Competitiveness Prioritization of Container Ports in Asia under the Background of China's Belt and Road Initiative: Multi-Attribute Decision Analysis Method and Case Study

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Abstract: The understanding of the competitiveness of different ports under the background of China's "Belt and Road Initiative" (BRI) is critical for drafting appropriate plans and taking suitable actions to select the best port in the logistics supply chains. A novel Multi-Attribute Decision Analysis (MADA) was proposed for the evaluation of port competitiveness. In the developed MADA method, the interval Analytic Hierarchy Process (AHP) and the projection method was combined for the evaluation of port competitiveness. Three container ports in Asia including Shanghai, Hong Kong, and Singapore were studied under the background of China's BRI. The results demonstrate that the port of Singapore is the most competitive at the initial stage of China's BRI, followed by Hong Kong and Shanghai in the descending order. The results were validated by SWM and TOPSIS method, and sensitivity analysis was also carried out. The competitiveness of the three ports in the next ten years were also studied with the consideration of the influences of China's BRI, and the results reveal that Shanghai port can even exceed Hong Kong port and Singapore port if it can effectively take the advantage s of China's BRI.

Keywords: Competitiveness; port; Multi-attribute decision analysis; interval AHP; projection method

1. Introduction

The concept of ”China’s Belt and Road Initiative” (BRI) refers to the Silk Road Economic Belt and the 21st Century Maritime Silk Road initiative unveiled by China’s President Xi Jinping in 2013 (Swaine, 2015).The Belt and Road Initiative which aims at building strong connectivity and cooperation between China and the rest of Eurasia has great potential to improve the relationships between China and these countries, stimulate the economic prosperity and enhance common security. Maritime transport plays a significant important role in the BRI. Accordingly, the construction of port infrastructure, the promotion of the cooperation among the ports, and the planning of logistics supply chains among different ports is of vital importance for appropriately designing the most suitable strategies for promoting the BRI. However, different ports should have different roles in the BRI due to the difference in geographical position, deep-water berth, berth length, container handling capacity, registered shipping capacity, and route accessibility, etc.. The difference in these influential factors leads to different port competitiveness. While the understanding of the competitiveness of different ports under the background of BRI can help the administrators to appropriately plan the future logistics network and select the most competitive port among multiple alternatives. Therefore, the evaluation of the competitiveness of the main ports is significantly beneficial for the decision-makers involved in the BRI.

Various studies have been carried out for competitiveness evaluation of ports. These studies can be divided into two types: one focusing on developing the criteria system for port competitiveness evaluation, and another focusing on developing Multi-Attribute Decision Analysis (MADA) methods for analyzing the competitiveness of the ports. As for the criteria system for port competitiveness evaluation, Yeo *et al.* (2008) developed a structure including a dozen of indicators in seven dimensions, including port service, hinterland condition, availability, convenience, logistics cost, regional center, and connectivity for evaluating the competitiveness of the ports in

Korea and China. Onut *et al*. (2011) employed the fuzzy analytic network process to select the best port among seven alternatives considering 20 sub-criteria in six main criteria. Lee and Hu (2012) employed the IPA (importance-performance analysis) to identity the implications for improving port service quality and further for port competitiveness enhancement. Van Dyck and Ismael (2015) developed a hierarchical structure which consists of 14 indicators in 6 dimensions for port competitiveness evaluation. Parola *et al*. (2017) summarized the key drivers of port competitiveness, including port costs, hinterland proximity, hinterland connectivity, port geographical location, operational infrastructures, operational efficiency, port service quality, maritime connectivity, nautical accessibility, and port site. Ha and Yang (2017) developed a port performance indicator system which consists of 6 dimensions, 16 principal port performance indicators, and 60 port performance indicators for port performance measurement, and the independency and interdependency among these indicators were also investigated.

As for the MADA method for analyzing the competitiveness of the ports, Jim Wu and Lin (2008) employed Data Envelopment Analysis (DEA) to investigate the efficiency of India's container port operations. Yuen *et al*. (2010) studied the competitiveness of the ports from the perspectives of the users by using Analytic Hierarchy Process (AHP) to investigate the relative weights of the influential factors using the judgments of the users. Yeo *et al*. (2011) employed the fuzzy methodology for measuring the port competitiveness based on the judgments of the experts. Yuen *et al.* (2012) used AHP to analyze the relative importance of the factors which influence container port competitiveness according to the preferences of port users, including shipping liners, forwarders and shippers. Yang *et al. (*2014) employed the fuzzy evidential reasoning model for quantitative evaluation of port security which is a critical issue of port competitiveness. Yeo *et al*. (2014) developed an innovative conceptual port choice method by integrating the fuzzy logic method. Zavadskas *et al*. (2015) combined AHP and fuzzy ratio assessment method as a multi-criteria tool for selecting the best deep-water port in the Eastern Baltic Sea.Lee and Lam (2015) developed a novel approach for competitiveness evaluation by overcoming the limitations of the previous studies through considering port competitiveness in relation to port devolution according to a globalized economy. Kim (2015) developed an applied market share index-AMS (additive market share) to analyze the revealed competitiveness of some major ports in the East Asian region. Wang and Chen (2016) used AHP method to prioritize the influential factors of port competitiveness and found the measures to improve the competitiveness. Nguyen *et al*. (2016) used the hierarchical cluster analysis method to classify 11 container ports in Northern Vietnam by using the data about competitiveness. Kim (2016) used the entropy weighting method which can avoid the subjectivity to determine the weights of the criteria for competitiveness evaluation of ports, and applied the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) to rank a set of ports in Korea and China. Huiling *et al.* (2017) used the correlation matrix weighting method to determine the influential factors of port competitiveness, and the matter-element model was employed to determine the competitiveness grade of the port. Hales *et al*. (2017) employed AHP to analyze the data collected in 72 largest seaports for an empirical test of the balanced theory, and the relative importance of the variables for volume competitiveness and that for investment competitiveness were identified. Ke and Wang (2017) firstly established an index system for competitiveness evaluation of major port cities, and then employed principal component analysis, hierarchical analysis, and cluster analysis to rank the major port cities in China according to their competitiveness. Zhen (2017) used Data Envelopment Analysis (DEA) to investigate the competitiveness of Shanghai port from 2008 to 2013, and 25 indicators were used as inputs and 6 indicators were used as outputs. Ha *et al.* (2017) employed the DEMATEL (Decision-Making Trail and Evaluation Laboratory) and ANP (Analytic Network Process) to determine the weights of the port performance indicators, and the fuzzy rule based evidential reasoning algorithm was employed to determine the integrated performances of the ports.

All these studies can effectively help the users to assess the competitiveness and prioritize the ports according to their relative competitiveness. However, there were still some research gaps:

(1) Port competitiveness evaluation is usually a multi-attribute decision analysis problem, and the calculation of the weights of the evaluation criteria of port competitiveness is critical for accurate evaluation (Yue *et al.*, 2010). The subjective weighting methods such as AHP and Delphi method were usually employed to determine the weights because these methods can reflect the preferences of the users. However, it is usually difficult for the users to use a single number to rating the relative importance of the evaluation criteria or compare the relative importance between each pair of criteria;

(2) There were two types of criteria for port competitiveness evaluation: one type is the hard criteria which can be descripted quantitatively with units, and another type is the soft criteria which cannot be descripted quantitatively with units and were usually depicted qualitatively. However, some of the previous literatures only consider one of the two types of criteria. Meanwhile, some studies only used the semi-quantitative approach for port competitiveness evaluation. For instance, some studies used fuzzy set theory or the Delphi approach to obtain the data of the ports to be evaluated; while the data of the ports regarding the hard criteria cannot be fully used. On the contrary, some studied only used the data of the ports about the hard criteria; however, the data about the soft criteria were not used.

