A Trial to Generalize Evaluation of Key Driving Factors of Port-City Waterfront Development

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Abstract:
This paper investigates the key successful factors in waterfront port development (WPD). Consistent Fuzzy Preference Relation (CFPR), with the combination of the Preference Ranking Organization METHods for Enrichment Evaluation (PROMETHEE), is applied to six ports, namely Busan, Incheon Inner Port, Bangkok, Kaohsiung, Montreal and Liverpool. The latter technique evaluates the performance of WPD among the studied cases, while the former draws the key successful factors (KSFs) of the selected ports. To draw meaningful comparison with the test results from past research, this paper takes the same evaluation hierarchy in the questionnaire form in the previous studies. With a further validity of the previous findings in WPD studies, this paper does not only provide insight on exploring the generalization of KSFs in WPD in a longitude manner, but also contributes to the literature of WPD and port-city interplays.

Keywords: Key successful factor, Waterfront port development, Consistent Fuzzy Preference Relation, Preference Ranking Organization METHods for Enrichment Evaluation (PROMETHEE), Shipping

1. Introduction

Scholarly research on waterfronts under the notion of ‘port-city interface’ can be dated back to the early 1980s (e.g., (Hayuth, 1982; Hilling, 1988; B. S. Hoyle, 1989; B.S. Hoyle, 1988; Robinson, 2008)). Since then, urban planning and port development literatures by human geographers had cited numerous cases of waterfront port development (WPD) (e.g., Brown, 2009; Charlier, 1992; Craig-Smith and Michael, 1995; Gordon, 2004, 1993; Hall and Jacobs, 2012; B. S. Hoyle, 2000; Olivier and Slack, 2006; Wang, 2014). Port cities in Asia, such as Bangkok, Busan, Incheon, Kaohsiung, to name but a few, face WPD challenges resulting from changes in their port functions, container port development, structural changes in port-city interactions in tandem with alterations of a port governance system and development of democracy.

A WPD project involves a couple of key stakeholders comprising of, among others, the port authority, national and local governments, port service users, citizen group, and waterfront port developers and investors. Therefore, diversified, and sometimes ambivalent, interests among port stakeholders often drift away the initial objectives of WPD projects, thus wasting social resources and posing negative externalities. For example, in a WPD project in Busan, several external forces, such as the change of northern Busan port function, conflict among the Busan Port Authority (BPA), Busan City government, the Korean national government, and a citizen group. In this case, port users complained about negative impact of WPD on their business, WPD investors demanded a certain level of profitability, and an increasing consciousness and assertiveness by the local community over the WPD to improve quality of life. Therefore, the identification of key success factors (KSFs) of WPD in tandem with mitigating conflicts among port stakeholders is a critical issue nowadays.

To cope with this problem, Lee et al. (2013) investigated KSFs of WPD cases worldwide and a case study of Bangkok Port in Thailand and Inchon Inner Port (IIP) in Korea (Lee et al., 2016). The former designed an efficient Analytic Network Process (ANP) questionnaire that facilitated the application of both Analytic Hierarchy Process (AHP) and ANP to identify KSFs of WPD by comparing the preferences of decision-makers, with special attention on the conflicting demands and needs of stakeholders and interdependence of their concerns. They argued that the application of AHP could not overcome its fundamental drawbacks, i.e., the assumption of independence of the upper part, or cluster, of the hierarchy, from all its lower parts, and from the criteria or items in each level. This was because real world problems, such as WPD, usually consisted of dependence or feedback between different elements. Their results showed that the top five dimensions by AHP were contribution to regional economy, transformation of port/city interface, efficiency/service of port, profitability of WPD, and land value, while the top five KSFs by ANP were connectivity, maritime clustering, transformation of port/city interface, accessibility, and port infrastructure. In other words, Lee et al. (2013) illustrated that ANP outcomes had a wider range of dimensionality consisting of economic, port and community function in contrast to the two dimensions of economic and port functions found from the top five by AHP. Despite their contribution to the WPD literature with identification of its KSFs, they did not conduct a wide range of real cases based on specific ports to further validate their approach.

To fill in this gap, Lee et al. (2016) conducted empirical case studies of IIP and Bangkok Port by applying the same approach with the same questionnaire design, comparing the two cases with the global case study in Lee et al. (2013; 2016). They found that from the experts' viewpoint of ranking WPD criteria, the ANP test results of the three cases (i.e., IIP, Bangkok, and the worldwide case) were more stable and consistent than the AHP ones; the top five criteria by ANP among the three cases share four in common (i.e., accessibility under community function, connectivity under port function, maritime clustering, and transformation of the port-city interface under economic function). Such stability confirmed that the ANP is more reliable and feasible than the AHP in the WPD context. However, the limitation was that the WPD sampling size was still rather small to generalize the evaluation of critical WPD factors.

Understanding such deficiency, the first aim of this study is to add more WPD cases from different countries and regions to further investigate KSFs aiming at generalization of knowledge in WPD. The second aim is to improve respondent's efficiency and consistency with a hybrid method in conducting the questionnaire efficiently designed by Lee et al. (2013); in this paper, Consistent Fuzzy Preference Relation (CFPR), with the combination of the Preference Ranking Organization METHods for Enrichment Evaluation (PROMETHEE), is applied instead of AHP and ANP due to the following reasons. The decision-makers in the questionnaire must give the exact number of preference in pairwise comparison. Our previous experience revealed that it is far from easy to attain respondent's preference from a lengthy questionnaire. The CFPR method will enable a decision-maker to give preference through consistency logic, i.e., transitive property, thus improving the consistency of his/her judgments. It also helps to mitigate the perplexity of decision-making, reducing the number of pairwise comparisons so it improves consistency in decision process compared to the conventional AHP/ANP method. CFPR is a subjective method capable of modelling decision-makers' perceptions on features of WPD which can be used to identify the factors' relative weights. From the methodological perspective, CFPR helps decision-makers efficiently evaluate the WPD criteria's positions according to the experts' ratings. Having said so, CFPR is the method helping respondents to do decision-making which is simple and efficient, thus guaranteeing consistency during the decision-making process.

