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# SERVICE INNOVATION AT KEELUNG INTERNATIONAL HARBOR

Ming-Chung Lii, Yuh-Ling Su, and Kung-Don Ye

Key words: service innovation, port innovation, fuzzy, quality function deployment.

## ABSTRACT

Growing competition among international harbors has changed the core port operating strategy from pursuing efficiency to innovation. Most academic studies of innovation have focused on products and manufacturing processes rather than on service innovation, especially in the field of international harbor. Accordingly, this study investigated service innovation in an international harbor to evaluate the applicability of the service concept for guiding the direction of effort by international harbors. Since the idea of service innovation is just in the initial stage, the purpose of this work is trying to explore set of indices that can well measure service innovation performance of an organization and Keelung Harbor is chosen as an example by applying the methods of Fuzzy and Quality Function Deployment (QFD). This study found that the biggest gap between perceived importance and satisfaction was in the "service improvement and reorientation" dimension, where the items of "creating new service process to increase profit" and "restructuring port operation in accordance with its status" should be the main focus for port management. For technical requirements, the most helpful items for strengthening service innovation were "possessing the sense to discover problems" and "possessing the ability to develop the customized system". Overall, creating the necessary ability/skill and possessing the critical resources are the main issues in response to the service innovation strategy.

## I. INTRODUCTION

The concept of service innovation was developed by IBM and applied in Service Science Management and Engineering. The core concept is that industries and academic institutions cooperate to gain a competitive edge through a novel model of services and products. The main service innovation issue is how to improve company competitiveness, even if the operating model must be revised, to increase added value through service innovation.

The service innovation concept is not limited to the service industry; any efforts committed to the utilization of an external service or review of working process to change the corporate operating mode and enhance competitive advantage can be regarded as service innovation. Most studies of port management and competition have focused on the route layout, the rate, and port operating conditions (such as the hinterland, logistical support, etc.) with few trying to do through the viewpoint of service innovation. However, a review of the efforts made by Singapore, Hong Kong and other developed countries that manage world leading international ports indicates that the objective conditions of these ports are similar to those of international ports in Taiwan but are more competitive, mainly as a result of having endless amounts of creativity. For instance, Singapore Port increases the service effectiveness through the development of information system as well as the concordance between port management and shipping companies; while Hong Kong integrates the flow of cargos and capital under the limited area of land to successfully create port value. Therefore, the competitive advantages of international ports must be studied from a service innovation perspective.

Although many academic studies have investigated service innovation (Gallouj and Weinstein, 1997; Windrum and Tomlinson, 1999; De Jong and Marsili, 2006), the research issue in most studies is the application of service innovation in the B2C industry (Johne and Davies, 2000; Miles, 2008). However, the value of service innovation is not limited to increasing the quality of service delivered to customers. The most important value is creating integrated value by applying the knowledge. Research in service innovation applied to B2B industry is insufficient, and global trends in international logistics have transformed commercial ports. The performance indices of international commercial ports are expanded from efficiency operation to value creation. Accordingly, indices are needed to assess the service innovation of international ports in Taiwan in order to achieve the objectives of operation management. Especially, Keelung Port is under transformation caused by the declining container volumes and vessels, and therefore is chosen as the research target.

This study applied QFD, a planning tool used worldwide,

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because it effectively translates customer needs and desires into product/service design and technical specifications. In developing the relationship matrix of QFD, the linguistic values were provided for respondents to assess the relationship level between customer requirements and ways for achieving these requirements easily. Therefore, fuzzy methodology was used to describe these linguistic values.

The rest of this paper is organized as follows. Section 2 summarizes the literature on the evolution of service innovation research perspective, port innovation, and factors affecting service innovation. Section 3 describes the methodologies of Fuzzy set theory and QFD together with data collection. Section 4 describes the empirical results. Finally, Section 5 concludes the study and suggests further research.

## II. LITERATURE REVIEW

### 1. The Evolution of Service Innovation Research Perspective

Innovation can be categorized into product innovation, manufacturing innovation and service innovation (Miles, 2008). Early studies of innovation in the service industry focused on conceptualizing service innovation and innovation activities in individual case studies (Gallouj and Weinstein, 1997; Toivonen and Tuominen, 2009). Later, it was realized that service innovation was not just introducing new service, but also improving existing service delivery system. Pavitt (1984) suggested "supplier dominated" and "information intensive" as two core dimensions of service innovation; the latter emphasized the use of information and communication technology in business models. Since 1990s, service innovation has slowly moved away from the manufacturing industry. Barras (1986) proposed the concept of Reverse Product Cycle and reckoned that the development of service innovation should differ from that in the manufacturing industry as manufacturing innovation tended to be a result of the drive of technology, whereas innovations in the service industry concentrated on the development of the application of information technology.

