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USING FUZZY AHP TO INVESTIGATE KEY FACTORS INFLUENCING THE QUALITY OF SERVICE DELIVERY SYSTEM FOR PORT OF KAOHSIUNG

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Abstract

The main purpose of this paper is to investigate the quality of service delivery system (SDS) in port of Kaohsiung and especially to find out what key factors in SDS are attracted by experts. To facilitate the main issue for obtaining key factors in SDS, the value chain analysis is employed to integrate preliminary important factors, which were discussed and publicized in academic and management fields and can be summarized as two activity systems, and eight functional activities with twenty-eight functional-related activities. Subsequently, the next issue faced how to evaluate the relative weights of multiple attributes. A fuzzy AHP approach is used to measure relative weights for evaluating these key factors. Finally, the systematic appraisal approach using fuzzy AHP is to perform the empirical survey via AHP expert questionnaires. The results show that all experts primarily care about that does Kaohsiung port authority provide flawless berth operation, customer service, harbor operation, traffic links, handling operation, storage and yard operation, and IT integration.

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1. Introduction

Kaohsiung is the largest international port of Taiwan as well as the sixth container port in the world in 2005. Taiwan government performs plan of Global Logistics Management Center and Free Trade Port with an aim to take advantage of geographic benefits and sound software and hardware facilities to speed up the development and further enhance the function of Kaohsiung harbor serving as the regional marine transportation center in the Asia-Pacific. Due to the China factor and the change of industrial structure, the source of cargoes and port throughput are decreasing, and this forms a predicament of port competitiveness. Port of Rotterdam faced the similar circumstance in 1987, but port specialists dare not ignore this vital loading center in Europe [27]. This is because Port of Rotterdam attached importance to the efficiency of goods flows, especially improved the efficiency and quality of service delivery system (SDS). Every link in the process of SDS influenced the performance of shipping-port chain and affected port choice ultimately. In light of this, this paper aims to investigate the quality of SDS in port of Kaohsiung, especially to find out what key factors in SDS are attracted and accepted by experts.

2. Service Delivery System for Port of Kaohsiung

2.1. The concept of SDS

Researchers have studied components of SDS from two perspectives in the literature, namely, system-based perspective and marketing-based perspective.

(1) The system-based perspective be of the opinion that an overall service system can be seen as a network composed of independently service system; however, customers deem that one as a throughout single SDS [10]. This system can be divided into front office and back office processing, where the former customer can obtain tangible evidence of the service, whereas the latter is out of customer view [9]. Lovelock and Wirtz [16] hold this service system are constructed from service operation

system and SDS, which the latter is interacted through both physical support and encounter person in front stage and invisible core technology in back stage. Normann [18] also indicated technology and physical support, personnel, and client are three major components in the SDS.

(2) On the other hand, marketing-based perspective argues that service provider can obtain differentiation in service through personnel, physical environment, and process [14]. Grönroos [10] indicated staff or personnel, technology, customer, and time are four main resources in a service system of customer-oriented. Chen [3] also indicated people, time, place, tangibles, and intangibles are five major components in service operation. Although Chen's paper did not refer technology as an independent element in service operation, in fact, today, the facilities in technical level have already considered in the service system. Lovelock and Wirtz [16] provided an integrated approach to service management, which highlighted the 8Ps, i.e., product elements, place, cyberspace, and time, process, productivity and quality, people, promotion and education, physical evidence, price and other user outlays, to any competitive service business.

In fact, the service transmitted by service providers should not only focus on their core service, but also consider how, why, where, and when in the SDS to ascertain the total customers' satisfaction [17, 23, 25]. As we know that an effective delivery process can be an important quality improvement tool that allows a port to obtain customer feedback which is serviceable in improving to increase customer satisfaction, loyalty, and profit margins in shipping chain [5, 6]. Inasmuch as customer service level is expected to be the highest philosophy of shipping chain, an SDS should design well to making improvement that increases overall performance [5].