On the other hand, PROMTHEE is capable of addressing decision-makers' evaluation problems through reasonable normalization, thus avoiding inconsistent ranking results with the characteristic functions, and providing them with visual software so as to easily deal with the evaluation problems and sensitive analysis. The above motivations have driven us to conduct this study with an empirical case study, taking Busan, IIP, Bangkok, Kaohsiung, Montreal and Liverpool, applying a combined method of the PROMETHEE with CFPR: the latter to evaluate performance of the WPD among the six studied cases, while the former to draw KSFs of the selected ports. The paper can significantly contribute to the literatures of WPD, given that there have been few studies applying this hybrid method to WPD. To draw meaningful comparison with the test results from Lee et al. (2013; 2016), it takes the same evaluation hierarchy in the questionnaire form in the previous studies. As a result, with a focus on the further validity of the previous findings in WPD studies, it provides insight on exploring the generalization of KSFs in WPD in a longitude manner. This paper does not only generalize common KSFs among the studied WPD cases, but also enriches Hoyle's classical six-stage model on the trends and problems of port-city interface that explains the retreat of port, and port facilities, from waterfronts since the 1960s, and its impacts on port-city interrelationships (see Hoyle (1989, 2000).

2. A hybrid method of MCDM and data collection

PROMETHEE is a popular Multiple Criteria Decision Making (MCDM) outranking method dealing with the evaluation problems, firstly introduced by Brans (1982) and Brans et al. (1984) elaborated the method as a new family of outranking methods in multi-criteria analysis (Lee and yang 2018; Qu et al., 2018). Brans and Vincke (1985) further developed it with sophisticated mathematical reasoning and published their work in *Management Science*.[1] Brans et al. (1984) introduced a decision support system and visual software, named as PROMCALC and GAIA, showing that some examples and requisites are provided to make the application of PROMETHEE more reasonable. It helps decision-makers to solve evaluation problems owing to following advantages: first, visual software provides end-users with an easy solution to dealing with the evaluation problems and sensitive analysis; secondly, the associated reasonable normalization method contributes to avoidance of inconsistent ranking results with the characteristic functions.

Behzadian et al. (2010) published a review paper on PROMETHEE, with 217 papers taken from 100 journals between 1985 and 2009. Among them, 55 papers used visual software, i.e., PROMCALC and GAIA, owing to its advantages mentioned above. It shows PROMITHEE's

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[1]On the chronological development of the method, see Nasiri et al. (2013).

superiority over other MCDM ranking methods such as VIKOR and TOPSIS, AHP, and ANP. Also, this method has not been applied to WPD. The first contribution of this paper is to explore whether the PROMITHEE method is applicable to finding the solution to the complicated WPD issue, and compare the test results with the stated previous studies by Lee et al. (2013; 2016). This is the main reason why PROMETHEE has been applied in this paper.

Besides the weighting method, normalization part in outranking method should also be discussed. Ishizaka and Nemery (2011) applied PROMETHEE to deal with the statistical distribution selection by following Wang et al. (2004) who introduced a transformation function, as found in $\mathbf{r}(\mathbf{v}) = \mathbf{1}/(\mathbf{1} + \mathbf{C}\mathbf{v}^{\mathbf{2}})$ $(\mathbf{1}$:

$$\mathbf{r}(\mathbf{v}) = \mathbf{1}/(\mathbf{1} + \mathbf{C}\mathbf{v}^{\mathbf{2}}) \quad (1)$$

where C is a positive constant, r is the transformation function and $\mathbf{v}$ is the value to be transformed/normalized.

In this regard, Ishizaka and Nemery (2011) noted that the normalization equation introduced by Wang et al. (2004) would cause different results by using different constant C. Ramanathan (2005) gave related examples about this finding and explained that different normalization process might lead to different evaluation results. This normalization problem can be solved by the characteristic function provided by PROMETHEE, which is a new and different normalization method combining the perceptions of decision-makers. However, PROMETHEE does not mention how to identify the weights of evaluation criteria, but only use equal weights or sensitive analysis to find the influence of weights. To overcome the above weight identification problem, Mareschal et al. (1998) applied direct rating method to find the weights of criteria, while Macharis et al. (2004) proposed an enhanced method, PROMETHEE combined with AHP features. Recently, Turcksin et al. (2011) applied the combined AHP-PROMETHEE method to deal with the appropriate policy scenario selection problem. Behzadian et al. (2010) confirmed that that 22.1% of the studied papers used the combined MCDM method with PROMETHEE to deal with weight identification of criteria. AHP is a popular method in dealing with weights identification job; however, the assumption behind has been challenged by several researchers, such as Beynon et al. (2000) and Saaty (1996). To overcome weight identification problem in PROMETHEE, in this paper, we combine PROMETHEE with CFPR introduced by Herrera-Viedma et al. (2004) instead of AHP. It is because CFPR identifies the relative weights of evaluation criteria in this research and can reduce the number of questions within a questionnaire compared to AHP. This is the second contribution of our paper as stated earlier. In other words, it applies an integrated MCDM method, i.e. PROMETHEE combined with CFPR features, to deal with the waterfront development problem.

