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Ta-Yuan Lin

Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

Cheng-Chi Chung

*Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.,
jackie@mail.ntou.edu.tw*

Tien-Chun Ho

Department of Marketing and Logistics, MingDao University, Changhua, Taiwan, R.O.C

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AN EVALUATION OF THE KEY INFLUENCING FACTORS FOR TRAMP SHIPPING CORPORATIONS SELECTING SHIP MANAGEMENT COMPANIES*

Ta-Yuan Lin¹, Cheng-Chi Chung¹, and Tien-Chun Ho²

Key words: tramp shipping corporations, ship management company, fuzzy analytic hierarchy process, revised decision making trial and evaluation laboratory analysis.

ABSTRACT

The shipping industry is a global business and the number of privately-owned ships represents the strength of the shipping industry. However, global trades and the shipping business today are in poor economic shape. The more ships a company owns, the greater the burden on shipping operators. For the tramp shipping industry, using ship leasing, besides convenience, flexibility, time-saving, and tax benefits, commissioning a ship management company (SMC) to handle its non-core business can also result in greater financial liquidity providing the shipping companies with increased investment and purchasing power in other areas. This study is based on a consideration of the direction of tramp shipping corporations (TSCs) towards a survey questionnaire of TSCs in Taiwan using the SAVE framework, including solution (S), access (A), value (V) and education (E), built on a model to analyze TSCs who have chosen to employ an SMC to handle their non-core business, and using the fuzzy analytic hierarchy process (Fuzzy AHP) and the revised decision making trial and evaluation laboratory (Revised DEMATEL) to seek the suitability of key influencing factors, their relevance, and their business strategy. The results of this study can provide an important research reference for TSCs' outsourcing strategies in the future.

I. INTRODUCTION

Affected by the global financial crisis in 2008 and 2012 and the slowdown of growth in China in 2015, global competition in transport operations has become increasingly fierce. The global economic downturn has caused traders to become even more concerned with financial liquidity, maximizing profit, and flexible operation and management efficiency (Gong et al., 2013). Facing fluctuations in supply and demand and market prices, the shipping industry has adopted a number of protective strategies to safeguard its profitability, such as delaying and canceling the delivery of new ships, scrapping old ships, temporarily suspending operations, and reducing the speed of ships. Besides these negative business coping strategies, the question of how to cut costs to improve operational performance and international competitiveness has also become an important consideration in the current business strategy of the shipping business. Ship management companies (SMCs) should have in-depth knowledge of the changes in the shipping market and the needs of TSCs based on the guiding principles of tramp shipping operators. Due to the size of the ships, the type of cargo, the voyage frequency, and the distribution of shipping routes, and considering the difference in charter period and the terms of the contract, it is not possible for TSCs to form a strategic alliance with container shipping operators to achieve cost savings, expand the scope of operation, control the number of berths, diversify operational risks and share existing resources. Therefore, in terms of shipping practices, most TSCs use ship pooling to carry out their shipping services. In addition to the difficulties in achieving synergy in strategic partnerships, this mode of operation also makes it more difficult to calculate capital infusion and revenue distribution. Given the special nature of TSC operations, implementing strategic alliances to reduce costs is more difficult than for liner shippers. In general, outsourcing enables enterprises to combine building up their core business while enhancing organizational efficiency (Arias-Aranda et al., 2011).

In recent years, international regulations have brought increased restrictions on vessels. Shipowners can reduce the impact of regulatory changes on their operations through SMCs (Gunton,

Paper submitted 11/20/18; revised 01/11/19; accepted 03/11/19. Author for correspondence: Cheng-Chi Chung (e-mail: jackie@mail.ntou.edu.tw).

¹ Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

² Department of Marketing and Logistics, MingDao University, Changhua, Taiwan, R.O.C.

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1997). TSCs achieve effective market segmentation, reduce operating costs, improve operational performance, and meet customer needs through using SMCs to handle their non-core business operations (Panayides, 2003). The operational problems faced by the ship management companies can also be solved through the marketing services provided by the ship management companies (Panayides and Gray, 1997). So, if TSCs can use an SMC to outsource operations, this business model should allow them to reduce their operating costs, diversify operational risks, and consolidate their core business, which is the primary task of the TSC industry at this stage. The purpose of this article is to establish which key influencing factors are important to TSCs when selecting an SMC and to determine how these TSCs rank the factors. This information can contribute to the establishment of a future ranking index for SMCs in Taiwan.

II. LITERATURE REVIEW AND MODEL DEVELOPMENT

1. Ship Management Companies

Since the first contract for third-party ship management was signed in 1957 up until today, third-party ship managed types of SMCs have evolved into independent industries (Mitroussi, 2004a). Early SMCs evolved from family-owned SMCs. In the mid-1960s, as the government reduced taxes, oil companies purchased large numbers of ships. However, their lack of expertise in ship management caused them to outsource this to an SMC, leading to the vigorous development of ship management (Mitroussi, 2003).

A survey by Panayides and Cullinane (2002) found in terms of shipowners and the types of vessels commissioned, except for liner shippers and containerships which were entrusted to an SMC to manage, the remainder were all drybulk carriers, tankers, car carriers, reefers, general-cargo ships, LNG and LPG tankers, and ferries commissioned by TSCs. The operations commissioned were ship trading, ship leasing, and fuel management, in that order.

A modern shipping company needs to have sound staff training and continuously absorb new knowledge to cope with the changing shipping market and management models (Damachi and Yang, 2005). However, with the changes in the structure of the industry, the cost of, acquisition of, and quality of crew, it has also become a problem affecting the operation of commercial traders (Guo et al., 2007; Ho et al., 2014). On the other hand, SMCs are able to provide charters with staff and crew with ship management expertise and knowledge, keeping them competitive in the marketplace (Plomaritou, 2008).

