A Framework Proposal for Evaluating the Organizational Reliability and Capability of a Liner Shipping Operator in a Fuzzy Context

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Abstract*: Reliability and capability have become significant concerns for Liner Shipping Operators (LSOs) to distinguish themselves from their competitors in the liner shipping industry. Many organizations including LSOs have accepted that having a highly reliable and capable performance at the organizational level is an important element in the drive for better overall performance, and commitment to achieve a better competitive advantage. However, to understand how far LSOs are reliable, internal and external factors (i.e. exogenous influential factors) that determine the Organizational Reliability and Capability (ORC) should be evaluated. As a result, the aim of this study is to evaluate the value of the ORC of an LSO by considering five main criteria, namely operational reliability, financial capability, knowledge management, compliance with regulations and service quality capability. Furthermore, the influence of the business environment on the organizational functions is investigated. This study makes uses of a Fuzzy Bayesian Belief Network (FBBN) for evaluating the value of ORC of an LSO. The results have shown that the financial capability is a strong indicator for the internal ORC of the LSOs. In addition, the sensitivity analysis has resulted the model output is more sensitive respectively to the security and safety compliances than the other 28 input variables. This method of assessment can help LSOs to conduct self-evaluation of the ORC for enhancing their business sustainability in the liner shipping industry. In addition, maritime researchers will benefit from the proposed methodology for evaluating the value of the ORC of an LSO.

***Index Terms*: Bayesian Network, liner shipping, organizational reliability, organizational capability.**

I. INTRODUCTION

Competition among liner shipping operators (LSOs) continues to evolve as a result of structural changes within the industry [1]. This industry has witnessing the evolution from liner conferences to market consolidation where three main alliances are formed which are THE Alliance Ocean Alliance and 2M. Historically, liner conferences (i.e. cartel agreements) were established in the 1970s with the purpose to limit competition by setting fixed prices and supply coordination among shipping lines. At the beginning of their establishment, these cartels were found to be useful, especially in indulging in retaliatory measures against independent LSOs which forced them to leave the trade route or join the cartel [1]. However, this cartel structure is viewed as irrelevant in today's market due to evolution within the industry. As an example, changes in European Union (EU) regulations banned the liner conference from operating in European countries. As a result, the monopoly power of the liner conference in this industry has depreciated.

Recently, many LSOs have practiced low freight rate initiatives, especially during economic recession, which finally led to price wars among LSOs. Price wars are commercial rivalry due to the frequent cutting of prices among competitors. Price wars can adversely affect the sustainability of the liner shipping industry since lower prices significantly reduce LSOs' profit margins and can threaten their survival. Therefore, practitioners and academicians suggest that low price-based competition should be limited, and mechanisms found to allow LSOs to provide a sustainable strategy according to the requirements of customer demand [2]. One useful mechanism is competing through service reliability. Under these new challenging circumstances, LSOs should seek high levels of operational and financial efficiencies for survival, generating the required level of cargo capacity with the minimum level of resources [1].

Nowadays, reliability and capability have become significant concerns for LSOs to distinguish themselves from their competitors in the liner shipping industry. Many organizations including LSOs have accepted that having highly reliable and capable performances at organizational level (i.e. operational reliability, financial capability, knowledge management capability, compliance with regulations, and service quality capability) are important elements in the drive for better overall performance and commitment to achieve a better competitive advantage. In addition, reliable and capable performances of LSOs have often received central consideration from shippers to find the best carrier selection. Therefore, to understand how far an LSO is reliable and capable, internal and external factors (i.e. exogenous influential factors) that determine its organizational reliability and capability (ORC) should be evaluated.

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In this paper, a new mathematical model for evaluating the value of ORC of an LSO is developed using a different combination of decision-making techniques such as a symmetric model, Fuzzy Logic (FL) and Bayesian Network (BN). Based on the extensive literature review and further consultation with domains experts in the liner shipping industry, five main reliability elements - 1) operational reliability, 2) financial capability, 3) knowledge management capability, 4) compliance with regulations and 5) service quality capability - are considered in the evaluation model. This evaluation model can help LSOs to conduct a self-evaluation of their ORC for enhancing business sustainability in liner shipping industry. In addition, with the help of the proposed methodology, shippers will be able to evaluate LSOs to select a reliable operator to transport their goods consistently.

The remainder of this paper is organized as follows. The literature review is explained in Section II. Section III presents the methodology for evaluating the value of ORC of an LSO. The case study and findings are conducted in Section IV. Finally, the conclusion is given in Section V.

II. LITERATURE REVIEW

Recent developments in maritime transportation has required LSOs to extend their geographical coverage and to offer highly reliable services [1]. In addition, shippers are increasingly looking for an LSO that can offer reliable global supply chain solutions whilst at the same time expecting a reduction in damage to goods. Therefore, having a mathematical tool for evaluating the value of ORC is essential for LSOs to set the ideal benchmark that suit customers' preferences. However, the major challenge is how to develop a model and evaluate the value of ORC of an LSO in the domain of the scope, as mentioned. Quantifying the ORC of an LSO is a major challenge since the business nature of the liner shipping industry is based on service orientation, which is different from physical production. On the other hand, the application of ORC requires complicated procedures including concept definition, factor identification, modelling, data collection, measurement, and quantification. These problems have not only resulted from the extension of the searching scope, but also originated from the uncertainty of the factors. Therefore, a critical process for developing the ORC model needs to be carefully prepared.

When investigating the key reliability factors of an LSO, a systematic approach is required to cluster them into functional entities comprising sub-systems and components. Development of the ORC model based on functional entities can provide a clear visualization and recognition of all the ORC factors. Based on an extensive literature review, five main factors that determine the ORC of an LSO are identified: 1) operational reliability, 2) financial capability, 3) knowledge management capability, 4) compliance with regulations and 5) service quality capability. In addition, the influence of the external business environment on the ORC is investigated in the evaluation model to understand the relationship between ORC and external environments. The criteria selection follows the recommendation and adaptation of various studies in the literature, and further consultation with the domain experts in liner shipping industry [1], [3]-[14].

A. Operational Reliability

Operational reliability is a substantial element in an LSO's attempt to enhance its overall business performance. Operational reliability can be defined as the ability of an LSO's operations in delivering cargo in a safe, secure and timely manner. Reference [6] expressed that the impact of not managing an operation properly goes beyond direct financial losses. Moreover, unreliable operational continuity such as delay, and disruption can cause distrust of an LSO and will lead to loss of its reputation among shippers. Several studies have been conducted about operational risk and reliability in maritime transportation, as in [8], [9], [10], [15] and [16]. In this study, based on the available literature and further consultation with domain experts in liner shipping industry, four main criteria are selected to indicate the operational reliability of an LSO which are: *vessel reliability* [10][11][17], *container management* [14], *schedule reliability* [14][18][19][20][21][22] and *port reliability* [20][22][23].

B. Financial Capability

Financial capability can be defined as the ability of an LSO to conduct effective management of the finance and to control the effects of external risks on the finance conditions [24]. Also, it deals with the effectiveness of LSOs to manage and support a company's strategic objectives through short and long-term financial planning [25]. Empirical studies have found that a strong financial capability can contribute to a higher level of ORC value [26]. On the other hand, financial capability also deals with the ability to control the effects of external risks (e.g. economic risks, etc.) on the financial capability of an LSO. In this paper, financial capability can be assessed by three criteria: *profitability ratio, finance structure ratio* and *liquidity ratio* [12]:

For assessing the profitability ratio of an LSO, Return on Net Operating Assets (RONOA) can be measured. RONOA is a key indicator for measuring returns on investments in the LSO's organization as it measures returns on operating activities of the company [12].