2.1 Combination of CFPR and PROMETHEE

PROMETHEE is applied as an outranking method in this paper owing to the advantage of good normalization method and visual software provided as described in the above section. However, it does not provide weight identification method so that Macharis et al. (2004) combined it with AHP, so-called an enhanced PROMETHEE-AHP. In this paper, CFPR is applied to replace AHP owing to the following reasons. A decision-maker in the AHP questionnaire is requested to give the exact number of preference in pairwise comparison. However, in reality, our survey experience suggests that it is difficult to acquire the respondents' preference. To cope with this problem, CFPR is applied to enable the decision-maker to give their preference by using consistency logic, i.e., transitive property. This helps to reduce respondent's perplexity of decision-making, thanks to the reduced number of pairwise comparison; it improves consistency in decision-making process compare to the conventional AHP method (Lee and Yang, 2018; Lee et al., 2018). We do not need to check the consistency of respondents' judgment in the survey, unlike the questionnaire required in AHP/ANP. To summarize, CFPR is a method that helps respondents to efficiently carry out decision-making, and ensure their consistency in the decision-making process. It has been applied in several areas, among others, including knowledge management implementation (Wang and Chang, 2007), business partner selection (Wang and Chen, 2007), forecasting the success of advanced manufacturing technology (Chang and Wang, 2009), merger strategy of commercial banks (Wang and Lin, 2009), supplier selection (Chen and Chao, 2012), and logistical outsourcing problem (Kumar et al., 2012).

Thus, the combined method PROMETHEE with CFPR features has been adopted, expecting contribution to expanding application of a hybrid MCDM to WPD studies. CFPR provides the feature of weights identification, while PRMETHEE the feature of outranking as described in Figure 1.

[INSERT FIGURE 1 ABOUT HERE]

2.2 Consistent Fuzzy Preference Relation (CFPR)

Fuzzy preference relation, different with multiplicative preference applied in AHP, is applied in the CFPR. The multiplicative preference investigated from the experts in a research field can be transferred into fuzzy preference by following Eq. (2):

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

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 may 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. a_{ij} is the pairwise comparison of criteria importance rated by experts. The characteristics of fuzzy preference can be described as the following Eq. (3):

$$p_{ij} + p_{ji} = 1\ \ \forall i,j \in \{1,\cdots,n\} \qquad (3)$$

The preference relations are conformed to the following relations (4) and (5) when they are consistent,

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \qquad (4)$$

$$p_{i(i+1)} + p_{(i+1)(i+2)} + \cdots + p_{(j-1)j} = j - i + 1/2\ \ \forall i < j \qquad (5)$$

All the p_{ij} in preference matrix can be calculated by the Eqs. (3), (4) and (5) mentioned above. The relative weights can be identified by Eq. (6) as follows.

$$w_i = {\sum_{j=1}^{n} p_{ij}} \Big/ {\sum_{i=1}^{n}\sum_{j=1}^{n} p_{ij}} \qquad (6)$$

The concept of CFPR is briefly described in this section[2].

2.3 Operation steps of PROMETHEE

1. Construct the performance matrix by Questionnaires

   Input data of PROMETHEE was collected from the questionnaires in the form of Eq. (7).

$$A = \begin{array}{c} \\ a_1 \\ \vdots \\ a_i \\ \vdots \\ a_m \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & \cdots & C_j & \cdots & C_n \end{array} \\ \begin{bmatrix} g_{11} & \cdots & g_{1j} & \cdots & g_{1n} \\ \vdots & & \vdots & & \vdots \\ g_{i1} & \cdots & g_{ij} & \cdots & g_{in} \\ \vdots & & \vdots & & \vdots \\ g_{m1} & \cdots & g_{mj} & \cdots & g_{mn} \end{bmatrix} \end{array} \qquad (7)$$

   Where g_{ij} in A denote the performance of alternatives.

2. Find the alternatives pairwise comparison matrix by preference function

[2]See Herrera-Viedma et al. (2004) and Lee et al. (2014)for further details on this method.

We first find the preference deviation of alternatives on criteria according to Eq. (8).

$$d_j(a,b) = g_j(a) - g_j(b) \quad (8)$$

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 as Eq. (9).

$$P_j(a,b) = F_j[d_j(a,b)] \quad (9)$$

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

3. Calculate the overall performance deviation of alternatives.

   The overall performance deviations of alternatives are calculated by Eq. (10).

$$\pi(a,b) = \sum_{j=1}^{n} P_j(a,b) \times w_j \quad (10)$$

   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.

4. Calculate the positive and negative ranking flows

   The results of Eq. (10) can be applied to calculate the positive and negative ranking flows using Eqs. (11) and (12).

$$\emptyset^+(a) = \frac{1}{n-1}\sum_{a_j \in A} \pi(a, a_j) \quad (11)$$

$$\emptyset^-(a) = \frac{1}{n-1}\sum_{a_j \in A} \pi(a_j, a) \quad (12)$$

   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.

5. Calculate the net ranking flow

   The net ranking flow can be calculated by Eq. (13).

$$\emptyset(a) = \emptyset^+(a) - \emptyset^-(a) \quad (13)$$

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

2.4 Data collection

The questionnaire consists of two parts, for CFPR and PROMETHEE, respectively. The same four dimensions and 18 criteria of WPD as those in Lee et al. (2013; 2016) are used in this paper (see Figure 1 and Table 1 in Lee et al. (2013)).

2.4.1 Questionnaire design

The questionnaire was designed to apply CFPR and PROMETHEE to evaluate the performance of WPD. Since both methods belong to MCDM requiring experts to answer the questionnaire, this study applied the experts' investigation method to collect data. The evaluation hierarchy is the most important element in dealing with MCDM applications. We used the same dimensions and criteria in hierarchy for waterfront development as shown in Table 1 (Lee et al. (2013; 2016)) for the purpose of comparing the results of KSFs with the previous two papers.

[INSERT TABLE 1 ABOUT HERE]

2.4.2 Questionnaire survey

After conducting a pilot survey of the originally designed questionnaire in November 2014, we modified it, and distributed the revised questionnaire to seven ports, i.e., Busan, Incheon Inner Port (IIP), Kaohsiung, Bangkok, Montreal, Vancouver and Liverpool. Researchers conducted the survey *via* face-to-face interviews with the most respondents between December 2014 and March 2015. The questionnaire was distributed to 33 respondents coming from local governments, port authorities, waterfront port developers and citizen groups (hereinafter called 'experts'). We collected 33 questionnaires from each group of the six ports except Vancouver and reduced them to 23 questionnaires, excluding ten questionnaires because of invalid and extreme answers and level of expertise of the respondents. One citizen group response from Vancouver was used as the citizen response of Montreal as a proxy. The average working period of the respondents' collected from six ports is 15.7 years. We would like to explain the reason why "small sample size" was used for this paper. We understand that MCDM requires expert's views/opinion/judgement. It is not questionable that the more the experts (respondents) are, the better. We think that the qualification and expertise of experts is more important than just number of experts. There is no standard for the sample size for MCDM technique (AHP, ANP, VIKOR and etc.) because it is contextual. Our sample size contains 23 experts, of which number is appropriate to infer valid and reliable results under the MCDM techniques (Opricovic and Tzeng, 2004; Saaty, 1996). In other words, the sample size is sufficient based on the MCDM technique.