In order to overcome the above-mentioned research limitations, a novel MADA model was developed by combining the interval AHP and the projection method, both the hard criteria and the soft criteria can be used in the competitiveness evaluation of ports, the data of the ports to be evaluated with respect to the soft criteria were determined by the interval AHP method according to the judgments of the experts. In addition, the weights of the evaluation criteria were also determined by the interval AHP. The projection method was used to assess the competitiveness of the ports and rank the ports after determining the decision-making matrix which includes the data of the ports about the evaluation criteria and the weights of the evaluation criteria. All in all, this study aims at developing a MADA method to measure the relative competitiveness of different container ports in Asia under the concept of China's "Belt and Road Initiative" initiative, and three major ports including Shanghai, Hong Kong and Singapore were studied by the proposed model. The main innovations of this study consist of (i) the interval AHP method which can capture the ambiguity of human's judgments and allows the users to use interval numbers instead of crisp numbers was employed to determine the weights of the indicators as well as the relative performances of the data with respect to the soft criteria; and (ii) the incorporation of both the hard criteria and the soft criteria for the evaluation of the competitiveness of ports.

Besides the introduction, section 2 presented in the MADA method for competitiveness evaluation of the ports; a case was illustrated in section 3; the results of the case study were discussed in section 4; finally, this study was concluded in section 5.

2. MADA method

The multi-attribute Decision Analysis (MADA) method was proposed in this study. The interval Analytic Hierarchy Process (AHP) was firstly introduced for calculating the weights of the criteria for competitiveness evaluation of ports, and the projection method was then proposed for determining the competitiveness degree of the ports.

2.1 Weighting method

There were usually three kinds of ways for determining the weights in MADA: one is based on human subjective judgments (subjective method), another is to determine the weights of the evaluation criteria based on the data of the alternatives with respect to the evaluation criteria (objective method), and the other way is the combined weighting method by combining the weights determined by the subjective method and that determined by the objective method. Subjective method which is based on human judgments can fully reflect the preferences/willingness of the decision-makers, thus, the subjective weighting methods, i.e. Analytic Hierarch Process (AHP) (Saaty, 1978) and Best-Worst (BW) method (Rezaei, 2015), have been widely used for weights determination. The subjective methods such as AHP and BW method usually used the numbers from one to nine and their reciprocals to establish the comparison matrix or the comparison vector, but it is usually for difficult for the users to establish the comparison matrices or the comparison vectors with absolute consistency. Meanwhile, it is also not easy for the users to use single number to depict the relative importance/priority of one element over another (He *et al*., 2017; Ren *et al*., 2014). In order to overcome the above-mentioned two problems, the interval AHP was used to determine the weights of the criteria in this study.

The interval AHP which consists of four steps was used in this study based on the works of Saaty (1978) and Ren *et al.* (2017):

Step 1: Employing the nice-point scale system (as presented in Figure 1) by Saaty (1978) to determine the comparison matrix. It is worth pointing out that the users were asked to use interval numbers rather than the crisp numbers to establish the comparison matrix. For instance, the superiority of one element comparing with another is between "essential superiority "(corresponding to 5) and "very strong superiority" (corresponding to 7), then, the interval [5 7] was used to depict the relative superiority between these two elements. In a similar, the other elements in the comparison matrix can also be determined for a case with n elements, as presented in Eq.1.

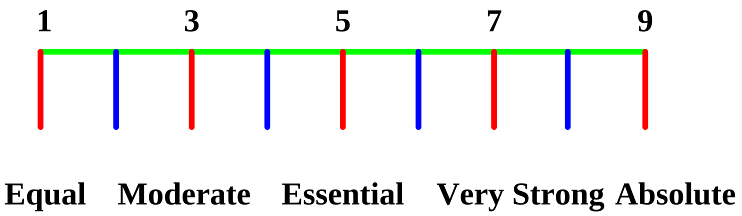

Figure 1: The nice-point scale system for comparison

$$\begin{bmatrix} 1 & [x_{12}^L, x_{12}^U] & \cdots & [x_{1n}^L, x_{1n}^U] \\ [x_{21}^L, x_{21}^U] & 1 & \cdots & [x_{1n}^L, x_{1n}^U] \\ \vdots & \cdots & \ddots & \vdots \\ [x_{n1}^L, x_{n1}^U] & [x_{n2}^L, x_{n2}^U] & \cdots & 1 \end{bmatrix} \tag{1}$$

where x_{ij}^L and x_{ij}^U are the lower and upper bounds of the element in cell (i,j) of the comparison matrix.

Step 2: Determining the ideal comparison matrix. In order to determine a comparison matrix satisfying the consistency check, a programming as presented in (2) was developed for determining the elements in the ideal comparison matrix (Ren *et al*., 2017).

$$\begin{aligned} & Min \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n}(x_{ij}^* x_{jk}^* - x_{ik}^*)^2 \\ & subject\ to \quad x_{ij}^* \in [x_{ij}^L, x_{ij}^U], x_{jk}^* \in [x_{jk}^L, x_{jk}^U], x_{ik}^* \in [x_{ik}^L, x_{ik}^U], x_{ii} = 1, x_{ij}^* x_{ji}^* = 1 \end{aligned} \tag{2}$$

where x_{ij}^* represents the element in cell (i,j) of the ideal comparison matrix.

Step 3: Determining the optimum weights. According to programming (2), the optimum solution a_{ij}^* could be obtained. Then, the ideal comparison matrix can be determined (see Eq.3). Finally, the optimum weights can be determined using the traditional AHP developed by Saaty (1978) based on the comparison matrix presented in Eq.3.

$$A' = \{x_{ij}^*\}_{n \times n} \qquad i, j = 1, 2, \cdots, n \tag{3}$$

$$W^{*} = (\omega_1, \omega_2, \cdots, \omega_n) \tag{4}$$

2.2 Projection method

Various MADA methods were used to evaluate the competitiveness of the ports, i.e. AHP (Yuen *et al.*, 2012; Song and Yeo, 2004; da Cruz *et al.*, 2013), grey relational analysis (Teng *et al.*, 2004), Fuzzy Multi-criteria Grade Classification (FMGC) (Huang *et al.*, 2003), fuzzy approach (Yeo and Song, 2006; Yeo *et al.*, 2011), fuzzy AHP (Wang and Li, 2011;Tao and Lu, 2010), Customer Satisfaction Degree Index (An and Liu, 2009), system dynamic (Briano *et al.*, 2010), and Chernooff Faces model (Liu *et al.*, 2013), etc.. All these methods can help the users to rank the ports according to their competitiveness; however, there is no method that can tell the users how the competitiveness of the ports fit with the best ideal port in their mind. In order to address this, the projection method was developed to evaluate the competitiveness of the ports in this study.

In the projection method, the decision-making matrix was firstly standardized and weighted; subsequently, the ideal best solution was also determined; then, the projection of each alternative to the ideal best solution was calculated; finally, the alternatives were ranked according to the projection of each alternative.

Assuming that there are m alternatives (A_1, A_2,…, A_m) to be assessed by n criteria (C_1, C_2,…,C_n), and the data in the decision-making matrix was presented in Table 1. μ_{ij} is the data of the *i*-th (i=1,2,…,m) alternative regarding the *j*-th (j=1,2,…,n) criterion, and $\omega_j\left(j=1,2,\ldots,n\right)$ represents the weight of the *j*-th (j=1,2,…,n) criterion.

Table 1: Decision-making matrix

	C_1	C_2	$\cdots$	C_n
A_1	μ_{11}	μ_{12}	$\cdots$	μ_{1n}
A_2	μ_{21}	μ_{22}	$\cdots$	μ_{2n}
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
A_m	μ_{m1}	μ_{m2}	$\cdots$	μ_{mn}
weights	ω_1	ω_2	$\cdots$	ω_n

After determining the relative importance/weights of the attributes, the projection method for multi-criteria decision making can be employed to prioritize the alternatives, and it consists of four steps based on the works of Xu and Da (2004), Xu (2004), and Sharma and Gandhi (2006):

Step 1: Standardizing the decision-making matrix. The objective of this step is to standardize all the data in the decision-making matrix to make them dimensionless and to eliminate the effects caused by physical dimensions (Zhang et al., 2013). The methods for standardizing the decision-making matrix were presented in Eqs.5-6. Note that Eq.5 can be used to standardize the data with respect to the benefit-type criteria, and Eq.6 can be used to standardize the data with respect to the cost-type criteria.

$$v'_{ij} = \frac{\mu_{ij}}{\sqrt{\sum_{i=1}^{m} \mu_{ij}^2}} \tag{5}$$

$$v'_{ij} = \frac{(\mu_{ij})^{-1}}{\sqrt{\sum_{i=1}^{m} \mu_{ij}^{-2}}} \tag{6}$$

where v'_{ij} is the normalized data about μ_{ij}.