For assessing the finance structure ratio, a solvency ratio can be estimated by dividing shareholders' equity by total assets [12]. A solvency ratio indicates the ability of the LSO's organization to pay long-term liabilities.

For assessing the liquidity ratio, current ratio of an LSO can be measured by dividing current assets by current liabilities. As financial managers are working with banks and other short-term lenders, an understanding of liquidity is essential [26].

C. Knowledge Management

Knowledge management can be defined as a set of processes for transferring data and information into valuable knowledge. Knowledge management efforts typically focus on achieving an organization's strategic objectives such as performance enhancement, better competitive advantage, innovation, knowledge sharing and continuous improvement of the organization [27]. In supply chain management, knowledge management is an important tool as there is evidence of a positive link between knowledge management and supply chain performance [28] [29]. In liner shipping industry, knowledge management is concerned with the effectiveness of the LSO to manage and decide on human resources, innovation and communication thereof. Strategically, knowledge management can help LSOs to minimize unnecessary costs, increase profit margins, and add value to tangible and intangible assets [30]. Market competitiveness, human resource management (HRM) efficiency, organization management and service innovation are four crucial factors in assessing knowledge management capability [13]:

Market competitiveness focuses on the ability of an LSO to enhance competitiveness in the international shipping market. This ability can be assessed by: the ability to reduce shipping costs and expenses; improvement of employees' efficiency; and strengthening of the shipping market penetration ability.

Human resource management (HRM) efficiency focuses on the ability of an LSO to improve HRM efficiency in shipping operation and management. This ability can be assessed by: fast and effective solution of repeated, routine and common problems; improvement of employees' ability to apply information to support decision-making; and standardization of working procedures to improve employees' business-handling ability.

Service innovation focuses on the ability of an LSO to improve shipping service quality and organizational innovation. This ability can be assessed by: improvement of the innovative abilities of the organization and its high-level managers through knowledge sharing; improvement of the shipping's online service quality; and improvement of communication channels with ports, agents and customers.

Organization management focuses on the ability of an LSO to improve knowledge learning, which can be assessed by: how effective the application of knowledge management to the overall shipping operation management system is to boost shipping competitiveness; and effective leadership in organizations.

D. Compliance with Regulations

Reference [6] claimed that failure to comply with safety and environmental regulations can reduce the overall reliability and capability at the strategic management level. It has been recognized that the best way of improving security and safety levels in maritime operations is by complying with all international regulations introduced in the shipping industry. The International Maritime Organization (IMO) is a well-known international body that adopts regulations (i.e. Conventions) related to maritime safety, marine environment protection, legal enforcement, development in shipping and others related to the maritime transportation system. There are many conventions adopted by the IMO; however, the three major conventions are International Convention for the Safety of Life at Sea (SOLAS), International Convention for the Prevention of Pollution from Ships (MARPOL) and International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) [31]. By considering the complexity in segregating all regulations, for assessing the effectiveness of an LSO to comply with regulations, three groups of compliances are formed, namely security and safety compliances, environmental compliances and miscellaneous compliances (i.e. other compliances: those not related to security, safety and environment).

Security and safety compliances have become a compelling and essential factor with which LSOs should comply. After the September 11, 2001 terrorist attacks, several laws and regulations were forged at international and national levels. There are two main regulatory frameworks for maritime security and safety: IMO packages and US initiatives. The IMO packages include The International Ship and Port Facility Security (ISPS) Code, SOLAS and STCW, while the US initiatives include container security initiatives (CSI), C-PTAT and the 24-h rule. The effectiveness of the LSO in complying with the security and safety regulations can be measured by accident ratio (i.e. number of accidents/total number of vessels).

Environmental compliances. Marine environmental pollution can be in the form of oil-spills, sewage, noises, air emissions, ballast water, etc. It is well accepted that the main source of marine pollution is shipping operations. In this regard, the international community has concentrated mainly on the ship and port industry because of the well-known marine accidents in this area. MARPOL is the main convention that adopted pollution regulations for maritime transportation. The effectiveness of the LSO in complying with MARPOL regulations can be measured by event ratio (i.e. number of pollution events/total number of vessels).

Miscellaneous compliances. IMO has adopted many conventions, not only ISPS, SOLAS and STCW, but many other conventions and regulations for LSOs to obey. In this study, miscellaneous compliances will cover all the regulations not related to security, safety and environmental regulations. To measure the effectiveness of the LSO in complying with miscellaneous regulations, record of involvement in accidents is considered. The effectiveness of the LSO in complying with the miscellaneous regulations can be measured by event ratio (i.e. number of events/total number of vessels).

E. Service Capability

In the international logistic systems, service quality capability could serve as a strategic weapon. Offering high-quality and reliable services are key strategies by which an LSO can distinguish itself from its competitors, building a close relationship with customers and attaining a better competitive advantage [5]. Due to this increasing awareness, the global nature of today's supply chain networks has entailed LSOs to offer high-quality services [1]. As a result, service quality capability needs to be considered in assessing the value of ORC for an LSO. For assessing service quality capability specifically for an LSO, four aspects are considered, namely claim responsiveness, documentation issues, customer relationship management (CRM) and asset and facility:

Claim responsiveness. Most LSOs make their best effort to provide quality services to customers; however, errors and accidents can happen during operations which can cause damage to goods. Due to that, the claim department is responsible for settling any customer claims as fast as possible. Based on reference [32] study, which obtained data from 210 respondents (i.e. 110 responses came from forwarders and 100 responses were from shippers), the result shows that the LSOs give their worst performance in settlement of cargo claims. The settlement of cargo claims should be improved to enhance the service quality capability. Claim responsiveness can be assessed by measuring the difference between submissions of a claim by a customer and settlement date of that claim.

Documentation issue. One of the documentation issues that received high attention from shippers is bill of lading (BL) issuance. Shippers are happy if they receive a BL as soon as the shipping instruction (SI) has been submitted. As a result, BL issuance can be considered as one of the elements in determining an LSO's service quality capability. Based on reference [14], BL issuance's performance can be assessed by measuring the difference between submissions of SI and receiving date of confirmed BL.

Customer Relationship Management (CRM). CRM has been a crucial organizational strategy to enhance competitive advantage [33]. CRM entails all aspects of interaction a company has with its customer, whether the company is product or service-related. The most important CRM attributes in the shipping industry are use of phone calls, e-mails, and personal visits to communicate with customers; promptly responds to customers' problems, suggestions, and complaints; actively responds to customer enquiries about their services; actively provides transportation-related information to customers; and actively understands customers' service requirements and expectations [34]. Furthermore, CRM is often used as a business strategy that enables LSOs to understand their customers, attract new customers, win new clients and contracts, and retain customers through better customer experiences. As a result, having a strong relationship with customers can ensure continuity and improve the service quality capability of an LSO.

Asset and facility. References [3] and [4] claimed that asset and facility tangibility are found to be valuable in determining an organization's service quality. In addition, tangibility can be described as how far physical facilities are visually appealing (e.g. ownership of vessels) and how well employees are neat in appearance (e.g. employees' skills) [3] [4]. In liner shipping industry, key assets and facilities for liner operations are vessels, container depots, containers, offices, warehouse, front desk employees, etc. From the shipper's point of view, clear tangibility of the LSO assets and facility could create high confidence to deal with that LSO.

