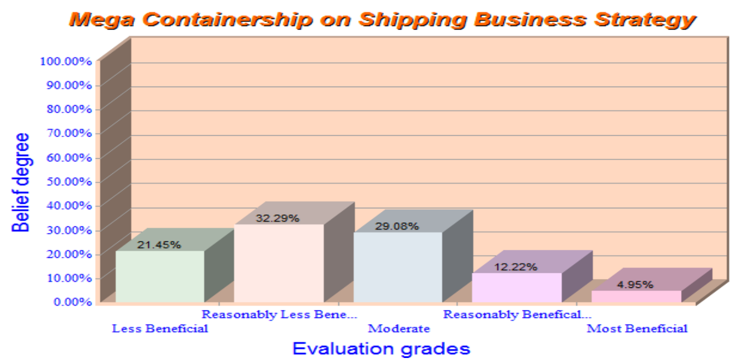

Figure 5: The output values of the alternative "Mega Containership"

The rest of the calculations are constructed using the *IDS* software in association with all weight values of the main and sub-criteria, and also the fuzzy output values of the main criteria. The output value of the alternative "Mega Containership" is summarised in Figure 5. The highest belief degree value is 32.29% associated with the evaluation grade "*Reasonably Less Beneficial*", followed by the evaluation grade "*Moderate*" at 29.08% of the belief degree value. The evaluation grade "*Less Beneficial*" is ranked in the third place at 21.45% of the belief degree value while the evaluation grade "*Reasonably Beneficial*" is in the fourth place at 12.22% of the belief degree value. The evaluation grade "*Most Beneficial*" has the lowest belief degree value at 4.95%.

The output values of other two alternatives are obtained using the *IDS* software and the three alternatives need to be ranked in determining the most beneficial shipping business strategy for containerships. To construct such a rank, a set of utility values is given to the evaluation grades of the parent "Shipping Business Strategy" as follows: {(*Most Beneficial, 1.00*), (*Reasonably Beneficial, 0.75*), (*Moderate, 0.50*), (*Reasonably Less Beneficial, 0.25*) and (*Less Beneficial, 0.00*)}. By using the belief degree values described in Figure 5 for the alternative "Mega Containership", the assessment value of this alternative is computed as follows:

Most Beneficial	:	$4.95\% \times 1.00 = 0.0495$ (+)
Reasonably Beneficial	:	$12.22\% \times 0.75 = 0.09175$ (+)
Moderate	:	$29.08\% \times 0.50 = 0.1454$ (+)
Reasonably Less Beneficial	:	$32.29\% \times 0.25 = 0.08073$ (+)
Less Beneficial	:	$21.45\% \times 0.00 = \underline{0.0000}$
TOTAL		$\underline{0.36738 \approx 0.3674}$

The assessment value of the alternative "Mega Containership" is known to be 0.3674. A similar calculation technique is applied for determining the assessment values of the alternatives "Business Sharing", "Mega Containership" and "a combination MC & RPoC".

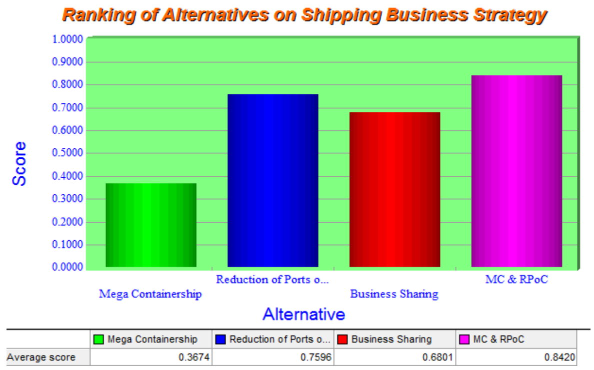

Figure 6: The ranking of the alternatives on shipping business strategy

Figure 6 summarises the assessment values / average scores associated with the ranking of all alternatives in selecting the most beneficial shipping business strategy for containerships. The alternative "combination of Mega Containership and Reduction of Port of Call (MC & RPoC)" is ranked at the first place (0.8420), followed by the alternative "Reduction of Ports of Call (RPoC)" at the second place (0.7596), the alternative "Business Sharing" at the third place (0.6801) and the alternative "Mega Containership" at the last place (0.3674). In general, the above results enable shipping companies to select the most beneficial shipping business strategy for operating their vessels. By selecting the strategy "MC & RPoC", shipping companies expect to gain benefits in operating containerships, such as 1) reduction of bunker fuel cost, 2) reduction of gas emissions, 3) saving in port fees, agent fees and pilotage fees, 4) increase in ships' turnover per year 5) reduction in total journey time and 6) reduction in the ships' operational costs and voyage costs.

4. Conclusions

A comprehensive structural assessment framework has been developed by incorporating a number of criteria, sub-criteria and four alternatives. The results produced by the decision making technique are capable of assisting shipping companies in the decision making process for choosing the most beneficial shipping business strategy. The developed model is dynamic and can be used in different situations where shipping companies face challenges under uncertainties. In practice, shipping companies can add more parameters whenever necessary. In addition, their own databases can be used with the flexibility in order to obtain the actual output of the test case. The model can also be applied in different service routes to facilitate the shipping business strategy selection to a wider extent.

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