Step 2: Determining the weighted data. After determining the standardized decision-making matrix, the weighted standardized decision-making matrix can be determined by Eq.7, and the results were presented in Table 2.

$$v_{ij} = v'_{ij}\omega_j \tag{7}$$

where v_{ij} is the weighted standardized decision-making matrix.

Table 2: The weighted standardized decision-making matrix

	C_1	C_2	$\cdots$	C_n
A_1	v_{11}	v_{12}	$\cdots$	v_{1n}
A_2	v_{21}	v_{22}	$\cdots$	v_{2n}
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
A_m	v_{m1}	v_{m2}	$\cdots$	v_{mn}
weights	ω_1	ω_2	$\cdots$	ω_n

Step 3: Determining the best-ideal solution and the worst ideal solution. After determining the standardized decision-making matrix, the best-ideal solution (BIS) and the worst ideal solution (WIS) could be determined, as defined in Eq.8 and Eq.9, respectively.

$$v^{+} = \begin{bmatrix} v_1^{+} & v_2^{+} & \cdots & v_n^{+} \end{bmatrix} \tag{8}$$

$$v^{-} = \begin{bmatrix} v_1^{-} & v_2^{-} & \cdots & v_n^{-} \end{bmatrix} \tag{9}$$

where

$$v_j^{+} = \max_{i=1,2,\cdots,m} v_{ij} \qquad j = 1,2,\cdots,n \tag{10}$$

$$v_j^{-} = \min_{i=1,2,\cdots,m} v_{ij} \qquad j = 1,2,\cdots,n \tag{11}$$

The best-ideal solution (BIS) and the worst ideal solution (WIS) are the constructed best and worst solutions which can be used as references to measure the alternatives.

Step 4: Determining the projection of each of the alternatives to the BIS and that of each of the alternatives to the WIS.

The *i*-th alternative can be recognized as a vector $v_i = \begin{bmatrix} v_{i1} & v_{i2} & \cdots & v_{in} \end{bmatrix}$, and the projection of the *i*-th alternative to the BIS can be calculated by Eq.12 (Xu, 2004; Xu and Da, 2004).

$$P(v_i \to v^{+}) = \|v_i\| \cos\left(v_i, v^{+}\right) \quad i = 1,2,\cdots,m \tag{12}$$

where $P(v_i \to v^{+})$ is the projection of each of the alternatives to the BIS , $\|v_i\|$ represents the norm of v_i and $\cos\left(v_i, v^{+}\right)$ is the cosine of included angel between v_i and v^{+} .

$\|v_i\|$ and $\cos\left(v_i, v^{+}\right)$ can be determined by Eq.13 and Eq.14, respectively (Xu and Da, 2004).

$$\|v_i\| = \sqrt{\sum_{j=1}^{n} \left(v_{ij}\right)^2} \tag{13}$$

$$\cos\left(v_i, v^+\right) = \frac{\sum_{j=1}^{n} v_{ij} v_j^+}{\left\|v_i\right\|\left\|v^+\right\|} = \frac{\sum_{j=1}^{n} v_{ij} v_j^+}{\sqrt{\sum_{j=1}^{n}\left(v_{ij}\right)^2}\sqrt{\sum_{j=1}^{n}\left(v_j^+\right)^2}} \tag{14}$$

According to Eq.13 and Eq.14, Eq.12 can be simplified as (Xu, 2004):

$$P(v_i \to v^+) = \frac{\sum_{j=1}^{n} v_{ij} v_j^+}{\sqrt{\sum_{j=1}^{n}\left(v_j^+\right)^2}} \quad i = 1, 2, \cdots, m \tag{15}$$

Therefore, Eq.15 can be employed to calculate the projection of the *i*-th alternative to the BIS. The greater the value of $P(v_i \to v^+)$, the closer the alternative to the BIS. Accordingly, the greater the value of $P(v_i \to v^+)$, the more superior the alternative will be. After determining the projection of each alternative to the BIS, the alternatives can be prioritized, and the greater the value of the projection, the more superior the alternative will be (Xu and Da, 2004; Xu, 2004).

3. Case study

The Belt and Road Initiative refers to the Silk Road Economic Belt and 21st Century Maritime Silk Road, a significant development strategy launched by the Chinese government with the intention of promoting economic cooperation among countries along the proposed Belt and Road routes. The Initiative has been designed to enhance the orderly free flow of economic factors and the efficient allocation of resources. It is also intended to further market integration and create a regional economic co-operation framework of benefit to all. Connecting Asia, Europe and Africa along five routes, the Silk Road Economic Belt focusses on: (1) linking China to Europe through Central Asia and Russia; (2) connecting China with the Middle East through Central Asia; and (3) bringing together China and Southeast Asia, South Asia and the Indian Ocean. The 21st Century Maritime Silk Road, meanwhile, focusses on using Chinese coastal ports to: (4) link China with Europe through the South China Sea and Indian Ocean; and (5) connect China with the South Pacific Ocean through the South China Sea (Huang, 2016; Liu and Dunford, 2016; Cheng, 2016).

Focusing on the above five routes, the Belt and Road will take advantage of international transport routes as well as core cities and key ports to further strengthen collaboration and build six international economic co-operation corridors. These have been identified as the New Eurasia Land Bridge, China-Mongolia-Russia, China-Central Asia-West Asia, China-Indochina Peninsula, China-Pakistan, and Bangladesh-China-India-Myanmar. Ports play a significantly important role for these five routes; however, the competitiveness of the ports is different.

In order to demonstrate how to use the developed model for competitiveness prioritization of the ports under the background of Belt and Road Initiative, three important ports including Shanghai, Hong Kong and Singapore were studied in this section. Ten criteria in three dimensions including *natural conditions* (N), *shipping conditions* (S), and *external conditions* (E) were used to measure the competitiveness of these three ports based on literature reviews (see section 1) and a focus group meeting in which six experts including two professor whose research focuses on maritime policy and technology, two senior researchers of green shipping, and two port managers who are very familiar with these three ports were invited to participate. There are three *natural conditions* including geographical position superiority (C_1), deep-water berth (C_2), and berth length (C_3). Container handling capacity (C_4), route accessibility (C_5), concentration of vessel (C_6), and registered shipping capacity (C_7) are the four *shipping conditions*. There are also three *external conditions*, including tax (C_8), market freedom (C_9), and political factor (C_{10}). Among these, deep-water berth (C_2), and berth length (C_3). Container handling capacity (C_4), concentration of vessel

(C_6), and registered shipping capacity (C_7) are hard criteria, and the residual criteria (i.e. geographical position superiority, tax, and market freedom) are soft criteria.

Table 3: The data of the three ports with respect to the five hard criteria

	Unit	Type	Shanghai	Hong Kong	Singapore
Deep-water berth (C_2)	units	Hard	46	24	42
Berth length (C_3)	m	Hard	12298	7694	10300
Container handling capacity (C_4)	1.00E+04TEU	Hard	3362	2229	3258
Concentration of vessel (C_6)	Units per month	Hard	2700	1520	3600
Registered shipping capacity (C_7)	1.00E+04tonnes	Hard	1393	3600	3300

Note: The data of the alternatives with respect to the hard criteria was adapted from Zhang (2015).

