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Transhipment port's competitiveness forecasting using analytic network process modelling

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ABSTRACT

This study proposes a novel approach to forecast a transhipment port's competitiveness on the basis of market share. The potential reasons for escalating or diminishing competitiveness are explored by utilising a multi-criteria decision-making (MCDM) methodology. We assess the competitiveness of transhipment ports by seven major components: connectivity, port facility, efficiency, cost factor, policy and management, information systems and green port management, and contribute to the understanding of the interdependence among the components. We investigate the Bangladesh container market due to the uniqueness of its regional context and dimensions of competitiveness. Bangladesh has direct connections to four regional hubs, namely, Singapore, Colombo, Port Klang and Tanjung Pelepas. These regional hubs compete to grasp a significant volume of container movements in line with the rapid growth of Bangladesh's industrialisation and national economy. We find that Singapore outperforms others in terms of competitiveness, but all ports perform below expectations in green port management practices. These findings would benefit port authorities for improving their competitiveness, and liner shipping companies and shippers in making strategic port choice decisions.

1. Introduction

In 2017, about 24.3 percent of world seaborne trade by volume was containerised cargo handled by seaports (hereinafter called 'ports') worldwide, and 25.8 percent of that was transhipment cargo (UNCTAD, 2018). Broadly, transhipment refers to the movement of containers or goods to an intermediate destination before transportation to the final destination. In the context of sea-sea transhipment, a container arriving *and* leaving the port terminal by ship is a transhipment container, and a container arriving *or* leaving the port by inland transport mode (barge, rail or truck) is a gateway container (Notteboom et al., 2019). Typically, ports that handle 65% or more transhipment containers are categorised as transhipment ports, and ports with 75% or more gateway containers are gateway ports (Notteboom et al., 2019).

The existing container shipping network connects the transhipment and gateway ports with the 'hub and spoke' and 'relay' networks (Ducruet and Notteboom, 2012). In a relay network, larger ships call at predetermined transhipment ports, covering long distances, following a schedule. On the other hand, in the hub and spoke network, comparatively smaller ships (also known as feeder vessels) connect transhipment ports with a smaller number of gateway ports covering shorter distances (see Fig. 1). Companies that deploy ships in the relay network are known as mainline shipping companies. In some cases, these companies also operate their ships in the feeder route. Besides, there exist dedicated feeder carriers, who mainly operate vessels within the hub and spoke network.

In the maritime network, the competitiveness of ports, transhipment or gateway, has implications for the global supply chains. The ability of international trade of a country relies heavily on its shippers' access to efficient logistics networks (Ekici et al., 2016). The gateway ports of a country are connected to the greater world through the transhipment ports. Hence, the competitiveness of the transhipment ports affects the competitiveness of the gateway ports. For instance, the Singapore port serves as a transhipment port to the Chittagong port of Bangladesh. If the container handling time at Singapore increases, the delivery time of goods from Bangladesh to its western buyers increases accordingly. As the number of transhipment ports in the world is limited, their competitiveness affects the logistics performance of countries that are

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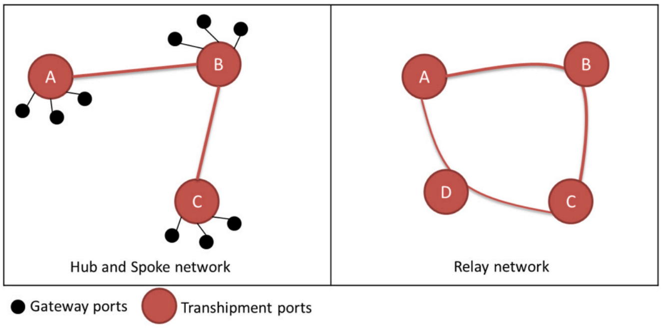


Fig. 1. Hub and spoke, and relay networks.

connected to them. There are several approaches to logistics performance assessment of countries. The Logistics Performance Index (LPI), published every two years since 2007, developed in collaboration between the World Bank and the Turku School of Economics, is probably the most widely adopted (Arvis et al., 2018). Among the six components of the LPI, Rezaei et al. (2018), found that 'infrastructure' is the most important. Recently, Kinra et al. (2020) proposed a big data approach to country logistics performance assessment using a text mining approach.

The country-level logistics performance is affected by its underlying components, including maritime transport. While analysing country-level logistics performance related documents, Kinra et al. (2020) found that "waterways" and "ports" are the most frequent words indicating the importance of ports for country-level logistics performance. Hence, assessment of port competitiveness matters not only for the shippers but for players in the whole logistics ecosystem, including shipping companies. Due to the increasing number of ports, liner shipping companies enjoy the privilege to choose transhipment ports among many for their port-of-calls. For example, Hong Kong lost some of its market shares to mainland Chinese ports (Yang et al., 2019). In addition, due to improving connectivity between transhipment and gateway ports through many local, regional and mainline vessel operators, the competition among transhipment ports serving overlapping gateway ports has become complex. As such, the oligopoly market structure of port service is coming to an end. Hence, studies on shipping lines' port choice have received substantial attention in the literature (Lirn et al., 2004; Ng, 2006; Tongzon and Sawant, 2007).

In the modern business model of container terminals, transhipment cargoes play significant roles in sustaining transhipment port's competitiveness. There are regional hub-and-spoke networks led by such a competitive environment. Transhipment ports implement strategies on marketing, pricing, network and productivity to develop their market share on particular destination ports. Increasing market share contributes to the economy of scale, and in turn, attracts more cargo volume with reduced cost and more connections. The market share would probably have a tipping point in which the hub port gains momentum and leadership to shift cargo movements in other networks (and other hub ports). It is also a forward-looking process to assess the competition, cargo movements, networks and required investments in terminal facility. By understanding the developments in market share (that is, future market share), a series of strategic decisions must be implemented to retain, improve or divest on terminal facility and network. For example, diminishing market share may not be reversed back due to aggressive and offensive strategies of competitors, and a terminal may prefer shifting efforts and capacity to other feeder connections to gain momentum. If there is potential for further improvements, a terminal operator would need to understand the weakness to mitigate, which is also challenging to identify and prioritize.

As such, we propose a novel approach to forecast the competitiveness of transhipment ports serving a particular market. We choose the Bangladesh container market as the case, which is connected with four transhipment ports — Singapore, Colombo, Port Klang and Tanjung Pelepas. This study contributes to the existing literature by offering an improved understanding of the port competitiveness assessment framework. First, we incorporate information systems and green port management within the assessment framework. Second, we provide understanding of the interdependence among the considered components of port competitiveness assessment, which is demonstrated by the superior market share predictability of the inner dependence Analytic Network Process (ANP) model.

