Use of the Fuzzy AHP Method to Evaluate Key Factors Influencing New Cross-Strait Shuttle Shipping Routes

AUTHORS

Ji-Feng Ding
Department of Aviation and Maritime Transportation Management, Chang Jung Christian University

Chiu-Hua Jhong
Department of Harbor and River Engineering, National Taiwan Ocean University

Wen-Chih Huang
Department of Transportation Technology and Management, Kainan University

Ata Allah Taleizadeh
School of Industrial Engineering, College of Engineering, University of Tehran

ABSTRACT

Since the volume of trade between second- and third-line cities and ports in China and Taiwan is growing steadily, ensuring the availability of shuttle shipping service within the current hub-and-spoke system has become the shared goal of government, carriers, and cargo owners. In the form of an increasingly competitive cross-strait shipping market, what key factors should carriers consider when developing a new shuttle shipping route? Hence, the main purpose of this paper was to apply the fuzzy analytic hierarchy process (FAHP) approach to evaluate key factors influencing new cross-strait shuttle shipping routes. Based on the literature and experts’ opinions, a hierarchical structure with 4 assessment aspects and 15 assessment factors was first constructed, and a FAHP algorithm model was then proposed. Finally, based on the AHP experts’ questionnaires, we used the FAHP approach to evaluate the key factors. The results showed that (1) competitive port features is the most important aspect in influencing new cross-strait shuttle shipping routes for ocean carriers and (2) in order of relative importance, the top five key factors in influencing new cross-strait shuttle shipping routes for ocean carriers are wharf service facilities, convenient customs clearance and administrative procedures, superior natural geographical location, computer software and hardware facilities, and adequate hinterland and cargo sources, respectively. Furthermore, some discussions and recommendations are provided in this article.

Keywords: shuttle shipping, Taiwan Strait, fuzzy analytic hierarchy process

Introduction

Following a long period of hostility in the wake of 1949, the cross-strait relationship progressively improved during the 1990s. Direct transport was initiated in 2008, after an almost 60-year shift from conflict to benign mutual interchange. The “Three Links” (postal, commercial, and shipping links) have opened the door to full-scale socio-economic contact and have given rise to greater demand for cross-strait cargo shipping. Motivated by the growing dependence of Taiwan and China on cross-strait trade, in 2010 the two parties signed the Economic Cooperation Framework Agreement (ECFA), which formally took effect in 2011. The government of Taiwan looks forward to ECFA increasingly highlighting the benefits of direct transport and promoting economic development. Because economic development has been the government’s foremost administrative goal in recent years, it has also relied on the promotion of free trade port areas and free economic demonstration areas to achieve its economic growth policy goals.

China is currently the world’s second largest economy, behind only the United States. As a result, China makes an enormous contribution to global economic growth and exerts a major, far-reaching influence on the global economy. Taiwan is located close to the Chinese market, and the growing volume of cross-strait trade over the last few years has caused cargo shipping volume between Taiwan and China to surge. In addition, the opening of cross-strait trade and ensuing rapid industrial development have stimulated growth in the cross-strait cargo shipping market. In order to ensure that cross-strait cargo can be quickly and efficiently shipped around the world, the development of an effective marine container shipping model has been an extremely important logistics undertaking.
Container shipping has evolved with the increasing size of container ships, and the use of flexible operating inter-modal transportation models and Internet shipping applications has resulted in the reconstruction of container shipping service functions and the establishment of today’s prominent hub and feeder port systems, which are also referred to as “hub-and-spoke” shipping networks (Alderton, 1999; Cable, 2001). Because of the immense cost of large container ships, carriers are adopting minimal mother ship berthing strategies intended to reduce the amount of time large vessels spend in port and associated costs, while maximizing the economies of scale derived from the use of large vessels (Comtois, 1994; Goon, 1995). In addition, carriers must rely on fast, efficient feeder shipping services to transport cargo between hub ports and feeder ports to ensure that cargo can be easily shipped to mother vessels in hub ports and thereby provide cross-strait shipping competitive logistics service.

Since the volume of trade between second- and third-line cities and ports in China and Taiwan is growing steadily, ensuring the availability of shuttle shipping service within the current hub-and-spoke system has become the shared goal of government, carriers, and cargo owners. Furthermore, many carriers are finding that they must re-think their shuttle line layout to ensure that their ships go to where the cargo is and consequently plan to change their shuttle shipping lines and berthing ports. Nevertheless, cross-strait shuttle shipping lines are still relatively novel, and there has been little study of related issues. In the form of an increasingly competitive cross-strait shipping market, what key factors should carriers consider when developing a new shuttle shipping route? This research question is worthy of in-depth investigation.

This study chiefly seeks to evaluate key factors influencing new cross-strait shuttle shipping routes. This issue faces how to evaluate the relative weights of these multiple criteria; however, the Saaty’s analytic hierarchy process (AHP) approach, proposed in 1980, is one of the commonly used techniques for this problem. In view of the qualitative characteristics of multiple-factor questions and the inherently fuzzy nature of individuals’ subjective views, it would be very difficult to express the importance of assessment factors in terms of precise values. The characteristic of multiple criteria problems, in which information is incomplete or imprecise, or views that are subjective or endowed with linguistic characteristics (Zadeh, 1975/1976) create a fuzzy environment; e.g., the phrase of “much more important than.” Hence, this study applies the fuzzy set theory (Zadeh, 1965) in conjunction with the AHP approach to construct a fuzzy analytic hierarchy process (FAHP) approach, which can be used as a model enabling ocean carriers to assess the key factors involved in new cross-strait shuttle shipping routes.

