Performance Evaluation of Asian Major Cruise Terminals

Abstract

Compared to cargo terminals, performance evaluation of cruise terminals sits in a backseat in the current port performance studies, particularly in the Northeast Asia. This paper aims to evaluate the performance of major cruise terminals in Asia taking into account the important dimensions and criteria influencing cruise terminal development, and using primary data by experts' responses to a questionnaire survey. Complementary data are also acquired by field trips and interviews to find the hidden information that is not revealed from the set questions in the questionnaire survey. To tackle the multiplicity and uncertainty in the collected data, the hybrid of Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and Consistent Fuzzy Preference Relation (CFPR) is employed to evaluate cruise terminal performance and highlight visual illustration of the test results. The findings provide useful insights for guiding cruise lines' terminal selection and for aiding cruise terminals to benchmark their performance to effectively improve their service and maximize their overall performance.

Keywords: Cruise shipping company, Cruise terminal, PROMETHEE, CFPR, Port performance

I. Introduction

Cruise tourism is defined as a pleasure voyage on a cruise ship where the voyage, the amenities of a cruise ship, and the ports of call are significant ingredients of the experience (Teye & Leclerc, 1998). During their cruise, passengers are offered with high quality services and facilities like shops, restaurants, accommodation, and swimming pools. Cruise passengers will experience the recreational leisure benefits provided by the cruise ship, entailing the staff and crew, as though it were a floating hotel (Lee & Yoo, 2015).

In recent years, the cruise industry has been one of the fastest growing and most dynamic sectors in the tourism industry (Sun et al., 2011). During the last decade, the industry has shown a high annual growth rate in terms of the passenger number. For example, the total number of cruise passengers worldwide increased by 5.1% annually, from 15.8 million in 2008 to 26.0 million in 2018 (Cruise Market Watch, 2019). In 2018, the North America market accounted for 54.5% of cruise passengers worldwide. During the period 2008-2018, the industry capacity increased at an average annual rate of 5.1% (Cruise Industry News, 2019). The new ships being built have passenger capacities of over 4000.

In line with the global trend, Asian cruise market has grown explosively. For example, the Asian cruise industry capacity increased by 488%, from 0.8 million in 2008 to 4.7 million in 2018 (Cruise Industry News, 2019). In 2018, the Asian cruise market occupied 9.2% of worldwide passengers (Cruise Market Watch, 2019). Such significant growth is primarily due to increasing cruise passengers from China. To respond to such growth, global cruise line companies has designated growing cruise tourism services from China to other countries in East Asia (Lee & Yoo, 2015). However, the COVID-19 pandemic in 2019 broke cruise shipping growing momentum and created a historically recorded low traffic in 2020 across the globe.

From such a critical analysis, it is evident that the performance evaluation of cruise terminals sits in a backseat compared to both other cruise shipping and cargo port performance studies. It is even worse when one considers the gap between the little research on this topic and the fast-growing cruising market in Asia before the pandemic. It is also crucial to investigate how the cruise industry overviews the performance of cruise terminals after the pandemic to allow its recovery subject to scientific rational. To fill this research gap, this paper aims to explore the importance of the dimensions and criteria influencing the performance of cruise terminals by experts and evaluate the performance of major cruise terminals in the Northeast Asia, including Singapore, Busan, Cheju, Shanghai, Tianjin, Hong Kong, Fukuoka, and Yokohama. In doing so, Preference Ranking Organization Methods for Enrichment Evaluations (PROMETHEE), a well-established multiple criteria decision making (MCDM) approach, is applied because it is not only a powerful tool, capable of visualizing the difference among different terminals' performance but also has characteristic functions for dealing with normalization problems (Brans et al., 1984). PROMETHEE is combined with grey relation analysis (GRA) and CFPR in a hybrid approach so as to measure experts' preference in evaluating performance of on cruise terminals and to compare the results of PROMETHEE and GRA, which are expected to draw more insights of this study.

II. Literature review

Given the scope of this work on the evaluation of cruise terminals using MCDM methods, this section is outlined in two parts: cruise terminal performance and MCDM methods

2.1 Problem analysis of cruise terminal performance evaluation

A literature review of cruise tourism has revealed the mainstream research themes in the sector include cruise port/terminal selection (e.g. Marti, 1990; Lekakou et al., 2009; Lau et al., 2014; Wang et al., 2014), cruise market segmentation (e.g.Marti, 1991; Petrick, 2005; Sun et al., 2011), cruise passenger's perception of cruise service (e.g. Teye & Leclerc, 1998; Qu & Hong, 1999; Johnson, 2006; Mark et al., 2010; Brida et al., 2012; Hur & Adler, 2013; Parola et al., 2014), economic impact of cruise tourism (e.g. Dwyer & Forsyth, 1996 & 1998; Vina & Ford, 1998; Chase & Mckee, 2003), strategic development and location of cruise port (e.g. Robert, 1998; McCarthy, 2003; Gui & Russo, 2011; Pallis et al., 2014), attributes of cruise tourism (e.g. Xie et al., 2012: Lee & Yoo, 2015), cruise terminal concession contracts (e.g. Wang et al., 2014), key success factors of cruise terminals (e.g. Lee, 2002), and cruise safety and crisis management (e.g. Mileski et al., 2014). Among the cruise shipping related studies, the research on cruise terminals sits on a backseat role and the previous relevant studies at large focus on the identification of the factors influencing cruise terminal performance from the economic and operational aspects. For instance, Lee et al. (2002) found the successful factors for cruise terminal development, and its results contributed to the development of the cruise terminals in Busan and Cheju in Korea. However, the evaluation of cruise terminals should take into account the overall dimensions and criteria in a holistic manner. Despite showing some attractiveness on the solutions to maritime problems such as the evaluation of the waterway congestions (Yan et al.,2017) and green port performance measurement (Wan et al.,2018), MCDM methods have yet been applied to evaluate cruise terminal performance systematically. It is probably because the high uncertainty in the demanded data. For instance, the performance evaluation of Asian cruise terminals, requires the configuration of the importance of the criteria and alternative (cruise terminal) performance. All the input data require the access to a large network of professionals involved in the cruise industry. Furthermore, the normalization methods are often considered in the ranking part of MCDM because it influences criteria or performance evaluation results (Ishizaka & Nemery, 2011). The issue as to how to improve the normalization part in the evaluation of cruise terminal performance remain unclear.

