



AN EVALUATION OF KEY SERVICE EFFECTIVENESS OF KEELUNG PORT

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AN EVALUATION OF KEY SERVICE EFFECTIVENESS OF KEELUNG PORT

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ABSTRACT

In the keen competitive port market, service effectiveness has become a key to customer satisfaction and loyalty for port operators in future business endeavors. The main purpose of this article was to apply the fuzzy analytic hierarchy process (AHP) model to evaluate key factors influencing service effectiveness for Keelung Port in Taiwan. Based on the port literature and experts' opinions, a hierarchical structure with 5 assessment aspects and 15 assessment criteria was first constructed. A fuzzy AHP model was then proposed. Finally, we employed the fuzzy AHP model to empirically evaluate the key criteria of service effectiveness. The results showed that the top seven key criteria influencing service effectiveness of Keelung Port are 'accuracy,' 'reliability,' 'availability,' 'totality,' 'increasing the efficiency of core logistics activities,' 'port pricing,' and 'reducing the time of non-value added activities,' respectively. Furthermore, some discussions and recommendations are provided in this article.

I. INTRODUCTION

Shipping routes of a shipping company are arranged according to cargoes. Therefore, cargo source has become an important part of port competitiveness. However, port competitiveness still needs to be strengthened by internal competitiveness. Otherwise, even if the port has adequate cargo sources, poor quality or circulation efficiency of the port service system may result in inefficiency of cargoes in entering/leaving the port. If this situation happened, cargoes will go to other relatively efficient ports (Ding, 2009a; 2009b). In

the report of Review of Maritime Transport 2012, the inefficiency or ineffectiveness of port service will result in the diversion of cargoes in the logistics chain from Port A to Port B (UNCTAD, 2012). Thus, it can be recognized that the service effectiveness of an international container port is closely related to the smoothness of the international container shipping service, and the subject of service effectiveness of an international container port thus will play an important role in port competitiveness (Brooks et al., 2011).

Generally speaking, there are many factors which influence the quality of services provided by an international container port, such as cargo source, freight rate or price, handling operational efficiency, the degree of port information, plant capacity, customer relationship management, etc. These service quality factors are usually key decision factor indices considered by carriers and consignors when choosing an international container port (Murphy et al., 1992; Lirn et al., 2003; Song and Yeo, 2004; Chang et al., 2008; Ding, 2009a; 2009b; Saeed, 2009; Chou, 2010; Brooks et al., 2011; Liang et al., 2012; Yuen et al., 2012; Yang et al., 2013). Therefore, the international container port operators should know how to elaborate these key decision factors as efficient instruments for selling, marketing and operating port services in the future. From another point of view, the port operators must obtain more loyal customers in order to enhance their competitiveness, and sustain their competitive advantage (Ding, 2009a; 2009b). Customer satisfaction must be enhanced in order to gain and retain loyal customers. In order to maintain customer satisfaction, greater customer values must be created and provided to increase favorable behavioral intentions (Yang et al., 2013). In order to enhance these behavioral intentions, port competitiveness can be enhanced by providing an efficient service system.

Keelung Port was founded in 1886, and has been in business for about 130 years. Keelung Port is located near regions with strong consumptive power and high cargo sources of the economic hinterland. It bears the heavy responsibility of promoting Taiwan's international trade and developing the shipping industry. Keelung Port is the main open port undertaking the cargo sources of northern Taiwan, and thus, plays an important role in the economic development of Taiwan. Keelung

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Port is not like Kaohsiung Harbor, which is the main port of transshipments for the oceanic routes of Taiwan. Current government policies orient Keelung Port as an international container port aimed at near-sea shipping lines that serve container carriers in East Asia. Therefore, Keelung Port is an important regional feeder port in Taiwan.

In terms of a successful shipping-port system, the hub port, feeder port, ocean routes, and regional lines, must work with each other closely to guarantee the smoothness of shipping-port logistics. In the increasingly competitive shipping-port market, service effectiveness has become the key to customer satisfaction and loyalty in the future for international container port operators. There are numerous literature regarding container ports, and many of them focused on port competitiveness (Chen, 2001; Lirn et al., 2003; Su et al., 2003; Veldman and Buckmann, 2003; Hwang and Tai, 2008; Chou, 2010; Brooks et al., 2011; Tai, 2012). Regarding the subject of enhancing the competitiveness of an international container port, hardware facilities can be extended, and service effectiveness can be enhanced, which can obtain more customers and enhance customer satisfaction.