The questionnaire consisted of three parts, the first of which was intended to elicit demographic information on the respondents. The second part was to measure the relative weights of evaluation criteria. The third part was designed to measure the performance of the waterfront development of the investigated ports where they were working during the survey period.

3. Results and discussions

3.1 CFPR results and discussions

Table 2 shows the average weights calculated by CFPR and the ranks of the criteria. The criteria with top five weights are (B4) Infrastructure for city branding, (E3) contribution to regional economy, (P4) Efficiency/Service quality, (E4) Profitability of waterfront (re-)development (WPD) and (P1) port infrastructure, respectively. On the other hand, the criteria with bottom three weights are (P2) Security/Safety, (E1) Land value, and (C2) Conservation. The average weights results reveal that the city branding is highly recognized by the experts rather than economy function, port function, and community function. Let's compare the experts' CFPR weight by port. The experts of Busan consider (B4) infrastructure for city branding, (E3) contribution to regional economy and (C3) quality of life are most important criteria out of 18 criteria. The experts of Kaohsiung put (P5) green port, (P3) connectivity and (P4) efficiency/service quality under port function on the top 3 ranks. The experts of Bangkok pay more attention to environmental issues, giving highest weight on (P5) green port and (C1) environment. The experts of Montreal are more concerned about economic and port functions, in which (P4) efficiency/service quality is ranked first and (E3) contribution to regional economy and (E4) profitability of WPD are in the second and third places, respectively. The experts of Liverpool think city branding issues are most important, in which (B3) International landmark building(s), (B2) Opportunities for national and international events within WPD, and (B4) infrastructure for city branding are among the top three. The experts of Incheon give top 3 ranks on (B4) infrastructure for city branding, (E4) profitability of waterfront (re)development, and (P1) Port infrastructure.

[INSERT TABLE 2 ABOUT HERE]

To move on and get more insight of and discuss about WPD, referring to the average weights evaluated by group, i.e., city government, port authority, waterfront developer and citizen (see Table 3). It is found that the thinking patterns of these four groups are different. The experts from the city governments, port authorities, and citizens ignore port function, economic functions and city branding, respectively; on the other hand, the WPD developer ignores port function and community function. The standard deviation (STD) represents the dispersion degree of data. Table 3 lists the STD of the experts' opinions, representing the dispersion degree of experts' opinions for a careful comparison and interpretation.

[INSERT TABLE 3 ABOUT HERE]

Table 4 shows top five criteria ranked in terms of relative weights by group among the six ports. It is noted that there are different priorities among experts in WPD. First, top five criteria of each group considered are different; (E3) Contribution to regional economy, (P4) Efficiency/service quality, (C1) Environment and (B4) Infrastructure for city branding are common criteria among the top five of the four groups. City government, port authority and WPD developer have common criteria (B4). Infrastructure for city branding and it is the most common criteria among the three experts. Port authority gives top priority to port efficiency and service quality so that WPD can minimize any negative impact on current port function. This is confirmed by interview from Busan and Incheon port. The most important criterion that waterfront port developers are concerned with is profitability, which is a prerequisite to attract and justify their investment. The results show that citizen group expects economic benefits from WPD as top priority, followed by environment criteria which aim to remove the negative scenery of port from the city's viewpoint, mitigate negative externalities of WPD, and plan comprehensive environmental protection in collaboration with city government and port authority. Although each expert shows differences in WPD, all the top five criteria evaluated by the four groups cover four functions in a well-balanced way. This implies that these findings provide useful information to solve conflicts in the process of negotiation among the experts.

[INSERT TABLE 4 ABOUT HERE]

The results indicate that the priorities of WPD largely focus on the commercial aspects (e.g., the profitability of WPD projects, employment opportunities, private investment environment). Moreover, the importance of infrastructure for city branding highlights the renewed trend of port-city association and historical heritage. Our results complement closely to Hoyle's view on the evolution of port-city interrelationships, where WPD since the turn of the century seems to focus on commercial interests and the re-integration between port and city (Hoyle, 1989; 2000). Increasing emphasis on environmental issues and green ports among certain studied ports also supports, subject to further research, Hoyle's view on the rising influences of communities and the gradual demolishment of the 'top-down' approach in WPD projects and planning.

An important finding is the perceived importance of port infrastructures and efficiency/service quality of ports from the experts. As per Hoyle's classical six-stage model on port-city relationship, industrial growth and the development of maritime technology gradually pushed ports out of city cores, causing segregation between port and city (Hoyle, 2000). Although he pointed out the possible re-integration between port and city since the 2000s, he did not directly address how such re-integration would impact on ports and port infrastructures. However, our results seem to provide some evidences that city branding, commercial interests, and thus the urge to attract tourists (and, in some cases, cruise ships) to the (re-)developed waterfronts have actually regenerated the pivotal functions of port, port facilities (especially passenger-related), and related connecting infrastructures. As shown in Table 3.1, (C4) Accessibility, (P3) Connectivity and (P4) Efficiency/service quality belong to the top three criteria by weight of the city government, port authority and citizen groups, respectively, indicating that most of the experts pay considerable attention to ports, port facilities, and related connecting infrastructure. While subject to further verification, the relationship between port (and port-related) facilities and WPD projects might have been understated in the existing WPD literature.