The paper is structured as follows. Section 2 presents a literature review of the transhipment port competitiveness literature and identify the key evaluation criteria. Section 3 introduces the context of this study. We show the detailed mathematical calculation of the ANP modelling in Section 4. Section 5 presents the results and sensitivity analysis. We discuss the implication of the results in Section 6 and draw conclusions in Section 7.

2. Literature review of transhipment port competitiveness literature

Typically, ports are evaluated based on their competitiveness criteria (also referred to as port choice or selection criteria). Literature on port competitiveness dates back to the mid-1980s. Slack (1985) examined shippers' port choice criteria for the North America–Western Europe route. He found that price and service quality of land and ocean carriers made a difference in shippers' port entry and exit decision. Since then, majority of the port competitiveness assessment studies rely on multiple-attribute assessment frameworks using weighted scoring methods or Analytic Hierarchy Process (AHP). Despite the availability of port competitiveness studies from different users' perspective, studies focusing on transhipment ports' competitiveness evaluation is limited. After reviewing the transport port competitiveness assessment literature extensively, we found 22 relevant criteria for transhipment port choice (reported in Appendix B), which can be aggregated to six factors (as reported in Table 1). In addition, due to increasing environmental awareness throughout the industry, we consider 'green port management' as an important factor for port competitiveness assessment, too. According to Kinra et al. (2020), sustainability is one of the emerging topics in logistic performance assessment. Wiegmans, Hoest, and Notteboom (2008) briefly mentioned that the environmental profile of ports should be considered in port choice studies, but to the best of the authors' knowledge, the inclusion of this factor is not evident in existing transhipment port competitiveness assessment studies. The seven

Table 1
List of transhipment port competitiveness criteria.

No.	Criteria	Reference
1	Maritime connectivity	Kavirathna, Kawasaki, Hanaoka, and Matsuda (2018a); Ng (2006); Song and Yeo (2004), Lirn et al. (2004), Tongzon and Sawant (2007), Wiegmans et al. (2008), Chang et al. (2008), Gohomene et al. (2016).
2	Port facilities	Kavirathna et al. (2018a); Ng (2006); Song and Yeo (2004), Lirn et al. (2004), Tongzon and Sawant (2007), Chang et al. (2008), Gohomene et al. (2016), Yang and Chen (2016).
3	Port efficiency	Kavirathna et al. (2018a); Ng (2006); Song and Yeo (2004), Tongzon and Sawant (2007), Yang and Chen (2016).
4	Cost factor	Kavirathna et al. (2018a), Lirn et al. (2004), Tongzon and Sawant (2007), Wiegmans et al. (2008), Chang et al. (2008), Gohomene et al. (2016), Yang and Chen (2016).
5	Policy and management	Kavirathna et al. (2018a); Ng (2006), Lirn et al. (2004), Tongzon and Sawant (2007), Chang et al. (2008), Gohomene et al. (2016), Yang and Chen (2016).
6	Information systems	Ng (2006), Kavirathna et al. (2018a).
7	Green port management	None.

criteria are listed in Table 1, along with their sources.

As per Table 1, the majority of the studies found that maritime connectivity, port facilities, cost and port policy are the most important factors in transhipment port choice decision by shipping lines. While some included port efficiency as an important factor, the quality of information systems and the existence of green port management practices are neglected. Heilig and Voß (2017) argued that the quality of information systems is crucial to a port's competitiveness and affects several dimensions of port performance, such as port facility and efficiency. Also, Lun (2011) found that a port terminal's green practices positively influence the port's performance. Thus, quality information systems and degree of green port management practices need to be incorporated in transhipment ports' competitiveness evaluation framework.

Meanwhile, transhipment port users do not make their decisions based on any single factors but 'packages' provided by different transhipment ports (Ng, 2006). The 'package' can be referred to as an overall offering by a transhipment port as a combination of multiple criteria, including connectivity, facilities, efficiency, cost, management, information systems and sustainable performance. However, an investigation of transhipment port choice decision based on 'packages' is rare. Methodological approaches based on weighted scoring often fails to capture the interdependence among the criteria involved in decision making, thus, ignoring port offering as a package. Therefore, we propose an ANP model that is capable of evaluating the several port competitiveness criteria as a package, which was not possible by most of the previous studies due to the use of factor analysis (e.g. Chang et al., 2008) or AHP (e.g. Lirn et al., 2004; Yang and Chen, 2016) as their methodology. Based on Table 1, in the ANP model, we include seven competitiveness criteria — connectivity (hub-and-spoke performance), port facility, efficiency (internal operations), cost factor (pricing terminal fees), policy and management (internal governance, local and regional maritime policies), information systems (technology for data sharing and electronic visibility of operations) and environmental management (i.e. green port management), which are capable of capturing the dimensions of a transhipment port.

3. Context: transhipment ports serving Bangladesh

We choose the four transhipment ports — Singapore, Colombo, Port Klang and Tanjung Pelepas, serving the Bangladesh container shipping market, as the context of the study. These four ports serve three feeder shipping markets, that is, Indian Ocean South Coast, East Coast and West Coast. Studies in this context are limited. Recently, Kavirathna et al. (2018a) and Kavirathna, Kawasaki, and Hanaoka (2018b) investigated the competitiveness of the four transhipment ports in this region but in a different context. Overall, they found that Singapore was the most competitive port in the region (Kavirathna et al., 2018b), but the world's largest shipping line — Maersk— has a dedicated terminal in Tanjung Pelepas, while the port of Colombo has been growing rapidly (Kavirathna et al., 2018a). An overview of the transhipment ports serving the Bangladesh container market is depicted in Fig. 2.

- Port of Colombo

The Port of Colombo is the busiest and largest port of Sri Lanka and ranks 24th in the Lloyds 2019 top 100 ports ranking (Lloyds Maritime Intelligence, 2019). The history of the port dates back to 1505, but the current port governing body —Sri Lanka Ports Authority (SLPA) — was established in 1979 (SLPA, n.d.). Since the 1990s, the port's container throughput has grown significantly. Alphaliner ranked Colombo as the world's fastest container throughout growing port in the first half of 2018 (SLPA, n.d.). In 2018, the port handled 7 million TEUs.[1]

- Port Klang

The Port Klang is the largest port of Malaysia and ranks 12th in the Lloyds 2019 top 100 ports ranking (Lloyds Maritime Intelligence, 2019). The port was known as Port Swettenham during the colonial times under the Great Britain but later in 1972 changed to its current name. The current governing body, the Port Klang Authority (PKA) was established in 1963 (PKA, n.d.). In 2018, the port handled over 12 million TEUs.[2]