SMCs can provide the most up-to-date regulations released by international organizations and, through crew members trained in line with international standards, provide regular ship maintenance and inspection to reduce ship pollution. In addition to meeting the requirements of international organizations (Triantafylli and Ballas, 2010), it is also possible to avoid having the ship unable to operate properly due to a lack of repair or improper maintenance technique (Damachi and Yang, 2005). In

terms of ship pollution and social responsibility, green shipping has been regarded as one of the performance requirements for the shipping industry's sustainable development.

International regulations on cargo safety are bound to be more stringent. Ships on international voyages must be equipped in accordance with international norms, good route planning (Meng et al., 2015), an optimally configured fleet (Christiansen et al., 2004), and a professional crew to ensure a certain degree of safety. In the bulk shipping sector the transportable moisture limit provision prevents the cargo from liquefying during the shipping process (Byrne, 2014). Good voyage planning and timing can enhance efficiency and reduce costs. Due to the capital intensive nature of shipping, besides taking into account the fuel required for the voyage and port mooring costs (Fagerholt, 2004), the number of ships, the ship's cargo capacity (Liu et al., 2011), and cargo capacity management, good route planning is crucial and less than optimal operation of vessels has significantly affected the bulk shipping industry.

If SMCs can actively provide solutions in emergencies (Lagoudis et al., 2006) and provide real time advisory services (Frankel, 1982), this will help enhance the loyalty of shipowners. Further, through the network of knowledge they have built, related operators can integrate relevant work experience so enterprises can learn the latest management models and professional expertise, which will help improve the value of goods transported (Devinder and Hillary, 2007; Song and Lee, 2012).

With the increased demand for transport expertise, shippers commission SMCs to take on its management (King, 1997). Understanding and mastering the changes in the international shipping industry can help policy makers in operational management strategy formulation and other investment activities (Chisté and van Vuuren, 2014). However, Mitroussi's (2004a) study found the failure of shipping companies to use SMCs was due to lack of confidence in them. Therefore, SMCs should build a good business reputation and brand image (Panayides, 2003; Mitroussi, 2004b) along with sound financial fundamentals (Kannan et al., 2012) to give shippers adequate transaction confidence, persuading them to turn over management to an SMC.

2. Influence Factors Assessment Framework

Marketing is often used to find customers, satisfy customers, and establish good customer relationships. Since McCarthy (1960) invented the 4Ps marketing theory (product, place, price, promotion), relevant scholars at home and abroad have extended the discussion based on this theory. With the competitive pressures of globalization, producer-oriented marketing has gradually declined. Lauterborn (1990) is more consumer-oriented and has developed the consumer-oriented 4Cs (customer, costs, communication, convenience) marketing theory based on the original 4Ps marketing theory. However, in the modern shipping market, there are many B2B-type trading patterns. Ettenson et al. (2013), in response to changes in the market and based on past marketing theories, proposed the SAVE (solution, access, value, education) marketing theory to meet the marketing goals of the modern market. According to the

Table 1. Implications of SAVE Facets and Shipping Marketing SAVE Facets.

Evaluation Facets	SAVE Implications	Shipping Marketing SAVE facets
Comprehensive Solutions (Solutions)	The provided product or service is defined by the customer’s needs rather than in terms of the product’s characteristics, functionality, or technological advantages.	Timely advice is provided to shipowners on specific proposals and problem solving methods, such as legal advice, provision of crew, technical support, and other professional services, thus enabling shipowners to enhance the company’s operating performance and achieve sustainable operations.
Market Access (Access)	Develop and integrate cross- channel deployments, taking into account the overall customer procurement process, rather than focusing on individual procurement locations or pathways.	Improve the ship management company’s accessibility for the shipowner; for example, improving the reputation of the company and providing timely consulting services so the shipowner will include the ship management company in the selection assessment loop, while also providing an integrated cross-channel service platform, giving shipowners a one-stop shopping service.
Professional Value (Value)	Emphasize the relative advantages beyond just price, excluding the production costs of products or services, profit margins, or the price of competitors.	As a ship owner compares costs, it places priority on whether a ship management company has a beneficial interest in the services it provides, for example ship safety, optimal voyage planning, and the sense of receiving beneficial services for the price, etc.
Shipping Knowledge (Education)	In the buying cycle, provide customers with information related to their specific needs instead of relying on advertising, public relations, or personal sales capabilities.	In the service cycle, provide ship owners or potential customers with specific ship management information required each time, such as the latest market status and changes in international regulations. In addition, actively cultivate shipping industry talent with a view to enhancing the professionalism of the company’s internal staff, for example, by setting up a shipping knowledge base and learning from shipping management knowledge.

Source: SAVE facets compiled from Ettenson et al. (2013); Shipping Marketing SAVE facets compiled from Wang, Sih-Chun (2015).

SAVE marketing theory and other perspectives, various factors are proposed. Descriptions of the implications of these facets and the assessment criteria are given in Table 1.