2.2 Methods of multiple criteria decision-making problem

MCDMs normally contain two parts, the weight configuration of all the criteria and the evaluation of the defined alternative against each criterion. Therefore, this section is organized into two parts: weight configuration in Section 2.2.1 and alternative evaluation in Section 2.2.2.

2.2.1 Weight configuration methods

In all MCDM methods, the criterion weights need to be calculated. Anojkumar et al. (2014) used the four MCDM methods including Fuzzy-Analytic Hierarchy Process (FAHP)-TOPSIS, FAHP-VIKOR, FAHP-ELECTRE, FAHP-PROMTHEE to solve a pipe material selection problem in the sugar industry. Emovon et al. (2015) applied two hybrid MCDM methods involving the Delphi-AHP and Delphi-AHP PROMETHEE to tackle the selection of appropriate maintenance strategies for ship machinery systems and other related ship systems. Mahmoudi et al. (2015) proposed a hybrid approach which employed both Fuzzy Rule Based System (FRBS) and PROMETHEE to solve a supplier selection problem (SSP) under group decision making and fuzzy environment. In the above applications, there are a few commonly used weight configuration methods. AHP was introduced by Saaty in 1970, and since then it has been one of the most widely applied methods for calculating the relative weights of criteria. AHP applies pairwise comparison to find the relative weights of criteria, and hence it causes a high demand on input data in the investigation process. When a questionnaire survey is conducted at a wide range, the high input information demand will often cause bias. Therefore, Consistent fuzzy preference relation (CFPR), introduced by Herrera-Viedma et al. in 2004, is often used for data consistency and quality. It is worth emphasizing a few critics when applying CFPR in factor weight analysis. The original concept of CFPR is Fuzzy Preference Relation (FPR) that was introduced by Herrera-Viedma et al. (2004). This research pointed out that researchers may apply the property of FPR directly to identify the relative weights according to the decision environment they faced, either fuzzy or crisp. Originally, this concept was applied to deal with the problems that lost information happened in the questionnaire investigation. Wang et al. (2007) applied incomplete linguistic preference relations to a supplier selection of an Enterprise Resource Planning (ERP) system. Further, there are growing studies that applied this method to solve some evaluation problems involving incomplete information in an investigation process. For instance, Wang & Hsu (2009) solved a group decision problem. Hsu et al. (2009) predicted the success of ERP implementation. Wang & Hsu (2009) evaluated the performance of web shop. Wang & Chen (2010) introduced an advanced evaluation method. Hsu & Wang (2011) applied this property to solve an incomplete information problem. Chang et al. (2012) measured the success possibility of ERP implementation. Besides, CFPR and Fuzzy Linguistic Preference Relation (FLPR) are utilized as a hybrid method to deal with MCDM evaluation problems. CFPR is applied to, among others, tackling knowledge management problems (Wang & Chang, 2007a; 2007b), partnership selection problems (Wang & Chen, 2007), and selection of merger strategies for commercial banks in new financial environments (Wang & Lin, 2009). On the other hand, Wang & Chen (2008, 2011) applied FLPR to improve the consistency of fuzzy AHP and the evaluation of transportation companies. Chang & Wang (2008) and Wang & Hsueh (2009) applied FPR to deal with MCDM problems. Owing to the fact that CFPR is well documented in the literature, the detail process of its algorithm is documented in Wang & Hsueh (2009).

2.2.2 Alternative evaluation methods

Alternative evaluation is the other important part of solving an MCDM problem. Yang et al. (2014) applied GRA to handle maritime problems about containership flag selection. Nguyen et al. (2014) applied a hybrid approach with GRA to deal with a machine tool selection problem. Chang et al. (2015) adopted the FAHP, VIKOR, GRA and TOPSIS to evaluate an appropriate business model for e-book firms in Taiwan. Chen et al. (2015) applied the GRA approach to study and analyze the relationship between capacity/state-of-charge (SoC) and various influencing factors, and proposed the segment grey prediction model in order to test and improve the accuracy of the capacity/SoC prediction. Sadhukhan et al. (2015) used TOPSIS, relative to an identified distribution unit (RIDIT) analysis, and GRA approach to investigate the importance of various transfer facility attributes in and around metro stations in India. Singh et al. (2016) adopted the GRA approach to determine the complete ranking of the brake pad formulation.

In the above studies, it is revealed that the normalization process in MCDM has some theoretical implications that have not been well address in the current literature. It therefore triggers the investigation on how to take the advantages of PROMETHEE and GRA methods to improve the MCDM normalization process and enable the evaluation of cruise terminal performance. On a review paper on PROMETHEE (Behzadian et al. 2010), 217 papers were investigated from 100 journals in the period of 1985 to 2009, highlighting the method's advantages and disadvantages. PROMETHEE does not provide the practical structure of a decision problem, which may increase the difficulty for the decision makers to obtain a clear view of the targeted problem. However, it has unique advantages when important elements of the decision are difficult to quantify or compare (Gavade, 2014). Moreover, it needs much less input data compared to other MCDM methods. In this regard, PROMETHEE provides eight generalized criteria functions to help the decision makers to normalize the performance of alternative cruise terminals. This normalization process provides the involved experts or decision makers with an opportunity to identify the types of generalized criteria functions of performance alternatives and their related threshold values. However, PROMETHEE is an evaluation method applied to outrank alternatives. Therefore, it is desirable to combine PROMETHEE with CFPR to address the inherent uncertainty in data in the decision-making process and hence to populate its applications.

III. Method and test results

3.1 Methodology framework

Figure 1 depicts the conceptual diagram of the proposed cruise terminal performance evaluation methodology. First, we obtain the evaluation dimensions and criteria by the combination of conducting the relevant literature review and using the concept of the 5th generation ports (5GP) (Suthiwartnarueput et al., 2020). Secondly, the questionnaires for investigating the relative weights and cruise terminal performance are designed based on the evaluation criteria. Thirdly, relative weights are calculated and obtained by CFPR and the performance of the cruise terminals is evaluated by PROMETHEE and GRA. Finally, a comparison analysis of performance evaluation of the cruise terminals is conducted, before the findings and insights of cruise terminal evaluation are concluded.

