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Fuzzy MCDM Approach for Evaluating Intangible Resources Affecting Port Service Quality*

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ABSTRACT

Intangible resources consist of soft resources such as knowledge, information and capabilities. It is important for ports to enhance intangible as well as tangible resources to obtain sustainable competitive advantage. In this connection, this study aims to identify port intangible resources which may contribute to the delivery of port service quality and to propose a fuzzy TOPSIS approach to solve the port choice problem focusing on intangible resources. Fuzzy TOPSIS is appropriate to assist decision making with ambiguous and uncertain problems such as port choice with respect to intangible resources. In this paper, five port intangible resources were identified and evaluated and five leading container ports in the Asia-Pacific region were assessed in terms of their intangible resources. A survey questionnaire was sent to 21 experts who are working in shipping companies in Korea and involved in the selection of ports. It was found that customer and relational resource contributes most to the delivery of port service quality while Hong Kong appeared to be the port where intangible resources were most highly evaluated. This research helps to enrich the literature on port service quality and port choice evaluation. Its findings can also be used as guidelines for port managers to prioritise resources that may have greater influence on the delivery of port service quality and the subsequent training and education programs.

1. Introduction

The trends of globalization and containerization have increased the competition among rival ports in recent years. Besides, port privatization and commercialization are also identified as the reasons which enhance port competition because private ports induce more competitive pressure

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than public ports (Yuen et al., 2012). Moreover, ports are nowadays integrating more into supply chains than what they used to be as a part of the maritime transport chain (Magala and Sammons, 2008). In this respect, escalating competition has become an important momentum for ports to identify ways to enhance their competitiveness and keep them ahead of their competitors. In case of having similar characteristics and facilities, ports are required to differentiate themselves using their core strengths and advantages to be ahead in the competition. As port competition is increasingly intensified, it is crucial to identify the core factors derived from both tangible and intangible resources of ports which can help to secure their competitiveness.

Minimizing cost has always been a major consideration to most shippers and plays a main role in determining port choice. According to Magala and Sammons (2008), cost competition and service quality provided by the port were the two most important factors in port choice. Likewise, ports have focused on port price and service factors such as port location, facility, accessibility, shipment information, and port turnaround time (Murphy et al 1988, 1989, 1992; Ha 2003; Song and Yeo 2004). Although many studies have emphasized these factors, there remains the question of how these service factors may influence port competition. For example, reputation, knowledge of technology, efficient process, skilled personnel are intangible resources that can contribute to the strength of a port and its delivery of service quality. From the resource-based view (RBV), Wernerfelt (1984) identified brand names, capital, in-house knowledge of technology, efficient procedures, employment of skilled personnel, trade contacts, etc. as examples of resources which can be considered as the firm's resource strength. The above resources, also including skills, information and reputation, and relational asset, are classified as intangible resources (Knott 2009) and they represent capabilities or competences of a firm (Coates and McDermott 2002). The RBV explains the long-term sources of a firm's competitive advantage and sustainability. Barney (1991) argued that intangible resources help a firm to sustain its competitive advantages because these resources are heterogeneous and not completely mobile. Hence, it is not easy for competitors to imitate a firm's core capabilities (Hall 1992). This paper adopts the RBV to identify intangible resources which may influence the delivery of port service quality and thus port competition. Apart from identifying port intangible resources, this study also aims to evaluate their importance weights. Furthermore, leading Asia-Pacific competing ports were also examined to evaluate their service quality with regards to selected intangible resources. The evaluation of port intangible resources in relation to service quality is considered a multiple criteria decision making (MCDM) problem that includes diverse stakeholders. In addition, due to the abstractive nature of decision data and uncertainties in the real world when judging preferences and making decisions using multiple criteria, it is difficult to quantify the weights of the criteria and the rating of feasible alternatives (Mahdavi et al. 2009). Hence, we present a fuzzy TOPSIS approach (a technique for order preference similar to an ideal solution) for the purpose of this study. Fuzzy TOPSIS, using linguistic variables which reflect experts' judgements including preferences, helps to overcome the subjectivity of decision makers.

The rest of this paper is organised as follows. A review of literature on port service quality in relation to port competitiveness and intangible resources is presented in Section 2. Section 3 identifies the intangible resources influencing port service quality and ports for the examination, as well as the fuzzy TOPSIS research methodology. The empirical analysis applying fuzzy TOPSIS with regards to intangible resources and the targeted ports is performed in Section 4. Finally, the conclusion which includes academic and managerial implications are presented.

2. Literature Review

The domain of port service quality was initially studied in Foster's research (1978, 1979) whose importance was indicated by Ha (2003) since they highlighted different criteria depending on various groups of decision makers. Specifically, service quality and charges emerged as the most important factors to select a port in the second study of Foster (1979). Similarly, Willingale (1981) suggested some factors such as port pricing level, pricing practices, accessibility to ports, port facilities, and stability of port labour for the development of future port-routing pattern.