A framework is constructed for assessing the factors affecting the choice of an SMC for TSCs. Integrated solutions includes four evaluation criteria ‘(S1) the scope of management services,’ ‘(S2) transport safety management,’ ‘(S3) increased operational effectiveness,’ and ‘(S4) sustainable shipping services’. Market access includes four evaluation criteria, including ‘(A1) corporate image and reputation,’ ‘(A2) high accessibility,’ ‘(A3) timely consulting service,’ and ‘(A4) a firm financial foundation’. Professional value includes four evaluation criteria, including ‘(V1) discounted management fees,’ ‘(V2) business relationship maintenance,’ ‘(V3) optimized ship deployment,’ and ‘(V4) market survey forecasting’, and shipping knowledge includes four evaluation criteria, including ‘(E1) information software application,’ ‘(E2) rules and regulatory compliance,’ ‘(E3) professional management staff,’ and ‘(E4) knowledge sharing network’. This paper integrates relevant literature related to TSCs selection of SMCs, to summarize the evaluation criteria and influencing factors affecting TSCs selection of SMCs, the definitions are presented in Table 2.

Following Table 1 and Table 2, this shows the 4 evaluation facets and 16 evaluation criteria. This study primarily focused on factors affecting TSCs' choice of an SMC. The framework development of 4 evaluation facets and 16 evaluation criteria is illustrated in Fig. 1.

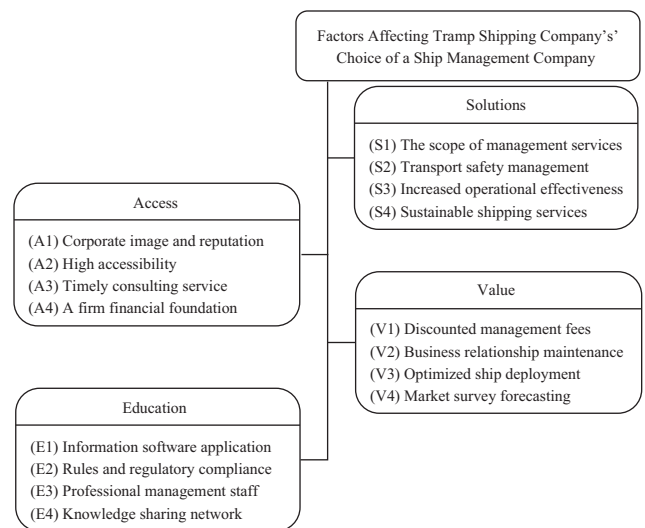


Fig. 1. Assessment Framework for Factors Affecting TSCs' Selection of a SMC.

III. RESEARCH METHODS

The assessment framework can be considered a typical Multi-Criteria Decision Making problem (MCDM). MCDM problems are widely used by researchers to solve multi-criteria problems. The Analytic Hierarchy Process (AHP) is one of the more popular methods of MCDM and has many advantages, as well as disadvantages. One of its advantages is its ease of use. Its use of pairwise comparisons can allow decision makers to weight

Table 2. Evaluation Criteria and Influencing Factors Affecting TSCs' Selection of an SMC.

Evaluation Criteria	Implications of the Evaluation Criteria	References
(S1) Management Services	Provide various customized services, such as crew supply, ship management, oil supply, technical support and ship insurance, certificate processing, etc., to meet the needs of shipping companies.	Triantafylli and Ballas (2010); Lagoudis et al. (2006); Damachi and Yang (2005); Fagerholt (2004); Mitroussi (2004a); Mitroussi (2003); Panayides and Cullinane (2002)
(S2) Transportation Safety Management	Assist in the handling of matters related to unexpected events, such as ship accidents, crew strikes, arrangements for follow-up handling of goods, ship dispatching, and other transportation safety management issues.	Triantafylli and Ballas (2010); Lagoudis et al. (2006); Mitroussi (2004a); Panayides and Cullinane (2002)
(S3) Improve Operational Efficiency	Shipowners can outsource the management of operational projects where they lack expertise, such as the integration of logistics operations, enabling shippers to focus on core businesses and increase operational efficiency	Mitroussi (2004a); Mitroussi (2003)
(S4) Sustainable Shipping Services	A ship management company with good quality service and a stable organizational structure has the ability to establish long-term cooperation agreements with shipowners and achieve both sides' goal of mutual benefit and sustainable operation.	Triantafylli and Ballas (2010); Wong et al. (2008)
(A1) Corporate Reputation and Image	Through the management ability of a professional team and upholding good-faith principles, build a good reputation to effectively attract shippers and increase cooperation opportunities with potential customers.	Bayazit and Karpak (2013); Lagoudis et al. (2006); Mitroussi (2004b); Panayides (2003); Panayides and Cullinane (2002)
(A2) Accessibility	Establish concrete customer contact channels such as official websites, proprietary communication software, or e-mail to enhance access to the company by shippers or potential customers	Lagoudis et al. (2006); Panayides and Cullinane (2002)
(A3) Instant Advisory Service	Provide timely advisory services so when the shipping company faces a problem and contacts the ship management company, it gets solutions and advice the first time.	Mitroussi (2004a); Panayides and Cullinane (2002); Frankel (1982)
(A4) Sound Financial Foundation	Based on a sound financial foundation, enable shippers to build confidence in transactions to successfully conclude contracts and maintain long-term relationships.	Bayazit and Karpak (2013); Kannan et al. (2012)
(V1) Discounted Management Fee	One of the main considerations in the choice of a ship management company by shipping lines is a sense of having received a benefit in exchange for reasonable management fees.	Panayides (2003); Panayides and Cullinane (2002)
(V2) Business Relationship Maintenance	Maintaining good interactions with shipowners or suppliers can not only preserve a good reputation but also increase opportunities for long-term cooperation.	Bayazit and Karpak (2013); Kannan et al. (2012); Panayides and Cullinane (2002)
(V3) Optimal Ship Deployment	Provide optimal voyage planning for ships, reducing the cost of ship operations, and enhancing ship operating efficiency and time management, thus resulting in an increase in the shipowner's profit margins.	Meng et al. (2015); Liu et al. (2011); Fagerholt (2004); Ronen (1993)
(V4) Market Survey Forecast	Focusing on the actual needs of the shipping lines and the real environment, use existing knowledge, experience, and methods to make appropriate analysis and judgments on the shipping companies and future market trends which can be used as the basis for the shipper's future operations.	Meng et al. (2015); Liu et al. (2011); Panayides (2003)
(E1) Information Software Applications	In the face of globalized competition, provide technological information software services for the ship owner's convenience, enabling shipowners to more quickly and professionally improve operational efficiency through relevant ship data while providing safe and reliable ship management services.	Bayazit and Karpak (2013); Lee and Song (2010)
(E2) Regulatory Compliance	Provide the latest information on international regulations for shipping companies so they comply with international regulations to ensure the protection of cargo assets and crew rights.	Mitroussi (2004a); Mitroussi (2003)
(E3) Professional Management Staff	Employ managers with professional knowledge in shipping logistics, such as accountants, lawyers, and maintenance technicians to make the service process more efficient to increase shipping lines' loyalty.	Florin (2012); Triantafylli and Ballas (2010); Plomaritou (2008); Lagoudis et al. (2006); Damachi and Yang (2005); Mitroussi (2004a); Mitroussi (2003); Panayides and Cullinane (2002); King (1997)
(E4) Knowledge Network Sharing	Study the latest international shipping management models and professional knowledge, and establish the company's shipping knowledge base, such that when problems are encountered, they can search for answers, and record how the issue was handled and its detailed results into the knowledge base, so ship owners can gain shipping industry knowledge, and internalize it into the company's relevant management methods.	Song and Lee (2012); Devinder and Hillary (2007); Mitroussi (2004a); Mitroussi (2003); Panayides (2003); Panayides and Cullinane (2002)

