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Terminal Vitalization Strategy through Optimal Route Selection Adopting CFPR Methodology

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A B S T R A C T

Container shipping route selection strategy has become an important component in attracting additional cargo volumes and increasing terminal competitiveness of small and medium ports (SMPs). Shipping route selection relies upon decisions based on real industry data and expert judgments. There is scant research that places emphasis on container shipping route selection as a vital aspect of SMPs. This paper bridges the gap by utilizing Consistent Fuzzy Preference Relations (CFPR) methodology, which handles both qualitative and quantitative factors in order to select optimal routes for SMPs. Donghae port, which is located on the east coast of South Korea, is analyzed as a case study. The results illustrate that volume commitment ranks first among the 19 established selection factors, followed by incentive system risk and head-haul ratio. This study also reveals that Donghae-Hochiminh is the optimal route for the Donghae port, while the container shipping route of Donghae-Port Kelang is ranked in the middle, and Donghae-Jakarta is considered to be the least optimal route amongst the three alternatives.

1. Introduction

As ocean vessels are a major method of transporting goods between countries, seaports have played an essential role in both national economic development and international trade (Dang & Yeo, 2017). However, the performances of small and medium sized container ports are comparatively worse than larger ports (Cabral & Ramos, 2014; Ding et al., 2015). In this case, the attraction of additional cargo volume and the increase of terminal competitiveness are needed. This can be done by utilizing container terminal vitalization strategies (Jeevan et al., 2015).

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Feng and Notteboom (2013) stated that there are two ways for small and medium ports (SMPs) to expand. SMPs can either develop independently based on unique competitive advantages, or develop cooperatively by collaborating with larger nearby ports.

Adolf (2012) studied comprehensive reviews of the latest advancements in liner shipping and business strategy trends, including shipping route selection and its impact on port development and competition. As container shipping route selection strategy has become an important component of global supply chains, designing and selecting routes have become a key issue for shipping lines and shippers.

Route selection is a fundamental problem of logistics management, which makes great contributions to real life applications (Zhang et al., 2012). Various studies that span many research fields, such as air logistics, emergency evacuation, railway networks, shipping logistics, and multimodal transportation networks have evaluated it (Lin & Chang, 2017; Sama et al., 2016; Cuesta et al., 2017; Zhang et al., 2012; Deveci, Demirel, & Ahmetoglu, 2016; Qu & Chen, 2008). Most previous studies pertaining to route selection problems adopt mathematical models such as stochastic programming or integer programming in order to maximize service quality and customer satisfaction (Wu, 2006; Song, Zhao & Tran, 2017; Haasis Buer & Ducruet. 2012; Notteboom & Yoshida 2004; Kim & Yang, 2012; Chen, Notteboom & Wang, 2014). However, this research rarely reflects factors that cannot be expressed as real data, such as port rotation competitiveness, service coverage, service punctuality, service stability, volume commitment, freight increase risk, and incentive system risk.

There is also a lack of research emphasizing container shipping route selection as a vital aspect of SMPs. This paper bridges this gap by utilizing Consistent Fuzzy Preference Relations (CFPR) methodology, which handles both qualitative and quantitative factors in order to evaluate the reasoning behind route selection, as well as to define the optimal container shipping route alternatives for SMPs. The Donghae port located on the east coast of South Korea will be used as a case study analysis.

2. The Current Situation of the Donghae Port

The economic rim of the northeast Asian countries (the Russian Far East, Japan, Korea, Northeastern China, and North Korea) is located within the geographic region surrounding the East Sea. One reason for economic growth in the East Sea region is the formation of the largest economic block in Northeast Asia, which consists of China, Japan, Korea, and the Russian Far East. Mongolia, the world's 10th largest resource-rich nation, is also engaged in a concentrated trade exporting mineral resources to its neighboring countries.