Lee et al. (2016) investigated criteria ranks in Bangkok port and IIP's WPD cases by AHP/ANP with the same questionnaire format used for this study. The former had the following top five criteria, i.e., accessibility, connectivity, maritime clustering, and transformation of port/city interface and port infrastructure in order; while the latter had maritime clustering, accessibility, connectivity, and transformation of port/city interface and profitability of WPD in order. However, as shown in Table 5, this study shows different top five criteria from the test results in Lee et al. (2016): Top five criteria of Bangkok port are land value, green port, environment, transformation of port/city interface, and infrastructure for city branding, while those of IIP are infrastructure for city branding, profitability of WPD, port infrastructure, contribution to regional economy, and international landmark building(s). We assume several reasons to show such differences. First, the experts for this study are different from those joined Lee et al. (2016). Second, the survey period is different between the 2016 study (Lee et al., 2016) and this study. Third, there are technical differences in ranking criteria by weight between CFPR and AHP/ANP techniques. This is a topic that requires further investigation.

[INSERT TABLE 5 ABOUT HERE]

3.2 PROMETHEE results and discussions

CFPR and PROMETHEE are combined to find the performance of WPD of the studied ports. The associated calculations of using the PROMETHEE method are done by the software -Visual PROMETHEE (1.4.0.0) developed by Bertrand, 2011-2013. The software produces a GAIA plane in Figure 2 with the inputs of criteria performance of WPD rated by the experts as shown in Table 6, i.e. g_{ij} in Eq (7).

[INSERT FIGURE 2 ABOUT HERE]

[INSERT TABLE 6 ABOUT HERE]

Figure 2 shows the performance of each port indicated by a square, and each criterion indicated by a diamond symbol. This plane is the result of principal component analysis, projecting the 18-dimensional space of criteria onto a two-dimensional plane with the explanation rate 88%. The 18 original variables are transformed into two new variables that are obtained by two linear combinations of the original variables in Figure 2.

The red line is an aggregated performance value of all the criteria of the six ports (decision axis, *pi*), while a blue line indicates an aggregated performance value of each criterion of the six ports. The length of the lines implies the level of the aggregated criteria performance. Figure 2 shows that all six ports do not move to the same direction; from the viewpoint of the decision axis *pi* on the u-axis, Liverpool and Busan are located in the first quadrant, while Montreal in the fourth quadrant. On the contrary, the directions of Bangkok, Incheon and Kaohsiung are opposite the decision axis. Thus, the GAIA plane gives us the visual assistance to understand the performance pattern of each port. Three ports (Montreal, Busan, and Liverpool) have better performance than Bangkok, IIP, and Kaohsiung. There are three criteria, i.e., similar criteria, independent criteria, and conflicting criteria in the GAIA visual descriptive analysis. Here the similar criteria with good performances have three clusters of (B2, P3, C1), (B3, B4, P4) and (P1, E1, E3); the independent relationship exists between C3 and P4, between P1 and P4, between E1 and P4, and between E3 and P4, respectively. The conflicting criteria are C3 and P1. Discovering those criteria of WPD among stakeholders helps have better understanding on possible compromise solutions in the process of negotiation for successful WPDs. Both independent and conflicting criteria are to be on the agenda to draw possible compromised solutions among the stakeholders.

Visual PROMETHEE calculates the evaluation results. The pairwise comparisons rated by the experts are calculated by CFPR to find the relative weights, i.e., w_j in Eq (10) (see Table 3.), which become the input weights of Visual PROMETHEE. Eqs. (8) ~ (13) together with the input values of w_j and g_{ij} are calculated by the Visual PROMETHEE, which consequently acquires the ranking value of PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking) (see Table 7.). PROMETHEE I applies$\emptyset^{+}$(Eq(11)) and $\emptyset^{-}$(Eq(12)) to find the partial ranking of the six ports, while PROMETHEE II applies$\emptyset$ (Eq(13)) to find the complete ranking of the ports. The integrated results of PROMETHEE reveal that the order of ranking of the WPD performance is Montreal>Busan > Liverpool> Bangkok> Kaohsiung > Incheon.

[INSERT TABLE 7 ABOUT HERE]

4. Conclusion

This paper has investigated the key successful factors of waterfront port development (WPD), taking six ports, namely, Busan, Incheon Inner Port, Bangkok, Kaohsiung, Liverpool, and Montreal, by applying CFPR and evaluated the WPD performance applying the PROMETHEE plus GAIA plane. This study has three major contributions: (1) a trial to generalize knowledge of key factors of WPD cases by expanding three more WPD cases followed by Lee et al. (2013; 2016), (2) to adopt an efficient method, CFPR, to evaluate weight of WPD criteria instead of complicated ANP technique, and (3) to evaluate performance of WPD of the six ports, visually describing characteristics and directions of 18 criteria on the GAIA plane. PROMETHEE plus the GAIA plane give us the visual assistance to understand the performance pattern of each port and all the criteria in aggregated values and to discover conflicting and independent criteria of the WPD among experts, which helps to find possible compromise solutions in the process of negotiation for the successful WPD. The CFPR test results top five weights are (B4) infrastructure for city branding, (E3) contribution to regional economy, (P4) Efficiency/Service quality, (E4) profitability of WPD and (P1) port infrastructure, respectively, highlighting each stakeholder has different top criteria in the economic, commercial, community and city brand functions. The integrated results of PROMETHEE reveal that the ranking order of the WPD performance is Montreal>Busan > Liverpool> Bangkok > Kaohsiung > Incheon. Also, while the findings largely complement Hoyle's model on port-city evolution, the increasing attention on port, port facilities, and related connection infrastructure pose further questions on port-city relationship in the contemporary world. Moreover, this study shows different top five criteria from the test results in Lee et al. (2016): top five criteria of Bangkok port are land value, green port, environment, transformation of port/city interface, and infrastructure for city branding; while those of IIP are infrastructure for city branding, profitability of WPD, port infrastructure, contribution to regional economy, and international landmark building(s).