A recently developed perspective is the synthesis perspective, which is aimed at a specific market network for research purposes, as it believes that there are interactions between the manufacturing industry and the service industry. This view extends the scope of service innovation from process oriented activities to accumulation of knowledge and abstract technology because service innovation is expected to have a role beyond R&D activities.

### 2. Port Innovation

Competition among international harbors is increasing in the current economic environment, and the functions of international harbors have gradually changed from the traditional loading and discharging operation to the logistic integration. Therefore, the ability to innovate is considered a core competence of international harbors (Acciaro et al., 2014). Regarding the issue of port innovation, some researchers have studied the operation innovation of international harbors from the service quality perspective. For example, Ugboma et al. (2007) tried to identify gaps in the service quality of the port operation by using the SERVQUAL model. Besides constructing service quality indices based on the SERVQUAL model, the authors studied the relationship between service quality and customer satisfaction and concluded that the meaning of exercising service quality was to provide over expected service to customers for increasing their satisfaction. Accordingly, increasing the service quality may strengthen the contact with customers, and the structure of the SERVQUAL model may be a useful guide for promoting innovation. Lee et al. (2013) then analyzed influential factors in service quality based on operating process and found that service quality was a result of service innovation, that is, through the improvement of operating process, service innovation could be exercised and better service quality would be followed. However, their study was performed from the perspective of shipping liners and focused on port operating process innovation. Other process innovation issues concerning international harbors that need further study include logistics operating, planning and management.

Ding (2009) and Yang et al. (2013) conceptualized international harbors as a system of service delivery and used fuzzy quality function deployment method (FQFD) to reveal factors that affect the performance of service delivery system from the dimensions of customer needs and technical requirements. Regarding customer needs, the important factors are advantageous port logistics operating costs, international port policy, port logistics operational efficiency, and high-quality logistics facilities (Yang et al., 2013); the most important technical requirements are improving the functional activities of customer services, berth operation system, traffic links to outskirts, handling operation system, IT integration management system, storage and yard operation system, and harbor operation system (Ding, 2009).

Lee and Hu (2012) compared the service quality of international harbors in major Asian countries, including the ports of Singapore, Shanghai, Hong Kong, Busan, and Kaohsiung, and discussed the key successful factors in the operating innovativeness of Singapore port, which was the most successful port. Analysis of data for 15 shipping liners revealed that Singapore port succeeded by investing limited resources into the new operating items that customers expected most. Therefore, the key factors in successful port innovation are grasping customer needs at all times and quickly responding to those needs but not investing in hardware infrastructure without reasons.

In addition to the concept of process and service quality, introducing the information technique is an important port innovation issue. However, this issue is rarely reported. According to Keceli (2011), communication, connection and coordination among international harbor organizations affect their operating efficiency and effectiveness. By applying the appropriate techniques of information and communication network, an information exchange and connection platform can be built to strengthen the response capability of international harbor as well as increase the effectiveness of internal communication to reach the objective of bettering service quality.

The focus of recent studies of port innovation has changed from administrative aspects to environmental-friendliness and logistical aspects. Peris et al. (2005) considered the sustainability of port management systems and deliberated on the environmental-friendliness of their operating process and management. Notteboom and Winkelmans (2001) used an international logistical operation model to explore the challenges faced by port authorities, including issues of adopting new roles to respond to climate change as well as establishing new operation strategies. De Martino et al. (2013) reported that port innovation has expanded from technology innovation to human, service, and organizational innovation. They suggested that port management should try to develop a knowledge-intensive organization because of the essential role of knowledge in innovation.

Although innovation is closely related to operating performance (Jenssen and Randoey, 2006), studies of the issue of innovation in the research field of international harbor and shipping company are limited. Additionally, studies of international harbor innovation are usually performed from the viewpoint of service quality to guide the innovation, and none of them are systematically applying the theory of innovation to lead the innovation activities of international harbor. An international harbor is essentially a service delivery system. Accordingly, this research studied the service innovation of international harbor by applying the viewpoint of service innovation. The objective was to fill the gap in the literature on international harbors and service innovation.

## 3. Factors Affecting Service Innovation

The important factors affecting service innovation differ in each industry. Panesar and Markeset (2008) discussed important factors in different stages of the development of service innovation and defined the source of innovation, planning aspects, decision affecting factors and aspects which aided service innovation. The authors recognized four factors that affect service innovation at different stages: organizational culture, structure and internal processes, source of service innovation, and internal and external connections. Regarding organizational development and change, the process of change results from external stimulation, which is a source of service innovation. A healthy organization that has sound internal and external connections can realize the meaning of environmental change clearly and start the service innovation process. In most organizations with good service innovation, the changes started from the structure and internal processes and then expanded to the organizational culture. Accordingly, this study considered the four factors as major influences to service innovation, from internal to external affecting organization to promote the service innovation process successfully.