Ha (2003) compared and evaluated leading container ports using their service quality factors including information availability of port-related activities, port location, port turnaround time, facilities availability, port management, costs of port customer convenience from ship operators' and logistics managers' points of view. Especially, he suggested the importance of improving data availability and information flows. Ugboma et al. (2004) investigated the service quality of two Nigerian ports and highlighted not only customers' perceptions of the importance of key service quality factors but also their expectations of a swifter service and staff being more willingness to customers' needs.

Some studies have emphasised the importance of service quality as a strategy to enhance port competitiveness through customer satisfaction. A recent study revealed that there is a significant causal relationship between port service quality factors and customer satisfaction (Thai 2015), in which those factors relating to intangible resources of the port such as management, outcomes, process and image have more positive impact on customer satisfaction. Lu et al. (2011) mentioned that it is possible to improve the port capability by identifying the customer service needs of container terminals. To do that, they conducted an evaluation of customer satisfaction and the perceived importance of container terminals' service attributes. Chou (2010) identified the influential factors of carriers' port selections and addressed that they might be useful operation strategies and important port policies to enhance the ports' competitiveness and to attract potential containership' callings. Port charge, port operational efficiency, load/discharge efficiency and size and efficiency of container yard, hinterland economy and depth of berth were identified by Chou (2010) as important selection factors. Meanwhile, the possible attributes influencing port service quality were presented and optimal attributes were identified by the principal component analysis in the study of Kolanović (2008). Following the same theme, a comparative study (Cho et al. 2010) of the ports of Incheon and Shanghai was conducted to provide strategic implications for both ports with regard to service quality.

Studies to examine the factors affecting port competitiveness from various perspectives also exist. Tongzon (2009) mentioned that most studies examining factors of port selection are from the shippers' perspective and those from freight forwarders' perspective are relatively scant. He then evaluated key factors influencing port selection from the perspective of Southeast Asian freight forwarders. Meanwhile, different perspectives between truck liners and feeder service providers in port selection were studied by Chang et al. (2008) and this study considered six significant factors including terminal handling charges, local cargo volume, port location, berth availability, transhipment volume and feeder network. De Langen (2007) analysed port choice factors from shippers' and forwarders' views. His study showed similar views between shippers and forwarders in port selection but highlighted that the forwarders' demand for port service is more price elastic than that of shippers'. Similarly, Yuen et al. (2012) explored important factors to determine the competitiveness of container ports from the port user's perspective and eight factors were identified including port location, costs, port facility, shipping services, terminal operators, port information systems, hinterland connections and customs and government regulation.

Previous studies dealing with port competition factors including service quality appear to generally have two determinants: quantitative and qualitative factors (Tongzon 2009). According to this study, quantitative factors can be evaluated and compared in an objective way, while qualitative factors embody subjective influences like the port's marketing, flexibility, the level of cooperation and tradition. In many cases of evaluating or analysing factors associated with port service quality, quantitative factors and qualitative factors have been used in the blend. Our study is to target the domain of qualitative factors because, compared to quantitative factors, they have not been much examined in the literature, and are also relatively easy to get data.

Although there have been studies in the literature examining port selection factors, not much have been done to examine factors contributing to the delivery of port service quality and, to a lesser extent, those factors deriving from the port's intangible resources. Hence, this paper focuses on intangible resources referred to in the RBV to identify the qualitative factors that contribute to the delivery of port service quality. When we expand the competitive factors to theories of strategic management, we can find similarities with those in the RBV, which can explain the parameters of a company's competitive environment (Das and Teng 2000). Barney (1991) explained that a company's competitive strategy is critically affected by its accumulated resources. In addition, intangible resources are more sustainable than other resources so it is much more essential for firms to understand how to accumulate intangible resources (Hall 1993).

This paper contributes to applying the concept of resource-based theory in the field of port service quality and targeting only intangible resources influencing the delivery of port service quality. Moreover, this paper aims to evaluate the leading Asia-Pacific ports which are in competition to examine their relative service quality in term of intangible resources.

According to Ang and Wight (2009), intangible resources are generally unobservable and hard to quantify. Thus, the fuzzy TOPSIS approach is chosen as the method to assess the relative importance of intangible resources in relation to their contribution to the delivery of service quality in leading Asia-Pacific ports. This is due to the abstractive nature of intangible resources and the need for evaluation under multi-criteria decision making (MCDM).

3. Methodology

3.1. *Selection of Port Intangible Resources*

According to Fernández et al. (2000), intangible resources basically consist of soft resources like knowledge or information. Those characteristics can be found in the concept of port service quality and are applicable to port competitiveness. With a view of determining port intangible resources, related literature review was carried out and six resource factors were chosen.