The data of the three ports with respect to the hard criteria were derived from the published work (Zhang et al., 2015), as presented in Table 3. However, it is impossible to gather the data about the soft criteria from the published works directly. The brainstorm method was used in this study to determine the relative scores of the three ports. The six experts were firstly asked to rank the three ports according to their superiority with respect to each of the soft criteria. Then, they were asked to use the interval numbers composed by the numbers 1 to 9 to establish comparison matrix. It is worth pointing out that each group of experts firstly discussed with their colleagues for collecting their opinions and preferences. Thus, the weighting method was used not only for determining the weights of the criteria/indicators, but also for determining the relative performances of the ports with respect to the soft criteria. It is worth pointing out that the experts' judgments were based on the effects of the corresponding ports for promoting China's BRI. Taking the relative scores of the three ports about the geographical position superiority (C_1) as an example, the superiority sequence of the three ports with respect to C_1 was firstly determined by the six experts, and the result from the best to the worst is Singapore, Hong Kong, and Shanghai after group decision-making. The relative preference of one of these three ports over another with respect to geographical position superiority was determined according to their geographical position in China's BRI. For instance, the six experts held the view that the comparison of Singapore with Hong Kong was recognized as "between equal superiority and moderate superiority" (corresponding to [1 3]). Then, the interval from 1 and 3 was used to depict the relative superiority of Singapore comparing with Hong Kong with respect to geographical position superiority. The interval comparison matrix for determining the relative superiorities of the three ports with respect to geographical position superiority (C_1) was presented in Table 4.

Table 4: The interval comparison matrix for determining the relative superiorities of the three ports with respect to geographical position superiority (C_1)

	Shanghai	Hong Kong	Singapore
Shanghai	1	[1/2 1]	[1/2 1]
Hong Kong	[1 2]	1	[1/3 1]
Singapore	[1 2]	[1 3]	1

According to programming (2), the programming for determining the ideal comparison matrix can be established for determining the relative scores of the three ports about the geographical position superiority.

$$
\begin{aligned}
&Min\,(x_{12}^{*}x_{23}^{*}-x_{13}^{*})^{2}+(x_{13}^{*}x_{32}^{*}-x_{12}^{*})^{2}+(x_{21}^{*}x_{13}^{*}-x_{23}^{*})^{2}+(x_{23}^{*}x_{31}^{*}-x_{21}^{*})^{2}+(x_{31}^{*}x_{12}^{*}-x_{32}^{*})^{2}+(x_{32}^{*}x_{21}^{*}-x_{31}^{*})^{2}\\
&x_{12}^{*}-\frac{1}{2}\geq 0\\
&x_{12}^{*}-1\leq 0\\
&x_{13}^{*}-\frac{1}{2}\geq 0\\
&x_{13}^{*}-1\leq 0\\
&x_{23}^{*}-\frac{1}{3}\geq 0\\
&x_{23}^{*}-1\leq 0\\
&x_{11}^{*}-1=0\\
&x_{22}^{*}-1=0\\
&x_{33}^{*}-1=0\\
&x_{12}^{*}x_{21}^{*}-1=0\\
&x_{13}^{*}x_{31}^{*}-1=0\\
&x_{23}^{*}x_{32}^{*}-1=0
\end{aligned}
\tag{16}
$$

After solving programming (16), the elements of the ideal comparison matrix for determining the relative scores of the three ports about the geographical position superiority can be obtained, and the results were presented in Table 5. Accordingly, the ideal comparison matrix can be determined, as shown in Eq.17.

Table 5: The elements in the ideal comparison matrix

x_{ij}^{*}	x_{11}^{*}	x_{12}^{*}	x_{13}^{*}	x_{21}^{*}	x_{22}^{*}	x_{23}^{*}	x_{31}^{*}	x_{32}^{*}	x_{33}^{*}
Value	1	0.8230	0.5527	1.2150	1	0.6715	1.8094	1.4892	1

$$\begin{array}{cccc} C_1 & Shanghai & Hong\ Kong & Singapore \\ Shanghai & 1 & 0.8230 & 0.5527 \\ Hong\ Kong & 1.2150 & 1 & 0.6715 \\ Singapore & 1.8094 & 1.4892 & 1 \end{array} \quad (17)$$

The optimum weights which represent the relative scores of the three ports with respect to the geographical position superiority can be determined, and the results were presented in Eq.18.

$$[\omega_1, \omega_2, \omega_3] = [0.2485, 0.3019, 0.4496] \quad (18)$$

Accordingly, the relative scores of the three ports with respect to the geographical position superiority were 0.2485, 0.3019, and 0.4496, respectively. In a similar, the relative superiorities of the three ports with respect to route accessibility (C_5), tax (C_8), market freedom (C_9), and political factor (C_{10}) can also be determined, and the results were presented in the Appendix.

In a similar way, the weights of the criteria in each aspect of competitiveness and that of the three aspects can also be determined. Taking the relative weights of the four indicators in shipping conditions including container handling capacity (C_4), route accessibility (C_5), concentration of vessel (C_6), and registered shipping capacity (C_7) as an example, the interval comparison matrix was presented in Table 6.

Table 6: The interval comparison matrix for determining the relative weights of the four

	C_4	C_5	C_6	C_7
Container handling capacity (C_4)	1	[1/2 1]	[2 4]	[1/3 1/2]
Route accessibility (C_5)	[1 2]	1	[3 5]	[1/2 1]
Concentration of vessel (C_6)	[1/4 1/2]	[1/5 1/3]	1	[1/6 1/4]
Registered shipping capacity (C_7)	[2 3]	[1 2]	[4 6]	1

The ideal comparison matrix for determining the relative weights of the four indicators in shipping conditions can also be determined, see Eq.19.

$$\begin{array}{ccccc} & C_4 & C_5 & C_6 & C \\ C_4 & 1 & 0.6492 & 2.0000 & 0.3585 \\ C_5 & 1.5404 & 1 & 3.0807 & 0.5523 \\ C_6 & 0.5000 & 0.3246 & 1 & 0.1793 \\ C_7 & 2.7892 & 1.8107 & 5.5784 & 1 \end{array} \tag{19}$$

Then, the local relative weights of container handling capacity (C_4), route accessibility (C_5), concentration of vessel (C_6), and registered shipping capacity (C_7) can be obtained by the traditional AHP method, and the results were presented in Table 7. It is apparent that registered shipping capacity was the most important indicator to measure the superiority of the shipping conditions, followed by route accessibility, container handling capacity, and concentration of vessel

Table 7: The local relative weights of container handling capacity (C_4), route accessibility (C_5), concentration of vessel (C_6), and registered shipping capacity (C_7)

Indicators	C_4	C_5	C_6	C_7
Weights	0.1715	0.2642	0.0858	0.4785

In a similar way, the weights of the three dimensions of port's competitiveness and that of the criteria in the other two dimensions can also be determined, and the results were presented in the appendix.

The global weight of each indicator can then be determined, and the results were presented in Table 8.

Table 8: The global weights of the ten indicators for measuring the competitiveness of the ports

Indicators	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Weights	0.1554	0.0487	0.0665	0.1022	0.1575	0.0511	0.2852	0.0513	0.0382	0.0437

The relative importance of the ten indicators can be divided into three categories: significantly important group, strongly important group, and weakly important group. The significantly important group consists of registered shipping capacity (C_7), route accessibility (C_5), geographical position superiority (C_1), and container handling capacity (C_4). The strongly important group includes berth length (C_3), tax (C_8), and concentration of vessel (C_6). The other indicators including deep-water berth (C_2), market freedom (C_9), and political factor (C_{10}) belong to the weakly important group.

Subsequently, the decision-making matrix for ranking the competitiveness of the three ports can be determined, as presented in Table 9.

Table 9: The decision-making matrix

	Unit	Shanghai	Hong Kong	Singapore	Weights
Geographical position superiority (C_1)	/	0.2485	0.3019	0.4496	0.1554
Deep-water berth (C_2)	/	46	24	42	0.0487
Berth length (C_3)	m	12298	7694	10300	0.0665
Container handling capacity (C_4)	10^4TEU	3362	2229	3258	0.1022
Route accessibility (C_5)	/	0.1764	0.3031	0.5205	0.1575
Concentration of vessel (C_6)	Month^{-1}	2700	1520	3600	0.0511
Registered shipping capacity (C_7)	10^4t	1393	3600	3300	0.2852
Tax (C_8)	/	0.1111	0.4444	0.4444	0.0513
Market freedom (C_9)	/	0.1484	0.4280	0.4236	0.0382
Political factor (C_{10})	/	0.5741	0.1799	0.2459	0.0437

After determining the decision-making matrix, the developed projection method for multi-criteria decision making was used for assessing the competitiveness of the three ports. The procedures of the projection method for ranking the three ports according to their competitiveness were presented as follows:

Step 1: According to Eqs. 5-6, the standardized decision-making matrix can be obtained. Taking the data of the three ports with respect to the geographical position superiority as an example, the standardized data can be obtained by Eqs.20-22.

$$v'_{Shanghai,C_1} = \frac{0.2485}{\sqrt{0.2485^2 + 0.3019^2 + 0.4496^2}} = 0.4171 \tag{20}$$

$$v'_{Hong\,Kong,C_1} = \frac{0.3019}{\sqrt{0.2485^2 + 0.3019^2 + 0.4496^2}} = 0.5067 \tag{21}$$

$$v'_{Singapore,C_1} = \frac{0.4496}{\sqrt{0.2485^2 + 0.3019^2 + 0.4496^2}} = 0.7546 \tag{22}$$

In a similar way, the other standardized data in the standardized decision-making matrix can also be determined, and the results were presented in the Appendix.