### *1) Service Innovation Management and Organizational Culture*

In the early stages of service development, administrators should take actions to support innovation activities, e.g., continuously communicating with other staff members and conveying the importance of innovation, or turning some innovative ideas and demonstrations into actions (Debackere et al., 1998). Since the results of service innovation are highly uncertain, even in a mature development stage, service innovation requires complete support from management. To encourage employees to make their best efforst, administrators can assure them that they will not be penalized for an innovation activity that fails. Additionally, when employees feel that they have enough freedom, the limitations on innovation activities are reduced, and the chance of developing innovation is increased (Vermeulen, 2001). Also, companies with an open culture are willing to support the exchange and collection of views on service innovation activities (Lievens and Moenaertm, 2000), but companies that have communication problems have slower innovation or a reduced chance of success in developing an innovation activity (Vermeulen and Dankbaar, 2002).

### *2) Organizational Structure and Internal Processes*

Enterprises with different organizational designs have different impacts on service innovation. Kanerva et al. (2006) proposed that the service industry implements different changes and innovations in organizations. The wholesale industry and financial industry are the most obvious examples. Enterprises that establish innovation departments support innovation activities by adjusting the structure of the organization. Rotation of jobs in an organization also allows employees to broaden their view by giving them different work and new challenges. Job rotation can also nurture creativity and problem solving skills.

### *3) The Source of Service Innovation*

Studies show service innovations often result from competitive imitations between companies in the same industry, and not from complicated procedures and methods to create new innovative ideas. Martin and Horne (1993) believed the service industry might gain innovative ideas from discussing with the clients. Additionally, formalized systems and tools can stimulate creativity in employees. For example, workers can brainstorm new ideas and unearth potential development in innovation activities; the standards and procedures of the organization can help employees to materialize the idea, and achieve procedural development.

### *4) The Internal and External Connections of Organizations*

From a system point of view, innovation is an interactive process among stakeholders in a dynamic environment when the enterprise is undergoing value activities (Vence and Trigo, 2009). That is, partners that cooperate with the organization and the method of cooperation are also factors that affect service innovation. Statistical data also show that service companies are inclined to work with relevant agencies during the innovation process than manufacturing companies. Vermeulen (2001) reported that organizations that keep in contact with external operations not only gain feedback and response from existing services, they also gain relevant information from competing companies. Some enterprises even use the innovation activities of their competitors as their main source of innovation. An empirical study by Teixeira and Ziskin (1993) found that about 80% of banks and insurance companies relied on their competitors as their main source of innovation. Therefore, managers must have the drive to motivate employees and external support systems or peripheral industries to maintain close interactions.

Clients have a vital role in the service innovation process. In the time of innovative ideas creating, product testing, and development assessment, the client is always involved (Martin and Horne 1993). Den Hertog (2000) discussed the possibility of service innovation through the client interface to allow clients to help make changes in the design of services or products. Therefore, a good client relationship should be a driving force of service innovation.

*5) Knowledge Management*

Some service industries are knowledge-intensive or use knowledge as the driving factor for service innovation. Evangelista (2006) reported that service industries that innovate frequently, e.g., the telecommunications and software industries, rely on inside knowledge while traditional service industries used technology to create new hardware, software and other functions. In Vence and Trigo (2009), service industries classified as knowledge-intensive and high innovation-intensive used a large amount of knowledge and were good at collection, integration and applying the knowledge, and this was the reason for fast innovation. Since this type of innovation is related to the client, high and positive interaction with clients leads to a positive effect on service innovation.

## III. METHODOLOGY

The Fuzzy set theory, Quality function deployment and data applied in this study are briefly described as following.

### 1. Fuzzy Set Theory

Zadeh in 1965 proposed that human thought, ratiocination and perception of the surrounding environment were unclear or confused in nature. Accordingly, the conventional quantity methodology was replaced with the Fuzzy set theory to solve the uncertainty and fuzziness of real environment in analysis of decision making. Fuzzy set theory is particularly useful for solving problems involving the criterion that are not precisely defined as well as information that is in vague and imprecise terms.

*1) Triangular Fuzzy Number*

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 $A$ to a real number in the interval [0, 1]. The function value $f_A(x)$ represents the grade of membership of $x$ in $A$. The larger the $f_A(x)$, the stronger the grade of membership for $x$ in $A$ would be.