2.2. Preliminary factors influencing the quality of SDS in port of Kaohsiung

In the coming year, customer service levels will be those that satisfy the customer needs and ultimately saving or cutting logistics cost which are based upon establishing more excellent SDS with the upstream and downstream linkages [6, 9]. Such SDS will focus on designing unhindered processes to create more value-added service or to decrease unnecessary cost for their customers. In today's environment, a well-designed SDS needs to be taken in terms of perspectives of customers. Heskett [11] have noted that basically prominent elements in view of strategic service consist of targeted market, well-defined service concept, focused operation strategy, and well-designed SDS. This well-designed SDS of achieving successful in such viewpoints is to provide services with a bundle of attributes to differentiate those from their competitors.

Inasmuch as 'value chain analysis' [19] is a suitable approach to induce these attributes. While interview with executive managers of international port and different working communities in Taiwan, the value chain of Kaohsiung port is a summary of primary activity system and support activity system. The former is involved in port services in terms of directly connecting with physical operations as well as customer service system. However, the later is required that supports the primary activity system. These preliminary factors have been discussed and made known in academic and management publications [1, 4, 7, 15, 22, 24]. Finally, the hierarchy of these factors is formed from the integration of two activity systems and eight functional activities with twenty-eight functional-related activities, as shown in Table 1.

Table 1. Hierarchy of preliminary factors influencing the quality of SDS

Activity system	Functional activities	Functional-related activities
C_1. Primary	C_{11}. Harbor operation system	C_{111}. Certification for arrival and departure vessels
		C_{112}. Navigation aids and VTS
		C_{113}. Pilotage, tugs and mooring gangs
		C_{114}. Dynamical status inquires
	C_{12}. Berth operation system	C_{121}. Berth dispatching and deployment
		C_{122}. Berth maintenance and expansibility
	C_{13}. Handling operation system	C_{131}. Deployment of handling equipment
		C_{132}. Handling and movement management capability
		C_{133}. Maintenance and expansibility of handling equipment
	C_{14}. Storage and yard operation system	C_{141}. Facility capacities and throughput
		C_{142}. Storage and management capability
		C_{143}. Maintenance and expansibility of storage and yard facility
	C_{15}. Traffic links to outskirts	C_{151}. Transportation service level of connecting road system
		C_{152}. Maintenance and expansibility of traffic links to outskirts
	C_{16}. Customer service	C_{161}. Port marketing
		C_{162}. Service and quality perception
		C_{163}. Creating customer value
		C_{164}. Supervise and analyze port performance
C_2. Support	C_{21}. General administration affair	C_{221}. Port planning capability
		C_{212}. Human resource management
		C_{213}. Control of vehicles, all modes, entering and leaving port
		C_{214}. Occupational safety and environmental protection
		C_{215}. Legal affairs and policy management
		C_{216}. Administration management of shipping and navigation
	C_{22}. Information technology (IT) integration management system	C_{221}. Electronic data interchange (EDI) capability
		C_{222}. Port-MIS capability
		C_{223}. Maritime information and communication network
		C_{224}. Applied capability of IT

3. Methodologies

There are many methods to evaluate relative weights of multiple attributes. One of the commonly used ones for multi-criteria is analytic hierarchy process (AHP), which was proposed by Saaty [21]. However, the relative weights based upon this measurement in which information is incomplete or imprecise or views that are subjective or endowed with linguistic characteristics creating a ‘fuzzy’ environment, e.g., the phrase of ‘much more important than.’ The use of fuzzy numbers would be more suitable in that situation. In light of this, a fuzzy AHP approach, which is modified Hsu’s method [12], is used to measure relative weights for evaluating these key factors. In this section, some of the concepts used in this paper are briefly introduced.