Firstly, several studies of resource-based approach referred to the human knowledge that increases their professional qualifications or productivity. This is called human capital or human resources in the RBV. This type of intangible resource is often included in studies about port service quality. In this respect, Ha (2003) mentioned port's labour performance and port workers' foreign language skills as important port service quality aspects. Similarly, port employees' responsiveness, knowledge and skill (Pantouvakis et al, 2008), labour force's quality (Celik et al. 2009), employees' high qualification/skill level (Kolanović 2011) and professionalism of staff (Lu et al. 2011) were also mentioned respectively. The above-mentioned factors are deeply involved in human knowledge or skills, so it can be classified as human resource.

Secondly, the RBV also appreciates the importance of innovation techniques and technology and it is classified as technology capital or technology resources by many studies (Teece et al. 1997; Powell et al. 1997; Fernández et al. 2000). In this connection, it was argued that the level of ICT applications in port operations and management is an important element of port service quality (Thai 2015). Discussing port service quality, Ha (2003) also argued that establishing EDI system and provision of cargo tracing system are efficient way to improve port service quality. Being included in this types of resource are information technology ability (Chang et al. 2008), shipment information (Murphy et al. 1994), information accuracy and IT management system (Lu et al. 2011), electronic information availability and accessibility (Yuen et al. 2012).

Thirdly, Thai (2015) highlighted that the ability of the port's staff to demonstrate professional attitude and behaviour in meeting customers' requirements, respond quickly to their enquiries and requests, and possess good knowledge of their needs constitutes an important component of port service quality. Pantouvakis et al. (2008) also emphasised the importance of port's high quality services to the customers and acceptance of passengers' specific needs and personal requirements. Kolanović et al. (2011) affirmed about the value of informing and listening to customers and the willingness to negotiate with customers was also highlighted by Lu et al. (2011). These papers extensively addressed customer relationship as a key factor contributing to the delivery of port service quality. The above perspective is generally called relational capital in the RBV. Relational capital which includes reputation, long-term customer relationship, customer loyalty and brands is greatly valued (Fernández et al. 2000; Baxter et al. 2004; Hitt et al. 2006). The concept of relational capital has also been included in the studies of port service quality. Ha (2003) considered the immediate handling of container port users' dissatisfaction an important aspect of port service quality. Similarly, claims handling ability (Murphy 1994), port reputation (Chang et al. 2008) and accessibility and simplicity in contract (Kolanović et al. 2011) were also essential to the delivery of port service quality.

Fourthly, organizational capital is treated as one of the categories of intangible resources in the RBV and basically includes norms, guidelines and corporate cultures (Fernández et al. 2000). Existing similar factors in port service quality research are efficient operation and quality of customs clearance (Ha 2003; Chang et al. 2008; Kolanović et al. 2011), reliability and accuracy of operating plan (Pantouvakis et al. 2008; Celik et al. 2009), policies for reducing bureaucracy in administrative issues (Celik et al. 2009) and continuous improvement of customer-oriented operations and management processes (Thai 2015).

Fifthly, Baxter et al. (2004) noted renewal and development as an intangible resource and argued that it will have a potential influence on future value even though it has not manifested. Similarly, Chang et al. (2008) pointed out the possibility of niche market as a factor of port choice while the opportunity of intermodal transportation integrity to improve container ports' competitiveness was considered by Celik et al. (2009).

Lastly, the core competitive advantage by organization's ability is important to consistently meet environmental changes and changes of industry structure in a competitive and dynamic environment (Carmeli 2004). In this regard, this study selects an additional factor named port safety and security. Recent studies considered port safety and security as a significant factor of port service quality and choice. Furthermore, safety and security represent a special characteristic of ports compared to other different kinds of industries. Specifically, maritime security has emerged as a major international issue after the event of the September 11th attacks in the USA. The emphasis on and having good record of operational and work safety is an essential component which defines port service quality (Thai 2015). Chou (2010) also selected port safety as an influential factor to choose container port, while Celik et al. (2009) considered the preparation for catastrophic risks during terminal operations as a competitive strategy of a port. Meanwhile, the factor of safety and accidents handing was chosen to evaluate port competitiveness from the user's perspective (Yuen et al. 2012). In consideration of their importance, port safety and security is selected as a factor of port intangible resources.

Consequently, the six factors of intangible resources which contribute to the delivery of port service quality were selected. To ensure the face validity and suitability of these chosen factors, in-depth interviews were carried out with one academic and four experts who are working in shipping lines in Korea. We prepared an interview information sheet containing the selected factors with detailed description used in the literature. On the basis of the discussion and getting consensus, the fifth factor of renewal and development was removed. As a result of the in-depth interviews, five factors of intangible resources which contribute to the delivery of port service quality were identified, namely, human resource, technological resource, customer and relational resource, organizational resource and port safety and security.

3.2. *Determining the Ports for Evaluation and Structure of Decision-making*

With the selection of the five intangible factors in the above section, this study also aims to evaluate the service quality in terms of intangible resources of leading container ports. The ports considered for the evaluation of their intangible resources are in the top 10 of the global ranking in terms of their average throughputs during 2010 - 2012 (Table 1).