coefficients and compare alternatives with relative ease. It is scalable, and can easily adjust in size to accommodate decision making problems due to its hierarchical structure (Velasquez

and Hester, 2013). In addition, fuzzy linguistic variables and associated fuzzy triangular numbers can be used for comparing the influencing attributes and, hence, provide solutions to vague

and uncertain problems in decision-making (Zadeh, 1965). Laarhoven and Pedrycz (1983) further developed the traditional AHP of Saaty (1980) to develop the Fuzzy Analytic Hierarchy Process (FAHP). Triangular fuzzy numbers are directly substituted into the pairwise comparison matrix to prevent ambiguity problems arising from the criteria measurement and judgment processes. However, FAHP is more appropriate than AHP in the area of people’s habits to express their feelings and values along with their levels of preferences in practical operation. Since human beings cannot clearly express their preferences, the semantic variables used in a questionnaire have a considerable degree of ambiguity, such that it is not suitable for calculating the criterion weights. FAHP can provide decision-makers with a broader evaluation range so they can obtain more suitable analysis results. It is with respect to this latter characteristic that FAHP exerts its most significant advantage over other MCDM techniques (Kabir and Akhtar Hasin, 2011; Tseng and Cullinane, 2018).

Although AHP is a powerful and flexible decision making technique that helps decision-makers set priorities and select the best alternative, the remarkable weakness of AHP is that it cannot deal with interconnections among the decision factors at the same levels, because the decision framework in the AHP assumes a one-way hierarchical relationship between decision levels. In many issues where interactions among the decision variables exist, AHP is not effective (Isik et al., 2007). Combining the AHP and DEMATEL methods can solve the above problem (Najmi and Makui, 2010). The AHP and DEMATEL represent a good mix to solve complex MCDM problems and have been widely used in research. Najmi and Makui (2010) developed a hierarchical approach for measuring supply chain performance combining the methodology of AHP and DEMATEL. Wu and Tsai (2012) integrated the AHP and DEMATEL methods in evaluating the criteria of the auto spare parts industry. Gandhi et al. (2016) combined AHP and DEMATEL for evaluating success factors in the implementation of green supply chain management in Indian manufacturing industries. Liu et al. (2017) used a hybrid multiple criteria decision-making approach in failure mode and effect analysis. Ding et al. (2018) applied AHP and DEMATEL to evaluate key determinants of attractiveness and their cause/effect relationships for container ports in Taiwan. This study develops the Fuzzy AHP and revised DEMATEL approach as follows.

1. Fuzzy AHP

AHP is a set of decision theories developed by Saaty (1971) which divide a complex problem into several layers according to different influencing factors and then it breaks the problem down into a simple hierarchical system to make it more structured, systematic and simplified. In view of the fact the Analytic Hierarchy Process cannot overcome the shortcomings of the fuzziness associated with decision making, Laarhoven and Pedrycz (1983) further developed the traditional AHP to the FAHP. We used the concept of the triangular fuzzy number to replace the pairwise comparison of AHP proposed by Saaty (1980). Geometric means were then applied to calculate fuzzy

Table 3. Preference value scale and corresponding fuzzy number.

Preference value	Numeric Value	Fuzzy Numbers
Equally preferred	1	(1, 1, 1)
Moderately preferred	3	(2, 3, 4)
Strongly preferred	5	(4, 5, 6)
Very strong preferred	7	(6, 7, 8)
Extremely preferred	9	(9, 9, 9)

weighting. This approach effectively solves the potential fuzzy problems during a criterion decision making process (Chen and Hwang, 1992). For the FAHP, interval values were applied to replace exact values in the conventional AHP; thus, experts could evaluate problems from a user-friendly scale and provide reasonable comparison values during the decision-making process (Wang et al., 2016). The pairwise comparisons for the alternatives and the criteria are made using a preference scale. They are subsequently used to obtain the fuzzy numbers for the fuzzy AHP computations. The preference scale and corresponding fuzzy numbers are presented in Table 3. (Diouf and Kwak, 2018).