This article mainly seeks to evaluate key criteria influencing service effectiveness of Keelung Port. How to evaluate the relative weights of these multiple criteria is the main task of this study. Saaty's analytic hierarchy process (AHP) approach proposed in 1980 is one of the commonly used techniques for this kind of problems. In view of the qualitative characteristics of multiple criteria questions, and the inherently fuzzy nature of individuals' subjective views, it would be very difficult to express the importance of assessment criteria in terms of precise values. The characteristic of multiple criteria problem, in which information is incomplete or imprecise or views that are subjective or endowed with linguistic characteristics (Zadeh, 1975; 1976) creating a fuzzy environment, e.g. the phrase of 'much more important than.' Hence, this study employed the fuzzy set theory (Zadeh, 1965) in conjunction with the AHP approach to construct a fuzzy AHP model, which was used as a research method to evaluate key criteria of service effectiveness of Keelung Port in Taiwan. The main contribution of this article with the fuzzy AHP method proposed can be employed as a useful implementation for the application of service effectiveness in the port industry. The following section presents the preliminary assessment criteria, and the third section described the method of fuzzy AHP model. In the fourth section consists of an empirical study, and the final section, presents some concluding remarks.

II. THE ASSESSMENT CRITERIA

Drucker (2006) considered "efficiency" as "doing things right," and "effect or effectiveness" as "doing the right things," meaning organizations should simultaneously seek effectiveness and efficiency. However, when it is impossible to consider both concurrently, "effect or effectiveness" should be the key point (DuBrin, 2006; Robbins et al., 2008), as there will be

no effect if efficiency is the only goal, meaning resources will be wasted. When effectiveness is the major direction, if the direction is wrong, even if efficiency is high, it is of no help. The first purpose of enterprise management is to attain organizational objectives efficiently and effectively (DuBrin, 2006; Robbins et al., 2008). This article uses the concepts of efficiency and effectiveness in port service, and indicates that port service effectiveness is the objective degree to be attained, as set by the port company. If the port service result approaches or exceeds the set objective, the service effectiveness is good.

Previous literature regarding service effectiveness on service quality mostly aimed at the influence on business performance and customer satisfaction, and applied the PZB five gaps model and SERVQUAL, as proposed by Parasuraman et al. in 1985 and 1988, to research service quality. However, in terms of service effectiveness, in addition to designing a complete scheme and putting efforts into service flow items (Ding, 2009a), in order to prevent customer dissatisfaction from occurring constantly, knowing customer service effectiveness becomes important work, as good port services can result in good transfer quality under the specifications of customer satisfaction and loyalty, thus, highlighting port service effectiveness.

This article classifies the important factors into five major assessment aspects and 15 important assessment criteria on the basis of views in the literature (Murphy et al., 1992; Johansson, 1993; Chen, 2001; Lirn et al., 2003; Su et al., 2003; Veldman and Buckmann, 2003; Bailey and Solomon, 2004; Song and Yeo, 2004; Brooks and Pallis, 2008; Chang et al., 2008; Hwang and Tai, 2008; Ding, 2009a; 2009b; Saeed, 2009; Saengsupavanich et al., 2009; Chou, 2010; Brooks et al., 2011; Liang et al., 2012; Tai, 2012; UNCTAD, 2012; Yuen et al., 2012; Liang et al., 2013; Monios and Wilmsmeier, 2013; Norsworthy and Craft, 2013; Yang et al., 2013; Chiu et al., 2014) and recommendations obtained from interviews with experts and scholars. The five major assessment aspects in this article comprise 'service,' 'quality,' 'cost,' 'time,' and 'sustainability,' and the assessment criteria under each aspect are listed and explained in Table 1.

III. METHODOLOGY

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

1. Triangular Fuzzy Numbers and Algebraic Operations

In a universe of discourse X , a fuzzy subset A of X is defined by a membership function $f_A(x)$, which maps each element x in X to a real number in the interval $[0, 1]$. The function value $f_A(x)$ represents the grade of membership of x in A .

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

Table 1. Preliminary assessment criteria.