Table 1
Throughputs of global top ten ports (2011-2012)

Unit: (Million TEUs)

Ports	2010 (Ranking)	2011 (Ranking)	2012 (Ranking)	Average throughputs from 2010 to 2012 (Ranking)
Shanghai	29.07 (1)	31.74 (1)	32.53 (1)	31.11 (1)
Singapore	28.43 (2)	29.94 (2)	31.65 (2)	30.01 (2)
Hong Kong	23.70 (3)	24.38 (3)	23.10 (3)	23.73 (3)
Shenzhen	22.51 (4)	22.57 (4)	22.94 (4)	22.67 (4)
Busan	14.18 (5)	16.17 (5)	17.04 (5)	15.80 (5)
Ningbo	13.14 (6)	14.72 (6)	16.83 (6)	14.90 (6)
Guangzhou	12.55 (7)	14.26 (7)	14.74 (7)	13.85 (7)
Qingdao	12.01 (8)	13.02 (8)	14.50 (8)	13.18 (8)
Dubai	11.06(10)	13.01 (9)	13.30 (9)	12.46 (9)
Rotterdam	11.14 (9)	11.88(10)	11.87(10)	11.63(10)

Among the global top ten ports, only those in the Asia-Pacific region are evaluated for their service quality in terms of intangible resources. In particular, the container service routes within the Asia-Pacific region were examined to identify the ports which are in competition with each other. Given the Asia-Pacific routes in the global top 10 ports, the route of shipping company 'A' is Busan - Shanghai – Ningbo- Singapore; shipping company 'B' is Busan – Shanghai - Ningbo; shipping company C' is Shanghai – Ningbo - Hong Kong. Therefore, considering the container service routes of global shipping companies among the global top ten ports, five ports were chosen, namely, Shanghai, Singapore, Hong Kong, Busan and Ningbo. The shipping companies' evaluation of service quality in terms of intangible resources of five leading container ports is analysed using the fuzzy TOPSIS approach. In summary, the hierarchical structure of decision-making is shown in Fig. 1.

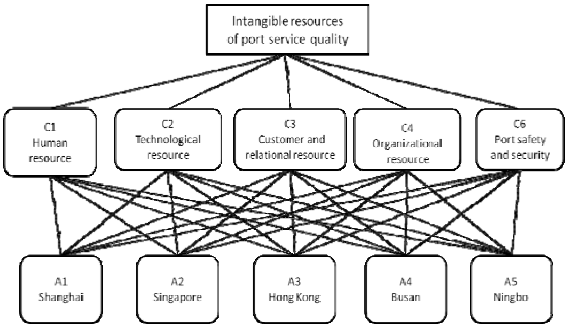

Fig. 1. Hierarchical structure of decision-making

3.3. *Fuzzy TOPSIS Method*

The technique for order preference by similarity to an ideal solution (TOPSIS), known as a technique of the most widely used multiple criteria decision-making (MCDM) methods, was proposed by Hwang and Yoon (1981). It is based on the basic principle that best chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution (Wu et al. 2009). The TOPSIS does not take into account the relative importance from two points (Mahdavi et al. 2009). Hence, Fuzzy TOPSIS is needed to take into consideration the relative importance of the criteria. Moreover, when evaluating values, there are various types of ambiguity and subjectivity. Numerous studies have attempted to apply fuzzy set theory in order to handle this ambiguity and subjectivity (Mahdavi et al. 2009). This study uses linguistic variable whose values are words or sentences to evaluate decision makers' subjective judgements. In other words, linguistic variables are used not only to get the importance weights of each criterion but also to measure the performance value of alternatives. The linguistic variables to evaluate the importance weight of each criterion for decision-makers are shown in Table 2. In addition, Table 3 shows linguistic variables to measure the preference of each alternative with regard to qualitative criteria.

Table 2
Linguistic variables for importance weight of each criterion

Linguistic scale	Triangular fuzzy numbers
Very Low (VI)	(0.1,0.1,0.3)
Low (L)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
High (H)	(0.5,0.7,0.9)
Very High (VH)	(0.7,0.9,0.9)

Table 3
Linguistic variables for importance weight of each alternative

Linguistic scale	Triangular fuzzy numbers
Very Poor (VP)	(1,1,3)
Poor (P)	(1,3,5)
Fair (F)	(3,5,7)
Good (G)	(5,7,9)
Very Good (VG)	(7,9,9)

The steps of fuzzy TOPSIS that were introduced by Awasthi et al. (2011) are applied in this paper. A fuzzy MCDM problem in case of m alternatives, n criteria and k decision makers can be presented in a fuzzy decision matrix format as:

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array} \qquad (1)$$

$$\tilde{W} = [\tilde{w}_1 \quad \tilde{w}_2 \quad \cdots \quad \tilde{w}_n],$$

where $i = 1,2,\cdots,m$, $j = 1,2,\cdots,n$ and $\tilde{w}_j$, $j = 1,2,\cdots,n$, are triangular fuzzy numbers. $A_1, A_2,\cdots,A_n$ represent alternatives to select, and $\tilde{w}_j$ is the weight of the j th criterion. $\tilde{x}_{ij}$ represents the performance rating of the alternative A_i with respect to the criterion C_j assessed by k decision makers.