In summary, the goal of this paper is primarily to construct a FAHP computation model able to assess the key factors influencing new cross-strait shuttle shipping routes. The following section presents the preliminary assessment factors, and the third section described the method of FAHP approach. The fourth section consists of an empirical study, and the final section presents some conclusions.

**Preliminary Factors Influencing New Shuttle Shipping Routes**

In view of the growing amount of cross-strait interchange and economic activity, which is placing increasing time pressure on cargo shipping, how to best provide a fast and efficient logistics network is a critical question. It will be necessary to establish convenient feeder corridors in China and Taiwan, accommodate the functions of free trade port areas and free economic demonstration areas, and develop cross-strait shuttle shipping routes to transport cargo to and from second- and third-line cities and ports on both sides of the Taiwan Strait, which will create even more industrial and economic activity. Based on this perspective, cross-strait shuttle shipping routes should reflect regional economic cooperation among cities and ports on both sides of the Taiwan Strait, seek to effectively expand the economic hinterlands of both Taiwan and China, attract a greater scale of private investment, and boost product added value and output.

This paper classifies the leading factors examined by carriers when planning cross-strait shuttle shipping routes into 4 major assessment aspects and 15 important factors on the basis of views in the literature and recommendations obtained from interviews with experts and scholars. The four major aspects in this paper comprise competitive port features, service standards of existing facilities, government performance and policies, and logistics costs and service conditions; the assessment factors under each aspect are listed and explained in Table 1.

**Method**

The concepts and methods used in this paper are briefly introduced in this section.

**Triangular Fuzzy Numbers and Algebraic Operations**

In a universe of discourse $X$, a fuzzy subset $A$ of $X$ is defined by a
| Competitive port features ($C_1$) | Superior natural geographical location ($C_{11}$) | The port possesses a favorable natural environment, including sufficient ship channel and berth water depth and stable water and climate conditions, allowing carriers to derive economic benefit from geographical conditions. | Cheng (2001); Chou (2009, 2010); Ding (2009); Ding & Liang (2003); Hwang & Tai (2008); Lin & Chang (2008); Su et al. (2003); Tai & Hwang (2005) |
| Adequate hinterland and cargo sources ($C_{12}$) | A large market hinterland, ample cargo sources, and market development potential in the hinterland are basic preconditions for the development of new routes by carriers. | Cheng (2001); Chou (2009, 2010); Ding (2009); Ding & Liang (2003); Hwang & Tai (2008); Lin & Chang (2008); Su et al. (2003); Tai & Hwang (2005) |
| Good access roads ($C_{13}$) | An effective port system must have good accompanying interior transportation services in order to successfully provide shipping logistics services. The absence of good access roads will severely compromise logistics efficiency. | Cheng (2001); Chou (2009, 2010); Ding (2009); Ding & Liang (2003); Hwang & Tai (2008); Lin & Chang (2008); Su et al. (2003); Tai & Hwang (2005) |
| Port future expansion potential ($C_{14}$) | The development of new routes must reflect whether a port is likely to be expanded in the future in response to growing demand and the possibility of insufficient port services. | Ding (2009); Ding & Liang (2003); Chou (2009, 2010) |
| Service standards of existing facilities ($C_2$) | Wharf service facilities ($C_{21}$) | The presence of excellent wharf service facilities, including wharf criteria, loading facilities, storage facilities, and sufficient back-line land for cargo handling, helping carriers to maintain shipping schedules. | Cheng (2001); Chou (2009, 2010); Ding (2009); Ding & Liang (2003); Hwang & Tai (2008); Lin & Chang (2008); Su et al. (2003); Tai & Hwang (2005); Tai (2011, 2012) |
| | Computer software and hardware facilities ($C_{22}$) | Excellent port computer information hardware and software can improve shipping and port operating procedures and handling efficiency, allowing logistics-related parties to enjoy better service performance. | Cheng (2001); Chou (2009, 2010); Ding (2009); Ding & Tsai (2012); Liang et al. (2012); Lin & Chang (2008); Su et al. (2003); Tai & Hwang (2005) |
| | Fleet type and size ($C_{23}$) | In order to improve route service performance, carriers should choose suitable vessel types in accordance with route service characteristics and their operations. | Hwang & Tai (2008); Lin & Chang (2008); Tai & Hwang (2005); Tai (2011, 2012) |