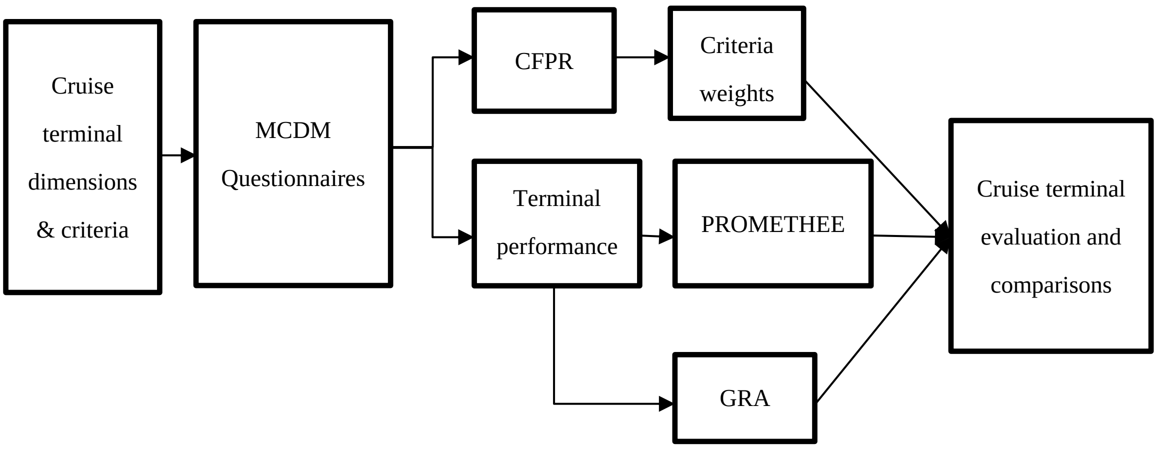


Figure 1 Conceptual diagram of cruise terminal evaluation

3.2 Operation steps of combined MCDM methods

The operation steps of this combined MCDM method can be divided into two parts, which are criterion weight calculation and alternative evaluation. They are described as followed, respectively.

a. Criterion weight calculation

Operation steps of CFPR (Consistent fuzzy preference relation)

Relative weights of evaluation criteria can be calculated by CFPR based on the following 4 steps:

1. Design a questionnaire to investigate the fuzzy preference relation

   The multiplicative preference investigated from domain experts can be transferred into fuzzy preference by Equation (1):

   $$p_{ij} = g(a_{ij}) = \frac{1}{2} \times (1 + \log_9 a_{ij}) \quad (1)$$

   Where a_{ij} is the average value of the pairwise comparison of criteria importance rated by the experts.

2. Find the fuzzy preference relation *P*

   The fuzzy preference relation *P* generated by *X* alterative is a fuzzy set of $X \times X$, that is characterized by a membership function $\mu_p : X \times X \rightarrow (0,1)$. The preference relation can be conveniently represented by the $n \times n$ matrix, $P=P(p_{ij})$, where $p_{ij} = \mu_{ij}(x_i, x_j)$ $\forall i, j \in \{1, \cdots, n\}$, p_{ij} is the degree of preference ration of criteria x_i and x_j rated by experts.

   The characteristics of fuzzy preference can be described by Equation (2):

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

   The preference relations are conformed to the following relations (3) and (4) when they are consistent,

   $$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \quad (3)$$

   $$p_{i(i+1)} + p_{(i+1)(i+2)} + \cdots + p_{(j-1)j} = j - i + 1/2 \quad \forall i < j \quad (4)$$

3. Derive the empty entries of the weights decision matrix by fuzzy preference relation

   All the p_{ij} in the preference matrix can be calculated by Equations (2), (3) and (4).

4. Calculate the relative weights of evaluation criteria

   The relative weights can be calculated by Equation (5) as follows.

   $$w_i = \sum_{j=1}^{n} p_{ij} \Big/ \sum_{i=1}^{n} \sum_{j=1}^{n} p_{ij} \quad (5)$$

b. Alternative cruise terminal evaluation

Table 1 shows the information collected from CFPR and questionnaire, in which the criteria weights (w_j) are derived from CFPR and alternatives' performance against each criterion ($g_j(i)$) are collected from questionnaires. The aspired value and the worst value are determined according to the characteristics of criteria. For the benefit criteria, the larger the performance value, the better. For the cost criteria, the smaller the better. After the information shown in Table 1, the alternative evaluation results can be found based on the operation steps of PRMETHEE and Grey relation, which are described as below:

Table 1 . Cruise terminal performance evaluation

Alternative	Criteria				
	C_1	$\cdots$	C_j	$\cdots$	C_n
	w_1	$\cdots$	w_j	$\cdots$	w_n
a_1	$g_1(1)$	$\cdots$	$g_j(1)$	$\cdots$	$g_n(1)$
$\vdots$	$\vdots$		$\vdots$		$\vdots$
a_i	$g_1(i)$	$\cdots$	$g_j(i)$	$\cdots$	$g_n(i)$
$\vdots$	$\vdots$		$\vdots$		$\vdots$
a_m	$g_1(m)$	$\cdots$	$g_j(m)$	$\cdots$	$g_n(m)$
Aspired value g^*	$g^*(1)$	$\cdots$	$g^*(j)$	$\cdots$	$g^*(n)$
The worst value g^-	$g^-(1)$	$\cdots$	$g^-(j)$	$\cdots$	$g^-(n)$

Operation steps of PRMETHEE

Four steps are outlined below for the use of PROMETHEE in this study.

1. Find the alternatives pairwise comparison matrix by a preference function

   We first find the preference deviation of alternatives on criteria according to Equation (6).

$$d_j(a,b) = g_j(a) - g_j(b) \tag{6}$$

Where $d_j(a,b)$ denotes the difference of the performance between alternative a and b on criterion j, while $g_j(a)$ and $g_j(b)$ are the entries of matrix A.

Second, preference functions are applied to normalize the performance of alternatives by Equation (7).

$$P_j(a,b) = F_j[d_j(a,b)] \tag{7}$$

Where $P_j(a,b)$ denotes the normalized performance deviation of alternative a and b, as a function of $d_j(a,b)$.

2. Calculate the overall performance deviation of all the alternatives.
   The overall performance deviations of alternatives are calculated by Equation (8).

$$\pi(a,b) = \sum_{j=1}^{n} P_j(a,b) \times w_j \quad (8)$$

   Where $\pi(a,b)$ is the overall performance deviation of alternatives and w_j is the relative weights of criteria identified by CFPR in this research.