Aspects	Criteria	Descriptions of criteria
Service (C_1)	Availability (C_{11})	If the port company can provide appropriate and adequate service systems (e.g. harbor, wharf, handling, warehousing, and access road systems), the procurable services have basic and significant influence on increasing port service effectiveness.
	Diversification (C_{12})	The port company can attract different customer groups by providing diversified services, and can create different added values and customer values for these customers. Therefore, the diversity of service can increase port service effectiveness.
	Reliability (C_{13})	The system function and operation effect of various service systems provided by a port company are accurate, and the reliability of such services can increase port service effectiveness.
Quality (C_2)	Totality (C_{21})	The ships and cargoes pass through many service systems in the port, the various service systems must complete services smoothly, and the service process and results can thoroughly conform to quality standards and customer requirements.
	Safety (C_{22})	The safety of ports includes political and physical safety. Political safety refers to a stable local political situation; while physical safety requires the port to guarantee the ships and cargoes to enter/leave (handling) and stay (storage) safely in all respects. Port service effectiveness can be increased by providing ships and cargoes with safety qualities.
	Accuracy (C_{23})	The ships and cargoes are received different service systems, the port company provides correct and accurate quality contributing to increasing customer satisfaction, thus, influencing customer retention and loyalty. The port company satisfies or increases customer requirements that contribute to obtaining customers, which influences profitability and increases port service effectiveness.
Cost (C_3)	Port pricing (C_{31})	Port pricing and charges are key factors in carrier's allocating lines, a reasonable port charge is helpful to attract docking, which influences port service effectiveness.
	Flexibility (C_{32})	The port company provides different services for customers of different scales, and flexible charges can satisfy different customer requirements, which increase port service effectiveness.
	Cargo disposal (C_{33})	Cargo disposal costs consist of the logistics of processing the costs of handling, warehousing, processing, and manufacturing, which are important factors in a consignor's selection of a carrier and a port. A lower cargo disposal cost contributes to attracting the consignor, thus, influencing port service effectiveness.
Time (C_4)	Reducing the time of non-value added activities (C_{41})	The activities and processes of port logistics are reviewed thoroughly in order to eliminate non-value added activities, and to shorten the time spent on them, to enhance the effectiveness of port value added activities.
	Increasing the efficiency of core logistics activities (C_{42})	The core logistics activities of a port include handling and warehousing activities. If the operating efficiency of such core logistics activities can be increased, the lead time of core logistics activities can be shortened, which shortens the operating time and contributes to increasing port service effectiveness.
	Executing port integrated information system (C_{43})	An integrated information system is the key to successful modern logistics operation. If the port company sets up and executes a port integrated information system, port service effectiveness will be increased.
Sustainability (C_5)	Friendly environmental policies (C_{51})	Port companies must deeply recognized the importance of business social responsibility for environmentally sustainable development when seeking company's growth. Therefore, port companies must review the environmental risks regarding service activities, and autonomously manage and reduce the probable environmental impact in order to achieve a green sustainable port.
	Software and hardware facilities construction (C_{52})	The port companies must take the practice of a green sustainable port as its environmental policy target, perform active and comprehensive green environmental measures with integrated coordinating functions (including the integration of software and hardware facilities, and the integration of port effectiveness), in order to reduce the adverse impact of port operating activities on the environment.
	Organizational culture (C_{53})	Organizational culture is the general term of group consciousness accepted by all members of the organization, including the concepts of values, behavior criteria, team spirits, thinking mode, work style, psychological expectations, and sense of belonging to a team. Therefore, the organizational culture of a sustainable port environment is pushed, and the environmental considerations of organizational employees are cultivated, thus, strengthening communications between adjacent communities, and co-creating the sustainable development of a port town.

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

$$f_A(x) = \begin{cases} (x-c)/(a-c), & c \leq x \leq a \\ (x-b)/(a-b), & a \leq x \leq b \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

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

The parameter a gives the maximal grade of $f_A(x)$, i.e., $f_A(a) = 1$; it is the most probable value of the evaluation data. In addition, ‘ c ’ and ‘ b ’ are the lower and upper bounds of the available area for the evaluation data. They are used to reflect the fuzziness of the evaluation data. The narrower the interval $[c, b]$, the lower the fuzziness of the evaluation data. By the way, the triangular fuzzy numbers are easy to use and easy to interpret; hence, the triangular fuzzy numbers are employed in this article.