Strengthening the competitiveness of the Donghae Port should be done in preparation for this upcoming growth of the northern economy. This is due to: the proximity of the Donghae Port to metropolitan areas such as Gangwon Province, Chungcheongbuk-do Province, and Gyeongsangbuk-do Province, accessibility to the Yangyang Airport, the advantages of the complex transportation system, the strength of the railway network connecting Donghae Port with Busan Port, and the improvement of logistics infrastructure and berthing capacity through the development of Donghae Port's third stage.

However, due to the slowing global economy and the limited growth of the main Eastern Sea port hub, the transaction volume of the Donghae Port has remained stagnant. Transaction volumes have plateaued, reflecting 34,637 thousand RT in 2014 and 39,793 thousand RT in 2015. In particular, the Maersk Group has suspended the Donghae port's only container service, which operated twice a week, for almost 18 months between March of 2015 and June of 2016. This was due to incomplete port infrastructure. An analysis of the Donghae port reveals that the number of vessels that passing through Donghae port in 2016 has increased by 48 ships when compared to the number of vessels from 2015. The number of vessels from 2015 have listed is 3, 985 and the number for 2016 is 4,033. Donghae Port is divided into six piers: Coal Wharf, Southern Dock, Northern Dock, Central Dock, West Dock, and Oil Dock (Table 1).

Table 1

Detailed Donghae port facilities

Dock Name	Berth number	Front Depth (m)	Length (m)	Berth ability (DWT)
Coal Wharf	10	(-) 13.0	270	50,000
	11		270	50,000
	12		270	50,000
Southern Dock	13	(-) 10.0 ~ (-) 13.0	270	50,000
	14		270	50,000
	15		202	20,000
	20		100	2,000
	21		270	50,000
	22		270	50,000
Northern Dock	23	(-) 9.0 ~ (-) 12.0	170	5,000
	24		195	20,000
	25		185	10,000 (G/T)
Central Dock	30	(-) 13.0	270	50,000
West Dock	41	(-) 10.0	195	3,000
	42		205	20,000
Oil Dock	Dolphin	(-) 6.50	-	3,000

The Donghae district is currently undergoing a three-stage development process with the aim of nurturing a logistics port hub in Youngdong. This will result in the improvement of loading capacity, cargo handling capacity, and the activation of the industrial complex in the Yeongdong area.

3. Methodology

Preference relations are often used when denoting information involved in several decision-making situations (Chang et al., 2013). Thus, the consistent fuzzy preference relations (CFPR) method was used within this study to establish pairwise comparison preference decision matrices for determining the prioritization of the nineteen selected factors. Not only does this method enable decision makers to express their alternative preferences with minimal judgment, it eliminates the need to check for consistencies within the decision-making process. The key definitions and propositions of CFPR methodology are listed below.

There are two types of preference relations: multiplicative preference relations and the fuzzy preference relations (Chao & Chen, 2009).

In the multiplicative preference relation, experts express their preferences for a set of alternatives, X. Let $X = \{x_1, x_2, \ldots, x_n, n \geq 2\}$ be a finite set of alternatives to be assessed by a finite set of experts ($E = \{e_1, e_2, \ldots, e_m, m \geq 2\}$) (Chao & Chen, 2009). X expressed by an expert can be denoted by a preference relation matrix $A \subset X \times X, A = (a_{ij}), a_{ij} \in \left[\frac{1}{5}, 5\right]$, in which a_{ij} denotes the ratio of the preference degree of alternative

x_i over x_j. $a_{ij} = 1$ indicates an indifference between x_i, and x_j, $a_{ij} = 5$ denotes that x_i is extremely preferable to x_j. A represents the following multiplicative reciprocal:

$$a_{ij} * a_{ji} = 1 \ \forall i.j \in \{1, \dots, n\} \quad (1)$$

Within the fuzzy preference relation, the ratio of the preference intensity of alternative x_i to that of x_j is indicated by the expert preferences of a set of alternatives where X is denoted by the positive preference relation matrix $P \subset X \times X$ with membership function $\mu_p(x_i, x_j) = p_{ij}$. Moreover, $p_{ij} = \frac{1}{2}$ implies an indifference between x_i and $x_j(x_i \sim x_j)$, $p_{ij} = 1$, indicating that x_i is preferred over x_j. $p_{ij} = 0$ indicates that x_j is preferred over x_i, and $p_{ij} > \frac{1}{2}$ indicates that x_i is preferred over $x_j(x_i > x_j)$. P is an additive reciprocal:

$$p_{ij} + p_{ji} = 1 \ \forall i.j \in \{1, \dots, n\} \quad (2)$$

Proposition 1. The reciprocal additive fuzzy preference relation (Wang and Lin, 2009) is illustrated as follows:

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \ \forall i, j, k \quad (3)$$

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \ \forall i < j < k \quad (4)$$

$$p_{i(i+1)} + p_{(i+1)(i+2)} + \cdots + p_{j(j-1)} + p_{ji} = \frac{j - i + 1}{2} \ \forall i < j \quad (5)$$

Proposition 2. Suppose the existence of the set of alternatives $X = \{x_1, x_2, \dots, x_n\}$ is associated with the multiplicative preference relation $A = (a_{ij})$, with $a_{ij} \in \left[\frac{1}{5}, 5\right]$. The corresponding reciprocal additive preference relation $P = p_{ij}$ with $p_{ij} \in [0,1]$ to $A = (a_{ij})$ is defined as follows (Wang and Lin, 2009) [28]:

$$p_{ij} = g(a_{ij}) = \frac{1}{2}(1 + \log_5 a_{ij}) \quad (6)$$

Equation 6 can be used to transform a multiplicative preference relation matrix into various preference relations.

If the preference matrix contains values that are not in the interval [0,1], but are in $[-a, 1 + a]$, a linear transformation is required in order to preserve the reciprocity and additive, which is $f: [-a, 1 + a] \to [0,1]$ transitivity (Wang and Lin, 2009). The transformation function is then denoted as follows:

$$f(p_{ij}^k) = (p_{ij}^k + a)/(1 + 2a) \quad (7)$$

The absolute value of the minimum negative value in this preference matrix is represented by a. In terms of quantitative factors, Herrera-Viedma et. al (2004) proposed that a multiplicative preference relation (X) on a set of alternatives (A) could be derived based on the ranking of alternatives.

$$X = \begin{bmatrix} 1 & A_{12} & A_{13} \\ A_{21} & 1 & A_{23} \\ A_{31} & A_{32} & 1 \end{bmatrix} \quad (8)$$

The ratio of comparison is then transformed to a scale of [1/5, 5] in order to preserve reciprocity and consistency by applying the function:

$$f(x) = x^{1/\log_5^b} \quad (9)$$

The absolute value of the maximum value in the multiplicative preference relation is denoted by b.

4. Case Study

4.1. *Evaluation structure and shipping routes*

In order to select the most suitable factors in solving the ship routing problem, a first-round interview was conducted, and questionnaires were distributed to several experts working in different Korean shipping companies. Most participants had approximately 15-20 years of work experience within their respective field. The departments the participants worked for include strategy and planning, overseas sales and marketing, trade management, operation, process innovation, and export and import sales teams. The process lasted for one month (1st of December to 31st of December, 2018) through face-to-face interviews, phone calls, and emails. In the end, 19 factors related to the problem of building a new sea route for the Donghae Port were established as shown in Table 2. Moreover, three alternative solutions regarding the research problem were suggested: a DHX service, a DPX service, and a DJX service.