A fuzzy number $A$ in $\Re$ (real line) is a triangular fuzzy number if its membership function $f_A$: $\Re \rightarrow [0,1]$ is

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

with $-\infty < c \le a \le b < \infty$. The triangular fuzzy number $A$ 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 possible value of evaluation data. The $c$ 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 would be.

*2) Fuzzy Linguistic Values*

In designing the questionnaire of relationship strength between the customer wants and technique solutions of service delivery systems of ports, the linguistic expressions, high related, medium related, low related and none related, are used for response of experts. The fuzzy set of the relationship degree is S = {*high, medium, low, none*}. The linguistic values are defined according to triangular fuzzy number as *high* = (0.5, 0.7, 1), *medium* = (0.3, 0.5, 0.7), *low* = (0, 0.3, 0.5), and *none* = (0, 0, 0).

*3) The Algebraic Operation of Fuzzy Number*

By the extension principle (Zadeh, 1965), the fuzzy addition, ⊕, of any two triangular fuzzy numbers is also triangular fuzzy numbers. But the fuzzy multiplication, ⊗, of any two triangular fuzzy numbers is only approximate triangular fuzzy numbers. That is, let $A_1 = (c_1, a_1, b_1)$ and $A_2 = (c_2, a_2, b_2)$ be fuzzy numbers, then the algebraic operation of $A_1$ and $A_2$ can be expressed as

$$\begin{aligned} &A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2); \\ &k \otimes A = (kc, ka, kb),\ k \in \Re,\ k \ge 0 \\ &A_1 \otimes A_2 \cong (c_1 c_2, a_1 a_2, b_1 b_2),\ \text{if } c_1 \ge 0 \text{ and } c_2 \ge 0 \end{aligned} \tag{2}$$

*4) Ranking of Triangular Fuzzy Numbers*

The ranking of fuzzy numbers is important for the fuzzy evaluation of service delivery systems of ports. In this study, the graded mean integration representation method proposed by Chen and Hsieh (2000) is used to determine the fuzzy number score ranking of each technique solutions.

Let $A_i = (c_i, a_i, b_i)$, $i = 1, 2, \ldots, n$, be n triangular fuzzy numbers, through the method of graded mean integration representation, the ranking value of $A_i$ is

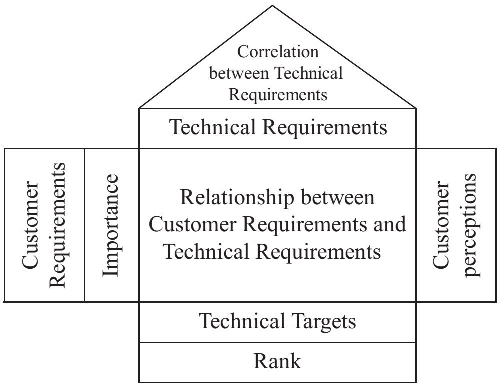


**Fig. 1. Basic components of the house of quality.**

$$R(A_i) = \frac{c_i + 4a_i + b_i}{6} \tag{3}$$

Let $A_i$ and $A_j$ be two triangular fuzzy numbers, the ranking order define as

$$A_i > A_j \Leftrightarrow R(A_i) > R(A_j)$$

$$A_i = A_j \Leftrightarrow R(A_i) = R(A_j)$$

$$A_i < A_j \Leftrightarrow R(A_i) < R(A_j)$$

By Eq. (3) and the definition of fuzzy ranking, the ranking value of $n$ triangular fuzzy numbers can be easily calculated and the ranking of the $n$ triangular fuzzy numbers can be effectively determined.

## 2. Quality Function Deployment

Quality function deployment introduced in 1966 by Yoji Akao was first implemented at Mitsubishi Kobe Shipyard in 1972 (Costa et al., 2001). After successful implementation by many well-known businesses in Japan, such as Toyota, Ford and Xerox began applying QFD in the late 1980s. Since then, QFD has been widely used by many Japanese, U.S. and European firms. The QFD is a planning tool that translates the "voice of customer", i.e., customer needs and desires, into product/service design as well as the technical process specifications. Accordingly, adoption of QFD not only increases customer satisfaction, it also minimizes costs by reducing cycle time and product designs. By establishing and maintaining QFD documentation, firms can also improve the effectiveness of communication between departments and enhance teamwork (Andronikidis et al., 2009).

### *1) House of Quality*

In conventional QFD, product design is a four-phase process that includes customer requirement planning, the part characteristics deployment, the manufacturing process and the operations condition or control (Cohen, 1995). These phases are developed by tied related matrices; that is, the columns of one matrix become the rows of the next matrix (Partovi, 1999). This study focused on the customer requirement planning phase that begins with the matrix called the "House of Quality (HOQ)" (Hauser and Clausing, 1988). Fig. 1 shows the basic components of the HOQ, which is denoted as the American style of HOQ. The Japanese style of HOQ is similar to that in Fig. 1 but does not contain the correlation matrix in the roof. Since the correlation between technical requirements is not the objective of this study, accordingly, the Japanese style of HOQ is applied.