- Port of Tanjung Pelepas

The Port of Tanjung Pelepas is the most recently developed one among the four considered transhipment ports, started its operation in 1999. The port ranks 18th in the Lloyds 2019 top 100 ports ranking (Lloyds Maritime Intelligence, 2019). The port has been successful in grasping market share from the Port of Singapore. In 2000, Maersk moved its dedicated terminal operation from Singapore to Tanjung Pelepas and still operating there. Later in 2002, Evergreen also shifted its dedicated terminal from Singapore to Tanjung Pelepas. In 2018, the port handled close to 9 million TEUs that is 8.5% increase from 2017.[3]

- Singapore Port

The Port of Singapore has been ranked the world's busiest port several times and currently ranks 2nd in the Lloyds 2019 top 100 ports ranking (Lloyds Maritime Intelligence, 2019). The port handled over 36.5 million TEUs in 2018.[4] Two major container terminals, Tanjong Pagar and Pasir Panjang terminals, are operated by the Port of Singapore Authority (PSA), while the third terminal project, Tuas Terminal, will replace both terminals with its gigantic capacity and technology. Pasir Panjang Terminal is one of the leading examples of automated (or remote) terminals in the world, which is operated with remote-controlled gantry cranes and automated guided vehicles (AGVs). The leadership of Singapore port relies on very high productivity and efficiency of terminal operations, geographical advantage and high level of connectivity to both regional and global liner networks. By utilising its unique features, Singapore Port develops its market share in major connections and gain additional momentum in attracting cargo movements.

4. Data and methodology

As mentioned in section 2, Lirn et al. (2004) used AHP to investigate global transhipment port choice decision. Similarly, Ugboma et al. (2006) also used AHP for Nigerian port choice decision making. In the AHP, each factor/criterion in the hierarchy of decision making is considered independent of all other factors. However, in port competitiveness or choice decision-making, each factor can be influenced by other factors as port users view port service as a combination of multiple factors (Ng, 2006). Thus, ANP is an appropriate method for investigating transhipment port choice decision as in ANP relevant factors which enable the 'package' to be clustered together in the decision-making process. The data collection and analysis process is depicted stepwise in Fig. 3.

Step 1 Clarify the goal

The first step in solving a complex problem is to identify the problem,

[1] https://lloydslist.maritimeintelligence.informa.com/LL1127854/24-Colombo-Sri-Lanka.

[2] https://lloydslist.maritimeintelligence.informa.com/LL1128294/12-Port-Klang-Malaysia.

[3] https://lloydslist.maritimeintelligence.informa.com/LL1128122/18-Tanjung-Pelepas-Malaysia.

[4] https://lloydslist.maritimeintelligence.informa.com/LL1127634/02-Singapore-Singapore.

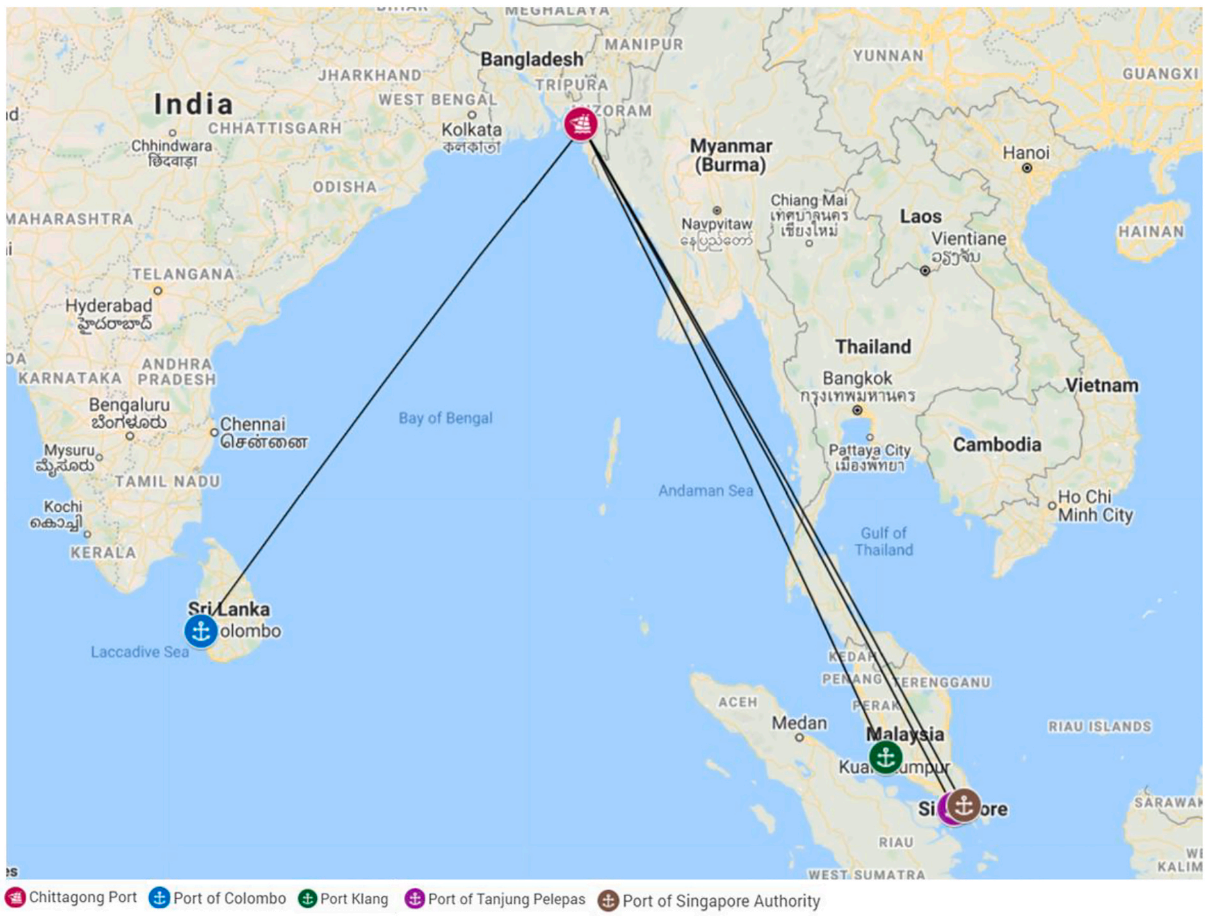


Fig. 2. Overview of transhipment ports in context (Source: Compiled by authors using map.google.com).