Table 2

Service route selection factors

Factor Types	Section	Factors	Sub Factors	
			Item	**Description**
Quantitative Factors	**Sales Revenue**	Load Factor	C1	Head Haul Fill-up ratio
			C2	Back Haul Fill-up ratio
			C3	In-Out balance ratio
		Ocean Freight	C4	Head Haul Rate
			C5	Back Haul Rate
			C6	Short Haul rate
	Cost	Cargo Cost	C7	Equipment Cost
			C8	Stevedoring Cost
			C9	Transportation Cost
		Operation Cost	C10	Bunker Cost
			C11	Time Charterage
			C12	Port Expense
Qualitative Factors	**Service Satisfaction**	Route Competitiveness	C13	Port Rotation Competitiveness
			C14	Service Coverage
		Service Reliability	C15	Service Punctuality
			C16	Space Stability
		Contract Reliability	C17	Volume Commitment
			C18	Freight Increase Risk
			C19	Incentive System Risk

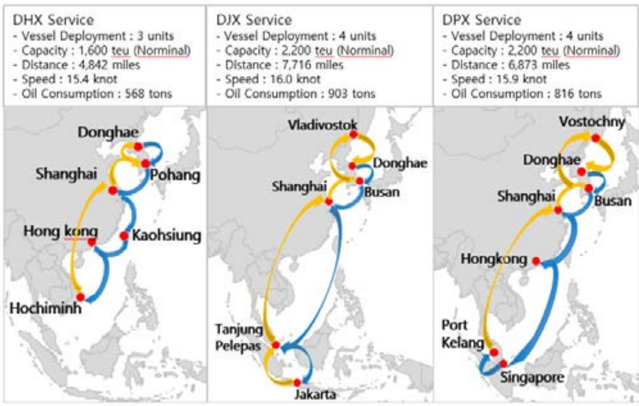

Fig. 1. Alternative Service routes

Estimated loading performance and empirical ocean freight data was collected from MCC transport (Maersk Group), a major Intra Asian shipping company. MCC was selected as a representative sample company, as it previously operated two Donghae services. These services were named PH4 (Philippines) and IA5 (Vietnam), and geared 700 TEU and 1,200 TEU vessels for 18 months between the years 2015-2016. The estimated ship operation cost can be computed by data aggregation of historical data (market charterage for 1,600 and 2,200 TEU-class vessels in 2017, and an average bunker cost of 380 CST in 2017) and simulation data (bunker consumption, vessel speed, and voyage distance). The summary of the data obtained is shown in Table 3.

Table 3

Estimated loading performance and ocean freight for service route

Service	Section	Capacity (TEU)	Loading Estimate		Rate	Freight (US $)
			TEU	Ratio		
DHX	H/Haul (L)	1,300	1,170	90%	$254.7	297,999
	B/Haul (L)	1,300	930	72%	$144.5	134,385
	H/Haul (S)	1,300	750	58%	$143.3	107,475
	B/Haul (S)	1,300	320	25%	$200.0	64,000
	Total	5,200	3,170	61%	$190.5	603,859
DJX	H/Haul (L)	1,800	960	53%	$325.4	312,384
	B/Haul (L)	1,800	1,240	69%	$167.3	207,452
	H/Haul (S)	1,800	1,320	73%	$262.2	346,104
	B/Haul (S)	1,800	1,240	69%	$205.6	254,944
	Total	7,200	4,760	66%	$960.5	1,120,884
DPX	H/Haul (L)	1,800	910	51%	$221.6	201,656
	B/Haul (L)	1,800	740	41%	$268.5	198,690
	H/Haul (S)	1,800	1,850	103%	$181.6	335,960
	B/Haul (S)	1,800	3,250	181%	$195.4	635,050
	Total	7,200	6,750	94%	$203.2	1,371,356

4.2. *Identifying the weightings of each selection factor*

Nineteen factors were determined when selecting the optimal Donghae port sea route. Both quantitative and qualitative factors were taken into account, causing difficulties for decision makers in ranking them logically. To overcome this problem, CFPR methodology was used. In order to allocate weightings to each factor, a second round-survey was distributed to 20 industry experts, including those who participated in the first-round survey. The process lasted for two weeks (18^{th} of January to 31th of January, 2018) through face-to-face interviews, phone calls, and emails. After collecting the questionnaires and sorting the data with corresponding scales, CFPR methodology was applied to calculate the weightings of each factor. Factors were then assigned to groups according to the linguistic variables shown in Table 4, in which expressions from "Equal Important (EQ)" to "Absolute Important (AI)" are used to evaluate the importance of factors and alternatives. The computational process is shown below:

(1) Based on the survey results, the importance weights of the 19 factors affecting the container shipping route selection were determined, and a comparison matrix of the 19 adjacent factors was established.