**Table 1. Customer requirements-objectives of service innovation.**

| Dimensions | Code | Items |
|---|---|---|
| Service re-engineering | C11 | Apply new technologies to develop new services |
| | C12 | Cooperate with suppliers to develop new services |
| | C13 | Provide favorable fares and agreements |
| | C14 | Create new service process to reduce cost |
| Customer response | C21 | Communicate with customers friendly |
| | C22 | Provide diversified new services in accordance with customers' needs |
| | C23 | Assist customers to proceed service innovation |
| Service improvement and reorientation | C31 | Create new service process to increase profit |
| | C32 | Improve service process to reduce waiting time for customers |
| | C33 | Repair and renew port equipment |
| | C34 | Restructure port operation in accordance with its status |

### *2) Customer Requirements and Technical Requirements*

In this study, QFD theory was used to explore the construction of service innovation indices for international harbors. According to the HOQ concept, the customer requirements representing the "voice of the customer" are available through the market research on the needs and desires of customers in the real world. Therefore, the objectives of service innovation in this study are defined as customer requirements. Technical requirements are technical specifications showing how the products or services are to be developed by the company, which include the resources to be input as well as the system and process to be built by service innovation. The items listed in customer requirements (the objectives of service innovation) and the technical requirements (the input and process of service innovation) are based on a review of the literature on service innovation, including organizational culture, structure and internal processes, and internal and external connections. These items were modified after discussion with port managers to suit port operations. Customer requirements are divided into three dimensions according to their characteristics: service re-engineering, customer response, and service improvement and reorientation. Table 1 shows that each dimension includes three to four items of requirements, which are self-explanatory.

**Table 2. Technical requirements-input and process of service innovation.**

| Dimensions | Code | Items |
|---|---|---|
| Service delivery reform and innovation | A11 | Possess the sense to discover problems |
| | A12 | Establish a well-designed knowledge exchanging and sharing network |
| | A13 | Have good relationship of horizontal division of labor |
| | A14 | Possess the ability to develop the customized system |
| | A15 | Integrate management functions within the organization |
| | A16 | Rotate jobs with learning orientation |
| | A17 | Establish a port education and training center |
| Partnership Reinforcement | A21 | Establish more cooperation relationship with foreign ports |
| | A22 | Enhance the communication with domestic and foreign ports |
| | A23 | Cooperate more with external knowledge research units |
| | A24 | Enhance the cooperation system with up-stream and down-stream partners |

Table 2 divides the technical requirements into two dimensions. Service delivery reform and innovation dimension includes 7 items of requirements and partnership reinforcement dimension includes 4 items.

### 3. Data Collection

Two-stage questionnaires were designed to evaluate the priorities of customer and technical requirements. In first stage, questionnaire was developed according to the customer requirements of Table 1. Respondents were asked to express the degree of importance and perceived satisfaction on each item of customer requirements by using Likert 5-point scale. Out of 250 questionnaires delivered in the first season of 2014 to customers of Keelung port, including managers and senior employees of ocean carriers, shipping agents, ocean freight forwarders and terminal stevedores, 199 questionnaires were retrieved. Of these, 154 of them were considered effective. The Cronbach's α values were as follows: service re-engineering (0.76), customer response (0.72), and service improvement and reorientation (0.77). In addition to the reliability, these questionnaires are conformed to content and construct validities.

The questionnaire in second stage was designed by a matrix that combined the items for customer requirements and technical requirements shown in the Table 1 and Table 2, respectively. Respondents were asked to express the extent to which the technical solution contributes to the needs and desires of the customer. Relationships were classified as high, medium, low, or none in this study. Seven experts in port operation respond the questionnaires. Three of them are top-level management of Keelung port, two are port authorities, and the last two are scholars.