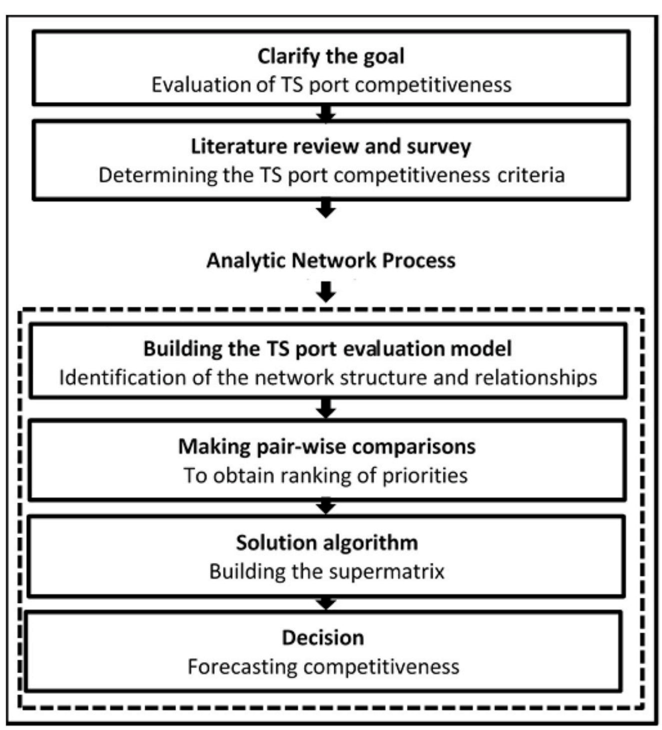


Fig. 3. Modelling transhipment port competitiveness evaluation.

the circumstances in which it happens and to have a clear vision of the outcome of the solution. Here, the problem is to find the best transhipment port serving the Bangladesh container shipping market based on seven transhipment port competitiveness factors. As we include all four transhipment ports serving the Bangladesh market, their respective competitiveness scores in percentage can be translated to their corresponding market share. Saaty and Vargas (2006) showed a similar approach to forecasting using the ANP.

Step 2 Literature review and survey

First, we identified 22 transhipment port choice/competitiveness criteria from the existing literature. In addition, we included three criteria representing green port management practices. Then, we distributed a questionnaire on the importance rating of the 25 criteria on a 7-point Likert scale among 23 executives of international liner shipping's local offices, international freight forwarders and feeder carriers. We received 20 complete and useable responses, which represent 16 companies, including local agents of Maersk, CMA CGM, COSCO, MSC, Yang Ming and PIL. We present the respondent demographics in Appendix A, and a descriptive summary of the survey in Appendix B. As the number of pair-wise comparisons increases exponentially with an increase in the number of criteria, we grouped the 25 criteria into seven transhipment port competitiveness factors based on iterative discussions with the 20 respondents.

Step 3 Building the transhipment port evaluation model

As a multi-criteria-decision-making (MCDM) method, we need a set of criteria and alternatives to form an ANP model. Here, the four transhipment ports serving the Bangladesh container shipping market are the alternatives, and the seven transhipment port competitiveness factors are the criteria for the ANP model. Also, each factor can influence other factors, which can be modelled through an inner dependence network. To identify the inner dependencies, we asked the respondents about the expected associations among the seven factors. The inner dependence associations among the seven factors are derived through an iterative discussion with the respondents, as shown in Table 2. Previous studies (for example, Farias et al., 2019) also finalised their ANP model through respondent interview. Finally, the proposed ANP model is shown in Fig. 4.

Step 4 Making pair-wise comparisons

According to the proposed ANP model (Fig. 4), we perform three categories of pair-wise comparisons. The first category is on the evaluation of each of the transhipment ports based on the seven competitiveness factors, which require 21 pair-wise comparisons for each port, that is, a total of (21 × 4) 84 pair-wise comparisons for four ports.[5] As an illustrative example, we present such a pair-wise comparison matrix of our first respondent (No. 1 in Appendix A) in Table 3. Each of the pairwise comparisons comes in two stages. For example, in the first stage, we ask the respondents: *"with respect to the Port of Colombo, which criteria is better between maritime connectivity and port facilities"*. For the Port of Colombo, our first respondent said that the maritime connectivity is better than facilities. Then in the second stage, we ask the respondent: *"with respect to the Port of Colombo, how much better is the maritime connectivity in comparison to port facilities?"* The respondent then make this comparison on a 9-point scale,[6] originally proposed by the founder of AHP/ANP, Saaty (1990). As we can see in Table 2, our first respondent said that the maritime connectivity of Port of Colombo is five times better than port facilities. This response corresponds to two values in Table 3, the cells (2,1) and (1,2). As both cells correspond to the same comparison, one value is simply reciprocal of the other. Likewise, 21 pair-wise comparisons with respect to the Port of Colombo generates all values in Table 3.

The second category of comparisons is on the evaluation of each of the competitiveness factors while considering the four alternatives, which require six pair-wise comparisons for each factor, that is, a total of (6 × 7) 42 pair-wise comparisons. Again, we present an example of such a pair-wise comparison matrix of our first respondent in Table 4. Similar to the previous category of pairwise-comparison, we ask the respondents: *"with respect to the maritime connectivity factor, which transhipment port is better between Colombo and Port Klang"*. Our first respondent said that the Port Klang is better than Colombo. Then, we ask the respondent: *"with respect to the maritime connectivity factor, how much better is the Port Klang in comparison to Colombo?"* As we can see in Table 4, with respect to maritime connectivity, our first respondent said that Port Klang is three times better than Colombo. Based on the same logic as discussed in the previous paragraph, six pair-wise comparisons with respect to the maritime connectivity factor generates the values in Table 4.

The third category of comparisons is on the associations between competitiveness factors that makes the inner dependences. Again, we present an example of such a pair-wise comparison matrix of our first respondent in Table 5. Similar to previous categories of pairwise-comparison, we ask the respondents: *"which competitiveness factor between port policy and management, and information system effects the port facility factor more?"* Our first respondent said that the information system of a transhipment port effects its port facilities more than port policy and management. Then, we ask the respondent: *"with respect to the port facility factor, how much more is the effect of information system in comparison to port policy and management?"* As we can see in Table 5, the first respondent said that the effect of information system on port facility is three times higher than port policy. Three pair-wise comparisons with respect to the port facility factor generate the values in Table 5. Note that all 300 [(4 × 20)+(7 × 20)+(4 × 20)] pair-wise comparison matrixes have an inconsistency ratio below 0.10, well below the upper limit of 0.20 as recommended by Satty and Kearns (1985).