Let all decision makers' fuzzy ratings be triangular fuzzy numbers $\tilde{R}_k = (a_k, b_k, c_k)$, $k = 1,2,\cdots,K$. The aggregated fuzzy performance rating is then given by

$\tilde{R} = (a,b,c)$, $\quad k = 1,2,\cdots,k$ where

$$a = \min_k \{a_k\}, \quad b = \frac{1}{K}\sum_{k=1}^{k} b_k, \qquad c = \max_k \{c_k\}. \qquad (2)$$

And, let the fuzzy rating and importance weight of the k th decision maker be and $\tilde{x}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$

$\tilde{w}_{jk} = \tilde{w}_{jk1}, \tilde{w}_{jk2}, \tilde{w}_{jk3}$, $i = 1,2,\cdots,m$, $j = 1,2,\cdots,n$ respectively, then the aggregated alternatives' fuzzy rating ($\tilde{x}_{ij}$) with respect to each criterion are given by $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ where

$$a_{ij} = \min_k \{a_{ijk}\}, \quad b_{ij} = \frac{1}{K}\sum_{k=1}^{k} b_{ijk}, \qquad c_{ij} = \max_k \{c_{ijk}\}. \qquad (3)$$

The aggregated fuzzy weights ($\tilde{w}_j$) of each criterion are computed as $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ where

$$w_{j1} = \min_k \{w_{jk1}\}, \quad w_{j2} = \frac{1}{K}\sum_{k=1}^{k} w_{jk2}, \quad w_{j3} = \max\{c_{jk3}\} \qquad (4)$$

Next, normalization is needed to transform the various criteria scales in multiple criteria decision making (MCDM). The linear scale transformation is considered here as a comparable scale. There are two kinds of criteria: benefit criteria (B, the higher the rating the better) and cost criteria (C, the lower the rating the better). Therefore, the normalized fuzzy-decision matrix $\tilde{R}$ is represented as

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}, \quad i = 1,2,\cdots,m, \qquad j = 1,2,\cdots,n \qquad (5)$$

Where,

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{C_{ij}}{c_j^*}\right), c_j^* = \max_i c_{ij}, \ j \in B, \qquad (6)$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), a_j^- = \min_i a_{ij}, \ j \in C, \qquad (7)$$

Multiplying the above normalized fuzzy decision matrix $\tilde{r}_{ij}$ with the weights ($\tilde{w}_j$) to compute the weighted normalized matrix $\tilde{V}$.

$\tilde{V} = [\tilde{v}_{ij}]_{m \times n}$, $i = 1,2,\cdots,m$, $\quad j = 1,2,\cdots,n$ where

$$\tilde{v}_{ij} = \tilde{r}_{ij}(\cdot)\tilde{w}_j \qquad (8)$$

Then, the fuzzy positive ideal solution (FPIS, A^*) and fuzzy negative ideal solution (FNIS, A^-) can be calculated as

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \cdots, \tilde{v}_n^*) \qquad \text{where} \qquad \tilde{v}_j^* = \max_i \{v_{ij3}\}$$
$$i = 1,2,\cdots,m, \quad j = 1,2,\cdots,n \qquad (9)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \cdots \tilde{v}_n^-) \qquad \text{where} \qquad \tilde{v}_j^- = \min_i \{v_{ij1}\}$$
$$i = 1,2,\cdots,m, \quad j = 1,2,\cdots,n \qquad (10)$$

The distance (d_i^*, d_i^-) of each alternative from A^* (FPIS) and A^- (FNIS) can be calculated as

$$d_i^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^*), \quad i = 1,2,\cdots,m \qquad (11)$$

$$d_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-), \quad j = 1,2,\cdots,m \qquad (12)$$

where $d_v(\tilde{m}, \tilde{n})$ represents the distance measurement between two fuzzy numbers which can be computed as

$$d_v(\tilde{m}, n) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]} \qquad (13)$$

The last step is to calculate the closeness coefficient (CC_i) which determines the ranking order of all alternatives. The closeness coefficient means the distances to the fuzzy positive ideal solution (A^*) and the fuzzy negative ideal solution (A^-). The closeness coefficient of each alternative can be calculated as

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \quad i = 1,2,\cdots,m \tag{14}$$

4. Empirical Analysis

A questionnaire was administered to 21 experts working in container shipping companies in Korea. These 21 experts have average work experience of 13 years and six of them have more than 15 years of work experience. They were asked to indicate the level of contribution of each of the five intangible resources to the delivery of the port service quality on a five-point categorical scale (from "very low" to "very high"). They were also to assess these intangible resources in the five leading Asia Pacific container ports at which their company's vessels are calling on a five-point categorical scale (from "very poor" to "very good"). These experts provided the linguistic evaluation of the five selected criteria (intangible resources) and five alternatives (leading container ports) as reflected in Figure 1. These linguistic evaluations were then converted into triangular fuzzy numbers and aggregated using equations (3) –(4) to determine fuzzy decision matrix and fuzzy weights of the five alternatives. The aggregate fuzzy weights of the criteria are presented in Table 4 and the fuzzy decision matrix of the five alternatives is shown in Table 5 respectively.