Step 2: According to Eq.7, the weighted standardized data in the decision-making matrix can be obtained. Taking the data of the three ports with respect to geographical position superiority (C_1) as an example, the weighted data can be obtained by Eqs.23-25.

$$0.4171 \times \omega_1 = 0.4171 \times 0.1554 = 0.0648 \tag{23}$$

$$0.5067 \times \omega_1 = 0.5067 \times 0.1554 = 0.0787 \tag{24}$$

$$0.7546 \times \omega_1 = 0.7546 \times 0.1554 = 0.1173 \tag{25}$$

Similarly, other elements in the weighted standardized decision-making matrix can also be determined, and the results were presented in the Appendix.

Step 3: According to Eqs. 8-11, the best ideal solutions and the worst ideal solutions can be obtained, and the results were presented in Table 10.

Table 10: The best ideal solutions and the worst ideal solutions

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
BIS	0.1173	0.0336	0.0460	0.0663	0.1306	0.0387	0.2022	0.0357	0.0264	0.0386
WIS	0.0648	0.0175	0.0288	0.0439	0.0443	0.0164	0.0782	0.0089	0.0091	0.0121

Step 4: According to Eqs.15-16, the projection of each port to the BIS and that of each port to the WIS can be determined, and the results were presented in Table 11.

Table 11: The projection of each port to the BIS and that of each port to the WIS

	Shanghai	Hong Kong	Singapore
Projection to BIS	0.1378	0.2340	0.2736
Ranking	3	2	1

It is apparent that the competitiveness of the three ports from the most competitive to the least is Singapore, Hong Kong, and Shanghai. However, the data of these three ports with respect to some criteria such as registered shipping capacity (C_7), tax (C_8), market freedom (C_9), and political factor (C_{10}) will change with the development of China's BRI, and there are several reasons:

(1) It is certainty that the promotion of China's BRI can stimulate the international trade among Asia, Europe and Africa, thus, the registered shipping capacities of these three ports will increase for undertaking more freight;

(2) More and more tax/tariff reduction measures will also be implemented in Shanghai, Hong Kong and Singapore to facilitate the international trade and increase the competitiveness of these three ports;

(3) Shanghai, Hong Kong and Singapore play a significant important role in China's BRI, and the market freedom of these three regions will also be improved by drafting some supporting policies and regulations to promote the benefits of the stakeholders in the international trade with the development of China's BRI; and

(4) The negative impacts of political factors on the competitiveness of the three ports will be mitigated because some top-level strategies shall be drafted to promote the development of

China's BRI in Chinese mainland and Hong Kong Special Administrative Region. Meanwhile, Singapore shall also draft some strategies to retain its geo-advantages in China's BRI.

Therefore, China's BRI will influence the registered shipping capacity, tax, market freedom, and political factor of these three ports, but the influencing levels on different ports may be different. Assuming that China's BRI has three levels of influences on the three ports including "significant influence", "moderate influence" and "weak influence". Significant influence, moderate influence and weak influence can lead to an annual increase of 30%, 10% and 5% for the data with respect to these four criteria (C_7, C_8, C_9 and C_{10}), respectively. Based on the results of the focus group meeting, China's BRI was recognized having "significant influence" on the port of Shanghai, "moderate influence" on the port of Hong Kong, and "weak influence" on the port of Singapore. The relative competitiveness of these three ports in next ten years can be determined, and the results were presented in Figure 2.

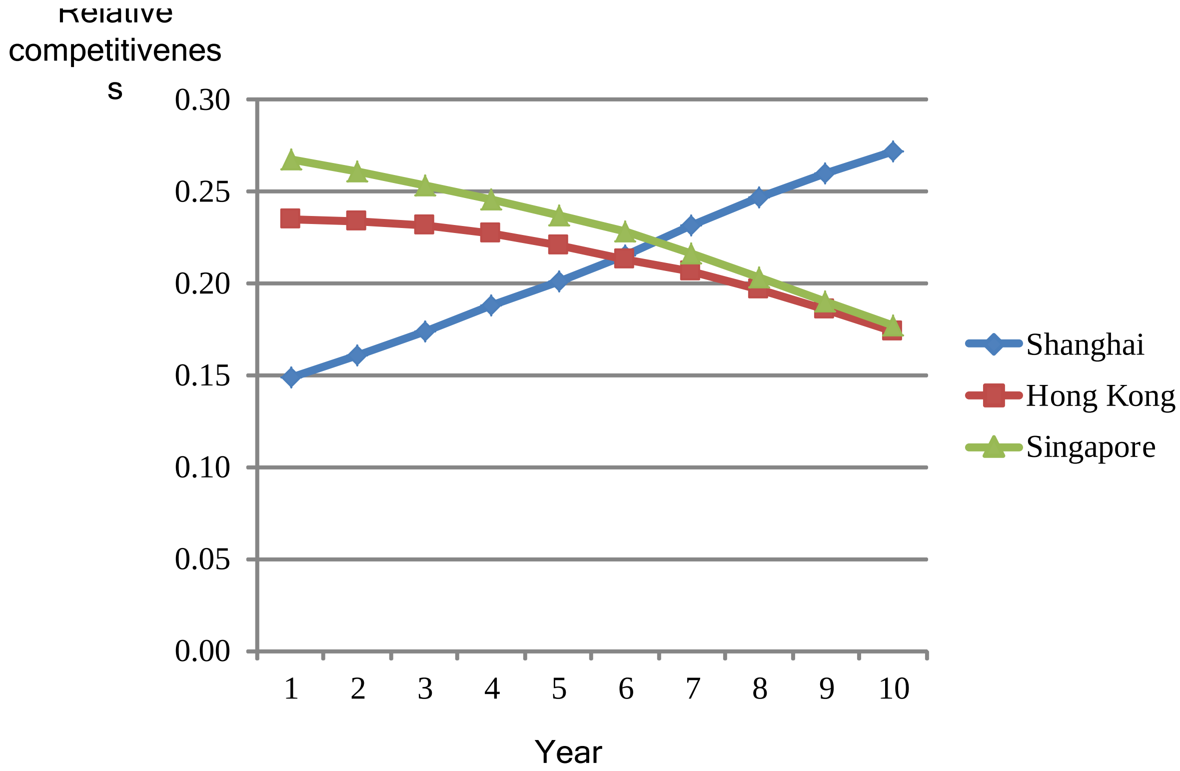

Figure 2: The competitiveness of the three ports in the next ten years with the considerations of the influences of China's BRI

According to the results presented in Figure 2, it is apparent that the port of Shanghai will become more competitive than the port of Hong Kong from the sixth year, and it will also exceed the port of Singapore and be the most competitive one among these three ports from the seventh year. Therefore, the following implications can be obtained:

(1) With the development of China's BRI, the infrastructure, the policy and regulation system, market environment and tax/tariff system related to the port of Shanghai may be significantly improved, and this port will become more and more competitive, and it can even exceed the port of Hong Kong and the port of Singapore and become the most competitive several years later if the port of Shanghai can effectively take the advantages of China's BRI;

(2) The development of China's BRI also has positive influences on the competitiveness of the port of Hong Kong and the port of Singapore, but the influential levels on these two ports are relatively lower than that on the port of Shanghai. This is the reason why the port of Shanghai will become more and more competitive. Comparing with the port of Shanghai, Hong Kong port and Singapore port will become less and less competitive though the competitiveness these two ports will also be improved with the development of China's BRI. Accordingly, some actions and measures should be taken to retain the competitive advantage of the port of Singapore and that of the port of Hong Kong. It is worth pointing out that the "competiveness" mentioned herein represents the relative competitiveness of these three ports, thus, the competiveness of three ports will all become more and more competitive comparing with their past status, but the improvement speeds of the three ports under the background of China's BRI are different.