F. Bayes' Theorem

Bayes' theorem is a mathematical formula for calculation of posterior probabilities (i.e. probability of each state of a node in a BBN when other variables' values are known) [35]. One of the main advantages of BBNs is that they allow interference based on observed evidence using Bayes' theorem. Bayes' theorem is represented as follows [36]:

$$P(X_a|X_b) = \frac{P(X_b|X_a)P(X_a)}{\sum_{all\_i} P(X_b|X_a = x_i)P(X_a = x_i)} \quad (1)$$

where "|" means "on the condition of" or "given that". Assume that node "X_b" is observed to be in state x_j, "$P(X_a)$" is called the probability of "X_a" occurring, whereas "$P(X_a|X_b)$" is called posterior probability of "X_a" occurring given that the condition "X_b" occurred. "$P(X_b|X_a)$" is called the likelihood distribution (conditional probability) of "X_a" occurring given that "X_b" occurs too. By applying Equation 1 to each state of "X_a", the probability distribution "$P(X_a|X_b=x_j)$" is calculated by using Equation 2 as follows:

$$P(X_a|X_b = x_j) = \frac{P(X_b = x_j|X_a)P(X_a)}{\sum_{all\_i} P(X_b = x_j|X_a = x_i)P(X_a = x_i)} \quad (2)$$

By using the same calculation, the posterior probability distribution for a large model can be computed. However, updating probability value using this method is practical only if the model is simple and each node has only a few states. In this regard, several software tools (e.g. *Hugin*, *Netica*, *etc*.) have been developed to solve complex problems which consist of multi-level nodes, many node states and complex dependency.

III. EVALUATION METHODOLOGY

To evaluate the value of ORC of an LSO, a generic model is constructed and a combination of different decision-making methods such as a symmetric model, FL and BBN are used. An AHP is employed to quantify the importance of attributes and is adapted into a deterministic weight vector [37]. A symmetric model is used to determine the conditional probabilities by synthesizing the AHP methodology [17]. A FL is used by exploiting membership functions, belief degrees and *If-Then* rules for assessing the ORC factors. Furthermore, a BBN is employed to demonstrate the fundamental concept of a probabilistic graphical model and to calculate marginal probabilities with the help of Bayes' chain rule. For the evaluation of the ORC, as illustrated in Fig. 1, six steps are followed.

Step 1: The critical influential factors were critically identified using several techniques including literature review and experts' consultation.
Step 2: States of each node were defined by using literature review and experts' consultation.
Step 3: A generic model for the ORC of an LSO is constructed using a BBN model.
Step 4: The strength of direct dependence of each child node to its associated parents is quantified by assigning each child node a conditional probability table (CPT) by using a symmetric model.
Step 5: The unconditional probabilities are determined by assessing all the root nodes in the model.
Step 6: The utility value is evaluated by using the expected utility approach.

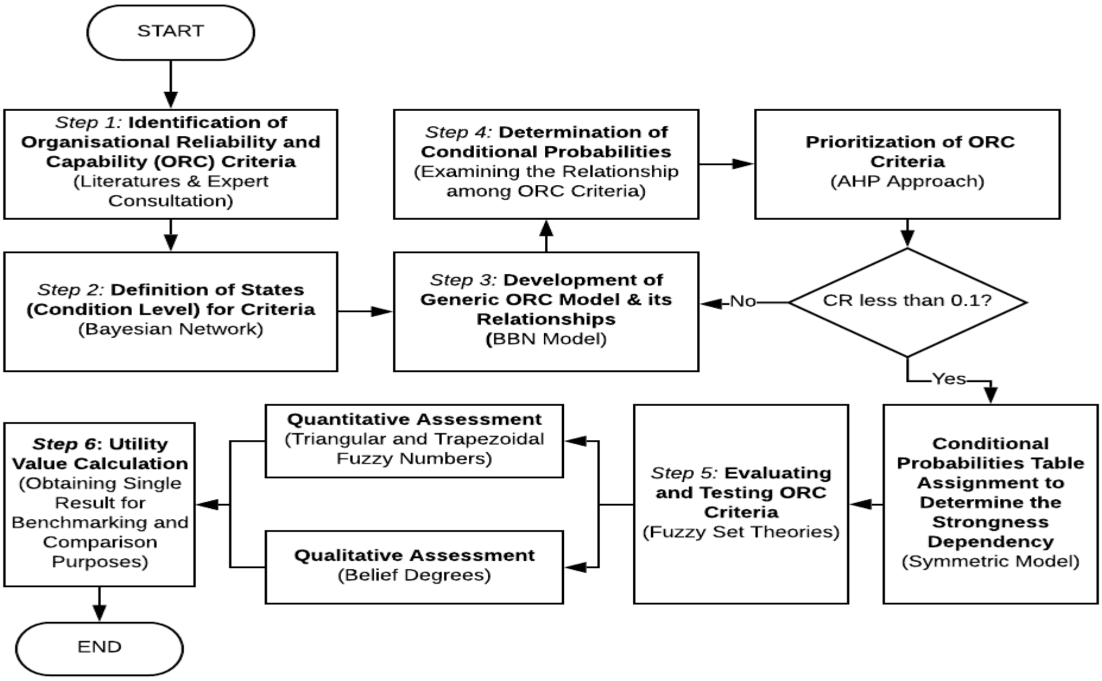

Fig. 1 Proposed Framework for Assessing the ORC of an LSO

A. Identifying the Critical Influential Factors of the ORC of an LSO (Step 1)

The process of identifying the critical influential factors for evaluating the ORC involves the listing of key factors and then classifying them into appropriate criteria in the categorization system. Extensive literature review which have been discussed in Sections II, and consultations with domain experts have been used to identify the potential factors for evaluating the ORC of an LSO. The summary of identified factors for evaluating the ORC of an LSO is presented in Table I. It is noteworthy to mention that these identified factors (i.e. five main criteria, 18 sub-criteria and 17 sub-sub-criteria) can be used in a generic model where it can be modified or adjusted based on decision-makers' preferences for their decision-making process.

Table I. Summary of Identified Factors for Evaluating the ORC of an LSO

Main Criteria	Sub-criteria	Sub-sub-criteria
Operational Reliability	Vessel Reliability	Age of Vessel, Technology Up-gradation, Ship Staff's Reliability
	Container Management Schedule Reliability	
	Port Reliability	
Financial Capability	Profitability Ratio	
	Finance Structure	
	Liquidity Ratio	
Knowledge Management	Market Competitiveness	Shipping Cost and Expense Reduction, Employee Efficiency Improvement, Market Penetration Ability.
	Human Resource Management Efficiency	Routine and Common Problem Solution, Standard Operation Procedure
	Organization Management	Knowledge Management Application, Leadership.
	Service Innovation	Innovation Improvement Ability, Online Communication.
Compliance with Regulations	Security and Safety Compliances	
	Environmental Compliances	
	Miscellaneous Compliances	
Service Quality Capability	Claim Responsiveness	
	Documentation Issuance	
	Customer Relationship Management	Communication with customers, Customer Inquiry Response, Customer Requirement Understanding.
	Asset and Facility	Appeal of Facilities, Employees' Appearance.

B. Defining the States of the Nodes (Step 2)

This step explains the states of the nodes in the BBN model established for the assessment of the ORC of an LSO. The purpose of defining the states of the nodes is to appropriately assign the prior probabilities [38].

The number of states of each node is identified by using an extensive literature review. A discrete fuzzy set membership function can be applied to define states of each node. A consistent number of states of each node can provide simplicity in the process of evaluation as decision-makers can perform the evaluation based on identical number and term of linguistic variables. It is worth mentioning that the number of states of each node used in the model can affect the complication of the calculations (i.e. CPT and Bayes' chain rule); therefore, it needs to be carefully defined. Based on this reason, three states are used for all nodes in the model and have been defined as "high", "medium" and "low".