This study has some limitations. First, the size of WPD sample is still small to generalize the knowledge of key successful factors of WPD, not to mention the small number of respondents, which is to some extent excusable when we consider the characteristics of CFPR and PROMETHEE techniques. Secondly, each port has different socio-economic-political situations that may affect weight evaluation of criteria of WPD. Further research is required so as to address such gaps.

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Figure 1 Flowchart of the combined methodology

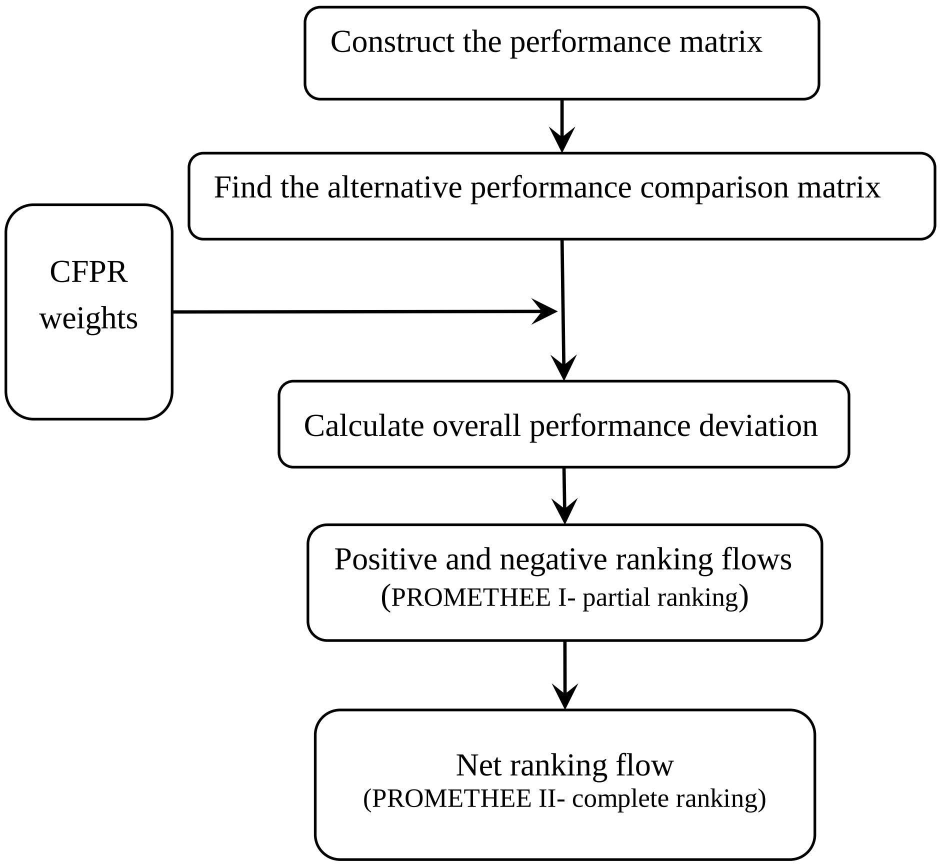

Figure 2 GAIA plane of the performance of waterfront development area

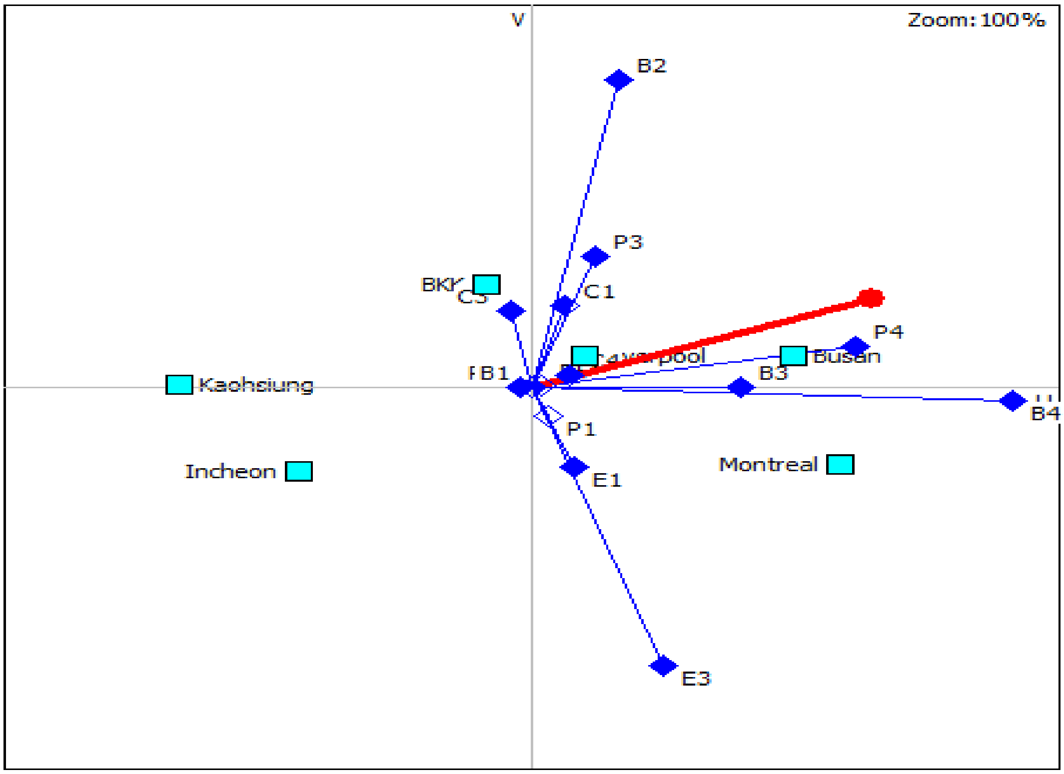

Table 1 Key dimensions and criteria of waterfront development

Dimensions /Criteria	*Description*
(E) Economic function	
(E1) Land value	➢ Increase of land value by WPD project ➢ Land value of surrounding sites ➢ Compatibility with surrounding land uses
(E2) Transformation of port/city interface	➢ Avoidance of social costs by mitigating conflicts between local government and port authority ➢ Efficiency of budget execution through integration and harmonization of urban planning and port development ➢ Maximization of benefits of rearrangement of port functions
(E3) Contribution to regional economy	➢ Job creation/employment opportunities ➢ Visitor/tourism expenditure ➢ Private investment/enhance investment environment
(E4) Profitability of Waterfront port (re)development (WPD)	➢ Prevention of subsidy of central and local government ➢ Financial returns to stakeholders of WPD such as private investors ➢ Commercial ability of business facilities within WPD area
(E5) Maritime clustering	➢ Synergy effect to promote industries related to maritime sector ➢ Compatibility with other industries ➢ Linkage effects (forward/backward linkage effects)
(P) Port function	
(P1) Port infrastructure	➢ Facilities ➢ Water depth in approach channel and at berth ➢ Multiple functions (including cruise port)
(P2) Security/Safety	➢ Terroists ➢ Casualties (e.g. accident avoidance)
(P3) Connectivity	➢ Efficient inland transport network/Inter-modal link ➢ Inland transportation cost ➢ Land distance and connectivity to major shippers
(P4) Efficiency/Service	➢ Congestion ➢ Terminal productivity

	➢ Reliability of schedules in port
(P5) Green Port	➢ Water quality ➢ Air quality
(C) Community function	
(C1) Environment	➢ Removing negative scenery of port from the city's viewpoint ➢ Mitigating negative externalities of WPD ➢ Comprehensive environmental protection planning in collaboration with city government and port authority
(C2) Conservation	➢ Re-use of historic buildings ➢ Protection of local maritime heritage
(C3) Quality of life	➢ Arranging amenity places and facilities for residents ➢ Better landscape ➢ Accessibility to waterfront area with leisure activities