3. Calculate the positive and negative ranking flows
   The results of equation (8) can be applied to calculate the positive and negative ranking flows using equation (9) and (10).

$$\emptyset^{+}(a) = \frac{1}{n-1} \sum_{a_j \in A} \pi(a, a_j) \quad (9)$$

$$\emptyset^{-}(a) = \frac{1}{n-1} \sum_{a_j \in A} \pi(a_j, a) \quad (10)$$

   Where $\emptyset^{+}$ and $\emptyset^{-}$ denote the positive and negative ranking flows, respectively. Partial ranking can be found by index $\emptyset^{+}(a)$ and $\emptyset^{-}(a)$, which is named as PROMETHEE I.

4. Calculate the net ranking flow
   The net ranking flow can be calculated by equation (11).

$$\emptyset(a) = \emptyset^{+}(a) - \emptyset^{-}(a) \quad (11)$$

   Complete ranking can be found by index $\emptyset(a)$, which is named as PROMETHEE II.

<u>Operation steps of Grey relation analysis (GRA)</u>

The input of GRA is the same with the input of PROMETHEE. The evaluation can be finished by the calculation of coefficients of grey relation and grade of grey relation, which can be calculated according to the characteristics of evaluation criteria. The relevant steps are shown as below:

1. Coefficients of grey relation for aspired values

$$\gamma\left(g^{*}(j), g_j(i)\right) = \frac{\min_i \min_j \left| g^{*}(j) - g_j(i)\right| + \varsigma \max_i \max_j \left| g^{*}(j) - g_j(i)\right|}{\left| g^{*}(j) - g_j(i)\right| + \varsigma \max_i \max_j \left| g^{*}(j) - g_j(i)\right|} \tag{12}$$

Grade (degree) of grey relation (larger is better)

$$\gamma(g^{*}, g_i) = \sum_{j=1}^{n} w_j \, \gamma\left(g^{*}(j), g_j(i)\right) \tag{13}$$

2. Coefficients of grey relation for worst values

$$\gamma\left(g^{-}(j), g_j(i)\right) = \frac{\min_i \min_j \left| g^{-}(j) - g_j(i)\right| + \varsigma \max_i \max_j \left| g^{-}(j) - g_j(i)\right|}{\left| g^{-}(j) - g_j(i)\right| + \varsigma \max_i \max_j \left| g^{-}(j) - g_j(i)\right|} \tag{14}$$

Grade (degree) of grey relation (larger is worse, the small is better)

$$\gamma(g^{-}, g_i) = \sum_{j=1}^{n} w_j \, \gamma\left(g^{-}(j), g_j(i)\right) \tag{15}$$

3. The scores of alternatives, which are applied to rank the alternatives, can be found by equation (16).

$$R_i = \frac{\gamma(g^{*}, g_i)}{\gamma(g^{-}, g_i)} \tag{16}$$

IV. Empirical Test results

4.1 Questionnaire design

A questionnaire was designed to apply CFPR, PROMETHEE and GRA to evaluate the performance of cruise terminals in the Northeast Asian region. The questionnaires are distributed internationally. For reducing the problems occurred in communications, type I (Usual criterion) preference function, in which the invited experts can directly respond their perceptions in the questionnaires, is applied in this research. Since these

MCDM methods require experts to respond to the questionnaires, this study applied the experts' investigation method to collect primary data. The evaluation hierarchy is the most important element in dealing with MCDM applications. The evaluation criteria are developed based on Lee et al. (2002), Lee & Lam (2014) and Suthiwartnarueput et al. (2014) and verified by benchmarking the concept of the fifth generation ports. The evaluation hierarchy is shown in Table 1, including five dimensions and 15 criteria.

Table 1 Evaluation criteria of cruise terminals

Dimensions (A~E)/Criteria (A1~E3)	Descriptions
(A) Port infrastructure	
(A1) Dedicated cruise berth	No sharing spaces and facilities with cargo terminals and no adjacent location; berth, apron and terminal features are well designed.
(A2) Marine navigation and access	Channels and anchorage area for cruise ships are well arranged.
(A3) Ground transportation areas	Cruise terminal has ample parking spaces for tour buses which can easily access to cruise berths.
(B) Port facilities and services	
(B1) Auxiliary services and ship provisions	Cruise port provides ship maintenance, bunkering, fresh water supply facility, fresh vegetable, ship stores, and salvage service.
(B2) Customs, Immigration, Quarantine (CIQ) services	One stop service available in the cruise terminal with less bureaucratic features
(B3) Medical services	Cruise port city has general hospital services at the international standard level.
(C) Connectivity	
(C1) Landside public transportation	Efficient and convenient linkages of public transportation such as MRT, taxi, city bus are available nearby cruise terminal.
(C2) Fly-cruise connectivity	Easy and frequent access between cruise terminal and airport with high frequency of flight service are available.
(C3) Connectivity with other destinations	The cruise port is frequently included in cruise itinerary product development with other destinations in the region.
(D) Tourism	
(D1) Shore excursions	Abundant tourist resources or variety options of shore excursions are available. Shopping centers are well developed.
(D2) Hotel availability and facilities	A variety of hotels with good facilities are available for Fly-cruise passengers.
(D3) Landside tour services	Standardized and qualified tour guide services are available.
(E) Sustainability	
(E1) Green port-community policy	Cruise terminal has green port policy in collaboration with community city to reduce gas emissions for passengers and community.
(E2) Port city safety and security	Cruise port city has high standard security system for tourist in the city center.
(E3) Risk management and resilience system	Cruise port city has risk management system to deal with terrorist attacks and in case of

service disruptions, has well designed resilient system.

4.2 Data collection

The questionnaire is designed on November 30, 2014. We first conducted a pilot survey on December 15, 2014. The main survey with the revised questionnaire was conducted in February 25, 2015. To reduce the effect of noisy data, we use field observation to purify the collected data against the criteria that have strong dynamic features in a cruise emerging market (e.g. C1, C2, and C3) in 2016-2018. In the end, fourteen responses were received and thirteen were accepted.

The involved experts are from Korea, Japan and China for evaluating the investigated terminals' performance, respectively. Among the thirteen respondents, six experts are from tourism companies, three from cruise terminals and four from cruise shipping companies. They present the stakeholder groups comprehensively. Their average job experience is 7.7 years. It should be recognized that the characteristics and development stage of the cruise industry in Northeast Asia were impediments to capture more sampling. To overcome the above shortcomings, the researchers had face-to-face interviews with stakeholders in the cruise industry to further verify the test results.