(2) An example of the first responding expert's (E1) use of the established linguistic variables is illustrated in Table 5. The corresponding numbers of linguistic variables are represented in Table 6.

Table 4

Linguistic variables for importance weights of factors and alternatives

Definition	Intensity of Importance
Absolute Importance (AI)	5
Very Importance (VI)	4
Strong Importance (SI)	3
Weak Importance (WI)	2
Equal Importance (EQ)	1
Less Weak Importance (LWI)	$\frac{1}{2}$
Less Strong Importance (LSI)	$\frac{1}{3}$
Less Very Importance (LVI)	$\frac{1}{4}$
Less Absolute Importance (LAI)	$\frac{1}{5}$

Table 5

Preference matrix by linguistic variables of E1

	E1	
C1	AI	C2
C2	LVI	C3
C3	LVI	C4
C4	AI	C5
C5	LAI	C6
C6	VI	C7
C7	LAI	C8
C8	AI	C9
C9	EQ	C10
C10	LVI	C11
C11	AI	C12
C12	LVI	C13
C13	VI	C14
C14	SI	C15
C15	LSI	C16
C16	LSI	C17
C17	VI	C18
C18	SI	C19

Table 6

Linguistic values translated into corresponding numbers

	E1	
C1	5	C2
C2	1/4	C3
C3	1/4	C4
C4	5	C5
C5	1/5	C6
C6	4	C7
C7	1/5	C8
C8	5	C9
C9	1	C10
C10	1/4	C11
C11	5	C12
C12	1/4	C13
C13	4	C14
C14	3	C15
C15	1/3	C16
C16	1/3	C17
C17	4	C18
C18	3	C19

The values shown in Table 6 require transformation to a [0, 1] interval. Thus, equation 6 was applied in order to calculate the transformation. The results are as follows:

P12= $\frac{1}{2}$ (1+log55) =1; P23= $\frac{1}{2}$ (1+log5$\frac{1}{4}$) =0.069; P34= $\frac{1}{2}$ (1+log5$\frac{1}{4}$) =0.069; P45=$\frac{1}{2}$(1+log55) =1;

P56= $\frac{1}{2}$ (1+log5$\frac{1}{5}$) =0; P67= $\frac{1}{2}$ (1+log54) =0.93; P78=$\frac{1}{2}$ (1+log5$\frac{1}{5}$) =0; P89=$\frac{1}{2}$(1+log55) =1;

P910= $\frac{1}{2}$ (1+log51) =0.5; P1011= $\frac{1}{2}$ (1+log5 $\frac{1}{4}$) =0.069; P1112= $\frac{1}{2}$(1+log55) =1;

P1213= $\frac{1}{2}$ (1+log5 $\frac{1}{4}$) =0.069; P1314= $\frac{1}{2}$ (1+log54) =0.931; P1415=$\frac{1}{2}$(1+log53) =0.841;

P1516= $\frac{1}{2}$ (1+log5 $\frac{1}{3}$) =0.159; P1617= $\frac{1}{2}$ (1+log5 $\frac{1}{3}$) =0.159; P1718=$\frac{1}{2}$(1+log54) =0.931;

P1819=$\frac{1}{2}$(1+log53) =0.841

The fuzzy preference relation matrix evaluated by E1 will be examined according to the above calculation method. Several values exist within the fuzzy preference relation matrix that does not exist within the interval [0, 1]. Therefore, a linear transformation provided by equation 7 is employed for the calculation of the transformation matrix. The use of a linear transformation ensures the additive transitivity of the preference relation matrix.

(3) The fuzzy preference relation matrix can be calculated by repeating the same process as above. The aggregated pairwise comparison matrix is then created by calculating the average value of the 20 evaluators.