Regarding the establishment of an evaluation index weight system, the steps are described as follows:

Step 1: Establish a fuzzy paired comparison matrix

Assume a fuzzy paired comparison matrix with \tilde{A}_r .

$$\tilde{A}_r = \begin{bmatrix} 1 & \tilde{a}_{12(U-R)} & \cdots & \tilde{a}_{1n(U-R)} \\ \tilde{a}_{21(U-R)} & 1 & \cdots & \tilde{a}_{2n(U-R)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1(U-R)} & \tilde{a}_{n2(U-R)} & \cdots & 1 \end{bmatrix}$$

$$\tilde{a}_{ij} = [l_{ij}, m_{ij}, u_{ij}], \tilde{a}_{ij} \cdot \tilde{a}_{ji} \approx 1,$$

$$\forall_{ij} = 1, 2, \dots, n.$$

where l_{ij} the lower is limit value, m_{ij} is the most promising value and u_{ij} is the upper limit value.

Step 2: Consistency check of the fuzzy matrix

The consistency of this paired comparison matrix needs to be judged to determine the ratio of the matrix and estimate whether the logical relationship of the sample collection is close to a random collection. Therefore, the consistency index (C.I.) and consistency ratio (C.R.) are used to test matrix consistency.

$$C.I. = 1/n - 1(\lambda_{\max} - n)$$

$$C.R. = C.I. / C.R.$$

where n is the number of criteria and λ_{\max} is the maximum

Eigenvalue.

Saaty (1977) suggested when $C. R. \leq 0.1$, the consistency of the evaluation matrix can be guaranteed. If $C. R. \leq 0.1$, the degree of matrix consistency is satisfactory.

Step 3: Calculate the fuzzy weight

When calculating the fuzzy weight, the column vector geometric average method is used to operate, in addition to the fuzzy weight of the fuzzy positive reciprocal matrix, the normalization can be achieved Buckley (1985). The fuzzy weight value \tilde{W}_i is calculated as follows:

$$\tilde{W}_i = \tilde{Z}_i \otimes (\tilde{Z}_1 \oplus \tilde{Z}_2 \oplus \dots \oplus \tilde{Z}_N)^{-1}$$

$$\tilde{Z}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \dots \otimes \tilde{a}_{iN})^{1/N}$$

Among which

\tilde{a}_{ij} : column i row j of matrix, $i, j = 1, 2, \dots, n$;

\tilde{Z}_i : column vector mean value of fuzzy number $i = 1, 2, \dots, n$;

\tilde{W}_i : weight of i th indicator.

\otimes : multiplication of fuzzy numbers

$$\tilde{A} \otimes \tilde{B} = (a_1, b_1, c_1) \otimes (a_2, b_2, c_2) = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2)$$

\oplus : addition of fuzzy numbers

$$\tilde{A} \oplus \tilde{B} = (a_1, b_1, c_1) \oplus (a_2, b_2, c_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$$

Step 4: Defuzzification

According to the center of area method proposed by Teng and Tzeng (1993) for defuzzification, the process for calculating the fuzzy weight value (DF_{ij}) is:

$$DF_{ij} = \left[(u_{ij} - l_{ij}) + (m_{ij} - l_{ij}) \right] / 3 + l_{ij}$$

Step 5: Normalization

The process of normalized weight calculation (NW_i) is:

$$NW_i = DF_{ij} / \sum DF_{ij}$$

Step 6: Calculate hierarchical fuzzy weights

If, in aspect i , the fuzzy performance score of criteria j is \tilde{a}_{ij} , and the weight of j is $\tilde{\omega}_j$, then the fuzzy weight value \tilde{u}_i of i is obtained by this conversion:

$$\tilde{u}_i = \sum_{j=1}^n \tilde{\omega}_j \tilde{a}_{ij}$$

2. The Revised DEMATEL Method

The decision making trial and evaluation laboratory (DEMATEL) method was developed by the Battelle Memorial Institute of Geneva between 1972 and 1976 (Gabus and Fontela, 1972) to solve complex, tangled problems and enhance understanding of specific issues (Tzeng et al., 2007). By comparing the interrelationships of the factors, we can calculate the direct influence, indirect influence, and comprehensive influence between the factors to clarify the essence of the problem and help research countermeasures against related issues (Liu and Lin, 2005). The DEMATEL method uses a combination of linear algebra and expert questionnaires to clarify the causality of complex problems. By examining the degree of influence between factors and using matrices and related learning algorithms to calculate the causality and impact strength of all factors, one can effectively understand the structure of complex causal relationships and the directionality of the factors' influence (Seyed-Hosseini et al., 2006; Hsu et al., 2013). Lee et al. (2013) defined the power of the normalized initial direct-relation matrix D , D^m , which is called m -indirect influence. The original DEMATEL assumes D^m would converge to zero matrix, but in some situations, $\lim_{m \rightarrow \infty} D^m$ may not converge to null matrix $[0]_{n \times n}$; therefore, $T = D + D^1 + D^2 + \dots + D^\infty$ might not converge. That is, DEMATEL is infeasible when $\lim_{m \rightarrow \infty} D^m$ does not converge to the null matrix. Finally, Lee et al. (2013) presented a revised DEMATEL model under which the infinite-direct influence becomes a null matrix such that the sum of the infinite series, the total influence, will converge. The structure and operational steps of the revised DEMATEL method are as follows:

Step 1: Define the factors and determine relationships

Define the factors that have been filtered by a review of literature and expert experience and displayed in the system.