In here, the extension principle (Zadeh, 1965) is used in this paper. 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

- fuzzy addition, \oplus :

$$A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2);$$

- fuzzy subtraction, \ominus :

$$A_1 \ominus A_2 = (c_1 - b_2, a_1 - a_2, b_1 - c_2);$$

- fuzzy multiplication, \otimes :

$$k \otimes A_2 = (kc_2, ka_2, kb_2), \quad k \in \mathfrak{R}, \quad k \geq 0;$$

$$A_1 \otimes A_2 \cong (c_1c_2, a_1a_2, b_1b_2), \quad c_1 \geq 0, \quad c_2 \geq 0;$$

- fuzzy division, \oslash :

$$(A_1)^{-1} = (c_1, a_1, b_1)^{-1} \cong (1/b_1, 1/a_1, 1/c_1), \quad c_1 > 0;$$

$$A_1 \oslash A_2 \cong (c_1/b_2, a_1/a_2, b_1/c_2), \quad c_1 \geq 0, \quad c_2 > 0.$$

2. Fuzzy AHP Model

A fuzzy AHP model (Hsu, 1998; Ding, 2006) is used to measure relative weights for evaluating assessment criteria of service effectiveness. The systematic steps are described below.

Step 1. Development of a hierarchical structure

A hierarchy structure is the framework of system structure. We can skeletonize a hierarchy to evaluate research problems and benefit the context. This article employs the hierarchical framework diagram shown in Fig. 1. In this framework, the problems lie on the L^{th} layer, and consist of assessment criteria with a major influence on the service effectiveness. There are

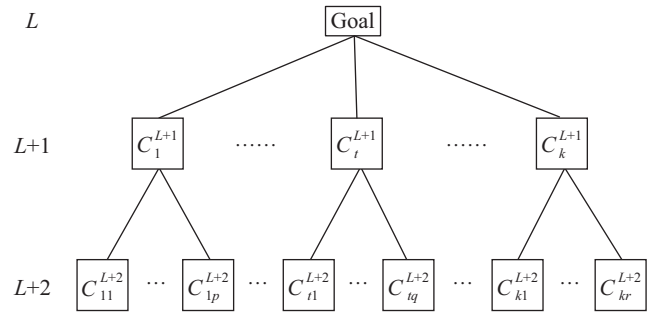


Fig. 1. Hierarchical structure.

k assessment aspects on the $L+1$ layer, and $p + \dots + q + \dots + r$ assessment criteria on the $L+2$ layer.

Step 2. Establishment of pairwise comparison matrices for assessment criteria

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

- (1) Let x_{ij}^h , $h = 1, 2, \dots, n$, be the relative importances 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 $[x_{ij}^h]_{k \times k}$.
- (2) Let x_{uv}^h , $h = 1, 2, \dots, n$, be the relative importances assigned to any two assessment criteria 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_1^{L+1} , C_t^{L+1} , and C_k^{L+1} .

Step 3. Establishment of triangular fuzzy numbers

The generalized mean is a typical representation of many well-known averaging operations (Klir and 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). 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).

$$\text{Let } x_{ij}^h \in \left\{ \frac{1}{9}, \frac{1}{8}, \dots, \frac{1}{2}, 1 \right\} \cup \{1, 2, \dots, 8, 9\}, \quad h = 1, 2, \dots, n,$$

$\forall i, j = 1, 2, \dots, k$, be the relative importances 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

$$\tilde{A}_{ij}^{L+1} = (c_{ij}, a_{ij}, b_{ij}),$$

where

$$c_{ij} = \min \{x_{ij}^1, x_{ij}^2, \dots, x_{ij}^n\}, a_{ij} = \left(\prod_{h=1}^n x_{ij}^h \right)^{1/n},$$

$$b_{ij} = \max \{x_{ij}^1, x_{ij}^2, \dots, x_{ij}^n\}.$$

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

$$\tilde{A}_{uv}^{L+2} = (c_{uv}, a_{uv}, b_{uv}),$$

$$\forall u, v = 1, \dots, p; \forall u, v = 1, \dots, q; \dots; \forall u, v = 1, \dots, r,$$

where

$$c_{uv} = \min \{x_{uv}^1, x_{uv}^2, \dots, x_{uv}^n\}, a_{uv} = \left(\prod_{h=1}^n x_{uv}^h \right)^{1/n},$$

$$b_{uv} = \max \{x_{uv}^1, x_{uv}^2, \dots, x_{uv}^n\}.$$

Step 4. Construction of 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

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

where $\tilde{A}_{ij}^{L+1} \otimes \tilde{A}_{ji}^{L+1} \cong \tilde{1}, \forall i, j = 1, 2, \dots, k.$

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 $\tilde{Z}_i^{L+1} \cong (\tilde{A}_{i1}^{L+1} \otimes \tilde{A}_{i2}^{L+1} \otimes \dots \otimes \tilde{A}_{ik}^{L+1})^{1/k}, \forall i = 1, 2, \dots, k,$ 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

$$\tilde{W}_i^{L+1} \cong \tilde{Z}_i^{L+1} \otimes (\tilde{Z}_1^{L+1} \oplus \tilde{Z}_2^{L+1} \oplus \dots \oplus \tilde{Z}_k^{L+1})^{-1}$$