continued
<table>
<thead>
<tr>
<th>Assessment Aspects</th>
<th>Assessment Factors</th>
<th>Explanation of Assessment Factors</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government performance and policies ($C_3$)</td>
<td>Convenient customs clearance and administrative procedures ($C_{31}$)</td>
<td>Convenient customs clearance and good administrative efficiency are extremely important to cargo movement. Especially when developing new routes, attention must be paid to important factors considered by cargo owners, including consumers’ perspectives, time, and convenience. In addition, the government’s provision of convenient single-window customs clearance can also enhance customs clearance and administrative performance.</td>
<td>Cheng (2001); Ding &amp; Liang (2003); Ding (2009); Lin &amp; Chang (2008)</td>
</tr>
<tr>
<td>Degree of integration of relevant laws and regulations ($C_{32}$)</td>
<td>If a country’s port logistics laws and regulations can be effectively integrated from the perspective of consumers and other interested parties, so that carriers and consumers believe that government policies facilitate the movement of cargo, carriers, and consumers will welcome the development of new routes. In particular, the establishment of consistent cross-strait inspection, quarantine, authentication, and certification standards will avoid wasted time and cost to carriers and cargo owners from redundant inspections.</td>
<td>Cheng (2001); Ding &amp; Liang (2003); Ding (2009); Lin &amp; Chang (2008)</td>
<td></td>
</tr>
<tr>
<td>Effective company recruiting measures ($C_{33}$)</td>
<td>The operation of a shuttle logistics area requires the presence of many important interested parties, especially carriers and cargo owners. Effective company recruiting measures can have a major impact on the willingness of carriers and cargo owners to occupy a shuttle logistics area.</td>
<td>Chou (2009, 2010); Ding &amp; Liang (2003); Lin &amp; Chang (2008)</td>
<td></td>
</tr>
<tr>
<td>Compliance with green sustainable shipping policies ($C_{34}$)</td>
<td>The issue of global climate change has become one of the major factors considered by governments when making policy decisions. Carriers must comply with governments’ green shipping policies in order to provide environmentally friendly shipping services and facilitate the development of a sustainable shipping industry.</td>
<td>Ding &amp; Cheng (2012); Dodridge (2011); Shiau (2012, 2013)</td>
<td></td>
</tr>
</tbody>
</table>
membership function \( f_A(x) \), which maps each element \( x \) in \( X \) to a real number in the interval \([0, 1]\). The value of function \( f_A(x) \) represents the grade of membership of \( x \) in \( A \).

A fuzzy number \( A \) (Dubois & Prade, 1978) in real line \( \mathbb{R} \) is a triangular fuzzy number if its membership function \( f_A: \mathbb{R} \rightarrow [0, 1] \) is

\[
\begin{align*}
   f_A(x) = & \begin{cases} 
   (x - c)/(a - c), & c \leq x \leq a, \\
   (x - b)/(a - b), & a \leq x \leq b, \quad \text{or otherwise}
   \end{cases}
\end{align*}
\]

with \(-\infty < c \leq a \leq b < \infty\). A triangular fuzzy number can be denoted by \((c, a, b)\).

In this paper, Zadeh’s (1965) extension principle is employed to perform algebraic operations involving fuzzy numbers. Let \( A_1 = (c_1, a_1, b_1) \) and \( A_2 = (c_2, a_2, b_2) \) be fuzzy numbers. The algebraic operations of any two fuzzy numbers \( A_1 \) and \( A_2 \) can be expressed as follows:

1. Fuzzy addition:

\[
A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2)
\]

2. Fuzzy subtraction:

\[
A_1 \ominus A_2 = (c_1 - c_2, a_1 - a_2, b_1 - c_2)
\]

3. Fuzzy multiplication:

\[
k \odot A_2 = (kc_2, ka_2, kb_2), k \in \mathbb{R}, k \geq 0
\]

\[
A_1 \odot A_2 \equiv (c_1 c_2, a_1 a_2, b_1 b_2), c_1 \geq 0, c_2 \geq 0.
\]

4. Fuzzy division:

\[
(A_1)^{-1} = (c_1, a_1, b_1)^{-1} \equiv (1/b_1, 1/a_1, 1/c_1), c_1 > 0;
\]

\[
A_1 \oslash A_2 \equiv (c_1/b_2, a_1/a_2, b_1/c_2), c_1 \geq 0, c_2 > 0.
\]

Note: The code names of each assessment aspect and assessment factor are shown in parentheses.

<table>
<thead>
<tr>
<th>Assessment Aspects</th>
<th>Assessment Factors</th>
<th>Explanation of Assessment Factors</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics costs and service conditions ((C_4))</td>
<td>Port taxes and fees ((C_{41}))</td>
<td>Excessive port taxes and fees will increase logistics costs, adding to the burden on carriers and discouraging carriers from developing new routes.</td>
<td>Chou (2009, 2010); Ding &amp; Liang (2003); Lee (2007)</td>
</tr>
<tr>
<td></td>
<td>Logistics operating costs ((C_{42}))</td>
<td>An increase in logistics operating costs will add to the burden borne by cargo owners, discouraging carriers from developing new routes.</td>
<td>Chou (2009; 2010); Liang et al. (2012); Lee (2007); Teng et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Loading and distribution performance ((C_{43}))</td>
<td>The better cargo handling performance, including loading and unloading, transport, storage, and distribution processes, the better port logistics service performance, and the easier to induce carriers to develop a new route.</td>
<td>Ding (2009); Ding and Tsai (2012); Lee (2007); Liang et al. (2012); Lin &amp; Chang (2008); Tai &amp; Hwang (2005); Teng et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Shipping service quality ((C_{44}))</td>
<td>The better a carrier’s shipping logistics service quality, the better it can satisfy cargo owners’ shipping needs.</td>
<td>Ding &amp; Liang (2003); Ding &amp; Tsai (2012); Lee (2007); Liang et al. (2012); Tai &amp; Hwang (2005); Teng et al. (2007)</td>
</tr>
</tbody>
</table>
Ranking Method