(C4) Accessibility	➢ Transportation ➢ Traffic situation ➢ Parking place
(B) City Branding	
(B1) Preserve/promote maritime heritage/history	➢ Development/enhancement of tourism resources ➢ Integrated urban planning with port development planning
(B2) Opportunities for national and international events within WPD	➢ Opportunity to advertise city through national events ➢ Promote city image in the world by hosting international conferences
(B3) International landmark building(s)	➢ Carving and symbolizing city image in the world by building landmark to symbolize the city ➢ City brand contributing to generating commercial profits
(B4) Infrastructure for city branding	➢ Availability of hotels/lodging facilities ➢ Communication/transport system (interrelated to accessibility/connectivity) ➢ Tourism quality control governing system

Note: The code of criteria has been changed to indicate the meaning of each function. For example, criteria belonging to Economic function has (E1) ~ (E5) coding numbers.

Sources: Lee et al. (2013 & 2015).

Table 2 Average relative weights by port calculated by CFPR

	Factor	***Busan***	*rank*	***Kaohsiung***	*rank*	***Bangkok***	*rank*	***Montreal***	*rank*	***Liverpool***	*rank*	***Incheon***	*rank*	***Average***	***rank***
E1	Land value	0.057	8	0.046	15	0.063	1	0.045	17	0.043	17	0.044	17	0.050	17
E2	Transformation of port/city interface	0.053	11	0.060	8	0.060	4	0.048	15	0.047	13	0.047	15	0.053	15
E3	Contribution to regional economy	0.064	2	0.063	5	0.055	9	0.069	2	0.047	12	0.061	4	0.060	2
E4	Profitability of WPD	0.056	9	0.061	7	0.051	17	0.066	3	0.046	14	0.066	2	0.058	4
E5	Maritime clustering	0.051	14	0.057	12	0.053	13	0.055	9	0.046	15	0.058	8	0.053	14
P1	Port infrastructure	0.060	5	0.058	10	0.054	12	0.066	4	0.043	16	0.065	3	0.058	5
P2	Security/Safety	0.047	17	0.058	11	0.052	15	0.052	12	0.042	18	0.060	6	0.052	16
P3	Connectivity	0.049	16	0.065	2	0.053	14	0.057	6	0.049	9	0.060	7	0.056	11
P4	Efficiency/Service quality	0.058	7	0.063	3	0.054	10	0.074	1	0.048	11	0.058	9	0.059	3
P5	Green Port	0.051	12	0.065	1	0.062	2	0.054	11	0.049	10	0.052	13	0.056	12
C1	Environment	0.045	18	0.063	4	0.062	2	0.054	10	0.053	7	0.045	16	0.054	13
C2	Conservation	0.051	13	0.061	6	0.048	18	0.042	18	0.050	8	0.040	18	0.049	18
C3	Quality of life	0.064	3	0.060	9	0.058	6	0.048	16	0.062	6	0.052	14	0.057	6
C4	Accessibility	0.055	10	0.049	14	0.055	7	0.057	7	0.070	5	0.054	12	0.057	9
B1	Preserve/promote maritime heritage/history	0.061	4	0.051	13	0.052	16	0.050	13	0.072	4	0.054	11	0.057	8
B2	Opportunities for national and international events within WPD	0.050	15	0.045	16	0.055	8	0.058	5	0.078	2	0.056	10	0.057	7
B3	International landmark building(s)	0.059	6	0.036	18	0.054	11	0.050	14	0.079	1	0.061	5	0.057	10
B4	Infrastructure for city branding	0.067	1	0.038	17	0.058	5	0.055	8	0.076	3	0.067	1	0.060	1