4. Discussion

In order to validate the results determined by the projection method, the sum weighted method (SWM) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method were also employed to determine the relative competitiveness of the three ports based on the data in the weighted standardized decision-making matrix and the standardized decision-making matrix. The results were presented in Figure 3.

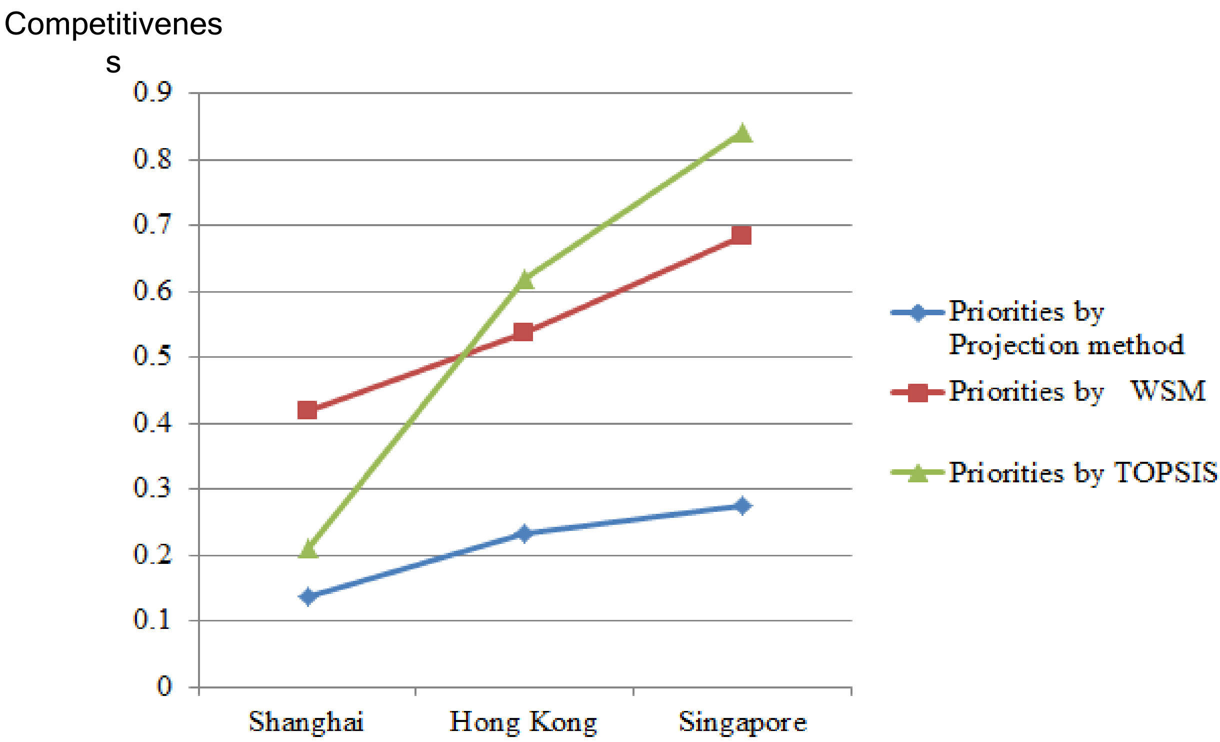

Figure 3: The comparison of the results determined by the projection method and that by WSM and TOPSIS

It is apparent that the priority order of the three ports with respect to the competitiveness determined by the projection method is consistent with that determined by WSM and TOPSIS. Thus, the projection is reliable for competitiveness evaluation of ports. Moreover, the results determined by the projection method can also show the projection of the competitiveness of the ports to the best ideal port in their mind.

Sensitivity analysis was also implemented by changing the weights of three dimensions for competitiveness evaluation of ports and keeping the local weights of the criteria in each dimension as the same with that determined by the interval AHP. The following cases were considered in this study:

Base case: $\omega_{natural\ conditions} = 0.2706$, $\omega_{shipping\ conditions} = 0.5961$, $\omega_{external\ conditions} = 0.1332$ (determined by interval AHP);

Case 1: $\omega_{natural\ conditions} = 0.4000$, $\omega_{shipping\ conditions} = 0.3000$, $\omega_{external\ conditions} = 0.3000$;

Case 2: $\omega_{natural\ conditions} = 0.3000$, $\omega_{shipping\ conditions} = 0.4000$, $\omega_{external\ conditions} = 0.3000$;

Case 3: $\omega_{natural\ conditions} = 0.3000$, $\omega_{shipping\ conditions} = 0.3000$, $\omega_{external\ conditions} = 0.4000$.

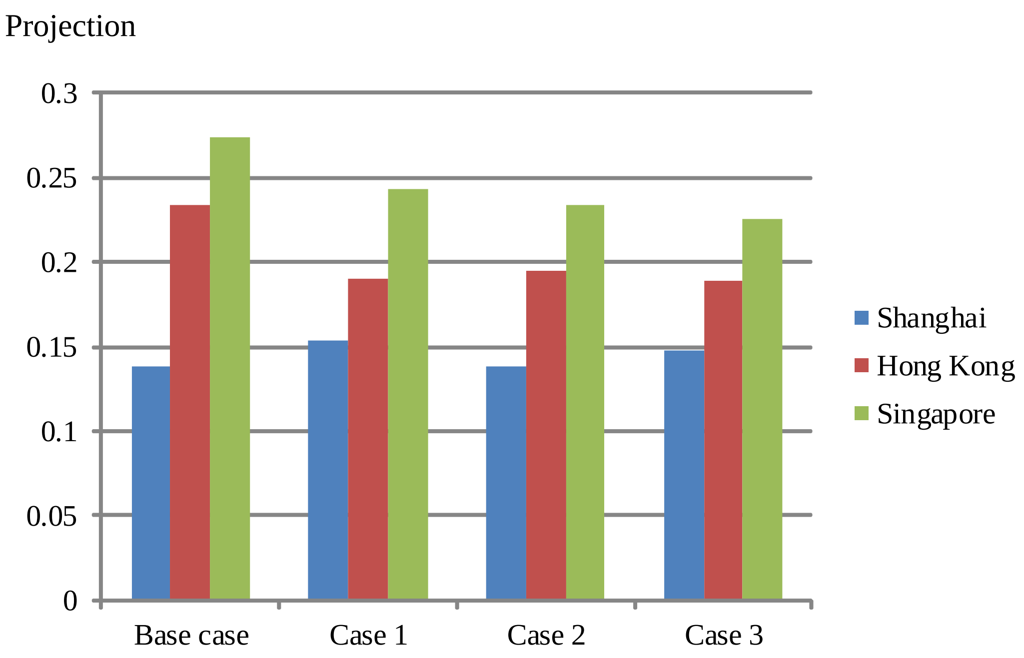

Figure 4: The results of sensitivity analysis

The results reveal that the weights of the criteria have significant effects on the projections of the three ports to the BIS (see Figure 4); however, the competitiveness order of the three ports kept the same even changing the weights of the ten criteria in the above-mentioned three cases.