3.1. Fuzzy set theory

The fuzzy set theory [26] is designed to deal with the extraction of the primary possible outcome from a multiplicity of information that is expressed in vague and imprecise terms. Fuzzy set theory treats vague data as possibility distributions in terms of set memberships. Once determined and defined, the sets of memberships in possibility distributions can be effectively used in logical reasoning.

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 [8] in real line $\Re$ is a triangular fuzzy number if its membership function $f_A : \Re \to [0, 1]$ is

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

with $-\infty < c \le a \le b < \infty$. 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.

The triangular fuzzy numbers are easy to use and easy to interpret. For example, 'a value approximately equal to 300' can be represented by $(295, 300, 306)$; and it can be represented with more leeway by $(290, 300, 313)$. In addition, the non-fuzzy number, an exact number, 'a' can be represented by (a, a, a). For example, 'a value of 300' can be represented by $(300, 300, 300)$.

Let $A_1 = (c_1, a_1, b_1)$ and $A_2 = (c_2, a_2, b_2)$ be fuzzy numbers. According to the extension principle [26], 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, $\otimes$:

$$k \otimes A_2 = (kc_2, ka_2, kb_2), \quad k \in \Re, \quad k \geq 0;$$

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

- Fuzzy division, $\varnothing$:

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

3.2. Fuzzy AHP

The systematic steps for evaluating relative weights using fuzzy AHP to be taken are described below.

Step 1. Develop 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. The hierarchy of preliminary factors, as shown in Table 1, can be constructed as same as Figure 1. Figure 1 is a hierarchical structure with

k activity systems on the $L+1$ layer, $p+\cdots+q+\cdots+r$ functional activities on the $L+2$ layer and $e_1+\cdots+e_p+\cdots+f_1+\cdots+f_q+\cdots+g_1+\cdots+g_r$ functional-related activities on the $L+3$ layer, respectively.

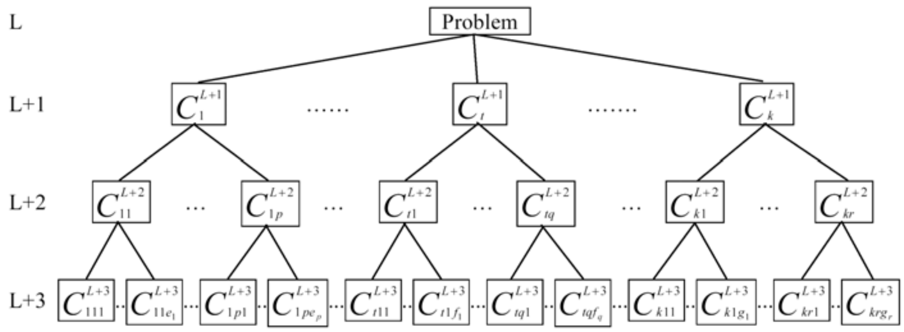

Figure 1. Hierarchy structure.

Step 2. Collect pair-wise comparison matrices of decision attributes

We choose experts to collect pair-wise comparison matrices of decision attributes, which is represented the relative importance of each pair-wise attribute.

(1) Let x_{ij}^h, $h = 1, 2, \ldots, n$, be the relative importance given to activity system i to activity system j by expert h on the $L+1$ layer. Then, the pair-wise comparison matrix is defined as $[x_{ij}^h]_{k\times k}$.

(2) Let x_{uv}^h, $h = 1, 2, \ldots, n$, be the relative importance given to functional activity u to functional activity v by expert h on the $L+2$ layer. Then, the pair-wise comparison matrix with respect to each activity system, i.e., C_1^{L+1}, C_t^{L+1}, C_k^{L+1} is defined as $[x_{uv}^h]_{p\times p}$, $[x_{uv}^h]_{q\times q}$, $[x_{uv}^h]_{r\times r}$.