Step 5 Solution algorithm

In this step, we solve the ANP model and calculate the unweighted supermatrix of priorities. Before doing so, we need to aggregate the 20 responses. We calculated the geometric mean of the 20 individual judgments to specify group judgment of the transhipment port users of Bangladesh for each of the pair-wise comparisons (Forman and Peniwati, 1998; Ossadnik et al., 2016). Although we calculated the unweighted supermatrix using *aggregated judgments* (see Appendix C), here in Tables 6–8, we present a three-stage priority calculation procedure from pair-wise comparison matrices based on the data of the first respondent, as shown in Table 5 as an example.

Step 6 Decision making

In the final step, we synthesise the priorities and calculate a normalised score for each of the alternatives, where the sum of all scores equals to one. From the forecasting perspective, the normalised scores for each transhipment ports represent their respective market shares. The normalised scores are simply the normalised values of raw scores for each alternative which we get from the limit matrix.

The calculation of the limit matrix is based on the Markov chain process — "a system that undergoes random transitions from one state to another with no memory from the past" (Ishizaka and Nemery, 2013, p. 76). In this process, the calculated weighted supermatrix (see Appendix E) is squared multiple times until all row-wise values stabilise and

[5] Number of required pair-wise comparisons can be calculated as $[n(n-1)/2]$. Here, n is the number of criteria/factors.

[6] 1→ both are equal; 2 & 3→ weakly better over another; 4 & 5→ strongly better than another; 6 & 7→ very strongly better; 8 & 9→ extremely better.

Table 2
Inner dependence associations.

Criteria/factors	1	2	3	4	5	6	7
(1) Connectivity				✓			
(2) Facilities			✓	✓			
(3) Efficiency				✓			
(4) Cost							
(5) Policy and management		✓	✓	✓			✓
(6) Information systems		✓	✓				✓
(7) Green port management		✓					

Here, √ indicates that the respective row-wise criteria effects the column-wise criteria. For example, port policy and management effect facilities of a port. indicates the diagonal of the matrix.

becomes identical (Saaty and Vargas, 2006). Appendix E is the result of multiplying the unweighted matrix with respective weights from the cluster matrix in Appendix D. The limit matrix from the weighted supermatrix of the 20 aggregated judgments is presented in Appendix F.

5. ANP results

5.1. Supermatrix from aggregated judgments

For the calculations presented in Step 4–6 of the aggregated judgments calculated through the geometric mean of 20 individual judgments, we used the Super Decisions software (https://www.superdecisions.com). Results presented in Tables 9–11 are part of the supermatrix (see Step 5), but here we present them separately for better interpretation. Table 9 shows priority scores of each transhipment port's competitiveness factors. Among the seven factors, the Port of Colombo scores highest in terms of cost competitiveness (0.197), followed by information systems (0.155). Port Klang's most competitive factor is also cost (0.239), followed by port facilities (0.158). For the Port of Singapore, information systems (0.190) is the most competitive factor, followed by port efficiency (0.181). Again, for the Port of Tanjung Pelepas, cost (0.213) is their most competitive factor, followed by port efficiency (0.175).

Table 10 shows the competitiveness scores of each of the seven factors across the four transhipment ports. The Port of Singapore performs better than other ports in six of the seven factors except for cost. Port Klang is taking advantage of providing cheaper service and is the most competitive in terms of cost (0.168), followed by the Port of Colombo. In an overall, the differences between the Port of Colombo and Port Klang are negligible for most factors, although Port Klang is slightly better than Colombo. Meanwhile, the Port of Tanjung Pelepas scores lowest in all competitiveness factors.

As discussed earlier in Step 3, some of the competitiveness factors can influence others (see Table 2), which we modelled using inner dependence relationships. Table 11 shows the associations among the inner dependencies. The port policy and management factor has a direct and strong influence on green port management (0.386) and port facilities (0.233). Port efficiency is most affected by port facilities (0.214), followed by port policy and management (0.152). Meanwhile, the cost factor is most affected by port efficiency (0.135) and port facilities (0.131).

Following Step 6, we get the synthesised scores for each of the four alternatives after normalising their respective scores from the limit matrix (see Appendix C). Table 12 presents the synthesised scores in percentage in the first column (a), which are the forecasted market share of the four transhipment ports based on the ANP model presented earlier

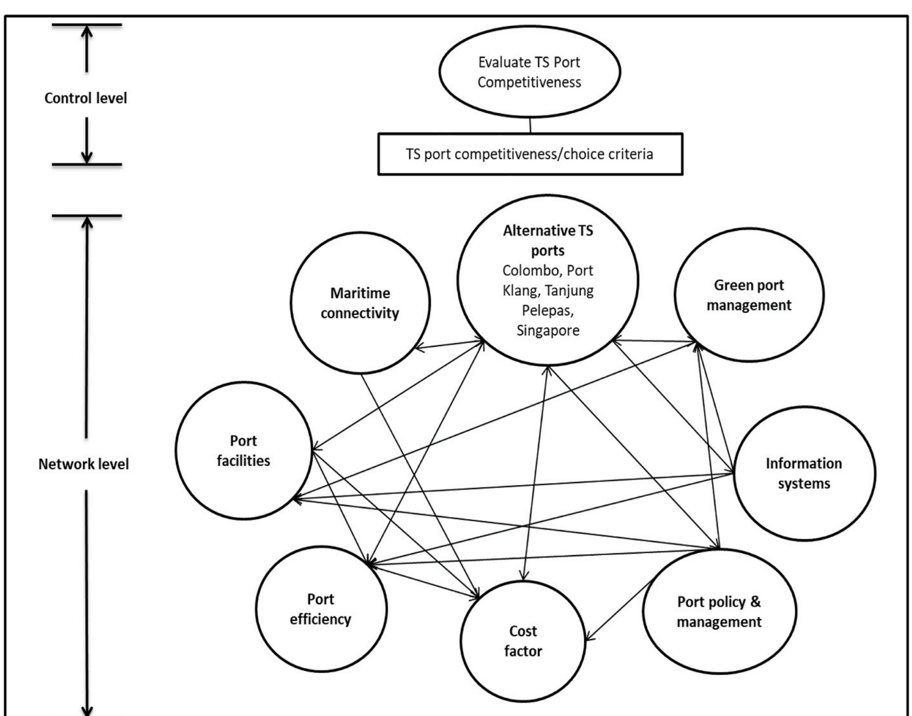
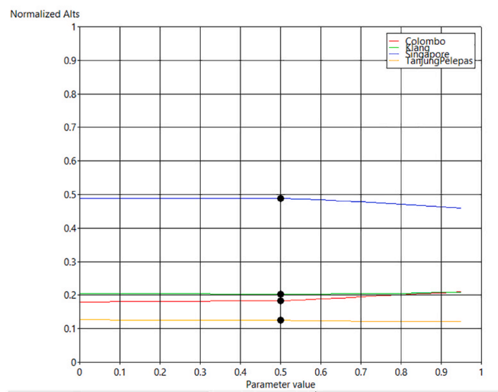
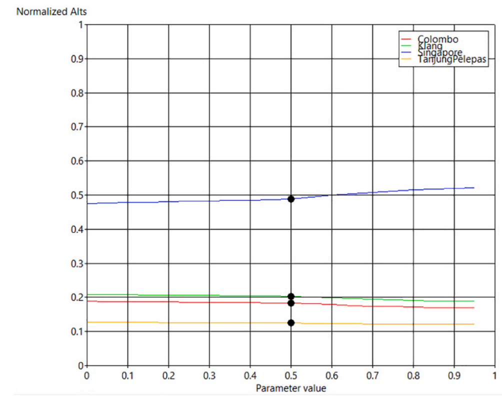