C. Developing the Generic ORC Model (Step 3)

A generic evaluation model is developed and can be used within a specified industry or organization. The kernel of the generic model is that it can be modified or adjusted to be used for a firm or industry. In case any manager of LSO intends to use this evaluation model, they can alter the model based on their preferences. In this study, the justified factors as listed in Table I are used to develop a generic model for the ORC of an LSO. As a result, a generic model for the ORC of an LSO is constructed using a BBN model, as shown in Fig. 2, and the abbreviations are listed in Table II.

As shown in Fig. 2, the structure of an LSO is directed by headquarters (i.e. main branch) while sub-branches in different places (e.g. country region) are represented by their agencies. The overall ORC (OORC) can be obtained by aggregating the values of all agencies, which are operated under their headquarters' directions. Based on Fig. 2, the OORC can be assessed by aggregating the ORC value $Agency_a$, $Agency_b$, $Agency_c$ and $Agency_n$ (i.e. n^{th} agency). This process follows the nature of LSOs structure where branches are established in many trading countries names as agencies.

D. Determining the Conditional Probabilities (Step 4)

The symmetric model has been proposed by references [17] [39] [40] to determine the conditional probabilities by synthesizing the AHP methodology. The symmetric model the expert's opinion is distributed by relative importance of each parent node for its associated child node. The advantage of a symmetric model is that it can deal with the conditional probability combination of multi-state parents. This model can calculate a CPT of parent nodes having a different number of states. In a symmetric model, to determine the dependency of each child node to its associated parents, their normalized weights ($\omega_1, \omega_2, \omega_3 \ldots \omega_n$) need to be assigned. In the normalized space, based on the influence of each parent node, the conditional probability of a child node "Y", given each parent node, "X_r" where "$r = 1, 2, 3 \ldots n$", can be estimated as follows:

$$P(Y = Present|X_1 = Present) = \omega_1$$
$$P(Y = Present|X_2 = Present) = \omega_2$$
$$\vdots$$
$$P(Y = Present|X_n = Present) = \omega_n$$
$$\sum_{r=1}^{n} \omega_r = 1 \quad (3)$$

Table II. Abbreviation of the ORC Criteria in a Generic Model

Abbreviation	Description
OORC	Overall Organizational Reliability Capability
Agencya	Agency A
Agencyb	Agency B
Agencyn	n^{th} agency
OR	Operational Reliability
FC	Financial Capability
KM	Knowledge Management
CWR	Compliance with Regulations
SQC	Service Quality Capability
COUNTRY	Country Reliability
VR	Vessel Reliability
CM	Container Management
PR	Port Reliability
SR	Schedule Reliability
PROFIT	Profitability Ratio
FS	Finance Structure
LIQUIDITY	Liquidity
MC	Market Competitiveness
HRM	Human Resource Management Efficiency
OM	Organization Management
SI	Service Innovation
SSC	Safety and Security Compliances
ENVC	Environmental Compliances
MISCC	Miscellaneous Compliances
CR	Claim Responsiveness
DI	Documentation Issues
CRM	Customer Relationship Management
AF	Asset and Facilities
VR1	Ship Staff's Reliability
VR2	Age of Vessels
VR3	Technology Up-Gradation
MC1	Shipping Cost and Expenses Reduction
MC2	Employee Efficiency Improvement
MC3	Market Penetration Ability
HRM1	Routine and Common Problem Solution
HRM2	Standard Operation Procedure (SOP)
OM1	Knowledge Management Application
OM2	Leadership
SI1	Innovation Improvement Ability
SI2	Online Communications
CRM1	Communication with Customers
CRM2	Customer Inquiry Response
CRM3	Customer Requirement Understanding
AF1	Appeal of Facilities
AF2	Employees' Appearance

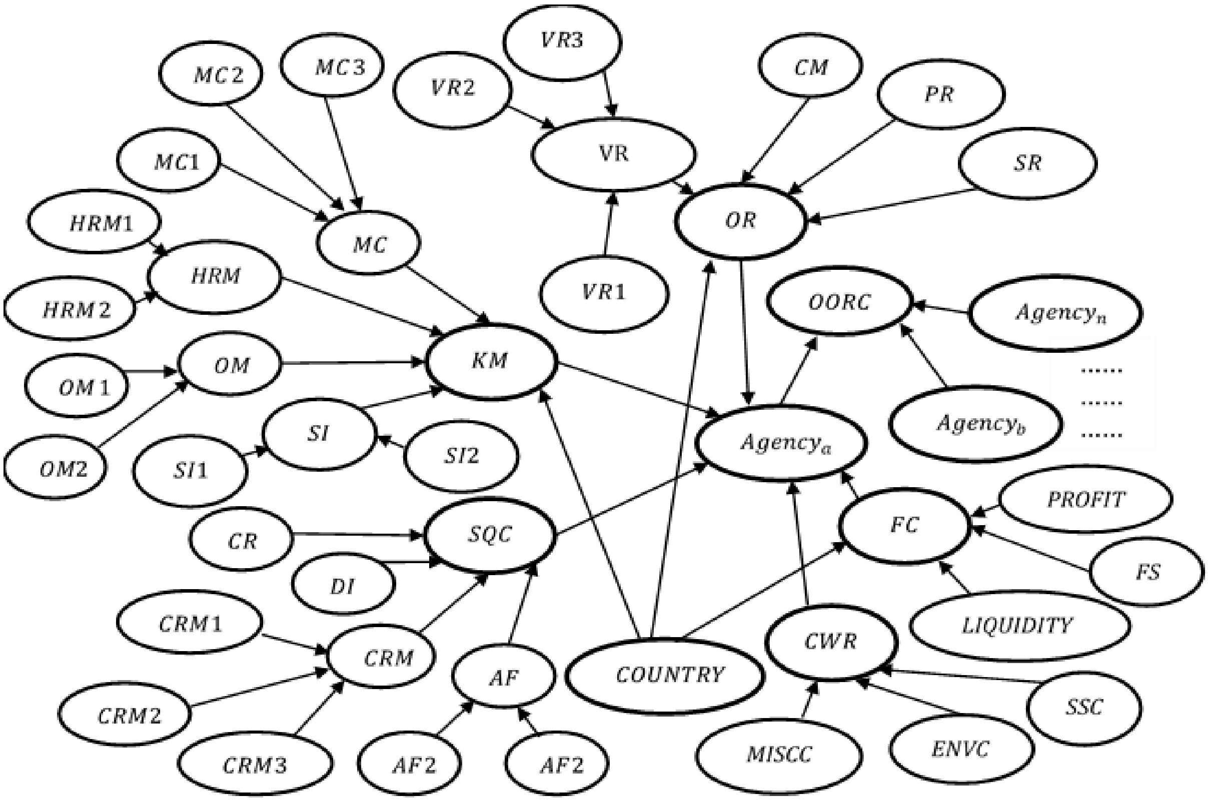

Fig. 2 A Generic FBBN Model of Organizational Reliability and Capability

E. Determining the Unconditional Probabilities (Step 5)

For determining the unconditional probabilities of the root nodes, all evaluation criteria (i.e. 29 root nodes) need to be assessed. While dealing with reliability and capability evaluations, quantitative data are a prime input. For assessing the ORC of an LSO, quantitative data can be obtained from financial, safety and management records of the targeted LSO. There are 15 criteria that need to be assessed quantitatively. From these 15 quantitative criteria, six criteria (i.e. PROFIT, FS, LIQUIDITY, SSC, ENVC and MISCC) will be assessed by using membership functions and later transformed into a qualitative estimate (i.e. high, medium and low). For example, for assessing the profitability ratio of an LSO, the Return on Net Operating Assets (RONOA) can be measured [12]. RONOA can be calculated as follows:

$$RONOA = \frac{Earning\ Before\ Interest\ and\ Tax\ (EBIT)}{Net\ of\ Operating\ Asset}$$

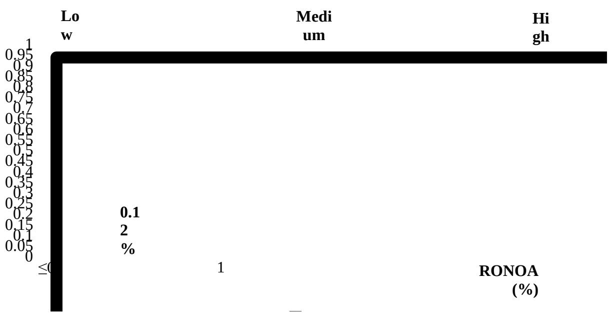

Fig. 3 Membership Functions for the Node "PROFIT"

As shown in Fig.3, based on [12], the best performing RONOA by the global liner shipping industry is 18% and above. Consequently, the reliability grade for the RONOA with value of 18% and above can be considered as highly reliable, between 1% and 17% as medium reliable and 0% and less as lowly reliable. By using the same concept, the nodes FS, LIQUIDITY, SSC, ENVC and MISCC can be measured by using membership functions.