(4) The ranking of the 19 selection factors is then conducted by normalizing the aggregated pairwise comparison matrix. The equation for this step is: $\frac{p_{ij}}{\sum_{i=1}^{n} p_{ij}}$. Using C1C2 as an example:

C1C2=0.551/11.100=0.050

The ranking of the 19 selection factors is listed as follows:

Volume commitment (C17) > Incentive System Risk (C19) > Head-Haul Rate (C4) > Service Punctuality (C15) > Port Rotation Competitiveness (C13) > Space Stability (C16) > Ocean Freight Increase Risk (C18) > Short-Haul Rate (C6) > Back-Haul Rate (C5) > Service Coverage (C14) > Stevedoring Cost (C8) > Bunker Cost (C10) > Port Expense (C12) > In/Out Balance Ratio (C3) > Head-Haul Fill-up Ratio (C1) > Time Charterage (C11) > Equipment Cost (C7) > Transportation Cost (C9) > Back-Haul Fill-up Ratio (C2).

The normalized matrix for the priority weights and ranks of the determined factors are listed in Table 7.

Table 7

Normalized matrix for weights and ranks the of determined factors

E1-E20	Weight	Rank
C1	0.049	15
C2	0.044	19
C3	0.049	14
C4	0.057	3
C5	0.052	9
C6	0.053	8
C7	0.049	17
C8	0.052	11
C9	0.046	18
C10	0.051	12
C11	0.049	16
C12	0.049	13
C13	0.056	5
C14	0.052	10
C15	0.057	4
C16	0.056	6
C17	0.063	1
C18	0.056	7
C19	0.058	2

Volume commitment (C17) is ranked first, with the highest point being (0.063). The analysis results indicate that container shipping carriers consider volume commitment as the most important factor for shipping route selection. Shipping carriers are at a high risk when launching and operating new shipping services for undeveloped terminals like the Donghae port, which require more voyage time and voyage deviations compared to standard service routes. In order to compensate for extra operation costs caused by extended voyage time and voyage deviation, stable volume commitment may be the most considerable factor for Donghae port route selection. Back-haul fill-up ratio (C2) is ranked last, with the lowest point being (0.044). Realistically, back-haul rates are considerably lower-priced compared to head-haul rates. Thus, back-haul fill-up ratios have significant implications, showing that service route options can attract empty container equipment to the Donghae port in order to save empty equipment positioning costs. However, a high back-haul fill-up ratio does not mean that shipping carriers can save empty equipment positioning costs. This is because back-haul cargo movement flow can be incongruous with specific empty container equipment needs.

4.3. *Measuring alternatives*

To calculate the priority weight matrix for Donghae port route selection, the linguistic variables shown in Table 4 are adopted. The computational process for the priority weights of three candidate sea routes are listed as follows:

(5) 20 evaluators were interviewed in order to estimate which route is most likely to increase cargo volume and bring higher profits to the Donghae port in respect to each evaluation factor. The preference intensity of E1 regarding decision criteria 1 (C14) is shown as the linguistic variables of Table 8.

Table 8

Preference matrix by linguistic variables of E1 toward C14

E1	A1	A2	A3
A1	1	VI	
A2		1	LVI
A3			1

(6) Table 9 illustrates the transformed corresponding numbers of the linguistic variables by using the fuzzy preference shown in Table 4.

Table 9

Translated linguistic terms into corresponding number

E1	A1	A2	A3
A1	0.5	0.93	
A2		0.5	0.07
A3			0.5

(7) The calculation steps for the fill in the blank cells are the same as the one for computing the selection factors weights. Repeating steps 3, 4, and 5, the normalized matrices of 20 evaluators regarding C14 are illustrated in Table 10.

Table 10

Normalized matrix of priority weight of C14

E1-16	A1	A2	A3	Average
A1	0.320251	0.320293	0.318450	0.3197
A2	0.319177	0.319222	0.317229	0.3185
A3	0.360573	0.360485	0.364321	0.3618

(8) The process is then repeated for the remaining decision factors, including factor 11 (C11), factor 12 (C12), factor 13 (C13), and factor 15 (C15). Notably, quantitative factors such as head-haul fill-up ratio (C1) and equipment cost (C7) are calculated with different equations using actual data.