Table 4
Fuzzy criteria weights (based on 21 experts' responses)

Criteria	Aggregate fuzzy weight
C1	(0.30, 0.66, 0.90)
C2	(0.10, 0.71, 0.90)
C3	(0.30, 0.69, 0.90)
C4	(0.10, 0.64, 0.90)
C5	(0.10, 0.67, 0.90)

Table 5
Fuzzy decision matrix (based on 21 experts' responses)

Criteria	Alternatives				
	A1	A2	A3	A4	A5
C1	(1, 5.29,9)	(3, 7.10, 9)	(3,6.62, 9)	(3, 7.19,9)	(1, 5.29, 9)
C2	(3, 5.76, 9)	(3, 7.19, 9)	(3, 6.81, 9)	(3, 7,48, 9)	(3, 5.76, 9)
C3	(1, 5.29, 9)	(3, 6.90, 9)	(3, 6.33, 9)	(1,6.24, 9)	(1, 4.81, 9)
C4	(1, 5.19, 9)	(3, 7.29, 9)	(3, 6.52, 9)	(1, 6.62, 9)	(1, 5, 9)
C5	(1, 5.38, 9)	(3, 7.48, 9)	(3, 6.90, 9)	(3, 6.71, 9)	(1, 5.38, 9)

At this step, it is necessary for the triangular fuzzy number of weights to be transformed to the actual number determining the ranking of five criteria. The Centre of Gravity (COG) of triangular fuzzy number (a, b, c) is calculated as follows:

$$COG = c - \left(\frac{(c-a)(c-b)}{2}\right)^{\frac{1}{2}} \tag{15}$$

The COG for the criteria is presented in Table 6. For example, the COG of C1 (Human resource) is given by:

$$C1_{cog} = 0.90 - \left(\frac{(0.90-0.30)(0.90-0.66)}{2}\right)^{\frac{1}{2}} = 0.633$$

Table 6
Ranking of criteria

Criteria	COG	Ranking
C1	0.633	2
C2	0.624	3
C3	0.649	1
C4	0.579	5
C5	0.598	4

As can be seen from Table 6, customer and relational resource is perceived as the most significant factor affecting port service quality, followed by human resource, technological resource, port safety and security and organizational resource.

The next step is the normalization of the fuzzy decision matrix of five alternatives using equations (5) –(7). It is noted that all criteria selected in this paper are benefit criteria so we apply equation (6). The normalized rating for alternative A1 (Shanghai) and criterion C1 (human resource), for instance, is as follows:

$$C_j^* = \max(9,9,9,9,9) = 9$$

$$\tilde{r}_{ij} = \left(\frac{1}{9}, \frac{5.29}{9}, \frac{9}{9}\right) = (0.111, 0.587, 1)$$

Likewise, the normalized fuzzy decision matrix for the remaining criteria is constructed as shown in Table 7.

Table 7
Normalized fuzzy decision matrix

Criteria	Alternatives				
	A1	A2	A3	A4	A5
C1	(0111, 0.587,1)	(0.333, 0.788,1)	(0.333, 0.735,1)	(0.333, 0.799,1)	(0.111, 0.587,1)
C2	(0.333, 0.640,1)	(0.333, 0.799,1)	(0.333, 0.757,1)	(0.333, 0.831,1)	(0.333, 0.640,1)
C3	(0.111, 0.587,1)	(0.333, 0.767,1)	(0.333, 0.704,1)	(0.111, 0.693,1)	(0.111, 0.534,1)
C4	(0.111, 0.577,1)	(0.333, 0.810,1)	(0.333, 0.725,1)	(0.111, 0.735,1)	(0.111, 0.556,1)
C5	(0.111, 0.598,1)	(0.333, 0.831,1)	(0.333, 0.767,1)	(0.333, 0.746,1)	(0.111, 0.598,1)

After the normalization of the fuzzy decision matrix, r_{ij} from Table 7 and $\tilde{w}_j$ from Table 4 were used to calculate the fuzzy weighted decision matrix (Table 8). For example, the fuzzy weight of C1 was computed using equation (8) as follows:

$$\tilde{v}_{ij} = (0.111, 0.587, 1)(.)(0.30, 0.66, 0.90) = (0.033, 0.389, 0.9)$$