On the other hand, the other nine criteria (i.e. VR2, CM, SR, PR, CRM1, CRM2, CRM3, CR and DI) will be assessed by using *If-Then* rules. The membership functions and *If-Then* rules for assessing all 15 quantitative criteria are constructed. For example, for assessing age of vessel, the year in which a vessel has been built would indicate its performance, as a younger vessel would perform better at sea than older ones [10]. Age of vessel can be measured by using *If-Then* rules as follows:

If a vessel is 10 (or less) years old, *then* the reliability is high.
If a vessel is between 11-20 years old, *then* the reliability is medium.
If a vessel is 21 (or more) years old, *then* the reliability is low.

For n vessels, if k of them are 10 (or less) years old, l of them are between 11-20 years old and m of them are 21 (or more) years old

Then, $\frac{k}{n}$ = with high, $\frac{l}{n}$ = with medium, and $\frac{m}{n}$ = with low.

By using the same concept, all root nodes VR2, CM, SR, PR, CRM1, CRM2, CRM3, CR and DI will be measured by using *If-Then* rules.

In a situation where there is a lack of existing data in the literature and imprecise information about past events, qualitative data can be obtained for assessing 13 criteria in the ORC model (i.e. VR1, VR3, MC1, MC2, MC3, HRM1, HRM2, OM1, OM2, SI1, SI2, AF1 and AF2). There are various methods of qualitative data collection information; one of them is through expert judgments. Qualitative data can be presented by linguistic variables (i.e. linguistic terms and their corresponding belief degrees), and simultaneously act as states of the variable. Consequently, states for each qualitative criterion in the ORC model can be presented by three linguistic terms (i.e. low, medium and high).

In this study, the probability values of each node in the FBBN model will be computed by using the *Netica* software tool. The *Netica* software can be used as a robust FBBN programme for modelling and interference. This can also deal with a complex network model involving multi-parents of nodes.

F. Evaluation of Utility Value (Step 6)

The result of an ORC evaluation will be presented by the three linguistic terms (i.e. high, medium and low). From this result, which is associated with a fuzzy set, a single value which is useful to professional decision-makers for ranking the alternatives and for comparison purposes can be evaluated. Consequently, a utility value approach concept developed by reference [41] is used in this study to obtain a single crisp number for a goal that can be calculated by using Equations 4 and 5.

$$u(H_n) = \frac{V_n - V_{min}}{V_{max} - V_{min}} \quad (4)$$

$$U_v = \sum_{n=1}^{N} \beta_n u(H_n) \quad (5)$$

where $u(H_n)$ denotes the utility value of each linguistic term (i.e. H_n) and can be estimated using Equation 5. V_n is the ranking value of the linguistic term that has been considered (Hn); Vmax is the ranking value of the highest-risk linguistic term HN; and Vmin is the ranking value of the lowest-risk linguistic term (H1). In Equation 6, the utility of the concerned criterion (i.e. goal) is denoted by Uv, and βn stands for the belief degree associated with the nth linguistic term of the concerned criterion.

IV. CASE STUDY

Case Study and Findings of the ORC of the Agency 'A'

Malaysian liner shipping industry has been selected as a test case for assessing the ORC of an LSO. To ensure that the ORC evaluation is conducted in a similar environment, one LSO's agency based in Malaysia and named Agency 'A' has been chosen in this test case. The assessment of Agency 'A' is based on its operation for the previous six months. Agency 'A' is one of the agencies under a Malaysian LSO. This Malaysian LSO was established in 1993 and is a public company listed on the main board of the Bursa Malaysia. The group has developed into a major regional shipping line principally involved in the provision of containerized shipping services. LSO 'A' currently operates a fleet of 10 containerships and they are currently deployed to provide services between ports in Malaysia, Singapore, Brunei, Hong Kong, China, Vietnam, Myanmar, Indonesia, India, Papua New Guinea, Thailand, Cambodia, Japan and Korea. In this test case, an internal team is appointed by headquarters (i.e. LSO 'A') to assess one of their agencies, named Agency 'A'. Eight experts (i.e. five industrial experts and three academic members) who have more than 15 years' experience in liner shipping industry are selected to give the relative importance of each parent node for its associated child nodes through an AHP approach in step 4. The following eight experts are listed as follows:

1. A company director who has been involved in the maritime industry for more than 16 years.
2. A general manager and shareholder of LSO 'A' who has more than 16 years' experience in the maritime industry.
3. A branch manager who worked at LSO 'A' who has more than 15 years' experience in the maritime industry.
4. A branch manager who works at LSO 'A' who has more than 16 years' experience in the maritime industry.
5. A senior manager who works at LSO 'A' who has more than 16 years' experience in the maritime industry.
6. A senior research fellow from the Maritime Institute of Malaysia who has been involved in the maritime industry for more than 15 years.
7. A senior lecturer who has been involved in the maritime industry for more than 20 years.
8. A senior lecturer who has been involved in Malaysian maritime policy for more than 15 years.

Table III shows the result of weight distribution through AHP approach. These AHP results (i.e. Table III) are then used to formulate conditional probability distributions through a symmetric model. For example, based on Equation 3, the CPT for the child node "CWR" (Compliance with Regulations) is constructed as shown in Table IV.

Based on Equations 3, data that need to be inserted in the CPTs for the child nodes "VR", "MC", "HRM", "OM", "SI", "CRM", "AF", "OR", "FC", "KM", "CWR", "SQC" and Agency 'A' are respectively 81, 81, 27, 27, 27, 81, 27, 729, 243, 729, 81, 243 and 729 (i.e. 3105 data in total).

A. Evaluating Reliability and Capability Values for Determining Unconditional Probabilities of the Root Nodes (Step 5)

The reliability and capability values for determining the unconditional probabilities of the root nodes are assessed and obtained from both qualitative and quantitative data.