(3) Let x_{yz}^h, $h = 1, 2, \ldots, n$, be the relative importance given to functional-related activity y to functional-related activity z by expert h on the $L+3$ layer. Then, the pair-wise comparison matrix with respect to each functional activity, i.e., C_{11}^{L+2}, C_{1p}^{L+2}, C_{t1}^{L+2}, C_{tq}^{L+2}, C_{k1}^{L+2}, C_{kr}^{L+2}

is defined as $[x_{yz}^h]_{e_1\times e_1}$, $[x_{yz}^h]_{e_p\times e_p}$, $[x_{yz}^h]_{f_1\times f_1}$, $[x_{yz}^h]_{f_q\times f_q}$, $[x_{yz}^h]_{g_1\times g_1}$, $[x_{yz}^h]_{g_r\times g_r}$.

Step 3. Transform relative importance into triangular fuzzy number

The generalized means is a typical representation of many well-known averaging operations [13], e.g., min, max, geometric mean, arithmetic mean, harmonic mean, etc. The min and max are the lower bound and upper bound of generalized means, respectively. Besides, the geometric mean is more effective in representing the multiple decision-makers' consensus opinions [21]. To aggregate all information generated by different averaging operations, we use the grade of membership to demonstrate their strength after considering all approaches. For the above-mentioned reasons, the triangular fuzzy numbers characterized by using the min, max and geometric mean operations are used to convey the opinions of all experts.

Let $x_{ij}^h \in [1/9, 1] \cup [1, 9]$, $h = 1, 2, \ldots, n$, $\forall\, i, j = 1, 2, \ldots, k$, be the relative importance given to activity system i to activity system j by expert h on the $L+1$ layer. After integrating the opinions of all n experts, the triangular fuzzy numbers can be denoted by

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

where

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

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

By the same concept, we can integrate the opinions of all n experts on the $L+2$ layer, i.e., the triangular fuzzy numbers can be denoted by

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

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

where

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

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

For saving space, the equation of triangular fuzzy number is omitted to reason by analogy on the $L + 3$ layer.

Step 4. Build fuzzy positive reciprocal matrices

We use the integrated triangular fuzzy numbers to build fuzzy positive reciprocal matrices. For the $L + 1$ layer, the fuzzy positive reciprocal matrix can be denoted by

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

where

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

For saving space, the equations of fuzzy positive reciprocal matrices are omitted to reason by analogy on the $L + 2$ and $L + 3$ layers.

Step 5. Calculate the fuzzy weights of the fuzzy positive reciprocal matrices

Let $\tilde{Z}_i^{L+1} \cong (\tilde{A}_{i1}^{L+1} \otimes \tilde{A}_{i2}^{L+1} \otimes \cdots \otimes \tilde{A}_{ik}^{L+1})^{1/k}$, $\forall i = 1, 2, ..., k$, be the geometric mean of triangular fuzzy number of ith activity system on the $L + 1$ layer. Then, the fuzzy weight of ith activity system can be denoted by

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

For being convenient, the fuzzy weight is denoted by $\widetilde{W}_i^{L+1} = (w_{ic}, w_{ia}, w_{ib})$. For saving space, the equations of fuzzy weights are omitted to reason by analogy on the $L+2$ and $L+3$ layers.

Step 6. Defuzzify the fuzzy weights to crisp weights

For solving the problem of defuzzification powerfully, the graded mean integration representation method, proposed by Chen and Hsieh [2], is used to defuzzify the fuzzy weights. Let $\widetilde{W}_i^{L+1} = (w_{ic}, w_{ia}, w_{ib})$, $\forall i = 1, 2, \ldots, k$, be k triangular fuzzy numbers. By the powerful method, the graded mean integration representation of crisp weights k can be denoted by $W_i^{L+1} = \dfrac{w_{ic} + 4w_{ia} + w_{ib}}{6}$, $\forall i = 1, 2, \ldots, k$.

For saving space, the defuzzifications of fuzzy weights are omitted to reason by analogy on the $L+2$ and $L+3$ layers.