**Table 3. Statistic results, weights and priority of customer requirements.**

| Item code | Mean of Importance $\overline{X}_i$ | Mean of Satisfaction $\overline{Y}_i$ | Original Weight $OW_i$ | Normalized Weight $NW_i$ | Customer Priority |
|---|---|---|---|---|---|
| C11 | 4.59 | 3.64 | 10.8324 | 0.0853 | 11 |
| C12 | 4.51 | 3.56 | 11.0044 | 0.0867 | 10 |
| C13 | 4.28 | 3.42 | 11.0424 | 0.0869 | 9 |
| C14 | 4.49 | 3.41 | 11.6291 | 0.0916 | 5 |
| C21 | 4.41 | 3.36 | 11.6424 | 0.0917 | 4 |
| C22 | 4.26 | 3.31 | 11.4594 | 0.0902 | 7 |
| C23 | 4.18 | 3.22 | 11.6204 | 0.0915 | 6 |
| C31 | 4.37 | 3.12 | 12.5856 | 0.0991 | 1 |
| C32 | 4.49 | 3.34 | 11.9434 | 0.0940 | 3 |
| C33 | 4.21 | 3.32 | 11.2828 | 0.0888 | 8 |
| C34 | 4.32 | 3.23 | 11.9664 | 0.0942 | 2 |

## IV. EMPIRICAL RESULTS

### 1. Customer Priority - Objectives of Service Innovation

In Table 3, the statistical results for each customer requirement items in stage one questionnaire are shown in the second and third columns. In the importance section, respondents recognize that C11: apply new technologies to develop new services (mean = 4.59) is the most important customer requirement item and the second important item is C12: cooperate with suppliers to develop new services (4.51), which is followed by C14: create new service process to reduce cost (4.49) and C32: improve service process to reduce waiting time for customers (4.49); while C23: assist customers to proceed service innovation (4.18) is the least important item that customers want. Compared to the mean value for importance, the mean value for each item in the satisfaction section is much smaller. The C11 (apply new technologies to develop new services (3.64)) and C31 (create new service process to increase profit (3.12)) had the highest and lowest perceived satisfaction, respectively.

Comparisons of the mean values for importance and satisfaction of each customer requirement items revealed that the item with high importance but low satisfaction should have high priority for improvement. Accordingly, the priority of each customer requirement items should be determined. Let $\overline{X}_i$ and $\overline{Y}_i$, $i$ = 1, 2, …, n, be the mean of users' importance and satisfaction of item $C_i$, respectively. Table 3 (fourth column) shows the original weight ($OW_i$) of $C_i$, which was calculated by $OW_i = \overline{X}_i\ (6 - \overline{Y}_i)$. To simplify the comparison, the crisp weights are normalized and denoted by $NW_i = OW_i / \sum_{i=1}^{n} OW_i$ as shown on the fifth column. The last column of Table 3 exhibits the customer priority order of services requirement. The first three items that should be improved to increase the quality of service delivery system for port of