The construction of membership functions and *If-Then* rules for evaluating quantitative criteria in the ORC model can be referred to Sub-section 3.5. Based on the constructed membership functions and obtained data, the unconditional probabilities of all the root nodes are assessed as follows:

For assessing the RONOA (i.e. the node "PROFIT"), based on the financial report of Agency 'A', it can be calculated as follows:

Table III. Relative Importance of Each Parent Node(s) for its Associated Child Node (s)

Goal	Main Criteria	Weights	Sub-criteria	Weights	Sub-sub-criteria	Weights
Agency A	Operational Reliability (OR)	0.2160	Vessel Reliability (VR)	0.2968	Ship Staff's Reliability (VR1)	0.3333
					Age of Vessels (VR2)	0.3333
					Technology Up-Gradation (VR3)	0.3333
			Container Management (CM)	0.1632	NA	
			Schedule Reliability (SR)	0.2416		
			Port Reliability (PR)	0.1897		
			Country Reliability (COUNTRY)	0.1087		
	Financial Capability (FC)	0.2362	Profitability Ratio (PROFIT)	0.2619		
			Finance Structure (FS)	0.1857		
			Liquidity Ratio (LIQUIDITY)	0.4222		
			Country Reliability (COUNTRY)	0.1302		
	Knowledge Management (KM)	0.1199	Market Competitiveness (MC)	0.2880	Shipping Cost and Expenses Reduction (MC1)	0.3333
					Employee Efficiency Improvement (MC2)	0.3333
					Market Penetration Ability (MC3)	0.3333
			Human Resource Management (HRM)	0.1738	Routine and Common Problem Solution (HRM1)	0.5000
					Standard Operation Procedure (HRM2)	0.5000
			Organisation Management (OM)	0.1901	Knowledge Management Application (OM1)	0.5000
					Leadership (OM2)	0.5000
			Service Innovation (SI)	0.1969	Innovation Improvement Ability (SI1)	0.5000
					Online Communications (SI2)	0.5000
			Country Reliability (COUNTRY)	0.1512	NA	
	Compliance with Regulations (CWR)	0.2135	Security and Safety Compliances (SSC)	0.5009		
			Environment Compliances (ENVC)	0.2989		
			Miscellaneous Compliances (MISCC)	0.2002		
	Service Quality Capability (SQC)	0.2144	Claim Responsiveness (CR)	0.1067		
			Documentation Issues (DI)	0.1405		
			Customer Relationship Management (CRM)	0.4134	Communication with Customers (CRM1)	0.3333
					Customer Inquiry Response (CRM2)	0.3333
					Customer Requirement Understanding (CRM3)	0.3333
			Asset and Facility (AF)	0.3394	Appeal of Facilities (AF1)	0.5000
					Employees' Appearance (AF2)	0.5000

Table IV. CPT for the child node "CWR"

If			*Then* CWR		
SSC	ENVC	MISCC	High	Medium	Low
High	High	High	1	0	0
High	High	Medium	0.7998	0.2002	0
High	High	Low	0.7998	0	0.2002
High	Medium	High	0.7011	0.2989	0
High	Medium	Medium	0.5009	0.4991	0
High	Medium	Low	0.5009	0.2989	0.2002
High	Low	High	0.7011	0	0.2989
High	Low	Medium	0.5009	0.2002	0.2989
High	Low	Low	0.5009	0	0.4991
Medium	High	High	0.4991	0.5009	0
Medium	High	Medium	0.2989	0.7011	0
Medium	High	Low	0.2989	0.5009	0.2002
Medium	Medium	High	0.2002	0.7998	0
Medium	Medium	Medium	0	1	0
Medium	Medium	Low	0	0.7998	0.2002
Medium	Low	High	0.2002	0.5009	0.2989
Medium	Low	Medium	0	0.7011	0.2989
Medium	Low	Low	0	0.5009	0.4991
Low	High	High	0.4991	0	0.5009
Low	High	Medium	0.2989	0.2002	0.5009
Low	High	Low	0.2989	0	0.7011
Low	Medium	High	0.2002	0.2989	0.5009
Low	Medium	Medium	0	0.4991	0.5009
Low	Medium	Low	0	0.2989	0.7011
Low	Low	High	0.2002	0	0.7998
Low	Low	Medium	0	0.2002	0.7998
Low	Low	Low	0	0	1

For assessing the RONOA (i.e. the node “PROFIT”), based on the financial report of Agency ‘A’, it can be calculated as follows:

$$\text{RONOA} = \frac{\text{RM}917{,}000}{\text{RM}760{,}413{,}000} \text{ X } 100\% = 0.1206\% \approx 0.12\%$$

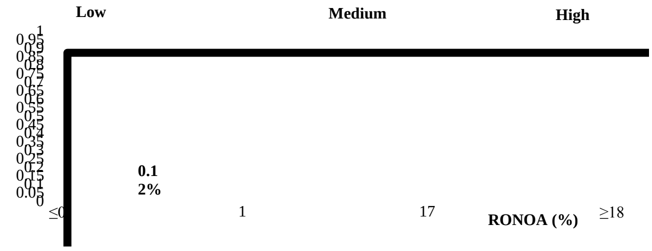

Fig 4. Membership Functions for the Node "Profit" for Agency "A"

Based on Fig. 4, the set for the node “PROFIT” is evaluated as:

PROFIT = {(Low, 0.88), (Medium, 0.12), (High, 0)}

By using the same concept, the root nodes PROFIT, FS, LIQUIDITY, SSC, ENVC and MISCC are evaluated, and the results are shown in Table V.

For evaluating the root nodes VR2, CM, SR, PR, CRM1, CRM2, CRM3, CR and DI, *If-Then* Rules are used. For example, based on Sub-section 3.5, an evaluation of age of vessel (VR2) is presented as follows:

Ten liner vessels are currently operated in liner services under Agency ‘A’. All these vessels are between 11-20 years old. As a result, the reliability set for age of vessel is calculated (i.e. $\frac{10}{10} \times 100$ = 100% medium) and presented as:

VR2 = {(Low, 0), (Medium, 1), (High, 0)}

The evaluation results for *If-Then Rules* measurement (age of vessel, container management, schedule reliability, port reliability, communication with customers, response to customers inquiry, customer requirement understanding, claim responsiveness and documentation issues) are presented in Table VI.

Table V. Membership Functions and Results of Quantitative Datasets

Quantitative Datasets	Membership Functions	Scale	Obtained Results
1. Profitability Ratio (PROFIT)	Return on Net Operating Assets (RONOA) is 18% or more	High	0.88
	RONOA is between 1-17%	Medium	0.12
	RONOA is 0% or negative	Low	0
2. Liquidity Ratio (LIQUIDITY)	Current Ratio is 1.5% or more	High	0

	Current Ratio is between 1.1% and 1.4%	Medium	0.2
	Current Ratio is 1.0% or less	Low	0.8
3. Financial Structure (FS)	Solvency Ratio is 40% or more	High	1
	Solvency Ratio is between 20% and 30%	Medium	0
	Solvency Ratio is 10% or less	Low	0
4. Safety and Security Compliances (SSC)	SSC Accident Ratio is 0	High	1
	SSC Accident Ratio is 0.1	Medium	0
	SSC Accident Ratio is 0.2 or more	Low	0
5. Environmental Compliances (ENVC)	ENVC Accident Ratio is 0	High	1
	ENVC Accident Ratio is 0.1	Medium	0
	ENVC Accident Ratio is 0.2 or more	Low	0
6. Miscellaneous Compliances (MISCC)	MISCC Accident Ratio is 0	High	1
	MISCC Accident Ratio is 0.1	Medium	0
	MISCC Accident Ratio is 0.2 or more	Low	0