Step 7. Normalize the crisp weights

For being convenient to compare the relative importance between each layer, these crisp weights are normalized and denoted by

$$NW_i^{L+1} = \frac{W_i^{L+1}}{\sum_{i=1}^{k} W_i^{L+1}}.$$

Step 8. Calculate the integrated weights for each layer

Let NW_i^{L+1}, NW_u^{L+2} and NW_y^{L+3} be the normalized crisp weights on the $L+1$, $L+2$ and $L+3$ layers, respectively. Then,

(1) The integrated weights of each activity system on the $L+1$ layer is

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

(2) The integrated weights of each functional activity on the $L+2$ layer is

$$IW_u^{L+2} = NW_i^{L+1} \times NW_u^{L+2}, \quad \forall i = 1, 2, \ldots, k;$$

$$\forall u = 1, \ldots, p; \ldots; \quad \forall u = 1, \ldots, q; \ldots; \quad \forall u = 1, \ldots, r.$$

(3) The integrated weights of each functional-related activity on the $L + 3$ layer is

$$IW_y^{L+3} = NW_i^{L+1} \times NW_u^{L+2} \times NW_y^{L+3}, \quad \forall i = 1, 2, \ldots, k;$$

$$\forall u = 1, \ldots, p; \ldots; \forall u = 1, \ldots, q; \ldots; \forall u = 1, \ldots, r;$$

$$\forall y = 1, \ldots, e_1; \ldots; \forall y = 1, \ldots, e_p; \ldots; \ldots; \forall y = 1, \ldots, g_1; \ldots; \forall y = 1, \ldots, g_r.$$

4. Empirical Study

In this section, an empirical study of obtaining key factors related with SDS for port of Kaohsiung is carried out to demonstrate the computational process as described above. The process of the algorithm is empirically implemented as follows.

4.1. Questionnaire design and data collect

In this section, two activity systems and eight functional activities with twenty-eight functional-related activities, as shown in Table 1, were used to design the AHP questionnaire and to obtain information on the relative importance of three layers. The AHP problem is involved the group decision-making, where Robbins [20] suggested five or seven decision-makers are suitable for dealing with group decision-making problem. The respondents are divided into three groups, i.e., government official, expert academics, and senior managers of ocean carriers and Kaohsiung port, respectively. The author selected seven experts in each group to answer the survey questionnaire in 2006. The surveys were completed through e-mails, phone calls and in-person interview by the authors. A total of 12 valid questionnaires (two government official, three expert academics, and seven senior managers of ocean carriers and Kaohsiung port) was collected from the twenty-one respondents, or which represents about 57.14% of the total ones.

4.2. Empirical results

In this Section, the author used the four functional-related activities (C_{111}-C_{114}) under the 'harbor operation system' (C_{11}) of valid questionnaires as an example for illustrating the computational process of fuzzy AHP. And, then calculate the integrated weights for each layer. The computing process and empirical results would be shown as follows.

4.2.1. Build fuzzy positive reciprocal matrix

The author used the data of relative importance of 12 valid questionnaires to collect fuzzy pair-wise comparison matrices and then transformed these data into fuzzy positive reciprocal matrix using geometric mean approach. The results can be shown as Table 2.

Table 2. The fuzzy positive reciprocal matrix of four functional-related activities

	C_{111}	C_{112}	C_{113}	C_{114}
C_{111}	(1, 1, 1)	(1, 1.642, 4)	(0.333, 1.886, 6)	(1, 2.891, 7)
C_{112}	(0.25, 0.609, 1)	(1, 1, 1)	(0.333, 1.189, 3)	(1, 1.603, 4)
C_{113}	(0.167, 0.530, 3)	(0.333, 0.841, 3)	(1, 1, 1)	(0.5, 1.477, 3)
C_{114}	(0.143, 0.346, 1)	(0.25, 0.624, 1)	(0.333, 0.677, 2)	(1, 1, 1)

4.2.2. Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Using the Step 5 in Subsection 3.2, the geometric mean of triangular fuzzy number ($\widetilde{Z}_y^{L+3}$) and the fuzzy weights ($\widetilde{W}_y^{L+3}$) of four functional-related activities can be shown as Table 3 and Table 4, respectively.