(9) The priority weights of the 19 selection factors, the preference weights of the targeted alternative ports, and the priority rates of the three alternative sea routes are represented in Table 11. The weighted rates of these three alternatives are calculated as follows:

DHX service = (0.049*0.379) + (0.044*0.665) + (0.049*0.563) + (0.057*0.122) + (0.052*0.121) + (0.053*0.107) + (0.049*0.640) + (0.052*0.619) + (0.046*0.554) + (0.051*0.584) + (0.049*0.640) + (0.049*0.619) + (0.056*0.320) + (0.052*0.334) + (0.057*0.332) + (0.056*0.339) + (0.063*0.363) + (0.056*0.317) + (0.058*0.352) = 0.409

DJX service = (0.049*0.112) + (0.044*0.169) + (0.049*0.141) + (0.057*0.523) + (0.052*0.357) + (0.053*0.392) + (0.049*0.198) + (0.052*0.223) + (0.046*0.308) + (0.051*0.268) + (0.049*0.198) + (0.049*0.223) + (0.056*0.319) + (0.052*0.295) + (0.057*0.309) + (0.056*0.316) + (0.063*0.304) + (0.056*0.317) + (0.058*0.313)= 0.283

DPX service = (0.049*0.508) + (0.044*0.166) + (0.049*0.296) + (0.057*0.355) + (0.052*0.522) + (0.053*0.501) + (0.049*0.162) + (0.052*0.157) + (0.046*0.137) + (0.051*0.148) + (0.049*0.162) + (0.049*0.157) + (0.056*0.362) + (0.052*0.371) + (0.057*0.359) + (0.056*0.345) + (0.063*0.333) + (0.056*0.367) + (0.058*0.335)= 0.307

By comparing the above calculation results, the ranking of the three route alternatives are as follows:

DHX service (0.409) > DPX service (0.307) > DJX service (0.283)

Therefore, all of the experts expressed a preference to the DHX service, showing it to be the most suitable choice for Donghae port's new sea route selection.

Table 11

Normalized matrix of priority weight of all criteria and preference rate of alternatives

	Weight	Priority Weight			Weighted Rate		
		DHX	DJX	DPX	DHX	DJX	DPX
C1	0.049	0.379	0.112	0.508	0.019	0.006	0.025
C2	0.044	0.665	0.169	0.166	0.029	0.007	0.007
C3	0.049	0.563	0.141	0.296	0.028	0.007	0.015
C4	0.057	0.122	0.523	0.355	0.007	0.030	0.020
C5	0.052	0.121	0.357	0.522	0.006	0.019	0.027
C6	0.053	0.107	0.392	0.501	0.006	0.021	0.027
C7	0.049	0.640	0.198	0.162	0.031	0.010	0.008
C8	0.052	0.619	0.223	0.157	0.032	0.012	0.008
C9	0.046	0.554	0.308	0.137	0.026	0.014	0.006
C10	0.051	0.584	0.268	0.148	0.030	0.014	0.008
C11	0.049	0.640	0.198	0.162	0.031	0.010	0.008
C12	0.049	0.619	0.223	0.157	0.031	0.011	0.008
C13	0.056	0.320	0.319	0.362	0.018	0.018	0.020
C14	0.052	0.334	0.295	0.371	0.017	0.015	0.019
C15	0.057	0.332	0.309	0.359	0.019	0.018	0.020
C16	0.056	0.339	0.316	0.345	0.019	0.018	0.019
C17	0.063	0.363	0.304	0.333	0.023	0.019	0.021
C18	0.056	0.317	0.317	0.367	0.018	0.018	0.021
C19	0.058	0.352	0.313	0.335	0.020	0.018	0.019
Value					0.409	0.283	0.307
Rank					1	3	2