To match the FAHP algorithm developed in this paper and to solve the problem powerfully, the graded mean integration representation (GMIR) method, proposed by Chen and Hsieh (2000), is employed to defuzzify the fuzzy weights.

Let \( A_i = (c_i, a_i, b_i) \), \( i = 1, 2, \ldots, n \), be \( n \) triangular fuzzy numbers. By the GMIR method, the GMIR value \( P(A_i) \) of \( A_i \) is

\[
P(A_i) = \frac{c_i + 4a_i + b_i}{6}.
\]

Suppose \( P(A_i) \) and \( P(A_p) \) are the GMIR value of \( A_i \) and \( A_p \), respectively. We define:

(i) \( A_i > A_j \iff P(A_i) > P(A_j) \),

(ii) \( A_i < A_j \iff P(A_i) < P(A_j) \), and

(iii) \( A_i = A_j \iff P(A_i) = P(A_j) \).

FAHP Approach

The steps of the FAHP approach are described below.

Step 1. Establishment of a hierarchical structure

This study employs the hierarchical framework diagram shown in Figure 1. In this framework, the problems lie on the \( L^{th} \) layer and consist of factors with a major influence on the new route of shuttle shipping services. There are \( k \) assessment aspects on the \( L+1 \) layer, and \( p + \cdots + q + \cdots + r \) assessment factors on the \( L+2 \) layer.

Step 2. Establishment of pairwise comparison matrices for assessment factors

Pairwise comparison of questionnaire results was employed to determine the experts’ views of the relative importance of paired assessment factors.

1. Let \( x_{ij}^p \), \( h = 1, 2, \ldots, n \), be the relative importance assigned to any two assessment aspects \( i \) and \( j \) by expert \( h \) on the \( L+1 \) layer. Then, the pairwise comparison matrix is defined as \( x_{ij}^p \).

2. Let \( x_{uv}^h \), \( h = 1, 2, \ldots, n \), be the relative importance assigned to any two assessment factors \( u \) and \( v \) by expert \( h \) on the \( L+2 \) layer. Then, the pairwise comparison matrix with respect to each assessment aspect, i.e., \( C_{i}^{L+1}, C_{i}^{L+1}, C_{k}^{L+1} \), is defined as \( x_{uv}^h \).

Step 3. Establishing triangular fuzzy numbers

The general mean is a typical representation of many well-known averaging operations (Klir & Yuan, 1995), including min, max, geometric mean, arithmetic mean, and harmonic mean, etc. The min and max represent the lower and upper bounds of generalized means. In addition, the geometric mean is most effective at representing the consensus views of multiple decision-makers (Saaty, 1980).

To aggregate all information generated by different averaging operations, we use the grade of membership to demonstrate their strength after considering all approaches. Triangular fuzzy numbers characterized through use of min, max, and geometric mean operations are therefore used to convey the views of all experts (Hsu, 1998).

Let \( x_{ij}^h \in \left[ \frac{1}{9}, \frac{1}{3}, 1 \right] \cup \{1, 2, \ldots, 8, 9\} \), \( h = 1, 2, \ldots, n \), \( i, j = 1, 2, \ldots, k \), be the relative importance assigned to any two assessment aspects \( i \) and \( j \) by expert \( h \) on the \( L+1 \) layer. After integrating the views of all \( n \) experts, the triangular fuzzy numbers can be expressed as

\[
\hat{A}_{ij}^{L+1} = (c_{ij}, a_{ij}, b_{ij})
\]

where

\[
c_{ij} = \frac{1}{n} \min \{x_{ij}^1, x_{ij}^2, \ldots, x_{ij}^n\}, \quad a_{ij} = \left( \prod_{b=1}^{n} x_{ij}^b \right)^{1/n}, \quad b_{ij} = \max \{x_{ij}^1, x_{ij}^2, \ldots, x_{ij}^n\}.
\]

FIGURE 1

Hierarchical structure.
We can integrate the views of all $n$ experts on the $L+2$ layer in the same way, so that the triangular fuzzy numbers can be expressed as

$$A_{uv}^{L+2} = (a_{uv}, b_{uv}, c_{uv}), \forall u, v = 1, \ldots, p; \quad \forall u, v = 1, \ldots, q; \quad \forall u, v = 1, \ldots, r,$$

where $c_{uv} = \min\{x_{uv}^1, x_{uv}^2, \ldots, x_{uv}^n\}, a_{uv} = \left(\prod_{i=1}^{n} x_{uv}^i\right)^{1/n}, b_{uv} = \max\{x_{uv}^1, x_{uv}^2, \ldots, x_{uv}^n\}.$