**Table 4. The Fuzzy solution of technical requirements for Port of Keelung.**

| Customer requirement | Technical requirements | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A11 | A12 | A13 | A14 | A15 | A16 | A17 | A21 | A22 | A23 | A24 |
| | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) | (c, a, b) |
| C11 | (0.37,0.54,0.77) | (0.44,0.64,0.91) | (0.20,0.40,0.59) | (0.30,0.53,0.77) | (0.24,0.39,0.54) | (0.13,0.26,0.37) | (0.37,0.59,0.84) | (0.19,0.36,0.53) | (0.29,0.49,0.71) | (0.37,0.54,0.77) | (0.16,0.33,0.49) |
| C12 | (0.47,0.67,0.96) | (0.37,0.54,0.77) | (0.37,0.59,0.84) | (0.34,0.51,0.73) | (0.24,0.43,0.61) | (0.13,0.30,0.44) | (0.23,0.43,0.63) | (0.16,0.29,0.41) | (0.16,0.37,0.56) | (0.19,0.40,0.60) | (0.47,0.67,0.96) |
| C13 | (0.19,0.36,0.53) | (0.09,0.23,0.34) | (0.04,0.16,0.24) | (0.23,0.39,0.56) | (0.24,0.43,0.61) | (0.04,0.24,0.39) | (0.04,0.16,0.24) | (0.30,0.49,0.70) | (0.19,0.31,0.46) | (0.00,0.17,0.29) | (0.40,0.57,0.81) |
| C14 | (0.23,0.43,0.63) | (0.16,0.33,0.49) | (0.33,0.56,0.81) | (0.31,0.53,0.76) | (0.37,0.59,0.84) | (0.16,0.29,0.41) | (0.27,0.41,0.59) | (0.24,0.43,0.61) | (0.17,0.37,0.54) | (0.17,0.37,0.54) | (0.43,0.60,0.86) |
| C21 | (0.27,0.46,0.66) | (0.27,0.46,0.66) | (0.23,0.39,0.56) | (0.47,0.67,0.96) | (0.34,0.51,0.73) | (0.16,0.29,0.41) | (0.27,0.46,0.66) | (0.11,0.21,0.31) | (0.19,0.44,0.67) | (0.09,0.27,0.41) | (0.21,0.34,0.50) |
| C22 | (0.47,0.67,0.96) | (0.37,0.54,0.77) | (0.37,0.59,0.84) | (0.50,0.70,1.00) | (0.40,0.61,0.89) | (0.20,0.40, 0.59) | (0.24,0.43,0.61) | (0.27,0.41,0.59) | (0.24,0.47,0.69) | (0.00,0.17,0.29) | (0.37,0.59,0.84) |
| C23 | (0.33,0.51,0.74) | (0.36,0.56,0.79) | (0.23,0.34,0.49) | (0.50,0.70,1.00) | (0.21,0.40,0.57) | (0.29,0.46,0.64) | (0.16,0.29,0.41) | (0.16,0.33, 0.49) | (0.20,0.31,0.44) | (0.13,0.30,0.44) | (0.30,0.49,0.70) |
| C31 | (0.44,0.64,0.91) | (0.36,0.56,0.79) | (0.30,0.49,0.70) | (0.30,0.44,0.63) | (0.39,0.59,0.83) | (0.11,0.30,0.46) | (0.16,0.37,0.56) | (0.13,0.30,0.44) | (0.21,0.40,0.57) | (0.16,0.37,0.56) | (0.40,0.57,0.81) |
| C32 | (0.41,0.61,0.87) | (0.27,0.50,0.73) | (0.21,0.39,0.57) | (0.40,0.61,0.89) | (0.36,0.59,0.86) | (0.26,0.46,0.67) | (0.31,0.49,0.69) | (0.16,0.29,0.41) | (0.11,0.34,0.53) | (0.16,0.37,0.56) | (0.30,0.44,0.63) |
| C33 | (0.19,0.31,0.46) | (0.16,0.29,0.41) | (0.13,0.30,0.44) | (0.09,0.27,0.41) | (0.13,0.30,0.44) | (0.13,0.34,0.51) | (0.09,0.31,0.49) | (0.09,0.23,0.34) | (0.20,0.36,0.51) | (0.09,0.27,0.41) | (0.09,0.27,0.41) |
| C34 | (0.33,0.56,0.81) | (0.31,0.53,0.76) | (0.11,0.30,0.46) | (0.17,0.37,0.54) | (0.37,0.59,0.84) | (0.19,0.36,0.53) | (0.23,0.43,0.63) | (0.27,0.41,0.59) | (0.33,0.47,0.67) | (0.13,0.26,0.37) | (0.23,0.39,0.56) |
| Relationship strength ($RS_j$) | (0.34,0.53,0.76) | (0.29,0.47,0.68) | (0.23,0.41,0.60) | (0.33,0.52,0.75) | (0.30,0.50,0.71) | (0.16,0.34,0.50) | (0.22,0.40,0.58) | (0.19,0.34,0.49) | (0.21,0.40,0.58) | (0.13,0.32,0.48) | (0.31,0.48,0.69) |
| Representation Value $R(A_j)$ | 0.5331 | 0.4745 | 0.4100 | 0.5272 | 0.4988 | 0.3338 | 0.3962 | 0.3399 | 0.3942 | 0.3134 | 0.4846 |
| Technique priority | 1 | 5 | 6 | 2 | 3 | 10 | 7 | 9 | 8 | 11 | 4 |

Keelung are C31: create new service process to increase profit, C34: restructure port operation in accordance with its status, and C32: improve service process to reduce waiting time for customers.

### 2. Technique Priority - Input and Process of Service Innovation

Table 4 shows the fuzzy solution of technique requirements for Port of Keelung. Four linguistic values (high, medium, low and none) were used in the stage two questionnaire to measure the relationship degree of customer requirement $C_i$, $i = 1, 2, \ldots, n$, corresponding to technique solution $A_j$, $j = 1, 2, \ldots, m$. Let $X_{ij}^h$, $h = 1, 2, \ldots, l$, be the linguistic value given to $C_i$ corresponding to $A_j$ by expert $h$, and then, these linguistic values were transferred into triangular fuzzy numbers. The answers obtained for the seven valid responses were used to calculate the integrated fuzzy relationship degree, $R_{ij} = (c_{ij}, a_{ij}, b_{ij})$, $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$, by arithmetic mean method. The first part of Table 4 shows how the integrated fuzzy relationship matrix, $[R_{ij}]_{n \times m}$ was constructed.