4.3 Test results

4.3.1 CFPR results - relative weights analysis

Relative weights are identified by experts' judgements using CFPR. Taking into account the average evaluations, the top five criteria are from three dimensions (aspects) including (A) Port infrastructure, (B) Port facilities and services and (D) Tourism. The top five criteria are (B2) Customs, Immigration, Quarantine (CIQ) services, (A1) Dedicated cruise berth, (D3) Landside tour services, (D1) Shore excursions and (A3) Ground transportation areas in order. The bottom three aspects are (B1) Auxiliary services and ship provisions, (D2) Hotel availability and (E1) Green port-community policy. We can see that the experts still have less concerns on environmental issues compared to other aspects.

Table 2 indicates that when comparing the results from different stakeholder groups, most of the criteria ranks are similar according to the experts' rating. However, some of them are different. For example, cruise shipping companies rank (C3) "Connectivity with other destinations" at the 4th position, while experts from cruise terminals and tourism companies regard it at the 15th rank. It is also noteworthy that the experts in cruise terminals rank (E2) "Port city safety and security" and (E3) "Risk management and resilience system" on the top, while the experts in shipping sector evaluate their weights much lower.

Table 2 Relative weights of evaluation criteria

Criteria	Terminal	Rank	Tourism	Rank	Shipping	Rank	Total	Rank
(A) Port infrastructure								
(A1) Dedicated cruise berth	0.077	3	0.077	4	0.084	2	0.079	2
(A2) Marine navigation and access	0.072	4	0.070	6	0.068	8	0.070	8
(A3) Ground transportation areas	0.071	6	0.068	8	0.075	3	0.071	5
(B) Port facilities and services								
(B1) Auxiliary services and ship provisions	0.050	14	0.060	12	0.055	13	0.056	13
(B2) Customs, Immigration, Quarantine (CIQ) services	0.071	5	0.080	1	0.087	1	0.080	1
(B3) Medical services	0.056	13	0.061	11	0.056	12	0.058	11
(C) Connectivity								
(C1) Landside public transportation	0.061	12	0.078	3	0.068	9	0.070	6
(C2) Fly-cruise connectivity	0.066	10	0.066	9	0.070	6	0.067	9
(C3) Connectivity with other destinations	0.049	15	0.049	15	0.075	4	0.058	12
(D) Tourism								
(D1) Shore excursions	0.068	7	0.077	5	0.070	5	0.072	4
(D2) Hotel availability and facilities	0.063	11	0.053	14	0.051	14	0.055	14
(D3) Landside tour services	0.068	7	0.078	2	0.069	7	0.073	3
(E) Sustainability								
(E1) Green port-community policy	0.067	9	0.055	13	0.045	15	0.054	15
(E2) Port city safety and security	0.080	1	0.069	7	0.064	10	0.070	7
(E3) Risk management and resilience system	0.080	1	0.062	10	0.063	11	0.067	10

Nine cruise terminals are selected as the alternatives in this study because of their size in terms of throughput in the region and evaluated in the following two sections. One of the novelties of this work lies in the pioneering application of PROMETHEE to analyze performance position of the cruise terminals using visual tools. Furthermore, it is combined with GRA and CFPR, to make it possible that the test results of each combination can be compared to evaluate overall performance of the cruise terminals. It means that the findings can aid cruise terminals to benchmark their performance to effectively improve their service against the criteria and maximize their overall performance.

4.3.2 PROMETHEE results

PROMETHEE can help decision makers easily understand the related evaluation results. The evaluation criteria for cruise terminals have been listed up in Table 1. This research utilizes the questionnaires to capture the experts' perceptions to find the performance of each cruise terminal. Table 4 shows performance of nine cruise terminals against 15 criteria.

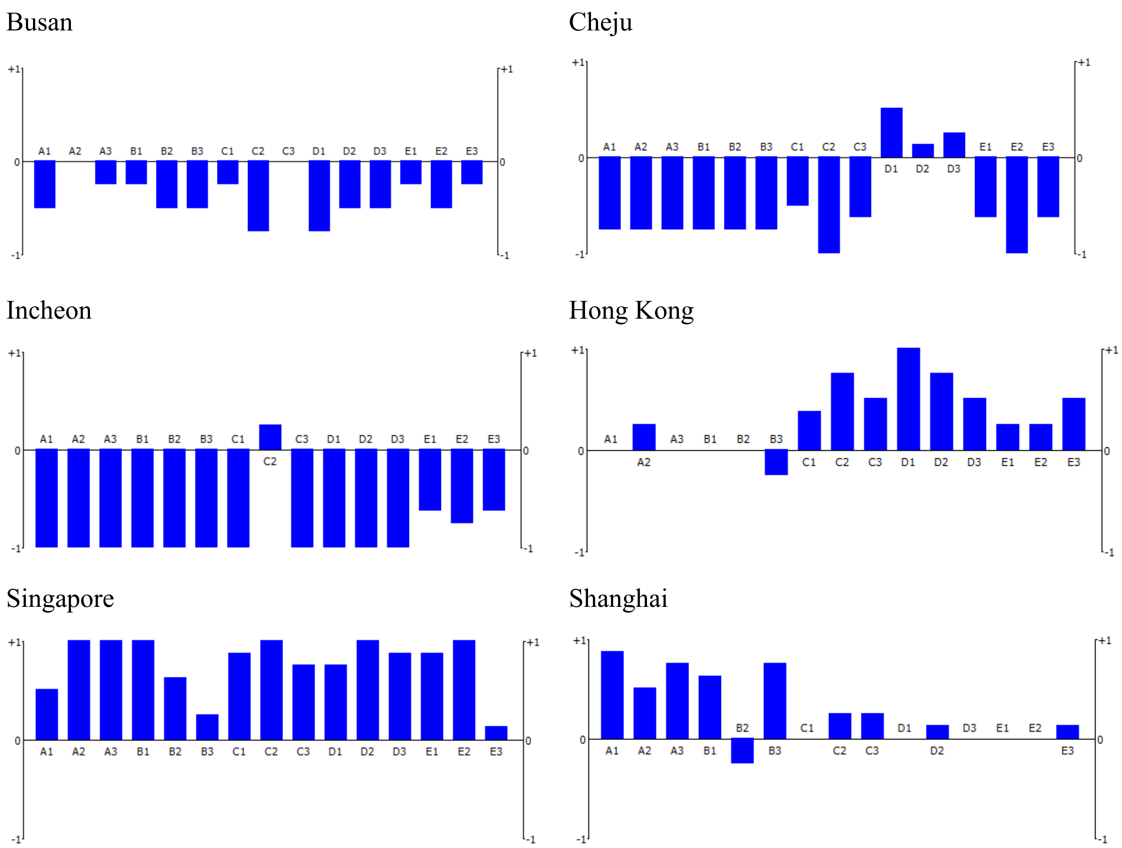
It can be found in Table 3 that Singapore is the best cruise terminal without considering the criteria weights (the same weight to all criteria). However, when different weights are assigned using GRA and PROMETHEE, Singapore is ranked first against nine out of fifteen criteria, while Yokohama has better performance against the other six criteria. Incheon and Busan show poor performance, since most performance values against the criteria are lower than three. Overall, Incheon is ranked at the bottom of the list.