**Step 4. Constructing fuzzy positive reciprocal matrices**

We use the integrated triangular fuzzy numbers to construct fuzzy positive reciprocal matrices. For the $L+1$ layer, the fuzzy positive reciprocal matrix can be expressed as

$$A = [A_{ij}^{L+1}] = \begin{bmatrix}
1 & A_{12}^{L+1} & \cdots & A_{1k}^{L+1} \\
1/A_{12}^{L+1} & 1 & \cdots & A_{1k}^{L+1} \\
\vdots & \vdots & \ddots & \vdots \\
1/A_{1k}^{L+1} & 1/A_{2k}^{L+1} & \cdots & 1
\end{bmatrix},$$

where $A_{ij}^{L+1} \odot A_{ji}^{L+1} \equiv 1, \forall i, j = 1, 2, \ldots, k.$

The equations of the fuzzy positive reciprocal matrices on the $L+2$ layer can be obtained using an analogous and methods.

**Step 5. Calculation of the fuzzy weights of the fuzzy positive reciprocal matrices**

Let $\tilde{Z}_{i}^{L+1} \cong (A_{i1}^{L+1} \times A_{i2}^{L+1} \times \cdots \times A_{ik}^{L+1})^{1/k}, \forall i = 1, 2, \ldots, k,$ be the geometric mean of triangular fuzzy number of the $i$th assessment aspect on the $L+1$ layer. The fuzzy weight of the $i$th assessment aspect can then be expressed as

$$\bar{W}_i^{L+1} \cong \tilde{Z}_{i}^{L+1} \odot \left(\tilde{Z}_{1}^{L+1} \oplus \tilde{Z}_{2}^{L+1} \oplus \cdots \oplus \tilde{Z}_{k}^{L+1}\right)^{-1}.$$

For convenience, the fuzzy weight is expressed as $\bar{W}_i^{L+1} = (w_{iu}, w_{id}, w_{ik}).$ The equations of fuzzy weights on the $L+2$ layer can be obtained using an analogous and methods.

**Step 6. Defuzzifying the fuzzy weights to obtain crisp weights**

To perform defuzzification in an effective manner, the GMIR method is used to defuzzify the fuzzy weights. Let $\bar{W}_i^{L+1} = (w_{iu}, w_{id}, w_{ik}), \forall i = 1, 2, \ldots, k,$ be $k$ triangular fuzzy numbers. The GMIR of crisp weights $k$ can then be expressed as

$$P(\bar{W}_i^{L+1}) = \frac{w_{iu} + 4w_{id} + w_{ik}}{6}, \forall i = 1, 2, \ldots, k.$$

The defuzzification of fuzzy weights on the $L+2$ layer can be performed using an analogous and methods.

**Step 7. Normalizing the crisp weights**

To facilitate comparison of the relative importance of evaluation dimensions on different layers, the crisp weights are normalized and expressed as

$$NW_i^{L+1} = \frac{P(\bar{W}_i^{L+1})}{\sum_{i=1}^{k} P(\bar{W}_i^{L+1})}.$$

**Step 8. Calculating the integrated weights for each layer**

Let $NW_{u}^{L+1}$ and $NW_{u}^{L+2}$ be the normalized crisp weights on the $L+1$ and $L+2$ layers. Then,

1. The integrated weights of each assessment aspect on the $L+1$ layer are

$$NW_i^{L+1} = NW_{u}^{L+1}, \forall i = 1, 2, \ldots, k.$$

2. The integrated weights of each assessment factor on the $L+2$ layer are

$$NW_{u}^{L+2} = NW_{u}^{L+1} \times NW_{u}^{L+2}, \forall i = 1, 2, \ldots, k; \forall u = 1, \ldots, p; \cdots; \forall u = 1, 2, \ldots, r.$$

**Empirical Study**

In this section, an empirical study for evaluating key factors influencing new cross-strait shuttle shipping routes is surveyed as follows.

**Data Collection**

This study assessed the relative importance of factors affecting the decision to develop new cross-strait shuttle shipping routes in order to determine the key factors influencing such decisions. The study conducted an AHP questionnaire survey of carrier and cargo owner upper managers, official representatives in charge of cross-strait transportation, and professors who have researched cross-strait navigation issues.

The AHP questionnaire with 4 major assessment aspects and 15 assessment factors was used to compile the pair-wise comparison matrices of each layer and express the relative importance of each assessment factor. To check whether the expressions/words were clear or important questions were missed, some experts and scholars were invited to pretest the AHP.
questionnaire. Finally, two rounds of corrections based on questionnaire design principles were carefully performed, and the final AHP questionnaire was completed. The surveys were completed through e-mails, phone calls, and in-person interviews conducted by the authors. The returned questionnaires were checked to determine whether the consistency index (CI) value of each matrix of every layer was lower than 0.1 (Saaty, 1980). When the CI value of a matrix is higher than 0.1, this implies that the respondent had made an inconsistent pair-wise comparison of two assessment aspects (or assessment factors). To prevent the occurrence of errors, the authors helped such respondents to correct their judgments until the CI value of each matrix was lower than 0.1.