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

Step 6. Defuzzification of the fuzzy weights to obtain crisp weights

To perform defuzzification in an effective manner, the graded mean integration representation (GMIR) method, proposed by Chen and Hsieh (2000), is used to defuzzify the fuzzy weights. Let $\tilde{W}_i^{L+1} = (w_{ic}, w_{ia}, w_{ib}), \forall i = 1, 2, \dots, k,$ be k triangular fuzzy numbers. The GMIR of crisp weights k can then be expressed as

$$G(\tilde{W}_i^{L+1}) = \frac{w_{ic} + 4w_{ia} + w_{ib}}{6}, \forall i = 1, 2, \dots, k.$$

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

Step 7. Normalization of the crisp weights

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

$$NW_i^{L+1} = G(\tilde{W}_i^{L+1}) / \sum_{i=1}^k G(\tilde{W}_i^{L+1}).$$

Step 8 Calculation of the integrated weights for each layer

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

- (1) The integrated weight of each assessment aspect on the $L + 1$ layer is $IW_i^{L+1} = NW_i^{L+1}, \forall i = 1, 2, \dots, k..$
- (2) The integrated weight of each assessment criterion on the $L + 2$ layer is $IW_u^{L+2} = NW_i^{L+1} \times NW_u^{L+2}, \forall i = 1, 2, \dots, k; \forall u = 1, \dots, p; \forall u = 1, \dots, q; \dots; \forall u = 1, \dots, r.$

IV. EMPIRICAL STUDY

In this section, an empirical study for evaluating key criteria influencing service effectiveness of Keelung Port is surveyed as follows.

1. Results

This article evaluated the relative importance of assessment criteria of service effectiveness for Keelung Port. We conducted an AHP questionnaire to experts. The questionnaires were distributed between November 2014 and January 2015. The surveyed experts were divided into industrial, official, and academic groups. There were 21 experts invited to complete this AHP questionnaire, with seven persons in each group.

The AHP questionnaire must meet consistency testing, namely, the consistency ratio (CR) and consistency index (CI) shall be less than or equal to 0.1, in order to guarantee consistency. If the CR and CI cannot be less than or equal to 0.1, the expert questionnaires are returned to the experts to check whether the pairwise comparison between the evaluation

Table 2. The computational results of five assessment aspects.

	C_1	C_2	C_3	C_4	C_5
C_1	(1, 1, 1)	(0.5, 2.682, 8)	(0.2, 0.614, 5)	(0.25, 1.593, 7)	(0.25, 1.266, 5)
C_2	(0.125, 0.373, 2)	(1, 1, 1)	(1, 2.237, 5)	(1, 2.758, 9)	(0.333, 2.460, 9)
C_3	(0.2, 1.628, 5)	(0.2, 0.447, 1)	(1, 1, 1)	(0.111, 0.543, 5)	(0.333, 2.084, 7)
C_4	(0.143, 0.530, 4)	(0.111, 0.363, 1)	(0.2, 1.840, 9)	(1, 1, 1)	(1, 3.333, 9)
C_5	(0.2, 0.790, 4)	(0.111, 0.407, 3)	(0.143, 0.480, 3)	(0.111, 0.30, 1)	(1, 1, 1)
\tilde{Z}_i^{L+1}	(0.3624, 1.2713, 4.2582)	(0.5296, 1.4143, 3.8168)	(0.2717, 0.9621, 2.8094)	(0.3165, 1.0334, 3.1777)	(0.2039, 0.5408, 2.0477)
\tilde{W}_i^{L+1}	(0.0225, 0.2435, 2.5284)	(0.0329, 0.2708, 2.2663)	(0.0169, 0.1842, 1.6681)	(0.0197, 0.1979, 1.8868)	(0.0127, 0.1036, 1.2159)
$G(\tilde{W}_i^{L+1})$	0.5875	0.5638	0.4037	0.4497	0.2738
NW_i^{L+1}	0.258	0.247	0.177	0.198	0.120

Table 3. The weights of each layer.