Table 8
Weighted normalized fuzzy decision matrix

Criteria	Alternatives				
	A1	A2	A3	A4	A5
C1	(0.033, 0.389,0.9)	(0.033, 0.559, 0.9)	(0.1, 0.508,0.9)	(0.033, 0.514,0.9)	(0.011, 0.394,0.9)
C2	(0.100, 0.424,0.9)	(0.033, 0.567,0.9)	(0.1, 0.522,0.9)	(0.033, 0.534,0.9)	(0.033, 0.430,0.9)
C3	(0.033, 0.389,0.9)	(0.033, 0.544,0.9)	(0.1, 0.486,0.9)	(0.011, 0.446,0.9)	(0.011, 0.359,0.9)
C4	(0.033, 0.382,0.9)	(0.033, 0.574,0.9)	(0.1, 0.501,0.9)	(0.011, 0.473,0.9)	(0.011, 0.373,0.9)
C5	(0.033, 0.396,0.9)	(0.033, 0.589,0.9)	(0.1, 0.530,0.9)	(0.033, 0.480,0.9)	(0.011, 0.401,0.9)

Then, the fuzzy positive ideal solution (FPIS, A^*) and the fuzzy negative ideal solution (FNIS, A^-) were determined using equations (9) and (10), and the results are as follows:

$$A^* = (0.9,0.9,0.9),(0.9,0.9,0.9),(0.9,0.9,0.9),(0.9,0.9,0.9),(0.9,0.9,0.9)$$

$$A^- = (0.011,0.011,0.011),(0.033,0.033,0.033),(0.011,0.011,0.011),(0.011,0.01110.011),(0.011,0.011,0.011)$$

The next step is to calculate the distance of each alternative from FPIS and FNIS using equations (11) and (12). The results are presented in Table 9. For example, the distances $d_v(A_1, A^-)$ and $d_v(A_1, A^*)$ of alternative Al and criteria C1 were calculated as follows:

$$d_v(A_1, A^-) = \sqrt{\frac{1}{3}\left[(0.033-0.011)^2 + (0.389-0.011)^2 + (0.9-0.011)^2\right]} = 0.558$$

$$d_v(A_1, A^*) = \sqrt{\frac{1}{3}\left[(0.033-0.9)^2 + (0.389-0.9)^2 + (0.9-0.9)^2\right]} = 0.581$$

Table 9
Distances $d_v(A_1, A^-)$ **and** $d_v(A_1, A^*)$

Criteria	$d_v(A_1, A^-)$					$d_v(A_1, A^*)$				
	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5
C1	0.558	0.603	0.590	0.590	0.559	0.581	0.538	0.514	0.548	0.590
C2	0.550	0.588	0.576	0.578	0.550	0.538	0.536	0.511	0.543	0.569
C3	0.558	0.599	0.584	0.571	0.551	0.581	0.541	0.520	0.576	0.601
C4	0.556	0.608	0.588	0.578	0.554	0.583	0.535	0.516	0.569	0.597
C5	0.559	0.612	0.596	0.580	0.560	0.579	0.532	0.509	0.556	0.558

Then, the distances d_i^* and d_i^- were calculated by applying equations (11) and (12). For instance, the distances d_i^* and d_i^- of alternative A1 and criteria C1 were computed in the following manner:

$$d_i^- = \sqrt{\frac{1}{3}\left[(0.033-0.011)^2 + (0.389-0.011)^2 + (0.9-0.011)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.1-0.033)^2 + (0.424-0.033)^2 + (0.9-0.033)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.033-0.011)^2 + (0.389-0.011)^2 + (0.9-0.011)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.033-0.011)^2 + (0.382-0.011)^2 + (0.9-0.011)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.033-0.011)^2 + (0.396-0.011)^2 + (0.9-0.011)^2\right]} = 2.781$$

$$d_i^* = \sqrt{\frac{1}{3}\left[(0.033-0.9)^2 + (0.389-0.9)^2 + (0.9-0.9)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.1-0.9)^2 + (0.424-0.9)^2 + (0.9-0.9)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.033-0.9)^2 + (0.389-0.9)^2 + (0.9-0.9)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.033-0.011)^2 + (0.382-0.9)^2 + (0.9-0.9)^2\right]}$$
$$+\sqrt{\frac{1}{3}\left[(0.033-0.9)^2 + (0.396-0.9)^2 + (0.9-0.9)^2\right]} = 2.861$$

After calculating the distances d_i^* and d_i^- , the closeness coefficient (CC_i) of the alternatives were computed using equation (14). For example, the closeness coefficient for alternative A1 was computed as follows:

$$CC_i = \frac{2.781}{2.781 + 2.861} = 0.493$$

The final results including d_i^* and d_i^- are shown in Table 10.

Table 10
d_i^-, d_i^* and closeness coefficient (CC_i) of the alternatives

	Alternatives				
	A1	A2	A3	A4	A5
d_i^-	2.781	3.009	2.934	2.897	2.775
d_i^*	2.861	2.681	2.570	2.793	2.946
CC_i	0.493	0.529	0.533	0.509	0.485

According to the closeness coefficients of five alternatives, Hong Kong (A3) was ranked first with respect to service quality in terms of intangible resources, followed by Singapore (A2), Busan (A4), Shanghai (A1) and Ningbo (A5) as reflected in Fig. 2.