Table VI. *If-Then* Rules and Results of Quantitative Datasets

Quantitative Datasets	*If*	*Then* the reliability is	Obtained Results
1. Age of Vessel	A vessel is 10 (or less) years old	High	0
	A vessel is between 11-20 years old	Medium	1
	A vessel is 21 (or more) years old	Low	0
2. Container Management	ETA-ATA is within 1 day or less,	High	0.3
	ETA-ATA is more than 1 and up to 2 days	Medium	0.3
	ETA-ATA is more than 2 days	Low	0.4
3. Schedule Reliability	AVA-ATA is within 1 day or less,	High	0.3
	AVA-ATA is more than 1 and up to 2 days	Medium	0.3
	AVA-ATA is more than 2 days	Low	0.4
4. Port Reliability	Dwell Time is within 4 days or less	High	0.3
	Dwell Time is more than 4 and up to 7 days	Medium	0.3
	Dwell Time is more than 7 days	Low	0.4
5. Communication with Customers	Once or more every week	High	0.2
	Once or more every month	Medium	0.7
	Once or more for more than a month	Low	0.1
6. Response to Customer Inquiry	Response is within 1 day or less	High	0.5
	Response is more than 1 day and up to 2 days	Medium	0.4
	Response is more than 2 days	Low	0.1
7. Customer Requirement Understanding	Session is done every 3 months	High	0.1
	Session is done only once every 3 – 6 months	Medium	0.3
	Session is done only once every 6 – 12 months	Low	0.6
8. Claim Responsiveness	Settlement is within 3 months or less	High	0.85
	Settlement is more than 3 months and up to 6 months	Medium	0.1
	Settlement is more than 6 months	Low	0.05
9. Documentation Issues	SI-BL is within 3 days or less	High	0.85
	SI-BL is more than 3 and up to 5 days	Medium	0.1
	SI-BL is more than 5 days	Low	0.05

For assessing qualitative data, three evaluators act as an internal team that have been selected based on their 15 to 20 years' experience in LSO 'A'. A profile of the three evaluators is listed as follows:

1. A general manager and also main shareholder of LSO 'A' who has 15 years' experience in the liner shipping industry.
2. A branch manager of Agency 'A' who has 15 years' experience in the liner shipping industry.
3. A senior operations manager of Agency 'A' who has 25 years' experience in the liner shipping industry. These three evaluators have to assess every reliability or capability set under a fuzzy environment; for

example, a HRM of the Agency ‘A’ has been assessed as follows:

Based on Table VII, for assessing the value of HRM efficiency, two questions have been asked during interviews (i.e. 1. How capable are your shore-based employees to solve routine and common problems? 2. How capable is your organization to standardize the Standard Operation Procedure (SOP) to improve employees’ business handling ability?). Three linguistic terms are set up from low, medium and high for each question. Each question and expert will have an equal weight to avoid pre-judgment. Based on Table VII, for assessing the ability of shore-based employees to solve routine and common problems (i.e. question 1), expert 1 has assessed it based on proportional value between medium (i.e. 60%) and high (i.e. 40%), expert 2 has assessed it as 70% medium and 30% high, and expert 3 has assessed it as 10% medium and 90% high. These assessments are then aggregated by using an evidential reasoning algorithm to obtain the reliability estimate of question 1 as {(Low, 0), (Medium, 0.4571), (High, 0.5429)}. The same technique is applied for assessing the organization’s ability to standardize the SOP (i.e. question 2) and the obtained result is {(Low, 0), (Medium, 0.4989), (High, 0.5011)}.

After all the reliability values have been obtained by using quantitative assessment, qualitative assessment and mapping process (i.e. country reliability), these sets will be used to determine the unconditional probability distributions for root nodes as listed in Table VIII:

Table VII. HRM Assessment under Fuzzy Environment

Reliability Criteria	Measurement Criteria	Weight	Assessment Grades Agency ‘A’			
			Source	Low	Medium	High
Human Resource Management (HRM)	Routine and Common Problem Solution (HRM1)	0.5	Expert 1	0	0.6	0.4
			Expert 2	0	0.7	0.3
			Expert 3	0	0.1	0.9
			Aggregation (ER)	0	0.4571	0.5429
	Standard Operation Procedure (HRM2)	0.5	Expert 1	0	0.7	0.3
			Expert 2	0	0.7	0.3
			Expert 3	0	0.1	0.9
			Aggregation (ER)	0	0.4989	0.5011

Table VIII. The belief Degree of All Root Nodes

No.	Root Nodes	Assessment Grade (Agency ‘A’)		
		Low	Medium	High
1.	VR1	0.0884	0.4845	0.4271
2.	VR2	0	1	0
3.	VR3	0.0884	0.4845	0.4271
4.	CM	0.4	0.3	0.3
5.	SR	0.4	0.3	0.3
6.	PR	0.4	0.3	0.3
7.	PROFIT	0.88	0.12	0
8.	FS	0	0	1
9.	LIQUIDITY	0	0.2	0.8
10.	MC1	0	0.7063	0.2937
11.	MC2	0.2172	0.5035	0.2793
12.	MC3	0	0.7867	0.2133
13.	HRM1	0	0.4571	0.5429
14.	HRM2	0	0.4989	0.5011
15.	OM1	0	0.6680	0.3320
16.	OM2	0.0571	0.5619	0.3810
17.	SI1	0.0850	0.5693	0.3457
18.	SI2	0	0.1262	0.8738
19.	SSC	0	0	1
20.	ENVC	0	0	1
21.	MISCC	0	0	1
22.	CR	0.05	0.1	0.85
23.	DI	0.05	0.1	0.85
24.	CRM1	0.1	0.7	0.2
25.	CRM2	0.1	0.4	0.5
26.	CRM3	0.6	0.3	0.1
27.	AF1	0	0.4587	0.5413

28.	AF2	0	0.4175	0.5825
29.	COUNTRY	0.0783	0.5788	0.3429

After all the values of conditional and unconditional probabilities have been obtained, the marginal probabilities of the child node (nodes) can be calculated based on Bayes' chain rule. Due to the complexity of manual calculation of Bayes' chain rule, a computer software tool called *Netica* is used to calculate the marginal probability of the ORC value of Agency 'A'. Therefore, as shown in Fig. 5, the set for the ORC of Agency 'A' is computed as {(Low, 0.146), (Medium, 0.284), (High, 0.571)}.

Since Agency 'A' has been assigned by three linguistic terms, the highest preference is given to the 'high' reliability grade and the lowest preference is given to the 'low' reliability grade. Based on Equations 4-5, the utility value of ORC of Agency 'A' is calculated as 71.25% reliable as compared to the most desirable reliability benchmark which is 100% reliable.

For industrial statistical comparison, the result of Agency 'A' is compared with Agency 'B' (i.e. Agency in Malaysia from a different LSO), as shown in Fig. 6. The evaluation of the ORC is again conducted on Agency 'B' (which has not been shown in this paper due to the limited page). The utility values of Agencies 'A' and 'B' are 0.7125 and 0.7283 respectively; it means that the utility value of Agency 'B' is greater than that of Agency 'A'. Based on the database provided by Alphaliner, as shown in Fig. 6, the ranking orders of Agency 'A' and Agency 'B' are 83rd and 44th respectively. Since the utility value of Agency 'B' is greater than that of Agency 'A' and the ranking order of LSO 'B' is better than LSO 'A', it can be concluded that the developed result in this research is accepted.

To ensure that the model developed in this research is further validated, this paper proposes the sensitivity analysis which can be conducted in the future research. Sensitivity analysis will demonstrate which factors in the model is critical that LSOs need to highlight in their business to maintain as high reliability organization.