Step 2: Calculate the initial average matrix

Let $A = (a_{ij})_{n \times m}$ be the average matrix of the direct matrix of an interviewee, where the entry is (i, j) and the i factor affects the direct influence of the j factor. The formula for the initial average matrix is:

$$A = \frac{1}{H} \sum_{k=1}^H B^{(k)}$$

In this example, $B^{(k)}$ is the resulting matrix of the answers respondent number k .

Step 3: Calculate the direct closed matrix

Normalized as X :

$$X = \frac{A}{S}$$

where the formula for S is:

Table 4. Relative Weights of Various Facets and Their Overall Ranking.

Aspect	Defuzzified Weight	Normalized Weight	Weight Ranking
Integrated Solutions	0.4643	0.4624	1
Market Access	0.1881	0.1873	2
Professional Value	0.1859	0.1852	3
Shipping Knowledge	0.1658	0.1652	4

Table 5. Weight Tables for Each Criteria and Their Individual Weight's Rank.

Assessment Criteria	Defuzzified Weight	Normalized Weight	Weight Ranking
(S1)	0.2060	0.2059	3
(S2)	0.3781	0.3779	1
(S3)	0.2480	0.2479	2
(S4)	0.1684	0.1684	4
(A1)	0.3095	0.3095	1
(A2)	0.2266	0.2265	4
(A3)	0.2367	0.2366	2
(A4)	0.2275	0.2274	3
(V1)	0.2763	0.2762	2
(V2)	0.2211	0.2211	3
(V3)	0.3329	0.3328	1
(V4)	0.1699	0.1699	4
(E1)	0.1436	0.1435	3
(E2)	0.4709	0.4707	1
(E3)	0.2890	0.2888	2
(E4)	0.0970	0.0969	4

$$s = \max \left(\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}, \varepsilon + \max_{1 \leq j \leq n} \sum_{i=1}^n a_{ij} \right)$$

where ε is a very small positive value.

Step 4: Calculate the total impact matrix

All matrices with indirect influence are: $X_2, X_3, \dots, X_k, \dots, X^\infty$, and the total influence matrix is:

$$S = X + X^2 + \dots, X^\infty = \sum_{k=1}^{\infty} X^k$$

And after calculating this, you get

$$S = X(I - X)^{-1}$$

IV. EMPIRICAL ANALYSIS AND DISCUSSIONS

In this paper, an expert questionnaire was used to conduct surveys and then, based on the responses of shipping industry experts with relevant expertise and work experience, software was used to analyze the relevance of and correlation between factors affecting the selection of SMCs by TSCs in Taiwan. The

data in this research was collected from an expert questionnaire. Fifty experts were selected from industrial and academic institutions with professional knowledge and experience, with an average of over eight years of work within the TSC industry. Twenty experts were high-level managers (i.e., general manager, deputy general manager, operation manager) and twenty experts were Intermediate-level managers (i.e., assistant general manager, section manager, manager) from TSC industrial. Ten experts were scholars from the Department of Shipping and Transportation that had studied in this area for more than ten years. Finally, thirty-six effective experts (fifteen high-level managers, twelve intermediate-level managers and nine scholars) were acquired, and the effective return ratio was 72%.

First, the geometric mean was used to integrate the thirty-six expert questionnaires using triangular fuzzy numbers to calculate the fuzzy weight values of each evaluation aspect. Then the fuzzy weight values were defuzzified to obtain the defuzzified weight values. Finally, a normalization process was performed to obtain the normalized weights and weights for each evaluation aspect (as shown in Table 4).

With the above steps, one can calculate the weight of each assessment criteria and their weights' ranking of the major aspects of the Integrated Solutions, Market Access, Professional Value, and Shipping Knowledge, as shown in Table 5.

Determine the hierarchical fuzzy weight between various

Table 6. Relative Weights of the Hierarchical Fuzzy Weights Criteria and Their Overall Ranking.

Aspect	Assessment Criteria	Normalized Weight	Hierarchical Series Weight	Weight Ranking
Integrated Solutions (0.4624)	(S1)	0.2059	0.0952	3
	(S2)	0.3779	0.1747	1
	(S3)	0.2479	0.1146	2
	(S4)	0.1684	0.0778	4
Market Access (0.1873)	(A1)	0.3094	0.0578	7
	(A2)	0.2265	0.0424	12
	(A3)	0.2366	0.0443	10
	(A4)	0.2274	0.0426	11
Professional Value (0.1852)	(V1)	0.2762	0.0511	8
	(V2)	0.2211	0.0409	13
	(V3)	0.3328	0.0616	6
	(V4)	0.1699	0.0315	14
Shipping Knowledge (0.1652)	(E1)	0.1435	0.0237	15
	(E2)	0.4707	0.0777	5
	(E3)	0.2888	0.0477	9
	(E4)	0.0969	0.0160	16

levels through the foregoing several steps, calculate the relative weight of the various assessment criteria, and then determine their overall ranking, as shown in Table 6.