A total of 20 questionnaires were distributed, and 16 were recovered, for a recovery rate of 80%. Since the AHP questionnaire in this study was an expert questionnaire, Robbins recommended that five to seven experts are ideally required in studies of group decision-making questions suggests that the valid recovered questionnaires in this study provided representative views (Robbins, 1994).

**Results**

In our case, with 4 assessment aspects and 15 assessment factors, there were six (1 + 4) pair-wise comparison matrices to compile. The authors use four assessment aspects (C1–C4) from the 16 valid questionnaires as an example to illustrate the computational procedures used in the FAHP approach. The other four pair-wise comparison matrices are omitted by reasoning of analogy. The computational process and empirical results are shown as follows.

**Step 1. Constructing a fuzzy positive reciprocal matrix**

The authors used relative importance data from the 16 valid questionnaires to compile a pair-wise comparison matrix and then transformed this data into triangular fuzzy numbers through geometric mean method. We then employed these triangular fuzzy numbers to construct a fuzzy positive reciprocal matrix. The fuzzy positive reciprocal matrix for the assessment aspects layer (C1–C4) is shown as Table 2.

**Step 2. Calculating the fuzzy weights of the fuzzy positive reciprocal matrix**

In keeping with Step 5 of the FAHP approach, the geometric means of the triangular fuzzy number (Zi,j+1) and the fuzzy weights (Wzi,j+1) of four assessment aspects are as shown in Table 3.

**Step 3. Defuzzifying the fuzzy weights and normalizing the crisp weights**

Using Step 6 of the FAHP approach, the fuzzy weights can be defuzzified by the GMIR method to obtain the crisp weights (P(Wzi,j+1)). Then, using Step 7 of the FAHP approach, we can obtain the normalized weights (NWzi,j+1). The results are as shown in Table 4.

**Step 4. Calculation of the integrated weights**

After encoding of the valid recovered questionnaires and combining the experts’ views, this study used the FAHP procedures described in the section on FAHP Approach to derive the relative weights of the assessment criteria at each level, which enabled us to rank the assessment aspects and assessment factors in terms of relative importance (see Table 5).

The findings are described as follows:

1. “Competitive port features,” ranking 1, is the most important aspect influencing new cross-strait shuttle shipping routes for ocean carriers. “Government performance and policies” and “service standards of existing facilities” are ranked in the second and third places. “Logistics costs and service conditions” is the lowest ranked. Although each assessment aspect had a different rank, their weights were all clustered around roughly 0.25, which indicated that all the experts believed that the weights of these four aspects differed by little.

2. For the competitive port features aspect by the normalized weights, the superior natural geographical location is the critical assessment factor. For the service standards of existing facilities aspect, the wharf service facilities is the critical assessment factor. For the government performance and policies aspect, the convenient customs clearance and administrative procedures is the critical assessment factor. For the logistics costs and service conditions aspect, the logistics operating costs is the critical assessment factor.

3. Daniel feels that most industries possess from two to six key elements (Daniel, 1961) that determine success, and a company that wishes to be successful must apply particular effort to these elements. As a consequence, after taking an integrated weight of 7% as a threshold, this study employed the 5 of the 15 assessment criteria that met this condition as the key factors affecting decisions whether to develop new cross-strait shuttle shipping routes. The total weight of these factors was 48.99% (approximately one half). The results
show that the top five key factors influencing new cross-strait shuttle shipping routes for ocean carriers are wharf service facilities, convenient customs clearance and administrative procedures, superior natural geographical location, computer software and hardware facilities, and adequate hinterland and cargo sources, respectively. Furthermore, we found that there would be four more key assessment criteria if the threshold was reduced to an integrated weight of 6%, in which case the total weight of the assessment criteria would be 75.53%; the four additional assessment criteria were good access roads (0.0693), logistics operating costs (0.0686), port taxes and fees (0.0675), and degree of integration of relevant laws and regulations (0.060). However, because there should not be too many key factors, this study only employed the foregoing five most important factors as key factors determining whether to develop new cross-strait shuttle shipping routes.

**Discussion**

This study provides a detailed explanation of only the top five assessment factors in accordance with their overall weighting rank. These assessment factors are discussed as follows:

- **Wharf service facilities**

  This assessment factor refers to the service standards of existing wharf facilities and was the most important assessment factor in the eyes of the experts. A competitive port should have a sufficient number of adequate wharves, various loading and transport equipment and machinery, storage facilities, dockworker services, and sufficient back-line land. These service facilities are among a port’s main physical resources. When a carrier decides to open a new route, substandard basic service facilities at the port may jeopardize the carrier’s subsequent development of the shipping market. Relevant literature (Hwang & Tai, 2008; Tai & Hwang, 2005; Tai, 2012) also indicates that carriers should strive to select ports that can provide good wharf service facilities, which will enable them to provide superior shipping services meeting cargo owners’ expectations. In summary, carriers tend to first consider whether the port can provide relatively high wharf service standards

---

**TABLE 2**

Fuzzy positive reciprocal matrix for four risk aspects.