Table 3 Investigated performance of nine cruise terminals

Criteria/Country	Busan	Cheju	Incheon	Hong Kong	Singapore	Shanghai	Tianjin	Yokohama	Fukuoka
(A) Port infrastructure									
(A1) Dedicated cruise berth	3.29	3.00	2.00	3.67	4.80	5.00	5.00	4.40	3.60
(A2) Marine navigation and access	3.71	2.70	2.40	4.00	4.60	4.20	3.50	4.40	3.60
(A3) Ground transportation areas	3.29	2.70	2.00	3.33	4.40	4.20	3.50	4.00	3.40
(B) Port facilities and services									
(B1) Auxiliary services and ship provisions	3.57	2.90	2.80	3.67	4.40	4.20	3.50	4.20	4.00
(B2) Customs, Immigration, Quarantine (CIQ) services	3.71	3.20	2.60	4.00	4.40	3.80	4.50	4.40	4.20
(B3) Medical services	3.29	2.80	2.60	3.33	3.60	3.80	3.50	3.80	3.80
(C) Connectivity									
(C1) Landside public transportation	3.29	3.10	2.40	4.00	4.20	3.60	3.00	4.20	4.00
(C2) Fly-cruise connectivity	3.29	3.00	3.80	4.33	4.40	3.80	3.50	3.80	3.60
(C3) Connectivity with other destinations	3.71	3.50	3.00	4.00	4.20	3.80	3.50	4.40	3.60
(D) Tourism									
(D1) Shore excursions	3.43	4.00	2.60	4.33	4.20	3.60	3.50	3.60	3.60
(D2) Hotel availability and facilities	3.71	4.20	2.60	4.33	4.80	4.20	3.00	4.20	4.20
(D3) Landside tour services	3.29	4.10	2.60	4.33	4.40	3.80	3.00	4.40	3.60
(E) Sustainability									
(E1) Green port-community policy	3.14	3.00	3.00	3.67	4.20	3.20	2.50	4.20	3.80
(E2) Port city safety and security	3.43	3.20	3.40	3.67	4.40	3.60	3.50	4.20	4.20
(E3) Risk management and resilience system	3.57	3.20	3.20	3.67	3.60	3.60	3.00	4.20	4.20

d Graphical Analysis for Interactive Aid (GAIA) is often integrated with PROMETHEE applications. GAIA provides a graphical diagram to help decision makers clearly identify the practical situation from investigated data. In the applications, the PROMETHEE software shows a plotting diagram with cruise terminal performance in terms of criteria (see Figure 2) and a two-dimensional plane, i.e., GAIA plane, from 15-dimensional space (see Figure 3) by principal component analysis (PCA).

Figure 2 shows a graphical representation of the uni-criterion net flow scores for the selected terminal, which is shown as upward and downward bars in blue indicating the performance of each terminal against 15 criteria. Positive scores (upward bars) reveal good performance while negative ones (downward bars) correspond to poor performance. That is, the upward bar of a criterion means that its performance is better than the average performance of the nine cruise terminals, while the downward bar means that its performance is worse than the average performance. Most criteria bars of Singapore and Yokohama cruise terminals are upward, indicating their outstanding performance. On the other hand, most criteria in Busan, Cheju and Inchon terminals in Korea show downward bars, implying that there are improvement rooms for their performance and services.



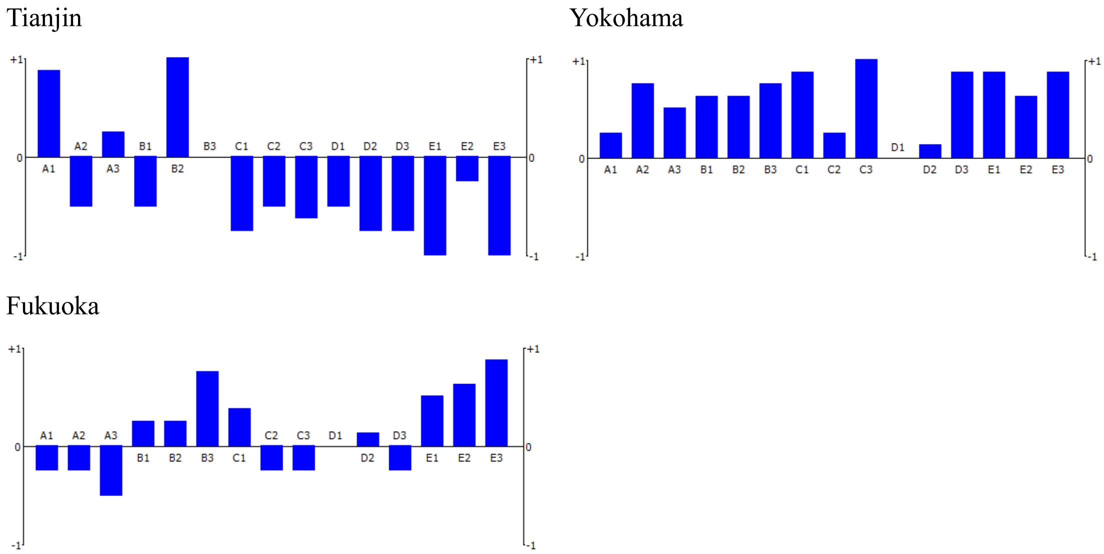


Figure 2 Performance profiles of major cruise terminals in northeast Asia

Figure 3 shows that the performance when all the criteria are transformed into two new variables (u, v) and projected onto a 2D plane, which is called GAIA plane, by utilizing PCA in the visual PROMETHEE software. Especially, u and v are derived from PCA, in which u and v are the first and second principal components respectively. In this test, the plane gathers 80.4% information. Each cruise terminal is represented by a point in the GAIA plane. Its position is related to its performance on the set of criteria in such a way that the terminals with similar profiles will be closer to each other. In this test, we can identify two different types of profiles:

1. Singapore, Yokohama, Fukuoka, Hong Kong and Shanghai are close to each other. Their performance is quite similar.
2. Busan, Tianjin, Cheju and Incheon are close to each other. They are also similar terminals, but have different performance compared to the ones in the first group.