Assessment aspects	Normalized weights/ Integrated weights (A)	Assessment criteria	Normalized weights (B)	Integrated weights (C) = (A)*(B)
Service	0.258 (1)	Availability	0.372 (2)	0.0960 (3)
		Diversification	0.245 (3)	0.0632 (8)
		Reliability	0.383 (1)	0.0988 (2)
Quality	0.247 (2)	Totality	0.364 (2)	0.0899 (4)
		Safety	0.222 (3)	0.0548 (10)
		Accuracy	0.414 (1)	0.1023 (1)
Cost	0.177 (4)	Port pricing	0.426 (1)	0.0754 (6)
		Flexibility	0.247 (3)	0.0437 (13)
		Cargo disposal	0.327 (2)	0.0579 (9)
Time	0.198 (3)	Reducing the time of non-value added activities	0.354 (2)	0.0701 (7)
		Increasing the efficiency of core logistics activities	0.413 (1)	0.0818 (5)
		Executing port integrated information system	0.233 (3)	0.0461 (12)
Sustainability	0.120 (5)	Friendly environmental policies	0.393 (1)	0.0472 (11)
		Software and hardware facilities construction	0.262 (3)	0.0314 (15)
		Organizational culture	0.345 (2)	0.0414 (14)

criteria meets the transitivity. After a three-month survey, there were 6, 5, and 7 effective questionnaires recovered from industrial, official, and academic circles, respectively for a total of 18 questionnaires, and an effective recovery ratio of 85.71%. Since the AHP questionnaire in this study was an expert questionnaire, Robbins recommended that 5-7 experts are ideally required in studies of group decision-making. The number of valid recovered questionnaires in this study suggested that representative views were obtained (Robbins, 1994).

After encoding of the valid recovered questionnaires and combining the experts' views, this study used the fuzzy AHP steps to derive the relative weights of the assessment criteria at each level, which enabled us to rank the assessment aspects and assessment criteria in terms of relative importance.

We used five assessment aspects (C_1 - C_5) from the eighteen valid AHP questionnaires as an example to show the systematic procedures of the fuzzy AHP model. For saving space, the

other pairwise comparison matrices are omitted by reasoning of analogy. At first, the relative importance data from the eighteen valid questionnaires are used to collect a pairwise comparison matrix (i.e. Step 2). We then transformed these data into triangular fuzzy numbers through geometric mean method (i.e. Step 3). These triangular fuzzy numbers are employed to construct a fuzzy positive reciprocal matrix (i.e. Step 4). The geometric means of the triangular fuzzy number (\tilde{Z}_i^{L+1}) and the fuzzy weights (\tilde{W}_i^{L+1}) of four assessment aspects are calculated (i.e. Step 5). Using the Step 6 to defuzzy the fuzzy weights, we can obtain the crisp weights ($G(\tilde{W}_i^{L+1})$). Finally, the normalized weights (NW_i^{L+1}) of five assessment aspects by using Step 7 are obtained. The computational results are shown in Table 2.

In summary, we used the same computational process of fuzzy AHP method for each assessment criterion to obtain the normalized weights and integrated weights. The empirical results are summarized in Table 3.

The findings summarized in Table 3 are described as follows:

1. 'Service,' ranking 1, is the most important aspect influencing service effectiveness of Keelung Port. 'Quality,' 'time' and 'cost' are ranked in the second, third and fourth places. 'Sustainability' is the lowest ranked. The weights of top two assessment aspects – 'service' and 'quality' – were summed of over 0.5, which indicated that service effectiveness of Keelung Port shall enhance the services for carriers and consignors, and give greater consideration to quality.
2. For the 'service' aspect by the normalized weights, the 'reliability' is the critical assessment criterion. For the 'quality' aspect, the 'accuracy' is the critical assessment criterion. For the 'cost' aspect, the 'port pricing' is the critical assessment factor. For the 'time' aspect, the 'increasing the efficiency of core logistics activities' is the critical assessment criterion. For the 'sustainability' aspect, the 'friendly environmental policies' is the critical assessment criterion.
3. Daniel recognized 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 efforts to these elements. Secondly, the total weight of the 15 evaluation criteria is arithmetically averaged ($1/15 = 6.67\%$), and 6.67% is used as the threshold of the criteria. If the criterion weight exceeds 6.67%, it is regarded as a major evaluation criterion. As a consequence, the empirical results show that the top seven key assessment criteria influencing service effectiveness of Keelung Port are 'accuracy,' 'reliability,' 'availability,' 'totality,' 'increasing the efficiency of core logistics activities,' 'port pricing,' and 'reducing the time of non-value added activities,' respectively.