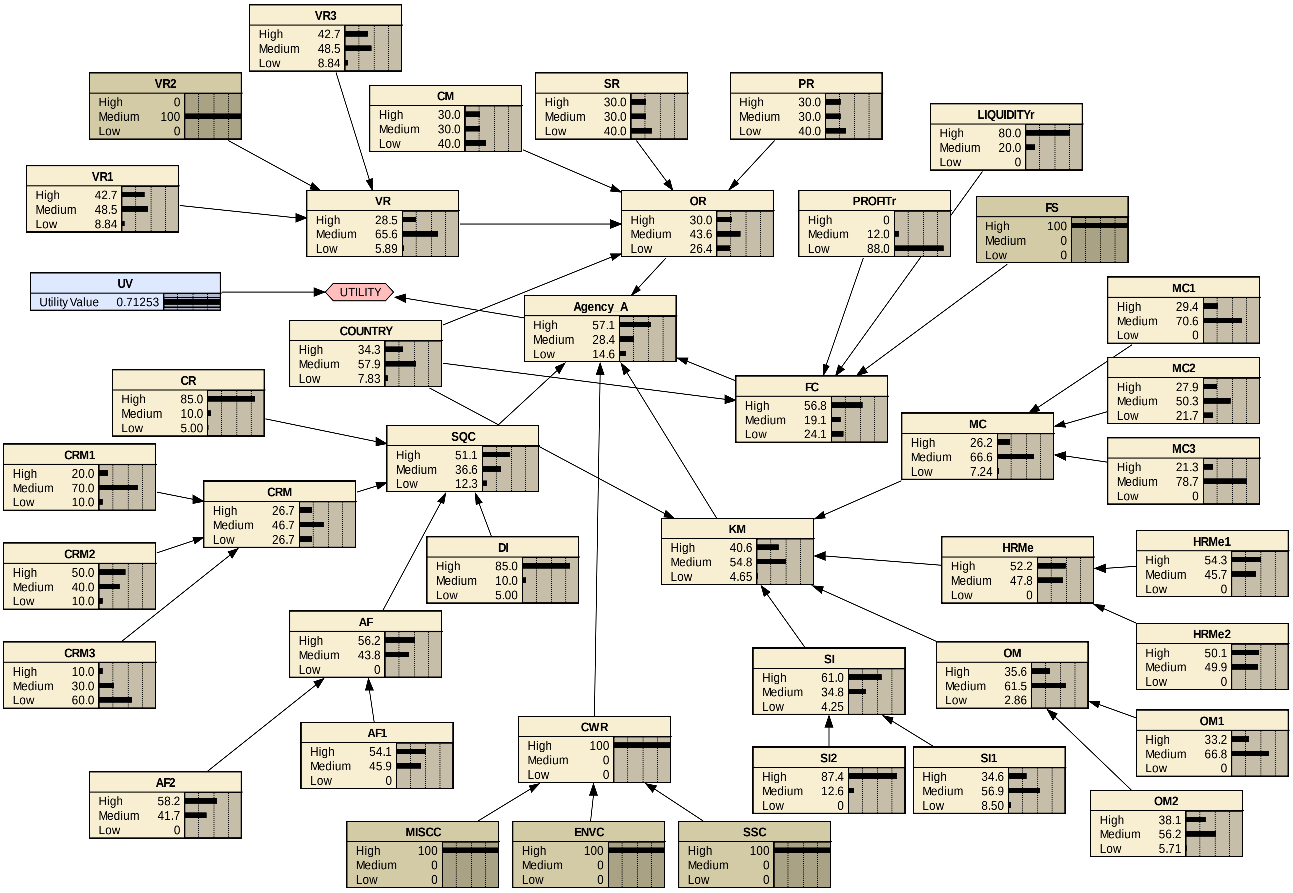

Fig. 5 The Evaluation Value of ORC of Agency "A" by using *Netica*

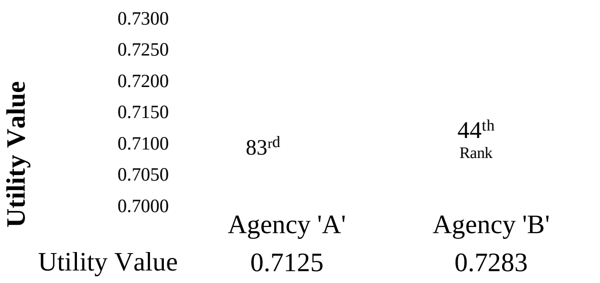

Fig. 6. ORC values versus Alphaliner orders ranking for Agency 'A' and 'B'

The assessment model of the ORC involved taking many criteria into consideration, namely operational reliability, financial capability, knowledge management, compliance with regulations and service quality capability. Based on Fig. 5, it is recommended that Agency ‘A’ should take several actions to improve its ORC value, which can be listed as follows:

- Improving operational reliability and its various parameters such as vessel reliability, container management and schedule reliability. From the customers’ point of view, they are more concerned about the operational reliability of an LSO. As a result, highly reliable operations need to be achieved.
- Improving vessel reliability by enhancing ship staff’s reliability (VR1) and upgrading the technology onboard vessels (VR3. Since the age of all operated vessels is between 11-20 years, these vessels are still reliable to operate. However, the maintenance department should monitor the vessels frequently to avoid any breakdown (e.g. engine breakdown, navigational technical failure, etc.) during operations.
- Improving the reliability of scheduling and container management (i.e. SR and CM). Only 30% on-time performance has been achieved during the evaluation period. Therefore, these parameters need to be improved to achieve a highly reliable performance.
- Improving the knowledge management (KM) of the LSO. Strategically, knowledge management is the foundation for any firm to enhance its sustainability in the industry. Agency ‘A’ should improve its market competitiveness, shipping innovation and organization management to establish a competitive advantage and good market positioning.
- Taking advantage from strong financial capability to improve the overall internal ORC by investing for improving operational reliability and knowledge management.

It is worth mentioning that the financial capability is a strong indicator for the internal ORC of the LSOs. The financial capability value was closely associated with the perspective of experts’ judgment. Experts suggested that financial capability is a core foundation for the LSO to enhance its ORC. Empirical studies have found that a strong financial capability can contribute to a higher value of the overall performance. As a result, a strong financial capability is found to be the most significant element for the LSO to enhance its ORC.

The model output is more sensitive respectively to the security and safety compliances than the other 28 input variables. This indicates that decrease of security and safety levels during operations can cause huge impacts on the value of the ORC of Agency ‘A’. This impact can be in the form of human injuries or loss, asset and infrastructure damage, supply chain disruptions, reputational risks and, finally, serious financial consequences. Safety operation and practices are the critical agenda in field of maritime transportation industry. Providing safe environment during operation is one of the objectives by LSOs to ensure safe environment for crews, cargos and vessels.

V. CONCLUSION

In a nutshell the LSO is significant to establish a competitive advantage and market positioning in the liner shipping industry. In addition, ORC is a foundation for LSO which need to be integrated to provide significant outcome. In this paper, a new framework to validate the ORC of LSO in a fuzzy context has been established and it requires continues validation by LSO to understand the internal resiliency. Firstly, the reviews from the literature and deep consultation with industrial experts especially in liner shipping have been incorporated to explore the influential factors of the ORC of LSO. Secondly, the states of each node have been defined by experts’ opinion and the review of the literature. Thirdly, a BBN model has been used as a guideline to generic a model for ORC. Next, a quantification technique was applied by assigning each child node a CPT by using a symmetric model to validate the strength of direct dependence of each child node to its associated parents. Further, the unconditional probabilities need to be determined and this has been done by assigning assessment grades to all the root nodes in the graph. However, the assessment grades will be either in quantitative or qualitative form and to ensure the data is in qualitative form and to preserve the invariance of the data, the existing quantitative data need to be transformed to a qualitative criterion by using membership functions. Subsequently, an expected utility approach has been employed to evaluate utility value of the model. Finally, the result and model have been validated through industrial statistical comparison and sensitivity analysis. The results indicate that the financial capability is a strong indicator for the internal ORC of the LSOs. In the meantime, the sensitivity analysis has caused the model output to be more sensitive to the security and safety compliances in comparison to remaining 28 input variables. From the managerial perspective, the method which has been employed in this paper will be significant to assist LSOs to conduct self-evaluation of the ORC specially to enhance business sustainability in the liner shipping industry. Consequently, from the methodological perspectives, this paper has proposed a robust approach for evaluating the value of the ORC of an LSO.

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