5. Conclusions

China's Belt and Road Initiative plays a significant important role in stimulating the economy growth of the world, and ports as one of the most important infrastructures undertake the tasks of assisting the shipping transport. Accordingly, the understanding of the competitiveness of the main ports related to this strategy will be beneficial for appropriately planning and designing the shipping transport in the Belt and Road Initiative. A novel multi-attribute decision analysis method by combining the interval Analytic Hierarchy Process and the projection method was developed for assessing the competitiveness of the ports. The weights of the criteria for competitiveness evaluation of the ports were determined by the interval AHP which can successfully overcome the difficulty of assuring the consistency in the traditional AHP method, and the users can also depict their opinions/preferences more accurately comparing with the other weighting methods. Besides the calculation of the weights of the criteria for competitiveness evaluation, the interval AHP was used to obtain the relative scores of the ports with respect to some soft criteria which were also used for competitiveness evaluation. The projection method was used to determine the projection of each port on the hypothetical best ideal solution for determining the competitiveness of the ports. Three ports have been studied by the developed multi-attribute decision analysis method, and the results reveal the feasibility and accuracy of the proposed method. The results demonstrate that the port of Singapore is the most competitive under at the initial stage of China's BRI, followed by Hong Kong and Shanghai in the descending order. This also demonstrates the strategic role of the port of Singapore in China's BRI. The results were also significantly important for China's administrators for promoting China's BRI. China should appropriately handle the geopolitical problems-especially the relationship with Singapore for adequate use of Singapore port as a critical strategic belt for shipping China to the world. The main factors which lead to the competitiveness difference between the port of Singapore and Shanghai consist of geographical position, route accessibility, registered shipping capacity, tax, and market freedom. It is apparent that the improvement of the soft power of the port of Shanghai is the key for improving its competitiveness under the background of China's BRI. The competitiveness of the three ports in the next ten years were also analyzed with the considerations of different influences on these three ports caused by China's BRI, and the results reveal that the port of Shanghai can even exceed the port of Hong Kong and Singapore with the improvement of the three ports with respect to registered shipping capacity, tax, market freedom, and political factor.

As for the weak point of the developed MADA method for competitiveness evaluation of the ports, the method cannot achieve group decision-making, because the determination of the weights of the evaluation criteria and the relative scores of the ports about the soft criteria when using interval AHP is based on the group discussion with a consensus. In other words, this method cannot fully use the opinions/judgements of all the decision-makers when evaluating the competitiveness of the ports. Meanwhile, the developed method cannot incorporate the interdependences and interactions among the criteria for the evaluation of port competitiveness, and all these criteria are assumed to be independent, but this assumption cannot fit well with the actual conditions (Liang *et al.*, 2016). Accordingly, developing a multi-person multi-attribute decision analysis method, which allows a set of different stakeholders to make their decisions and can address the interdependences and interactions among the criteria for the evaluation of port competitiveness, is needed in the future work.

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Appendix A

Table A1: The relative superiorities of the three ports with respect to route accessibility (C_5), tax (C_8), market freedom (C_9), and political factor (C_{10})

C_5	Shanghai	Hong Kong	Singapore	Relative Superiorities
Shanghai	1	[1/2 1]	[1/3 1/2]	0.1764
Hong Kong	[1 2]	1	[1/2 1]	0.3031
Singapore	[2 3]	[1 2]	1	0.5205
C_8	Shanghai	Hong Kong	Singapore	Relative Superiorities
Shanghai	1	[1/4 1/3]	[1/5 1/3]	0.1111
Hong Kong	[3 4]	1	[1 1]	0.4444
Singapore	[3 5]	[1 1]	1	0.4444
C_9	Shanghai	Hong Kong	Singapore	Relative Superiorities
Shanghai	1	[1/3 1]	[1/3 1/2]	0.1484
Hong Kong	[1 3]	1	[1 2]	0.4280
Singapore	[2 3]	[1/2 1]	1	0.4236
C_{10}	Shanghai	Hong Kong	Singapore	Relative Superiorities
Shanghai	1	[3 4]	[2 3]	0.5741
Hong Kong	[1/4 1/3]	1	[1/2 1]	0.1799
Singapore	[1/3 1/2]	[1 2]	1	0.2459

Table A2: The relative weights of the three dimensions and the local relative weights of the indicators in natural conditions and external conditions

	Natural conditions	Shipping conditions	External conditions	Relative weights
Natural conditions	1	[1/3 1/2]	[2 3]	0.2706
Shipping conditions	[2 3]	1	[3 5]	0.5961
External conditions	[1/3 1/2]	[1/5 1/3]	1	0.1332
	C_1	C_2	C_3	Relative weights
Geographical position superiority (C_1)	1	[3 5]	[2 3]	0.5741
Deep-water berth (C_2)	[1/5 1/3]	1	[1/2 1]	0.1799
Berth length (C_3)	[1/3 1/2]	[1 2]	1	0.2459
	C_8	C_9	C_{10}	Relative weights
Tax (C_8)	1	[1 3]	[1 2]	0.3851
Market freedom (C_9)	[1/3 1]	1	[1/2 1]	0.2871
Political factor (C_{10})	[1/2 1]	[1 2]	1	0.3279

Table A3: The standardized decision-making matrix

	Shanghai	Hong Kong	Singapore
Geographical position superiority (C_1)	0.4171	0.5067	0.7546
Deep-water berth (C_2)	0.6891	0.3595	0.6292
Berth length (C_3)	0.6912	0.4325	0.5789
Container handling capacity (C_4)	0.6484	0.4299	0.6283
Route accessibility (C_5)	0.2811	0.4829	0.8293
Concentration of vessel (C_6)	0.5684	0.3200	0.7579
Registered shipping capacity (C_7)	0.2743	0.7089	0.6498
Tax (C_8)	0.1741	0.6963	0.6963
Market freedom (C_9)	0.2393	0.6901	0.6830
Political factor (C_{10})	0.8833	0.2768	0.3783

Table A4: The weighted standardized decision-making matrix

	Shanghai	Hong Kong	Singapore
Geographical position superiority (C_1)	0.0648	0.0787	0.1173
Deep-water berth (C_2)	0.0336	0.0175	0.0306
Berth length (C_3)	0.0460	0.0288	0.0385
Container handling capacity (C_4)	0.0663	0.0439	0.0642
Route accessibility (C_5)	0.0443	0.0761	0.1306
Concentration of vessel (C_6)	0.0290	0.0164	0.0387
Registered shipping capacity (C_7)	0.0782	0.2022	0.1853
Tax (C_8)	0.0089	0.0357	0.0357
Market freedom (C_9)	0.0091	0.0264	0.0261
Political factor (C_{10})	0.0386	0.0121	0.0165

References

An, N., Liu, J. L. (2009). Port Competitiveness Evaluation Based on Customer Satisfaction Degree Index . China Harbour Engineering, 1, 022. (in Chinese).

Briano, E., Caballini, C., Mosca, R., Revetria, R., Testa, A. (2010). Proposing a system dynamic approach to assess and improve Italian ports competitiveness. In Proceedings of the 12th WSEAS international conference on Automatic control, modelling & simulation (pp. 219-222). World Scientific and Engineering Academy and Society (WSEAS), 2010, May.

Cheng, L. K. (2016). Three questions on China's “Belt and Road Initiative”. China economic review, 40, 309-313.

da Cruz, M. R. P., Ferreira, J. J., Azevedo, S. G. (2013). Key factors of seaport competitiveness based on the stakeholder perspective: An Analytic Hierarchy Process (AHP) model. Maritime Economics & Logistics, 15(4), 416-443.

Ha, M. H., Yang, Z. (2017). Comparative analysis of port performance indicators: Independency and interdependency. Transportation Research Part A: Policy and Practice, 103, 264-278.

Ha, M. H., Yang, Z., Notteboom, T., Ng, A. K., Heo, M. W. (2017). Revisiting port performance measurement: A hybrid multi-stakeholder framework for the modelling of port performance indicators. Transportation Research Part E: Logistics and Transportation Review, 103, 1-16.

Hales, D. N., Chang, Y. T., Lam, J. S. L., Desplebin, O., Dholakia, N., Al-Wugayan, A. (2017). An empirical test of the balanced theory of port competitiveness. The International Journal of Logistics Management, 28(2), 363-378.

He, C., Zhang, Q., Ren, J., Li, Z. (2017). Combined cooling heating and power systems: Sustainability assessment under uncertainties. Energy, 139, 755-766.

Huang, W. C., Teng, J. Y., Huang, M. J., Kou, M. S. (2013). Port competitiveness evaluation by fuzzy multicriteria grade classification model.Journal of Marine Science and Technology, 11(1), 53-60.