2. Discussions

This article provides a detailed explanation of the top seven assessment criteria in accordance with their overall weighting ranks. These assessment criteria are discussed as follows:

- **Accuracy**

Providing accurate quality is of the "do things right" category. Which is to say, the ships and cargoes receive different services in the port, where the purpose is to smoothly load, unload, or transfer cargoes in the port, in order to complete the goods transportation trip. Therefore, smoothly completing the various operating activities of ships and cargoes in the port allows stakeholders, including customers and port operators, to reach their best operating performance, which is of the "port effectiveness" (do the right things) category. However, whether port effectiveness can be reached effectively and accurately depends on correct and accurate port activities. If port service is correct, accurate, and good, it means things are done right. Therefore, port operators shall provide correct and accurate service in order to enhance the satisfaction of shipping companies and consignors. This quality influences customer loyalty

and the willingness to purchase again, and the operating performance of the port is eventually influenced.

- **Reliability**

The feeling of reliability allows people to be confident that their expectations of customers service will be met. When a service system presents 'reliable service,' it means users will be satisfied with the service quality. Therefore, port 'reliable service' represents the ability of port operators to perform promised port services correctly and reliably, and makes port users satisfied with the service quality.

- **Availability**

Availability is a basic characteristic of port service. For users, available port services shall simultaneously satisfy the accessibility and usability of various service systems. If the port service system is difficult to approach and use, the service system is hardly procurable. Therefore, port accessibility and usability mean the service system is easy for customers' use, and shall simultaneously consider accessibility, usability, and availability. In addition, available port services must guarantee that the provided service system can be available at any time. Port operators must ensure the service systems can provide services effectively, and offer sophisticated service quality through various routine supervision and control activities.

- **Totality**

Total quality management (TQM) contains three concepts, of quality sophistication, including human, processes, and products/services. All departments and members of a business organization must take part in quality management and handle business well, where quality is well controlled through service flows and handling procedures. Finally, quality management shall consider all aspects of the service system in order to smoothly complete various services. Therefore, TQM means all departments and persons of an organization participate in effective quality improvements in order that the processes and results of different service systems can satisfy customers' requirements, and enterprise costs can be reduced.

- **Increasing the efficiency of core logistics activities**

The port service provider must confirm his core logistics activities, such as cargo handling and warehousing or storage activity systems, in order to reduce logistics costs and increase logistics efficiency and economic benefit, thus, guaranteeing port logistics efficiency and effectiveness. As Keelung Port is small, the wharf area space is insufficient. According to expert survey findings, lead time and operating time can be shortened by increasing the efficiency of core logistics activities (e.g. handling or warehousing activity system), in order to increase the port service effectiveness. Therefore, the port service provider shall improve the efficiency of core logistics operation activities to increase time value. In increasingly competitive environments, carriers and consignors are relatively sensitive to time, thus, port companies shall aim at time-based

competitive performance, and compress the time of various core logistics operation activities, in order to reflect port logistics costs and increase profit.

- **Port pricing**

The port charge is a carrier cost, thus, reasonable port pricing and charges can attract carriers to berth, especially when carriers have several optional ports in one region, as port charges and pricing competitions are common considerations of carriers, which consider handling capacity, handling performance, and service level. Therefore, port pricing shall be rationally and flexibly adjusted to consider the competitiveness of the port, against the competitive conditions of adjacent ports, as well as the requirements of carriers and consignors for commercial port facilities, in order to evaluate different commercial port pricing models that enhance the profitability and competitive advantage of the port.

- **Reducing the time of non-value added activities**

The added value in economics refers to the value created by production manufacturing of enterprises, i.e. the output value minus input cost equals product or service value. Therefore, higher added value represents better profitability of a product or service. Porter (1985) indicated that the source of competitive advantages of enterprises can be analyzed using the value chain, which strategically considers various value activities inside the enterprises, as well as the interactive relationship between value activities, and then evaluates the influence on costs. In this view, the port service system is divided into main activities and support activities, and the port service provider shall identify the value added activities and non-value added activities in the system, thus, increasing value added activities, while reducing non-value added activities. By improving time effectiveness, port service effectiveness is eventually increased.

V. CONCLUDING REMARKS

In the keen competitive port market, service effectiveness has become a key to customer satisfaction and loyalty for port operators. This study applied the fuzzy AHP model to evaluate key factors influencing service effectiveness for Keelung Port. A hierarchical structure with 5 assessment aspects and 15 assessment criteria was constructed. We employed the fuzzy AHP model to empirically evaluate the key criteria of service effectiveness. The results showed that:

- (1) 'Service' is the most important aspect influencing service effectiveness of Keelung Port. 'Quality,' 'time,' 'cost' and 'Sustainability' are ranked in the second to fifth places.
- (2) Top seven key service effectiveness of Keelung Port are 'accuracy,' 'reliability,' 'availability,' 'totality,' 'increasing the efficiency of core logistics activities,' 'port pricing,' and 'reducing the time of non-value added activities,' respectively.