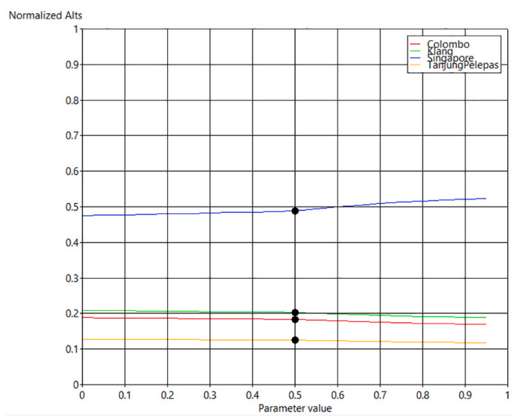
Fig. 4. The transhipment port competitiveness evaluation ANP model.



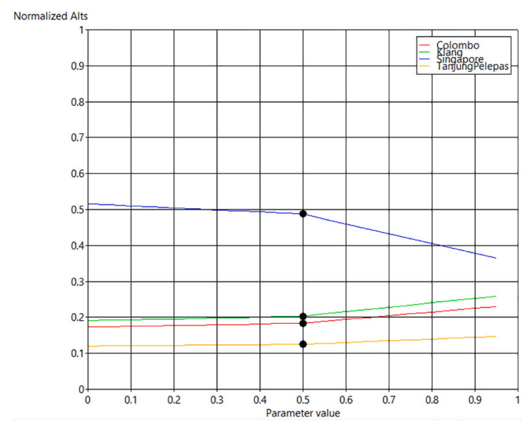
(a) w.r.t. geographic location



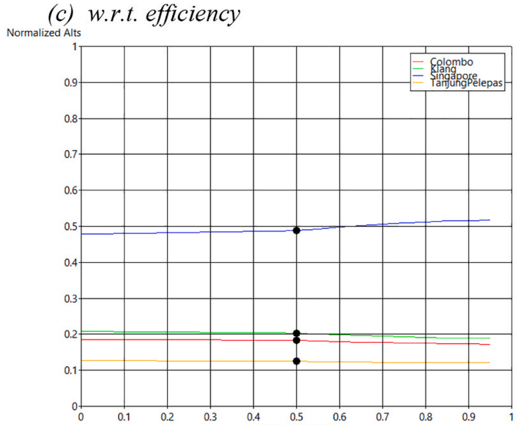
(b) w.r.t. facilities



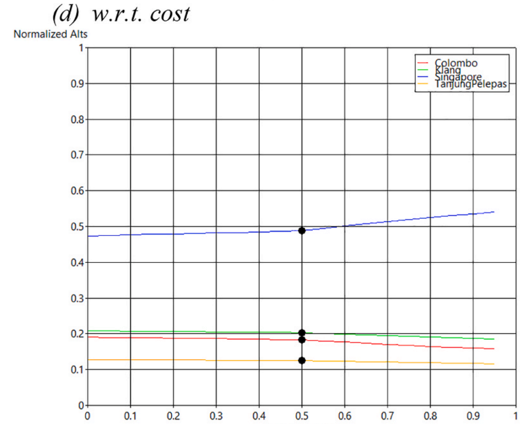
(c) w.r.t. efficiency



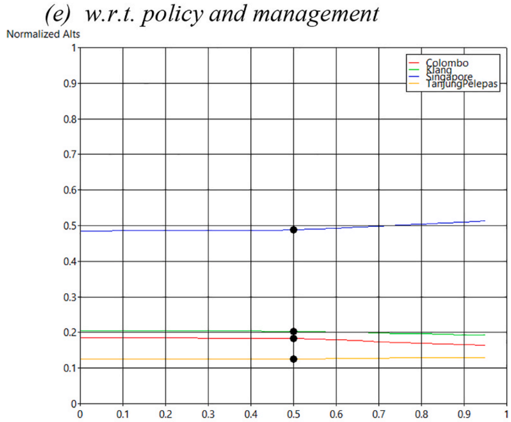
(d) w.r.t. cost



(e) w.r.t. policy and management



(f) w.r.t. information systems



(g) w.r.t. green port management

Fig. 5. Sensitivity analysis with respect to (w.r.t.) port competitiveness criteria.

Table 3
Pairwise comparisons between competitiveness factors with respect to Colombo Port.

Colombo Port	1	2	3	4	5	6	7
(1) Connectivity	1	5	1/4	1/5	1/4	1/5	4
(2) Facilities	1/5	1	1/4	1/4	1/3	1/4	3
(3) Efficiency	4	4	1	1/5	1	1	5
(4) Cost	5	4	5	1	4	3	7
(5) Policy and management	4	3	1	1/4	1	1	5
(6) Information systems	5	4	1	1/3	1	1	5
(7) Green port management	1/4	1/3	1/5	1/7	1/5	1/5	1

Inconsistency: 0.099.

Table 4
Pairwise comparisons between transhipment ports with respect to maritime connectivity.

Maritime connectivity	1	2	3	4
(1) Colombo	1	1/3	1/5	4
(2) Port Klang	3	1	1/3	7
(3) Singapore	5	3	1	7
(4) Tanjung Pelepas	1/4	1/7	1/7	1

Inconsistency: 0.070.

Table 5
Pairwise comparisons of the determinants of port facility.

Port facility	1	2	3
(1) Port policy and management	1	1/3	2
(2) Information systems	3	1	3
(3) Green port management	1/2	1/3	1

Inconsistency: 0.052.

Table 6
(Stage 1) Calculate column-wise sum.