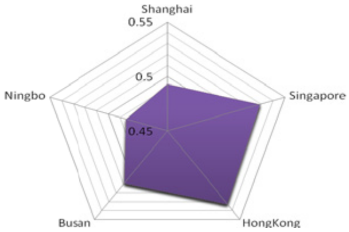

Fig. 2. Closeness coefficients of ports

Although the ranking order has been determined, there is a more realistic approach to divide interval [0, 1] into five sub-intervals (Chen et al. 2006). Using the intervals, the port levels can be classified with similar levels. Sub-intervals are grouped into five classes and the classes are modified instead of defining at an interval of 0.2 as presented in the study of Chen et al. (2006) because the alternatives are mostly distributed around 0.5. The five classes for evaluation are presented in Table 11.

Table 11
Class types for CC_i

Class	Closeness coefficient (CC_i)	Evaluation status
I	$CC_i \in$ [0.00, 0.45]	Do not recommend
Ⅱ	$CC_i \in$ [0.45, 0.50]	Usually recommended
Ⅲ	$CC_i \in$ [0.50, 0.55]	Approved
Ⅳ	$CC_i \in$ [0.55, 0.60]	Highly Approved
Ⅴ	$CC_i \in$ [0.60, 1.00]	Highly Approved and preferred

Following this, Singapore (A2), Hong Kong (A3) and Busan (A4) belong to Class Ⅲ, the assessment status of which are 'Approved' while Shanghai (A1) and Ningbo (A5) belong to Class Ⅱ which means 'usually recommended'. However, Hong Kong (A3) is preferred to Singapore and Busan in class Ⅲ according to the closeness coefficient. Therefore, the preferred order is Hong Kong > Singapore > Busan. In the case of class Ⅱ, the preferred ranking is Shanghai (A1) > Ningbo (A5) because of the closeness coefficient. Finally, the ranking order of five ports is {Hong Kong > Singapore > Busan} > {Shanghai >Ningbo} as illustrated in Fig. 3.

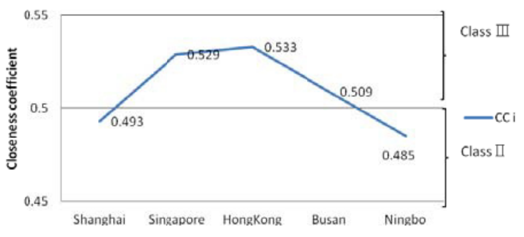

Fig. 3. Class types of ports

5. Conclusion

This paper investigates both the intangible factors affecting port service quality and the evaluation of service quality in terms of intangible resources of leading container ports using the fuzzy TOPSIS methodology. Unlike previous studies in the literature, we distinguished port's intangible resources from those of tangible nature and examined their contribution to the delivery of port service quality. Dealing with intangible resources involves the analysis of data with vague and imprecise nature, and therefore fuzzy theory is adequate to address this problem. Intangible resource factors cannot be represented by numerical value so this study used linguistic variables to reflect experts' knowledge, experience and subjective assessment. Moreover, fuzzy TOPSIS method is able to deal with the ratings of both qualitative and quantitative criteria and thus facilitate the assessment of the port's intangible resources effectively.

To achieve the purpose of this study, we selected leading container ports in the Asia-Pacific region based on their throughputs for the evaluation as well as six port intangible resource factors from the review of port service quality and RBV literature. The selected port intangible resource factors were then modified to consist of five factors following an in-depth interview with shipping academic and professional experts. A survey questionnaire to evaluate the contribution of intangible resources to the delivery of port service quality and the assessment of these resources at leading container ports was distributed to 21 experts who are working in shipping companies in Korea. The returned questionnaires were analyzed to generate a performance score to conduct these evaluations and assessments using the fuzzy TOPSIS methodology. Following this, it was perceived that customer and relational resource would contribute most to the delivery of port service quality. In addition, Hong Kong was ranked first in terms of port intangible resources, followed by Singapore, Busan, Shanghai and Ningbo. Besides, following the approach suggested by Chen et al. (2006), the five sub-intervals of five linguistic variables were established to divide the evaluation status of ports into five classes. As a result, Hong Kong, Singapore and Busan are included in the same class (Class Ⅲ) while Shanghai and Ningbo are in another class (Class Ⅱ).

This research is of academic contribution as it addresses a long-forgotten issue in port studies - the importance of intangible resources in the delivery of port service quality. It also introduces an appropriate method to analyse qualitative data dealing with port intangible resources in a more accurate manner. Findings of this research are also of managerial values as they help port managers to understand the role of intangible resources and implement appropriate service quality strategies to stay ahead in the port competition. This also includes the design and implementation of education and training programs for port employees to enhance the intangible resource factors which contribute most to the delivery of port service quality.

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