<table>
<thead>
<tr>
<th></th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
<th>$C_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>(1, 1, 1)</td>
<td>(0.25, 1.604, 8)</td>
<td>(0.111, 1.615, 8)</td>
<td>(0.143, 1.238, 7)</td>
</tr>
<tr>
<td>$C_2$</td>
<td>(0.125, 0.623, 4)</td>
<td>(1, 1, 1)</td>
<td>(0.25, 1.144, 8)</td>
<td>(0.2, 1.191, 9)</td>
</tr>
<tr>
<td>$C_3$</td>
<td>(0.125, 0.619, 9)</td>
<td>(0.125, 0.874, 4)</td>
<td>(1, 1, 1)</td>
<td>(0.167, 1.910, 9)</td>
</tr>
<tr>
<td>$C_4$</td>
<td>(0.143, 0.808, 7)</td>
<td>(0.111, 0.840, 5)</td>
<td>(0.111, 0.524, 6)</td>
<td>(1, 1, 1)</td>
</tr>
</tbody>
</table>

**TABLE 3**

Geometric means of triangular fuzzy number and fuzzy weights.

<table>
<thead>
<tr>
<th></th>
<th>$\tilde{z}_{j}^{L+1}$</th>
<th>$\tilde{w}_{j}^{L+1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i = 1$</td>
<td>(0.251, 1.338, 4.601)</td>
<td>(0.015, 0.328, 4.777)</td>
</tr>
<tr>
<td>$i = 2$</td>
<td>(0.281, 0.960, 4.120)</td>
<td>(0.017, 0.235, 4.278)</td>
</tr>
<tr>
<td>$i = 3$</td>
<td>(0.226, 1.008, 4.243)</td>
<td>(0.013, 0.247, 4.406)</td>
</tr>
<tr>
<td>$i = 4$</td>
<td>(0.205, 0.772, 3.807)</td>
<td>(0.012, 0.189, 3.953)</td>
</tr>
</tbody>
</table>

**TABLE 4**

Defuzzified and normalized weights of the four assessment aspects.

<table>
<thead>
<tr>
<th></th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
<th>$C_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defuzzified weights</td>
<td>1.017</td>
<td>0.873</td>
<td>0.901</td>
<td>0.787</td>
</tr>
<tr>
<td>Normalized weights</td>
<td>0.284</td>
<td>0.244</td>
<td>0.252</td>
<td>0.220</td>
</tr>
</tbody>
</table>
and added-value port services when deciding whether to develop a new route.

- **Convenient customs clearance and administrative procedures**

  The convenience of government administrative procedures and customs clearance is another important factor considered by carriers and cargo owners. Especially when new policies and regulations are first issued, companies may have to face many bureaucratic hurdles and tedious administrative procedures. Provision of a single-window application service system can simplify administrative procedures and customs clearance processes, effectively shorten customs clearance time, and facilitate the handling of various administrative matters. It is clear that convenience and time savings are considered very important by both carriers and cargo owners. In the wake of cross-strait and regional economic development, regional cargo sources have been increasing steadily. If governments can provide efficient administrative services, this will meet carriers’ expectations of government service performance, while also satisfying carriers’ need for shorter operating times and enhanced service quality. Whether the government’s administrative efficiency is high is consequently another factor considered by carriers when deciding whether to develop a new route.

- **Superior natural geographical location**

  A superior natural geographical location can be extremely attractive to carriers, and the ability to expand the geographical scope of a port’s hinterland can enable a carrier to attract more sources of cargo. As a consequence, a port’s geographical location

<table>
<thead>
<tr>
<th>Assessment Aspects</th>
<th>Normalized/Integrated Weights (A)</th>
<th>Assessment Factors</th>
<th>Normalized Weights (B)</th>
<th>Integrated Weights (C) = (A)*(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competitive port features</td>
<td>0.284 (1)</td>
<td>Superior natural geographical location</td>
<td>0.315 (1)</td>
<td>0.0895 (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequate hinterland and cargo sources</td>
<td>0.261 (2)</td>
<td>0.0741 (5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good access roads</td>
<td>0.244 (3)</td>
<td>0.0693 (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Port future expansion potential</td>
<td>0.180 (4)</td>
<td>0.0511 (10)</td>
</tr>
<tr>
<td>Service standards of existing facilities</td>
<td>0.244 (3)</td>
<td>Wharf service facilities</td>
<td>0.558 (1)</td>
<td>0.1362 (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Computer software and hardware facilities</td>
<td>0.309 (2)</td>
<td>0.0754 (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fleet type and size</td>
<td>0.133 (3)</td>
<td>0.0325 (14)</td>
</tr>
<tr>
<td>Government performance and policies</td>
<td>0.252 (2)</td>
<td>Convenient customs clearance and administrative procedures</td>
<td>0.455 (1)</td>
<td>0.1147 (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degree of integration of relevant laws and regulations</td>
<td>0.238 (2)</td>
<td>0.060 (9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Effective company recruiting measures</td>
<td>0.197 (3)</td>
<td>0.0496 (11)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compliance with green sustainable shipping policies</td>
<td>0.110 (4)</td>
<td>0.0277 (15)</td>
</tr>
<tr>
<td>Logistics costs and service conditions</td>
<td>0.220 (4)</td>
<td>Port taxes and fees</td>
<td>0.307 (2)</td>
<td>0.0675 (8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Logistics operating costs</td>
<td>0.312 (1)</td>
<td>0.0686 (7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loading and distribution performance</td>
<td>0.209 (3)</td>
<td>0.0460 (12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shipping service quality</td>
<td>0.172 (4)</td>
<td>0.0378 (13)</td>
</tr>
</tbody>
</table>