Lastly, this article provides the following recommendations of the assessment aspects for Keelung Port branch, Taiwan International Ports Corporation.

- **Recommendations for aspect of service**

According to the findings, carriers and consignors consider reliable service and available service. Therefore, the Keelung Port branch shall provide a promise of reliable and correct port services for carriers and consignors, as well as provide appropriate and sufficient port service systems, in order to satisfy port users' requirements for service quality. While Keelung Port has some advantageous conditions, it also has many disadvantageous conditions. Providing an available and reliable port service may seem to be an easy task, it is difficult to achieve in the actual port field. At present, Keelung Port is oriented as a near-sea shipping line-based container port, a port of call for cargo and passenger ships of the two sides of the Taiwan Strait and international passenger liners, as well as a logistics distribution center of the Asia-Pacific region. Therefore, how the port branch co-operates in the development orientation, and proposes a set of sophisticated strategies and measures to increase service effectiveness, and thus, advance towards a value added logistics port, should be an important direction for the port branch. To sum up, providing available and reliable services is an important task of service providers, and creating a more competitive service environment for Keelung Port to attract carriers is an important direction for the port branch to increase competitiveness.

- **Recommendations for aspect of quality**

According to the findings, carriers and consignors consider correct and accurate port service system quality, and service quality shall be improved by thoroughly meeting customer requirements. The Keelung Port branch shall thoroughly improve its services, including TQM improvement on organization and personnel, service flows, procedures, and service system operating performance, in order to reduce the cost of the port service provider and satisfy carriers and consignors with the quality. Therefore, this article suggests that the port branch shall aim at customer service demand at all times, in order to improve service quality, and service level, processes, and results can meet customers' expectations.

- **Recommendations for aspect of time**

According to the findings, carriers and consignors consider the core logistics services of a port branch, as well as the activities that create added value, to increase operating efficiency and reduce operating time. Therefore, the Keelung Port branch shall recognize the main service activities or support service activities, value added service activities, and non-value added service activities of port service systems. Secondly, how the port branch profits carriers and consignors, how to create significant value added profit for customers, and how to improve the efficiency of core logistics operation activities to increase the time value are evaluated on the principle that higher added

value represents better profitability of products and services. Finally, based on the goal of a win-win strategy, the logistics time stress of carriers and consignors is reduced, thus, enhancing operating performance.

• Recommendations for aspect of cost

According to the findings, carriers and consignors consider port pricing and charges carefully. Because the port charge is an operating cost item of carriers and consignors, a reasonable port charge is the key factor in carriers' port selection. Therefore, the Keelung Port branch shall create a flexible and reasonable pricing model according to its internal and external environmental conditions, in order to implement a win-win situation for port service providers and users. In addition, the port branch must consider charging policies in the pricing model, such as a pure economic approach pricing policy, a financial approach pricing policy, or a public enterprise approach pricing policy.

• Recommendations for aspect of sustainability

According to the findings, present carriers and consignors do not care as much about the development of a sustainable environment. Energy saving and greenhouse gases reduction are important national policies. A green port with green shipping initiations is on track of global ocean shipping development. Sustainable port development is aiming at reducing related pollution under the leadership of governmental policies. To form a friendly environment and to create a sustainable green environment will become more essential in future port development. To fulfill corporate responsibility, Keelung Port branch should actively conduct green port initiations for sustainable environment protection.

In addition, this article provides the recommendations concerning follow-up research. Future research may collect more assessment criteria based on the relevant literature and practical experience for port service effectiveness. Apart from this, to assess the best port service effectiveness, the alternatives can be placed at the lowest layer in a hierarchical assessment framework, which will help clarify the sequential order of best port implementation of service effectiveness. Furthermore, the five assessment aspects and their assessment criteria, while mutually exclusive and independent, were not fully comprehensive. We therefore suggest that future researchers can provide a clearer discussion on the relationships between assessment criteria. Moreover, if dependent relationships exist between assessment criteria, the analytic network process (ANP) method (Saaty, 1996) or the decision making trial and evaluation laboratory (DEMATEL) method (Tzeng et al., 2007) can be employed to make clear that situation.

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