Port facility	1	2	3
(1)Port policy and management	1.000	0.333	2.000
(2)Information systems	3.000	1.000	3.000
(3)Green port management	0.500	0.333	1.000
Sum	4.500	1.667	6.000

in Fig. 4. In column (b), we also present the forecasted market shares of the four ports using an ANP model without the inner dependencies. In an overall, the Port of Singapore is the most competitive and has the highest market share (Table 12). This is in line with Kavirathna et al. (2018b), although they have a different context. As we collected data from respondents in mid-2017, we compare the forecasted market shared with actual market shares of 2017. To check forecast accuracy, we use the most common indicator, mean absolute percentage error (MAPE). MAPE can be calculated using the following equation:

$$MAPE = \frac{100}{n} \sum_{1}^{n} \left| \frac{(d - z)}{d} \right| \tag{1}$$

Here, we calculate forecast error as $(d - z)$, d is the actual market share in 2017, z is the forecasted market share for 2017, n is the total number of observations.

Based on the MAPEs, when forecasting competitiveness in terms of market shares of four transhipment ports serving the Bangladesh container market, our original ANP model (MAPE 14.64%) performs betters than the model without inner dependencies (MAPE 16.96%).

Table 7
(Stage 2) To standardize, divide each value with the column-wise sum.

Port facility	1	2	3
(1)Port policy and management	0.222	0.200	0.333
(2)Information systems	0.667	0.600	0.500
(3)Green port management	0.111	0.200	0.167

Table 8
(Stage 3) The row-wise average is the priority of the criteria.

Port facility	1	2	3	Average
(1)Port policy and management	0.222	0.200	0.333	**0.252**
(2)Information systems	0.667	0.600	0.500	**0.589**
(3)Green port management	0.111	0.200	0.167	**0.159**

Table 9
Intra-port competitiveness evaluation of each transhipment ports.

Criteria/port	Colombo	Klang	Singapore	Tanjung Pelepas
Maritime connectivity	0.145	0.141	0.101	0.116
Port facilities	0.141	0.158	0.178	0.168
Port efficiency	0.146	0.137	0.181	0.175
Cost factor	**0.197**	**0.239**	0.123	**0.213**
Policy and management	0.144	0.122	0.144	0.110
Information systems	0.155	0.124	**0.190**	0.139
Green management	0.072	0.078	0.082	0.079
Coefficient of variation	0.257	0.345	0.297	0.319

*Bold indicates highest score.

5.2. Sensitivity analysis

In ANP, sensitivity analysis plays an important role as we can check the robustness of the forecasts considering changes in priorities (Saaty and Vargas, 2006). Therefore, we conduct a sensitivity analysis to investigate whether changes in any of the port competitiveness factor priorities will alter the outcome of the ANP. The results from the Super Decisions Software are presented in Fig. 5. The horizontal axis represents changes in priorities of a particular port competitiveness criteria, and the vertical axis represents changes in forecasted market share (normalised scores) of the transhipment ports. In an overall, we find that the Port of Singapore will remain dominant in serving the Bangladesh container market despite changes in priorities of the seven port competitiveness criteria (Fig. 5a-g). However, the Port of Singapore will face a significant loss of market share if the priority of cost factor increases, particularly to the Port of Colombo and Port Klang (Fig. 5d). Meanwhile, we observe a signal of intense competition between Port Klang and the Port of Colombo as they move together with respect to changes in priorities of most of the competitiveness criteria (Fig. 5 a-g). However, the Port of Tanjung Pelepas remains the least competitive port regardless of changes in priorities of the competitiveness criteria (Fig. 5 a-g).

6. Discussion

The application of the ANP model in forecasting the competitiveness of the four transhipment ports serving the Bangladesh container market reveals some interesting findings. These findings contribute to improving the current understanding of the transhipment port competitiveness literature. Also, the findings have several managerial implications. We discuss the implications of the finding in four themes.

Table 10
Inter-port competitiveness evaluation under each criterion.

Port/criteria	Connectivity	Facilities	Efficiency	Cost	Policy	Information systems	Green management
Colombo	0.214	0.086	0.087	0.145	0.172	0.155	0.078
Klang	0.211	0.095	0.095	**0.168**	0.188	0.184	0.098
Singapore	**0.454**	**0.258**	**0.260**	0.098	**0.518**	**0.545**	**0.254**
Tanjung Pelepas	0.121	0.061	0.058	0.089	0.121	0.116	0.070

*Bold indicates highest score.

Table 11
Inter-criteria associations.

Criteria/criteria	1	2	3	4	5	6	7
(1) Maritime connectivity	0.000	0.000	0.000	0.116	0.000	0.000	0.000
(2) Port facilities	0.000	0.000	0.214	0.131	0.000	0.000	0.000
(3) Port efficiency	0.000	0.000	0.000	0.135	0.000	0.000	0.000
(4) Cost factor	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(5) Policy and management	0.000	0.233	0.152	0.118	0.000	0.000	**0.386**
(6) Information systems	0.000	0.191	0.134	0.000	0.000	0.000	0.114
(7) Green management	0.000	0.076	0.000	0.000	0.000	0.000	0.000

*Bold indicates highest score.

Table 12
Port competitiveness forecasting.

Transshipment port	(a) Market share (%), original model	(b) Market share (%), without inner dependence	(c) Actual market share, 2017 (%)[a]	(c-a) Absolute error I (%)	(c-b) Absolute error II (%)
Colombo	18.35	19.42	20.74	2.39	1.32
Port Klang	20.35	21.70	13.70	6.65	8.00
Singapore	48.75	45.77	53.42	4.67	7.65
Tanjung Pelepas	12.54	13.11	12.13	0.41	0.98
MAPE	–	–	–	**14.64**	**16.96**

[a] Data from a publicly unavailable market report from a local liner agent. MAPE refer to Mean Absolute Percentage Error.

6.1. *The 'package' of criteria*

Ng (2006) argued that transhipment port competitiveness evaluation must be done as a package of criteria rather than based on a single factor. Although it has been more than a decade since then, to the best of the authors' knowledge, no study attempted such a 'package' model. One reason could be limitations from the methodological perspective as most studies used AHP (Lirn et al., 2004; Song and Yeo, 2004) or factor analysis (Chang et al., 2008) which fail to consider inter-relationships among the criteria. Using ANP, we modelled not only bi-direction associations between the criteria and alternatives, but also inter-relations among the criteria using inner dependencies. This is similar to modelling the transhipment port competitiveness criteria as a package. Also, less variability in scores, measured by the coefficient of variance (CV), of the Port of Colombo and the Port of Singapore indicate that they perform better in delivering a service 'package' to the users (see Table 9). This could be the reason for the Port of Colombo's rapid market share growth in the Bangladesh container market being the latecomer in the market. Besides, we observed an association between the transhipment port's predicted competitiveness with their liner shipping connectivity index (LSCI). Port level LSCI score measures the connectivity of ports worldwide based on five shipping service-related components (for detail, see https://unctadstat.unctad.org). Fig. 6 shows that the transhipment port with the highest predicted market share, that is, Singapore has the highest LSCI score as well.