Table 3. The geometric mean of triangular fuzzy number ($\widetilde{Z}_y^{L+3}$)

$\widetilde{Z}_{111}^{L+3}$	$\widetilde{Z}_{112}^{L+3}$	$\widetilde{Z}_{113}^{L+3}$	$\widetilde{Z}_{114}^{L+3}$
(0.760, 1.730, 3.60)	(0.537, 1.038, 1.861)	(0.408, 0.901, 2.280)	(0.330, 0.618, 1.189)

Table 4. The fuzzy weights $(\widetilde{W}_y^{L+3})$

$\widetilde{W}_{111}^{L+3}$	$\widetilde{W}_{112}^{L+3}$	$\widetilde{W}_{113}^{L+3}$	$\widetilde{W}_{114}^{L+3}$
(0.085, 0.404, 1.769)	(0.060, 0.242, 0.915)	(0.046, 0.210, 1.120)	(0.037, 0.144, 0.584)

4.2.3. Defuzzify the fuzzy weights and normalize the crisp weights

The fuzzy weights can be defuzzified by the graded mean integration representation method to obtain the crisp weights, and then, to normalize these crisp ones. The results can be shown as Table 5.

Table 5. The defuzzified and normalized weights of four functional-related activities

	C_{111}	C_{112}	C_{113}	C_{114}
Defuzzified weights	0.578	0.324	0.334	0.20
Normalized weights	0.403	0.225	0.233	0.139

4.2.4. Calculate the integrated weights for each layer

For saving space, the author used the same computational process of fuzzy AHP for each criterion (activity system, functional activity, and functional-related activity) of three layers to obtain the normalized weights. And then, the results of the integrated weights of each layer can be shown as Table 6.

Table 6. The normalized weights and integrated weights of each layer

Activity system	Normalized/ Integrated weights (A)	Functional activities	Normalized weights (B)	Integrated weights (C) = (A)*(B)	Functional-related activities	Normalized weights (D)	Integrated weights (E) = (A)*(B)* (D)
C_1	0.719 (1)	C_{11}	0.188 (2)	0.1352 (3)	C_{111}	0.403 (1)	0.0545 (4)
					C_{112}	0.225 (3)	0.0304 (19)
					C_{113}	0.233 (2)	0.0315 (17)
					C_{114}	0.139 (4)	0.0188 (27)
		C_{12}	0.176 (3)	0.1265 (4)	C_{121}	0.544 (1)	0.0688 (1)
					C_{122}	0.456 (2)	0.0577 (3)
		C_{13}	0.137(4)	0.0985 (6)	C_{131}	0.269 (3)	0.0265 (22)
					C_{132}	0.397 (1)	0.0391 (8)
					C_{133}	0.334 (2)	0.0329 (15)
		C_{14}	0.124 (5)	0.0892 (7)	C_{141}	0.226 (3)	0.0201 (26)
					C_{142}	0.391 (1)	0.0349 (10)
					C_{143}	0.383 (2)	0.0341 (11)
		C_{15}	0.108 (6)	0.0777 (8)	C_{151}	0.572 (1)	0.0444 (7)
					C_{152}	0.428 (2)	0.0332 (14)
		C_{16}	0.267 (1)	0.1920 (1)	C_{161}	0.242 (3)	0.0465 (6)
					C_{162}	0.318 (1)	0.0610 (2)
					C_{163}	0.264 (2)	0.0507 (5)
					C_{164}	0.176 (4)	0.0338 (12)
C_2	0.281 (2)	C_{21}	0.572 (1)	0.1607 (2)	C_{211}	0.138 (5)	0.0222 (25)
					C_{212}	0.114 (6)	0.0183 (28)
					C_{213}	0.197 (2)	0.0317 (16)
					C_{214}	0.186 (3)	0.0299 (20)
					C_{215}	0.158 (4)	0.0254 (24)
					C_{216}	0.207 (1)	0.0333 (13)
		C_{22}	0.428 (2)	0.1203 (5)	C_{221}	0.256 (2)	0.0308 (18)
					C_{222}	0.213 (4)	0.0256 (23)
					C_{223}	0.226 (3)	0.0272 (21)
					C_{224}	0.305 (1)	0.0367 (9)