The CFPR analysis results show that the DHX service is ranked first. This is because a large number of potential customers use the DHX service (Table 12). Therefore, it is essential to design and launch the DHX route and attempt to operate it as a preliminary of Donghae port vitalization. Donghae port's 2016 handling performance implies that Donghae container services mainly attract metal, nonferrous metal, machinery, and beverage commodities for head-haul. For back-haul, the DHX service can secure wooden pallet inbound cargoes by calling to Hochiminh, which is a major wooden pallet production country. Wooden pallets are a major source of thermal power generation in the Donghae area. The DHX port rotation is also very compact, making cargo and operation costs considerably less than other routes. For these reasons, carriers prefer the DHX service.

Table 12

Handling performance in Donghae by Commodities

(Unit: 1,000 RT/year)

Cargoes		2016 Handling Performance (Year)			Remark
Commodity	**Type**	**Ocean Ship**	**Home-Trade**	**TTL**	**(Potential Customers)**
Ore & Metal (CNTR & Bulk)	C&B	3,335	11,932	15,267	Young Poong
Nonferrous Metal	CNTR	55	0	55	Dong Bu Metal
Machinery	CNTR	29	0	29	Yura
Beverage	CNTR	10	0	10	Lotte Liquor
Oil Refined Product	C&B	44	886	930	
C&B	C&B	91	0	91	
Fishes and Shells	C&B	13	0	13	
Wood Material	C&B	14	0	14	
Steel Product	C&B	8	0	8	
Cement	Bulk	4,223	6,357	10,580	
Iron Ore	Bulk	0	404	404	
Coal	Bulk	5,245	0	5,245	
Grain	Bulk	15	0	15	
Etc. (Sand & Plastic)		12	6	18	
Total		13,094	19,585	32,679	

The DPX service is valued less than the DHX service. This is because the DPX service has larger vessels than the DHX service capacity (DPX: 2,200 TEU and DHX: 1,600 TEU). In terms of vessel fill-up ratio, a higher vessel capacity is more difficult for full vessel utilization. Furthermore, the DPX port rotation composition may cause service punctuality problems due to Vladivostok calling before arriving at Donghae. Vladivostok is widely known for port congestion, bad weather conditions, and low terminal productivity in the winter season. Because of this, an evaluation of the DPX service may be unattractive compared to the DHX service.

Lastly, the DJX service is ranked lowest in this study. The DJX service has a higher cargo demand than the DPX service based on long-haul lifting performance. However, the DJX vessel utilization for the short-haul lane is considerably lower than the DPX vessel utilization. Therefore, this comprehensive evaluation indicates that market demand is not properly reflected within the DJX route design. Therefore, it is necessary that cargo market demands and supply space be analyzed while designing shipping route services.

5. Conclusion

CFPR methodology was proposed in this paper in order to aid in selecting the optimal container-shipping route that will gain additional cargo, improve the regional economy, and connect the Donghae port neighboring ports. The results are based on several factors, which were evaluated by experts working in different Korean shipping companies. Among the 19 determined selection factors, volume commitment was ranked first, followed by incentive system risk and head-haul ratio. The performance weights of the three alternative routes were evaluated by conducting a case study. Based on the results of this study, it can be concluded that most experts prefer the Donghae-Hochiminh route. While the Donghae-Port Kelang container shipping route ranked in the middle, the Donghae-Jakarta route was considered to be the least preferred route.

Both academic and industrial implications can be obtained through this study's CFPR results. The academic implications of this paper underscore the influential selection factors that optimize shipping routes in order to vitalize the Donghae port. Moreover, the weight and ranking of each factor establish the optimal shipping route selection. This research is fundamental for the future creation of new routes in order to solve similar problems. In terms of industrial implications, this study provides decision-making solutions for designing and selecting shipping route options based on an analysis of cargo demand in the Donghae area. Selecting shipping routes is complicated issue involving with many perspective stakeholders. Future research should support the inclusion of other interested parties, such as local port authorities, policy makers, and researchers working in national institutes.

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