Each criterion is represented by an axis drawn from the center of the GAIA plane. The orientation of these axes is significant as they indicate how closely the criteria are related to each other. Criteria expressing similar preference have the axes that are close to each other and conflicting criteria have the axes that are pointing in an opposite direction. In Figure 3, all the criteria axes point in the similar direction. In the GAIA plane of this test, each blue line indicates the aggregated performance value of the nine terminals against each criterion . Its length means the performance level of the aggregated performance.

The red line (decision axis) in Figure 3 is a representation of the weighting of the criteria. The orientation of the decision axis indicates which criteria are in agreement with the PROMETHEE rankings and which are not. That is, the decision axis shows the aggregated performance values of the nine cruise terminals against all criteria in considering with the relative weights of criteria. If the aggregated performance of each cruise terminal's criteria moves to the same direction of the decision axis, it means that the performance of the terminal is conformed to the best alternative. In Figure 3, Singapore and Yokohama are almost in the same direction of the red line, which means the performances of the two terminals are better than the others. Singapore's performance is better than Yokohama's because the former is farther located in the same direction to the red line than the latter's. Hong Kong, Fukuoka and Shanghai are in the positive direction to the red line, which means these terminals are better than those terminals in the opposite direction to the red line, such as Tianjin, Busan, Cheju and Incheon.

Figure 3 GAIA plane of the performance of cruise terminal

The calculation results of PROMETHEE include two parts: PROMETHEE I and II, which are *partial ranking* and *complete ranking*, respectively. The pairwise comparisons rated by the experts are calculated by CFPR to find the relative weights of criteria, which become the input weights of Visual PROMETHEE. Their results calculated by Visual PROMETHEE are shown in Table 4 and Figure 4. The partial ranking, i.e. PROMETHEE I, evaluates terminals by $\emptyset^{+}$ and $\emptyset^{-}$; $\emptyset^{+}$ value represents the superior degree of an alternative's performance, while $\emptyset^{-}$ value represents the inferior degree of an alternative's performance. In other words, the higher $\emptyset^{+}$ value of a terminal, the better the terminal performance, while the lower $\emptyset^{-}$ value of a terminal, the better the terminal performance. For example, $\emptyset^{+}$ value of Yokohama cruise terminal is 0.7320, which means that its performance is better than the other ports except Singapore terminal. $\emptyset^{-}$ value of Incheon cruise terminal is the highest, 0.9107, which means that the performance terminal is the worst among the nine ports. The partial ranking diagram in Figure 4 shows the consistency of performances evaluation of terminals except Hong Kong and Shanghai; the performance of Hong Kong is better than that of Shanghai in terms of $\emptyset^{+}$ value, while the performance of Shanghai is slightly better than that of Hong Kong in terms of $\emptyset^{-}$ value. The complete ranking ($\emptyset$), i.e PROMETHEE II, combines $\emptyset^{+}$ with $\emptyset^{-}$ to evaluate the overall evaluation of terminals. The right diagram in Figure 4 shows the overall evaluation ranks of nine cruise terminals.

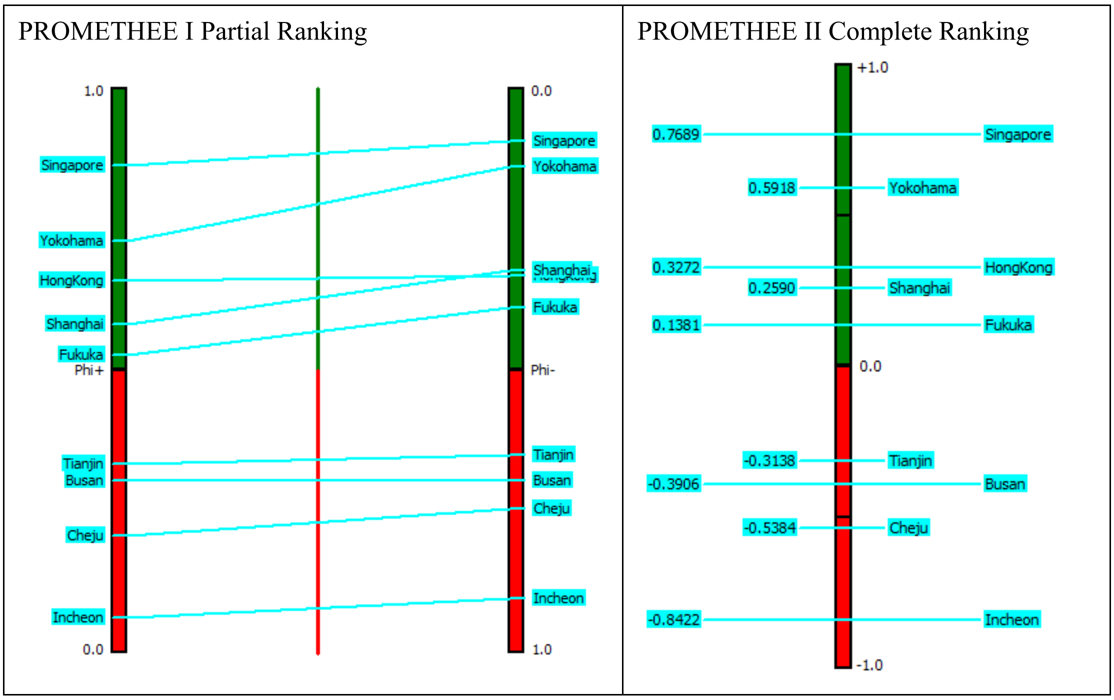


Figure 4 Diagrams for the results of PROMETHEE I and PROMETHEE II

In the PROMETHEE Diamond as shown in Figure 5, each terminal is represented as a point in the ($\emptyset^{+}$, $\emptyset^{-}$) plane. The plane is angled 45° degrees so that the vertical dimension (green-red axis) corresponds to the $\emptyset$ net flow. A cone is drawn for each terminal. When a cone is overlapping another one, it means that the terminal is preferred to the other one in the PROMETHEE I partial ranking. Intersecting cones correspond to incomparable actions. In Figure 5, each terminal is comparable, except Hong Kong and Shanghai are incomparable owing to their intersecting cones, which means that their ranks results are different in $\emptyset^+$ and $\emptyset^-$. The vertical dimension corresponds to $\emptyset$, so it is possible to visualize both PROMETHEE rankings at the same time.