Since each customer requirement had a different priority for improvement, the fuzzy relationship strength, $RS_j$, of total customer wants corresponding to each technical solution can be calculated by integrated fuzzy relationship degree, $R_{ij}$, multiplying the normalized weight, $NW_i$, of each customer requirement, that is, $RS_j = (\sum_{i=1}^{n} c_{ij} \times NW_i, \sum_{i=1}^{n} a_{ij} \times NW_i, \sum_{i=1}^{n} b_{ij} \times NW_i)$, $j = 1, 2, \ldots, m$. The graded mean integration representation method is used to defuzzify the fuzzy relationship strength, $RS_j$. Accordingly, the representation value, $R(A_j)$ is calculated using Eq. (3), and the rank of technique priority is determined according to the ranking rules. The fuzzy relationship strength, representation value and the rank of technique priority are shown on the bottom of Table 4, which shows that the technical solutions that the management of Keelung Ports should apply to satisfy customer needs and desires are A11: possess the sense to discover problems, A14: possess the ability to develop the customized system, A15: integrate management functions within the organization, A24: enhance the cooperation system with up-stream and down-stream partners, and A12: establish a well-designed knowledge exchanging and sharing network.

## V. CONCLUSION AND SUGGESTION

### 1. Conclusion and Discussion

In this study, QFD methods were used as the analysis instrument to explore the construction of service innovation indices for international harbors. The analysis results showed that the three most important priority indices in the customer requirements, the objectives of service innovation, were: create new service process to increase profit; restructure port operation in accordance with its status; and improve service process to reduce waiting time for customers. To achieve these objectives, five technique priority indices were found most relevant: possess the sense to discover problems; possess the ability to develop the customized system; integrate management functions within the organization; enhance the cooperation system with up-stream and down-stream partners; and establish a well-designed knowledge exchanging and sharing network. Based on the concept of Input-Process-Output (IPO), the indices for measuring service innovation were separated into two groups, result (the objectives of service innovation), and input and process (ways to implement service innovation).

Since service innovation concepts are very abstract and cannot be completely measured by result indices, this research introduced the ways and means indices by applying the concept of IPO, which resemble to the concept of employee performance appraisal adopted by the business organization. If the concrete results of employee performance cannot be evaluated, the ways and means indices could be used as an auxiliary instrument for analysis. Therefore, the service innovation performance of international harbors should be evaluated from the perspective of result and ways for objectivity and thoughtfulness. However, the ways and means are highly correlated with the results. Compared to the indices for the ways and means dimension, the results indices are more objective and should be the main indices for evaluating service innovation performance. Besides being an auxiliary instrument in measurement, when the result indices are not clear and definite, the ways and means indices can be used as guidelines for achieving the performance objectives.

In the future, international harbors can innovate by regenerating profit model (create new service process to increase profit), transforming business (restructure port operation in accordance with its status) and reducing process time (improve service process to reduce waiting time for customers). These indices essentially represent the operating environment of international harbors, which are now applying a new model of innovation that integrates the flows of logistics, capitals and labors. The operations are no longer limited to vessels steering into and out of harbors, cargos loading and discharging as well as peripheral services. According to the service innovation concept, ports such as the major international harbors in Asia can move forward to become free trade zone ports and provide diversified business operation. In such operation model, the capability, collaboration network, and knowledge management system possessed by port authority shall be the means to carry out the foregoing service innovation performance.

Finally, application of the service innovation concept to international port management reveals that "knowledge" is the most important issue in port operations. By changing the role of international ports, management can reevaluate the value of port stakeholders instead of emphasizing the efficiency alone. The hardware structures need to match with the software (systems, procedures, cultures, etc.) in order to attain the expected objectives in the process of creating integrated value.

**2. Suggestion**

Based on the findings from data analysis, this study provides the following suggestions.

(1) In response to trends and the needs of international logistics, port service innovations should integrate free trading zones with logistical innovation in order to create a new operating model that increases the added value of port.

(2) Service innovation should consider internal and external environmental conditions. That is, port management should investigate the external environment to find factors which hinder the promotion of service innovation, and eliminate the relevant obstacle through the coordination of internal and external resources.

(3) To establish a culture that emphasizes the sharing of knowledge, the port management should create the common value of service innovation. Accordingly, the common consensus of objectives, methodology, organizational structure, and procedures should be gradually implemented.

(4) Port management should introduce external knowledge and work closely with academic research institutes and foreign international ports to gain the ability to promote process innovation.

(5) This study investigated the issue of service innovation from the viewpoint of port management. Following the diversified development of international harbors, the stakeholders involved with ports are shipping industry in the past but expanded to public society (hydrophilic ports), environments (sustainable development), and governments (national safety and competitiveness). Different stakeholder viewpoints would result in service innovation performance indices with different contents and importance. Therefore, future studies should integrate the perspectives of all stakeholders to develop broad-minded performance indices of service innovation.

(6) This study was exploratory. After building the indices, confirmatory evidence shall be proceed for assuring the reliability and validity of indices. Future studies can perform the analysis in a larger sample according to the two dimension structure (three items in result dimension and 5 items in input and process dimension) provided by this study.

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