Remark: Numbers in parentheses are ranks.

5. Concluding Remarks

This paper aims to investigate the quality of SDS in port of Kaohsiung and especially to find out what key factors in SDS are attracted and accepted by experts. To facilitate the main issue for obtaining key factors in SDS, the value chain analysis proposed by Porter in 1985 is employed to integrate those preliminary important factors firstly. These preliminary important factors have been discussed and publicized in academic and management fields and can be summarized as two activity systems, and eight functional activities with twenty-eight functional-related activities.

Subsequently, the next issue faced how to evaluate the relative weights of multiple attributes. The AHP approach is the commonly used one for multi-criteria problem. However, the relative weights based upon this measurement in which information is incomplete or imprecise or views that are subjective or endowed with linguistic characteristics creating a 'fuzzy' environment. The use of fuzzy numbers would be more suitable in that situation. Therefore, a fuzzy AHP approach is used to measure relative weights for evaluating these key factors.

Finally, the systematic appraisal approach using fuzzy AHP is to perform the empirical survey via AHP expert questionnaires. The surveys selected twenty-one experts to answer the survey questionnaires in 2006. A total of 12 valid questionnaires (two government official, three expert academics, and seven senior managers of ocean carriers and Kaohsiung port) was collected from the twenty-one respondents, or which represents about 57.14% of the total ones. The results of empirical study are shown as follows:

(1) Customer service (C_{16}) is the most important factor in primary activity system, as well as general administration affair (C_{21}) in support activity system.

(2) The top four key factors in functional activities are customer service, general administration affair, harbor operation system, and berth operation system $(C_{16}, C_{21}, C_{11}, \text{and } C_{12})$, respectively. The integrated weights of these four functional activities accounted for 61.44%.

(3) The top ten key factors in functional-related activities are berth dispatching and deployment, service and quality perception, berth maintenance and expansibility, certification for arrival and departure of vessels, creating customer value, port marketing, transportation service

level of connecting road system, handling and movement management capability, applied capability of IT, storage and management capability (C_{121}, C_{162}, C_{122}, C_{111}, C_{163}, C_{161}, C_{151}, C_{132}, C_{224}, and C_{142}), respectively. The integrated weights of these ten functional-related activities accounted for 49.43%, or equally about one half.

(4) There is at least one key factor in each functional activity (C_{11}-C_{16}, and C_{22}), excepting general administration affair (C_{21}). This activity (C_{21}) plays an important factor in functional activity; however, the sub-criteria (C_{211}-C_{216}) in the functional-related activities are not very critical. This is because too much factors in general administration affair shared the weighting loads, but the results should be interpreted with a lot of caution. Having said this, the two functional-related activities (C_{213} and C_{216}), i.e., control of vehicles, all modes, entering and leaving port, and administration management of shipping and navigation, are more contributed to general administration affair.

(5) The results in functional-related activities show that all experts primarily care about that does Kaohsiung port authority provide flawless berth operation, customer service, harbor operation, traffic links, handling operation, storage and yard operation, and IT integration.

Furthermore, the overall results show that the combination of fuzzy decision-making with AHP could become a useful tool for implementing quality function deployment (QFD) in the future research.

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