From Table 4 to Table 6, it can be seen among the four aspects of the hierarchical evaluation framework of this study, ‘integrated solution’ is the most important factor involved in TSCs choosing an SMC. After calculating the weight from the hierarchical weight, ‘transport safety management,’ ‘enhanced operational effectiveness,’ ‘scope of management services,’ ‘sustainable shipping services’ and ‘compliance with regulations and rules’ are the top five key influencing factors. The *C.I.* and *C.R.* values of the single paired comparison matrix, the verification of the consistency of the entire hierarchy, and the consistency of the interviewee’s questionnaires were all less than 0.1. This indicates a high rate of consistency among the matrices, that is, the respondents’ decision making process was rational and consistent with the decision making factors. Therefore, the results of the study should fully express the opinions of the respondents.

To explain the structural relation among the factors while keeping the complexity of a system to a manageable level, it is necessary to set a threshold value p to filter out some negligible effects in the matrix T . While each factor of matrix T provides information on how one factor affects another, the decision-maker must set a threshold value to reduce the complexity of the structural relation model implied by matrix T . Only some factors, whose effect in matrix T is greater than the threshold value, should be chosen and shown in an impact-relations-map (IRM) (Lee et al., 2013). The threshold value can be decided through the brainstorming of experts. When the threshold value and relative IRM have been decided, the IRM can be shown. (Ou Yang et al., 2008). The threshold value can be computed by the sensitivity analysis method of the elements in total re-

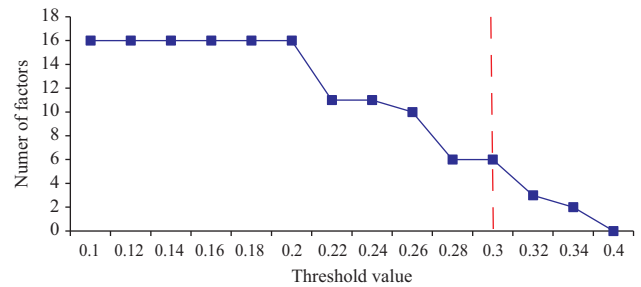


Fig. 2. Sensitivity analysis of setting threshold values and analyzing the number of influencing factors.

lation matrix T (Ho et al., 2016).

This paper’s analysis of the sensitivity of the threshold given and the number of factors is shown in Fig. 2. We can see this paper uses 0.3014 as a threshold to obtain a strong correlation factor. The main purpose is to remove the less relevant factors, and so, if the direct and indirect relationship between the influencing factors is greater than 0.3014, it is more significant. After totaling the sum of each row and each column by means of determinants, the total influence of the factors and the degree of influence are calculated and the key influence factors are sorted. D_i indicates the total extent of this factor’s influence on other factors, R_j indicates the total extent to which this factor is influenced. $D_k + R_k$ Indicates the intensity of the relationship between this factor and other factors - the larger the value, the greater the total impact of the factor. $D_k - R_k$ indicates the impact of this factor and the degree of impact, if $D_k - R_k$ is positive, it indicates this factor is the influencing factor; if it is negative, it means the factor is affected. After assessing the threshold value, the analysis of key correlated influencing factors in a TSC’s choice of SMCs is shown in Table 7.

Table 7. Analysis of the Relevance of Key Factors Affecting TSCs' Selection of an SMC

Key Influence Factors	D_k	R_k	$D_k + R_k$	$D_k - R_k$
(S1)	0	0.7000	0.7000	-0.7000
(S2)	0.9411	0.3426	1.2837	0.5984
(S3)	0.6317	0.6555	1.2873	-0.0238
(S4)	0.3155	1.2601	1.5756	-0.9446
(A1)	0	1.9680	1.9680	-1.9680
(A3)	0.9625	0.0000	0.9625	0.9625
(V2)	0.3082	0.3236	0.6318	-0.0154
(E3)	2.0908	0	2.0908	2.0908

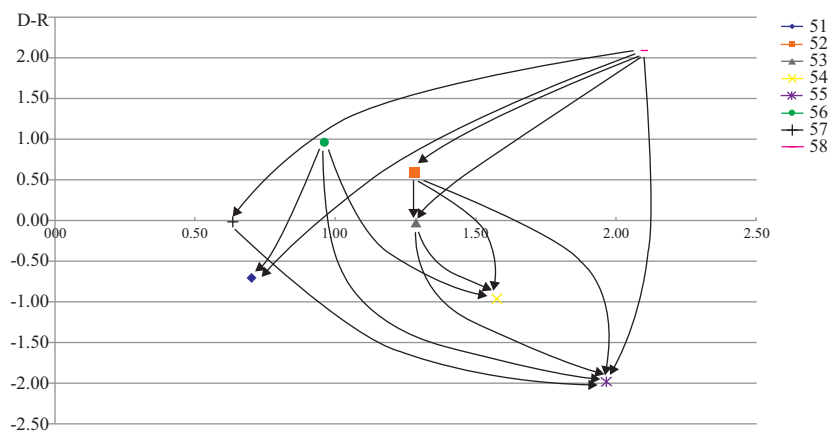


Fig. 3. Causal links between key influencing factors in TSC's selection of SMCs.

Table 7 shows after the threshold is settled, the eight most highly relevant factors include ‘scope of management services,’ ‘transport security management,’ ‘enhancing operational efficiency,’ ‘sustainable shipping services,’ ‘corporate image and reputation,’ ‘timely advisory services,’ ‘business relationship maintenance,’ and ‘professional management staff.’ After being given the threshold value, the causal relationship between key influencing factors influencing TSCs’ choice of an SMC is shown, as in Fig. 3.