Table 3 Average weights rated by groups

		City gov.	*Rank*	*STD*	***PA***	*Rank*	*STD*	***Developer***	*Rank*	*STD*	***Citizen***	*Rank*	*STD*
E1	Land value	0.045	18	0.012	0.039	18	0.025	0.068	2	0.013	0.047	18	0.022
E2	Transformation of port/city interface	0.062	5	0.012	0.046	17	0.017	0.051	15	0.017	0.054	13	0.019
E3	Contribution to regional economy	0.065	2	0.013	0.047	16	0.014	0.063	3	0.017	0.063	1	0.025
E4	Profitability of WPD	0.050	13	0.015	0.052	12	0.020	0.069	1	0.014	0.057	7	0.021
E5	Maritime clustering	0.052	11	0.019	0.051	14	0.012	0.052	12	0.016	0.057	4	0.021
P1	Port infrastructure	0.059	7	0.018	0.062	3	0.015	0.052	13	0.021	0.057	8	0.016
P2	Security/Safety	0.049	16	0.011	0.051	13	0.017	0.054	10	0.012	0.053	17	0.011
P3	Connectivity	0.057	9	0.016	0.062	2	0.013	0.049	16	0.016	0.054	14	0.008
P4	Efficiency/Service quality	0.052	12	0.008	0.067	1	0.008	0.057	7	0.020	0.058	3	0.006
P5	Green Port	0.056	10	0.018	0.059	9	0.011	0.051	14	0.015	0.057	5	0.011
C1	Environment	0.049	15	0.017	0.061	5	0.010	0.046	18	0.008	0.058	2	0.016
C2	Conservation	0.048	17	0.022	0.047	15	0.006	0.048	17	0.018	0.053	16	0.013
C3	Quality of life	0.062	4	0.009	0.060	7	0.006	0.055	9	0.012	0.053	15	0.012
C4	Accessibility	0.062	3	0.018	0.057	11	0.009	0.053	11	0.009	0.056	10	0.012
B1	Preserve/promote maritime heritage/history	0.060	6	0.008	0.059	8	0.017	0.055	8	0.020	0.055	11	0.013
B2	Opportunities for national and international events within WPD	0.050	14	0.008	0.061	6	0.018	0.059	4	0.019	0.056	9	0.014
B3	International landmark building(s)	0.057	8	0.021	0.058	10	0.016	0.058	6	0.021	0.055	12	0.022
B4	Infrastructure for city branding	0.066	1	0.016	0.061	4	0.018	0.059	5	0.022	0.057	6	0.023

Table 4 Top five criteria by weight by group

Rank	*City government*	*Port authority*	*Waterfront port developer*	*Citizen group*
1	(B4) Infrastructure for city branding	(P4) Efficiency/ Service quality	(E4) Profitability of WPD	(E3) Contribution to regional economy
2	(E3) Contribution to regional economy	(P3) Connectivity	(E1) Land value	(C1) Environment
3	(C4) Accessibility	(P1) Port infrastructure	(E3) Contribution to regional economy	(P4) Efficiency/ Service quality
4	(C3) Quality of life	(B4) Infrastructure for city branding	(B2) Opportunities for national and international events within WPD area	(E5) Maritime clustering
5	(E2)Transformation of port/city interface	(C1) Environment	(B4) Infrastructure for city branding	(P5) Green port

Source: Table 3 in this paper.

Table 5 Top-five criteria rank comparisons between ANP and CFPR

Method	*Rank*	*Incheon Inner Port*	*Bangkok Port*
ANP Top 5	1	Accessibility	Maritime clustering
	2	Connectivity	Accessibility
	3	Maritime clustering	Connectivity
	4	Transformation of port/city interface	Transformation of port/city interface
	5	Port infrastructure	Profitability of WPD
CFPR Top 5	1	B4 Infrastructure for city branding	E1 Land value
	2	E4 Profitability of waterfront (re)development (WPD)	P5 Green Port
	3	P1 Port infrastructure	C1 Environment
	4	E3 Contribution to regional economy	E2 Transformation of port/city interface
	5	B3 International landmark building(s)	B4 Infrastructure for city branding

Sources: Lee et al. (2015) and Table 4 in this paper.

Table 6 Performance of the waterfront area of each port

	Factor	***Busan***	***Kaohsiung***	***Bangkok***	***Montreal***	***Liverpool***	***Incheon***
E1	Land value	2.75	2.75	3.75	4.00	3.75	3.25
E2	Transformation of port/city interface	3.00	3.25	3.75	3.67	4.25	3.25
E3	Contribution to regional economy	3.75	3.75	2.75	4.67	3.75	3.25
E4	Profitability of WPD	3.25	3.25	4.00	3.33	3.50	3.25
E5	Maritime clustering	2.75	2.50	2.50	3.33	2.50	2.25
P1	Port infrastructure	3.25	3.50	3.50	4.33	3.25	3.25
P2	Security/Safety	2.75	3.00	3.50	3.67	4.00	3.00
P3	Connectivity	3.75	3.50	3.75	3.67	3.00	2.50

P4	Efficiency/Service quality	4.50	3.00	3.75	4.67	4.00	3.00
P5	Green Port	3.00	2.25	3.25	2.00	2.75	2.50
C1	Environment	3.50	3.00	3.75	3.67	3.25	2.50
C2	Conservation	3.50	3.25	2.50	3.00	3.25	3.00
C3	Quality of life	3.50	3.50	4.25	3.00	3.75	3.25
C4	Accessibility	4.00	2.75	3.50	3.67	3.75	3.25
B1	Preserve/promote maritime heritage/history	3.75	3.50	2.75	3.33	3.75	3.00
B2	Opportunities for national and international events within WPD area	3.75	3.50	4.00	3.33	4.00	2.50
B3	International landmark building(s)	3.75	2.50	3.50	4.00	3.25	2.50
B4	Infrastructure for city branding	4.50	2.25	3.25	4.33	3.75	3.00

Table 7 PROMETHEE flow table

Rank	*Action*	$\emptyset$	$\emptyset^{+}$	$\emptyset^{-}$
1	Montreal	0,0659	0,0717	0,0058
2	Busan	0,0396	0,0479	0,0082
3	Liverpool	0,0162	0,0171	0,0009
4	Bangkok	0,0032	0,0174	0,0142
5	Kaohsiung	-0,0584	0,0000	0,0584
6	Incheon	-0,0665	0,0000	0,0665