**Remark:** Numbers in parentheses are ranks.
Computer software and hardware facilities

The port information system should integrate the systems of all members of the port logistics network, including port information systems, trade automation systems, cargo customs clearance automated service systems, loading and transport automation systems, internal corporate network, and corporate chain network systems. Effective integration of these information systems can improve the productivity of logistics network members. Because information infrastructure capabilities (hardware systems) and information system applications (software systems) can enhance corporate productivity and give a competitive advantage, the influence of port information systems on port logistics networks is growing steadily. Gustin et al. (1995) suggest that superior information technology and systems are key factors in logistics, and there is a close relationship between the availability of information and integration of logistics. The upgrading and improvement of information systems and technology can therefore strengthen a port’s ability to manage relevant logistics activities. Therefore, because they can facilitate the improvement of service performance by interested parties in logistics networks, port information systems constitute another factor that is taken into consideration by carriers pondering developing new shuttle shipping routes.

Adequate hinterland cargo sources

Because there is a close relationship between cargo sources and a port’s economic hinterland, port hinterland also constitutes a major factor of concern to carriers. If a port’s economic hinterland contains adequate sources of import/export cargo, developing new routes to that port will be a simple decision complying with the axiom that “ships follow cargo.” For instance, with the recent economic emergence of the Pearl River delta area in southern China (Song, 2002), the development of various industries in conjunction with value-added logistics activities in the Shenzhen area has intensified the clustering of cargo sources in the area, which has increased the number of containers shipped from this region. As a result, carriers from many countries and various shipping-related auxiliary businesses have been flocking to the area, which has catalyzed the rapid development of the shipping industry. This shows that the presence of adequate hinterland cargo sources is a very important factor encouraging carriers to develop new shuttle shipping routes.

Conclusions

In the recent years, the volume of trade between second- and third-line cities and ports in China and Taiwan is growing steadily. To ensure that cross-strait cargo can be quickly and efficiently shipped around the world, how to best provide a fast and efficient logistics network is a critical question. To create even more industrial and economic activity to transport cargo on both sides of the Taiwan Strait, developing the availability of shuttle shipping service has become the shared goal of government, carriers, and cargo owners. In the form of an increasingly competitive cross-strait shipping market, however, what key factors should carriers consider when developing a new shuttle shipping route? This study seeks to analyze key factors involved in new cross-strait shuttle shipping routes and chiefly applied a FAHP approach to assess these factors.

The study’s empirical analysis employed an AHP expert questionnaire to systematically assess the importance weights of individual factors and obtained the following results:

1. Competitive port features is the most important aspect influencing new cross-strait shuttle shipping routes for ocean carriers.

2. The superior natural geographical location is the key factor in the aspect of competitive port features. The wharf service facilities is the key factor in the aspect of service standards of existing facilities. The convenient customs clearance and administrative procedures is the key factor in the aspect of government performance and policies. The logistics operating costs is the key factor in the aspect of logistics costs and service conditions.

3. The top five key factors influencing new cross-strait shuttle shipping routes for ocean carriers are wharf service facilities, convenient customs clearance and administrative procedures, superior natural geographical location, computer software and hardware facilities, and
adequate hinterland and cargo sources, respectively.

Lastly, this paper recommends that carriers perform further analysis of the foregoing key factors in order to facilitate development of their shipping operations in the future. This study further makes the following recommendations for further research:

1. Although very few scholars have pursued a research direction similar to that of this paper, the shuttle shipping route development assessment indicators were drafted solely on the basis of relevant past literature. Future research on this subject may collect literature and practical experience that is more up-to-date and relevant to the shipping industry and seek to construct assessment aspects and criteria from different perspectives with the goal of establishing a more clear-cut and comprehensive assessment framework. Apart from this, in order to facilitate the establishment of a hierarchical assessment framework, future researchers can place shipping development strategy issues at the solution level, which will help clarify the sequential order of future assessment strategy implementation.

2. Indicators should ideally be comprehensive, mutually exclusive, and independent. This study collected the views of many parties in the process of constructing indicators, which should satisfy the comprehensiveness requirement. Nevertheless, the four major assessment aspects and their assessment factors, while mutually exclusive and independent, were not fully comprehensive. We therefore recommend that future researchers provide a clearer account of the relationships between individual indicators, which will ensure better conformance with indicator construction principles. Apart from this, if a dependent relationship exists between indicators, the analytic network process (ANP) method (Saaty, 1996) can be used to clarify the situation.

Corresponding Author:
Ji-Feng Ding
Department of Aviation and Maritime Transportation Management
Chang Jung Christian University,
Tainan City 711, Taiwan
Email: jfding@mail.cjcu.edu.tw

References