Huang, Y. (2016). Understanding China's Belt & Road Initiative: Motivation, framework and assessment. China Economic Review, 40, 314-321.

Huiling, Z., Yuehua, O., Jianwei, C., Yanchun, W. (2017, June). Empirical study on sustainable competitiveness evaluation of Guangzhou Port based on improved matter-element model. In Service Systems and Service Management (ICSSSM), 2017 International Conference on (pp. 1-6). IEEE. This file is available at http://ieeexplore.ieee.org/abstract/document/7996229/ (Access in February 2018)

Jim Wu, Y. C., Lin, C. W. (2008). National port competitiveness: implications for India. Management Decision, 46(10), 1482-1507.

Ke, R., Wang, C. (2017). Comparative Analysis of the Shipping Center Competitiveness of Major Port Cities in China. Transportation Journal, 56(1), 35-53.

Kim, A. R. (2016). A study on competitiveness analysis of ports in korea and china by entropy weight topsis. The Asian Journal of Shipping and Logistics, 32(4), 187-194.

Kim, T. S. (2015). The Revealed Competitiveness of Major Ports in the East Asian Region: An Additive Market Share Analysis. The Asian Journal of Shipping and Logistics, 31(4), 429-435.

Lee, P. T., Hu, K. C.(2012). Evaluation of the service quality of container ports by importance-performance analysis. International Journal of Shipping and Transport Logistics, 4(3), 197-211.

Lee, P. T. W., Lam, J. S. L.(2015). Container port competition and competitiveness analysis: Asian major ports. In Handbook of Ocean Container Transport Logistics (pp. 97-136). Springer International Publishing.

Liang, H., Ren, J., Gao, Z., Gao, S., Luo, X., Dong, L., Scipioni, A. (2016). Identification of critical success factors for sustainable development of biofuel industry in China based on grey decision-making trial and evaluation laboratory (DEMATEL). Journal of Cleaner Production, 131, 500-508.

Liu, Y., Lu, S., Zhang, P. (2013). Port Competitiveness Evaluation Research based on Chernooff Faces Model. Procedia-Social and Behavioral Sciences, 96, 1961-1966.

Liu, W., Dunford, M. (2016). Inclusive globalization: Unpacking China's belt and road initiative. Area Development and Policy, 1(3), 323-340.

Nguyen, M. D., Kim, S. J., Jeong, J. S. (2016). Hierarchical Cluster Analysis on Competitiveness of Container Terminals in Northern Vietnam. Journal of Korean Navigation and Port Reserch, 40(2), 67-72.

Onut, S., Tuzkaya, U. R., Torun, E. (2011). Selecting container port via a fuzzy ANP-based approach: A case study in the Marmara Region, Turkey. Transport Policy, 18(1), 182-193.

Parola, F., Risitano, M., Ferretti, M., Panetti, E.(2017). The drivers of port competitiveness: a critical review. Transport Reviews,37(1), 116-138.

Ren, J., Andreasen, K. P., Sovacool, B. K. (2014). Viability of hydrogen pathways that enhance energy security: a comparison of China and Denmark. International Journal of Hydrogen Energy, 39(28), 15320-15329.

Ren, J., Ren, X., Liang, H., Dong, L., Zhang, L., Luo, X., Yang, Y., Gao, Z. (2017). Multi-actor multi-criteria sustainability assessment framework for energy and industrial systems in life cycle perspective under uncertainties. Part 2: improved extension theory. The International Journal of Life Cycle Assessment, 22(9), 1406-1417. Ren, J., Ren, X., Liang, H., Dong, L., Zhang, L., Luo, X., Yang, Y., Gao, Z. (2017). Multi-actor multi-criteria sustainability assessment framework for energy and industrial systems in life cycle perspective under uncertainties. Part 1: weighting method. The International Journal of Life Cycle Assessment,22(9), 1397-1405.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. Omega, 53, 49-57.

Saaty TL.(1978). Exploring the interface between the hierarchies, multiple objectives and the fuzzy sets. Fuzzy Sets Sys.,1: 57–68.

Sharma, B. C., Gandhi, O. P.(2006). RUL assessment of lube oil using AHP and vector projection approach. Industrial Lubrication and Tribology, 58(4), 187-194.

Song, D. W., Yeo, K. T.(2004). A competitive analysis of Chinese container ports using the analytic hierarchy process. Maritime Economics & Logistics, 6(1), 34-52.

Swaine, M. D. (2015). Chinese views and commentary on the ‘One Belt, One Road’initiative. China Leadership Monitor,47, 1-24.

Tao, C., Lu, Z. (2010). The Research of Suzhou Port Competitiveness Based on FAHP. Journal of Ningxia University (Natural Science Edition) ,3, 024. (in Chinese).

Teng, J. Y., Huang, W. C., Huang, M. J. (2004). Multicriteria evaluation for port competitiveness of eight East Asian container ports. Journal of Marine Science and Technology, 12(4), 256-264.

van Dyck, G. K., Ismael, H. M. (2015). Multi-criteria evaluation of port competitiveness in West Africa using analytic hierarchy process (AHP). American Journal of Industrial and Business Management, 5(06), 432.

Wang, Z., Li, X. G. (2011). Evaluation and research of port competitiveness based on FAHP. Port & Waterway Engineering, 2, 021. (in Chinese).

Wang, X., Chen, M.. (2016). A Comprehensive Research on Evaluation of Port Competitiveness Factors. In Computational Intelligence and Security (CIS), 2016 12th International Conference on (pp. 362-365). IEEE. This file available at http://ieeexplore.ieee.org/abstract/document/7820479/?reload=true (Access in February 2018).

Xu, Z. (2004). Theory Method and Applications for Multiple Attribute Decision-Making with Uncertainty, Tsinghua University Press, Beijing, 2004.

Xu, Z., Da, Q. (2004). Projection method for uncertain Multiattribute decision analysis with preference information on alternatives. International Journal of Information Technology & Decision Making, 3(03), 429-434.

Yang, Z., Ng, A. K., Wang, J.(2014). A new risk quantification approach in port facility security assessment. Transportation research part A: policy and practice, 59, 72-90.

Yeo, G. T., Roe, M., Dinwoodie, J.(2008). Evaluating the competitiveness of container ports in Korea and China. Transportation Research Part A: Policy and Practice, 42(6), 910-921.

Yeo, G. T., Song, D. W., Dinwoodie, J., Roe, M.(2010). Weighting the competitiveness factors for container ports under conflicting interests. Journal of the Operational Research Society, 61(8), 1249-1257.

Yeo, G. T., Song, D. W.(2006). An application of the hierarchical fuzzy process to container port competition: policy and strategic implications. Transportation, 33(4), 409-422.

Yeo, G. T., Roe, M., Dinwoodie, J.(2011). Measuring the competitiveness of container ports: logisticians' perspectives. European Journal of Marketing,45(3), 455-470.

Yeo, G. T., Ng, A. K., Lee, P. T. W., Yang, Z. (2014). Modelling port choice in an uncertain environment. Maritime Policy & Management, 41(3), 251-267.

Yuen, C. L. A., Zhang, A., Cheung, W.(2012). Port competitiveness from the users' perspective: An analysis of major container ports in China and its neighboring countries. Research in Transportation Economics, 35(1), 34-40.

Zavadskas, E. K., Turskis, Z., Bagočius, V. (2015). Multi-criteria selection of a deep-water port in the Eastern Baltic Sea. Applied Soft Computing, 26, 180-192.

Zhang, G.H.(2015). The pathway of ports transformation and upgrading under the One Belt and One Road Strategy. 2015.This file is available at: http://www.tranbbs.com/renwu/Zgh/renwu_163163.shtml. (in Chinese).

Zhang, X., Jin, F., Liu, P. (2013). A grey relational projection method for Multiattribute decision analysis based on intuitionistic trapezoidal fuzzy number. Applied Mathematical Modelling, 37(5), 3467-3477.

Zhen, W. (2017). The Evaluation of Soft Power Investment Effect on Shanghai Port Competitiveness Using DEA method. Journal of Maritime Research, 12(2), 45-52.