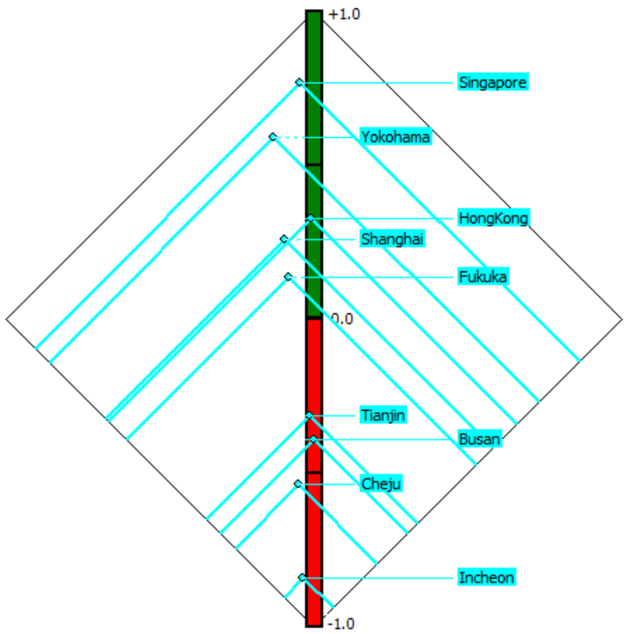


Figure 5 PROMETHEE diamond diagram for ranks results

Table 4 PROMETHEE flow

Rank	Action	$\emptyset$	$\emptyset^+$	$\emptyset^-$
1	Singapore	0.7712	0.8641	0.0929
2	Yokohama	0.5926	0.7320	0.1394
3	Hong Kong	0.3227	0.6570	0.3342
4	Shanghai	0.2624	0.5836	0.3212
5	Fukuoka	0.1177	0.5194	0.4016
6	Tianjin	-0.2889	0.3470	0.6359
7	Busan	-0.3912	0.3044	0.6956
8	Cheju	-0.5333	0.2119	0.7451
9	Incheon	-0.8534	0.0574	0.9107

Apparently, PROMETHEE I applies $\emptyset^+$ and $\emptyset^-$ to find the partial ranking of nine cruise terminals, while PROMETHEE II applies $\emptyset$ to find the complete ranking of the ports. The integrated results of PROMETHEE reveal that the ranking order of the cruise terminal performance is Singapore> Yokohama > Hong Kong > Shanghai > Fukuoka > Tianjin> Busan> Cheju> Incheon.

4.3.3 GRA results analysis

MCDM evaluation methods create different normalization equations for different aspired levels of criteria so that different evaluation results may be drawn. GRA has the same function with PROMETHEE. For the purpose of comparison, the results by PROMETHEE plus CFPR with those from GRA plus CFPR are compared in this section. When evaluating the cruise terminals, relative weights and terminals' performance are needed. The same with the process of PROMETHEE, relative weighs are identified by CFPR, and terminals' performance is measured by the respondents. Besides, the same normalization method is applied to evaluate the terminals' performance. The results of GRA in terms of the ranking of cruise terminals are shown in Table 5.

Table 5 Evaluation results of GRA for cruise terminals

Rank	Action	GRA
1	Singapore	1.9629
2	Yokohama	1.7468
3	Hong Kong	1.3900
4	Shanghai	1.3558
5	Fukuoka	1.3273
6	Tianjin	0.9688
7	Busan	0.9385
8	Cheju	0.7843
9	Incheon	0.5147

It is very interesting to note that the results of using GRA and CFPR to evaluate performance of the nine cruise terminals are in harmony with those acquired by PROMETHEE II and CFPR. This implies that the PROMETHEE approach deliveries a robust result in terms of performance evaluation of the investigated cruise terminals.

V. Conclusions

In this paper, nine cruise terminals in the Northeast Asia have been evaluated against the identified important fifteen criteria by applying the hybrid of PROMETHEE and

CFPR. This hybrid method makes the investigation results reliable because the information demand is reduced by the use of CFPR while PROMETHEE is capable of detecting the incomparable and indifferent alternatives. To conduct a cross-check of the test result, the well-established GRA -CFPR approach has been employed. This study shows that the two test results are in line with each other. Consequently, the major findings are verified and the derived implications are obtained as follows.

Relative importance of criteria of cruise terminals

Relative weights and terminals performance in terms of evaluation criteria are evaluated by utilizing the primary data collected from the same group of experts. Most data from the experts are consistent within the same groups, despite some inconsistent parts. For example, (E2) port city safety and security and (E3) Risk management and resilience system are ranked at the top by terminal operators, but they are at the 7th and 10th ranked by shipping companies and the tourism sector, respectively.

Evaluated performance of cruise terminals by the experts from different countries

Nine cruise terminals are evaluated in this research. Incheon port has shown the poorest performance overall and against eleven criteria, individually. It therefore provides useful insights for the relevant stakeholders such as the authorities in Korea to take right directions for improvement measures. The authorities need to improve the performance of Incheon based on the relative importance of the related criteria to make the improvement effectively. Comparatively speaking, Singapore is ranked the best overall, having the best performance against nine out of the fifteen criteria.

Key successful factors (KSFs) of cruise terminals

Key successful factors (KSFs) can be found from the CFPR results. However, each port has different performance against 15 criteria. Obviously, the KSFs will be a good reference for the local authorities to improve their terminals. Similarly, the countries may choose the best terminals for cooperation according to their performance in terms of KSFs. Of course, the terminals should be considered in not only their current performance, but also their future potential development.

Future Research

This paper still reveals some shortcomings. First, despite the complementary data using field observation, the number and distribution of respondents are relatively small, which is caused by emerging cruise market in Northeast Asia. Future studies with more data could be collected to better generalize the findings. Second, this study addresses the 15 criteria independently. The casual relation among the criteria can, if any, be further investigated to analyze their effect on the findings. The Decision-Making Trial and Evaluation Laboratory method looks promising in this direction.

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