Regarding the importance of key influencing factors, the top five factors influencing TSC’s selection of SMCs are ‘transport safety management,’ ‘enhancing operational efficiency,’ ‘scope of management services,’ ‘sustainable shipping services,’ and ‘rule and regulatory compliance.’ TSCs mainly transport difficult to package bulky industrial raw materials and necessary bulk materials, such as iron ore, coking coal, thermal coal, grains, and fertilizers. The biggest factor affecting the profits of charters is the bulk market demand and the volume of global bulk trades. Uncertainties, such as a natural disaster, unstable oil prices, or foreign policy issues, etc., encountered during the process of transport and thus causing global bulk cargos prices to weaken, will cause bulk shipping prices to stagnate in turn. If an SMC can assist in dealing with matters related to unexpected events, such as ship accidents, crew strikes, ship dispatch, and other transport safety management issues, enabling the ship to operate

normally, ‘transport safety management’ would be regarded as a primary key influencing factor. Following that are ‘enhancing operational efficiency’ and ‘management service scope’. Through TSCs’ delegation of their operation to SMCs, this operational management model reduces operational costs. Through outsourcing their operations, they can diversify operational risks and enable companies to achieve a combination of building the scope of their core business and improving organizational efficiency (Arias-Aranda *et al.*, 2011). The SMCs have professional service personnel and provides various customized services, such as crew supply, ship management, fuel supply, technical support and ship insurance, certificate processing, etc., meeting the needs of TSCs both before and during a voyage.

Regarding ‘sustainable shipping services’ and ‘rule and regulatory compliance,’ the bulk shipping industry is not only affected by the economic conditions, but also by constant fluctuations in ship prices, freight rates, etc. In the past, when bulk carriers invested in new ships, switched to leases, or sold or dismantled old ships, they had to rely on their own experience to achieve cost control and make related decisions. In addition, new international marine environmental protection and safety regulations require global shipowners to abide by relevant equipment and operational regulations, inevitably increasing the cost of new ship construction and ship operation. International conventions have imposed increasingly severe restrictions on the sulfur con-

tent of fuel oil. The International Maritime Organization will impose the use of 0.5% low sulfur fuel oil (currently 3.5%) globally from 2020, requiring shipowners to actively respond to sulfur emission limits over the next few years. Whether it is the direct use of low sulfur oil, the use of LNG fuel instead of fuel oil, or the installation of marine exhaust gas desulfurization equipment, the operating costs of ships will increase dramatically. With the increased restrictions on ships because of international regulations, shipowners can reduce the impact of these regulatory changes on operations through an SMC (Gunton, 1997). It is also possible to leverage the professional management of SMCs to enhance their expertise and reduce costs to achieve economies of scale (Spruyt, 1994).

Considering the main influencing factors, 'professional managers' is also a significant factor. For TSCs to complete complex decision making assessments, coordination, and formulation of related policies, they must be assisted by professional accountants, lawyers, and technicians (Mitroussi, 2003). Understanding and mastering the changes in the international shipping industry helps decision makers in formulating of operational management strategies and other investment activities (Chisté and van Vuuren, 2014). The SMCs provide professional management personnel for consideration and assessment prior to the selection of the SMCs. Therefore, SMCs employ professional management personnel not only to provide the necessary services and technical support for bulk carriers during navigation, but also to expand the scope of services to meet the needs of shipping corporations.

Continuing looking at the major factors affected, 'corporate image and reputation' is another factor, followed by 'business relationship maintenance,' 'scope of management service,' 'transport safety management,' and 'sustainable shipping service.' 'corporate image and reputation' is affected by 'transport safety management,' and, 'enhancing operational efficiency,' 'sustainable shipping service,' 'timely consulting service,' 'business relationship maintenance,' and 'professional management personnel.' It means if an SMC can improve operational efficiency and sustainable shipping service by providing good transportation safety management, expanding the scope of service, offering timely, effective consulting services, and supplying professional management personnel, these will enhance the company's image and reputation.

V. CONCLUDING REMARKS

According to the statistics of the United Nations Conference on Trade and Development (UNCTAD, 2018), the vessel tonnage supply in Taiwan was the eleventh in the world in 2018, but its TSCs failed to be listed in the world's top 20 largest TSCs. This illustrates there is still room for development of the tramp shipping industry in Taiwan. This paper, based on a consideration of Taiwanese TSCs, constructs a framework for assessing the key influencing factors for the outsourcing operations to SMCs by bulk carriers. The study design is based on the four needs of charters, i.e., integrated solutions, market access, pro-

fessional value, and shipping knowledge, and 16 assessment criteria, targeted on the Taiwanese tramp shipping industry. It begins with an analysis of the key influencing factors using the fuzzy AHP, and then the revised DEMATEL analysis was used for a correlation analysis of the various aspects and the criteria, to explore the relevance of the key influencing factors for TSCs outsourcing operations to SMCs.

The paper analyzes the key factors influencing TSCs outsourcing operations to SMCs from 5 perspectives - transport safety management, enhancing operational efficiency, scope of management services, sustainable shipping services, and rule and regulatory compliance.

Considering the overall relevance of the key influencing factors, the main influencing factor includes professional management personnel. The main factors influenced by this factor are corporate image and reputation, business relationship maintenance, scope of management service, transport safety management, and sustainable shipping services. This information can contribute to the establishment of a future ranking index for SMC in Taiwan and can be extended to other developing and developed countries.

Considering the relevance of the key influencing factors for TSCs outsourcing operations to SMCs, this paper could be conducted with more relevant industry experts to make the research results more complete. Note, the evaluation results from different experts will incur different effects under their different backgrounds. The research method suggested a follow-up study could also use the factor analysis to explore the contribution of each evaluation criterion and an artificial neural network method, may also use the technique for order preference by similarity to ideal solution to analyze the relevance of the assessment criteria for further research results.

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