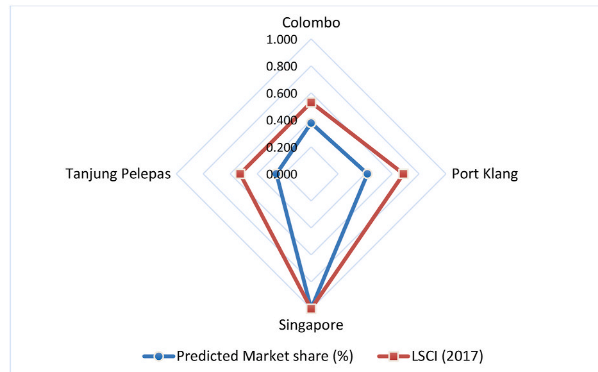


Fig. 6. Predicted market share and LSCI (normalised values for the four ports).

6.2. *Attention to green port management*

Although green port development has become an important issue in recent years (Davarzani et al., 2016; Munim et al., 2020), we find that, in general, transhipment ports are lagging in improving their environmental competitiveness in comparison to their other competitive criteria. This is evident in Table 9 as all the four ports have the lowest score on their green port management criteria. While some focus on innovation (Acciaro et al., 2014) and technological advancements (Yang and Chang, 2013) for environmental sustainability of ports, the port governance model is actually the main driver of environmental sustainability of ports (see Chapter 3 in Faulin et al., 2018). Similarly, we find that port policy and management drive green port management the most (Table 11).

6.3. *Quality comes with cost*

To the feeder carriers of Bangladesh, quality is the most important factor. Despite being the most expensive alternative, the Port of Singapore is the most preferred by the feeder carriers because of its high service quality in term of better connectivity, cutting-edge facilities, high efficiency, state-of-the-art policy and management, best information systems and comparatively better implications of green port management practices (Table 10). The transhipment port users do not hesitate to pay a higher price for better service quality. This indicates that transhipment port authorities which envision to be the most competitive in their target market should focus more on providing the best service quality rather than stressing on cost reduction.

6.4. *Intense competition between Port Klang and Port of Colombo*

In Table 10, the scores for the seven competitiveness factors of the Port of Colombo and Port Klang are identical, although Port Klang has a higher score in six factors except for maritime connectivity. Similarly, in

Fig. 6, the values of the Port of Colombo and Port Klang moves in the same direction with respect to changes of priorities of most criteria. Even their market shares intersect with respect to changes in the priorities of maritime connectivity criteria. Thus, a clear signal of intense competition between these two ports is evident. Kavirathna et al. (2018b) also found a similar indication of competition between these two ports. Thus, authorities of these two ports need to be careful in making strategic decisions to sustain the competition.

7. Conclusion

This study proposed an ANP modelling framework to forecast the competitiveness of transhipment ports in terms of market share, serving a given market. Typical uses of the ANP method consists of selection, ranking and rating in the extent literature, but it can be utilised for forecasting in certain predictive problems. In the context of forecasting, ANP is preferred when there are immeasurable variables in the problem set to quantify and transfer factors from judgmental space to numerical and measurable basis. This paper proposed an adaptation of the implementation of ANP for the port competitiveness evaluation and forecasting in terms of market share, a novel approach to utilising the ANP modelling framework.

To demonstrate the implication of the framework, we use the four transhipment ports — Singapore, Colombo, Port Klang and Tanjung Pelepas, serving the Bangladesh container market as the case. We find that Singapore is the most competitive and Tanjung Pelepas is the least. Besides, there exists intense competition between the Port of Colombo and Port Klang. The proposed ANP model is capable of forecasting transhipment ports competitiveness with a MAPE of 14.64%.

In addition to the market share forecasting, the proposed approach lies down factors driving the forecasted market structure and competitiveness, which can be considered in the strategic planning. In other words, the proposed structure provides a testbed for policymakers to simulate certain characteristics and predict potential market structure resulted from a given initial setting. In this regard, the ANP-based framework can be employed by port operators, policymakers and regional developers, including government agencies, to assess the future of hub-and-spoke networks and the role of a particular port.

The ANP based approach to forecast transhipment port competitiveness can be adopted in other relevant domains of maritime research, such as in forecasting major shipping line's market share in a port, forecasting intermodal transhipment market share of gateway ports serving distant hinterlands or forecasting market shares of terminal operators within a port. Meanwhile, the application on ANP requires a large number of pairwise comparisons, which increases with the number of criteria involved. Hence, we suggest an application of the proposed ANP framework for forecasting or evaluating port competitiveness using another MCDM model that requires comparatively fewer pairwise comparison, such as the recently developed Best-Worst Method (Rezaei, 2015).

Author statement

Ziaul Haque Munim: Conceptualization, Data collection, Methodology, Formal Analysis, Writing - original draft, review & editing. Okan Duru: Validation, Writing - original draft, review & editing. Adolf K.Y. Ng: Validation, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2021.07.015.

Appendix A. Respondent demographics

No.	*Data collection date (mm/dd/yy)	Job Title	Company Type	Experience (years)	Company age (years)
1	7/16/2017	Assistant Manager-Operations	Carrier/local office	6	4
2	7/17/2017	Assistant Manager	Carrier/local office	5	4
3	7/17/2017	Senior Executive	Carrier/local office	5	4
4	7/17/2017	Finance Manager	Carrier/local office	7	10
5	7/17/2017	Assistant Manager-Export	Carrier/local office	7	10
6	7/18/2017	Manager- SOC Marketing	Carrier/local office	12	50
7	7/18/2017	Executive-Operations	Carrier/local office	2.5	50
8	7/20/2017	Executive-Sea freight	Freight Forwarder	14	2
9	7/20/2017	Managing Director	Freight Forwarder	23	20
10	7/20/2017	Deputy General Manager	Carrier/local office	12.5	24
11	7/23/2017	Senior Executive	Carrier/local office	4	40
12	7/24/2017	Senior Manager	Freight Forwarder	19	20
13	7/25/2017	Senior Executive	Carrier/local office	6	12
14	7/27/2017	Assistant Manager	Carrier/local office	10	20
15	7/29/2017	Senior Executive	Feeder Carrier	4	25
16	7/29/2017	Import DOC Specialist	Carrier/local office	17	25
17	7/30/2017	Assistant Manager	Feeder Carrier	7	12
18	7/30/2017	Senior Manager	Carrier/local office	9	15
19	7/30/2017	Senior Executive	Carrier/local office	3.5	19
20	7/17/2017	General Manger	Carrier/local office	10	3

*The corresponding author visited offices of each of the respondents for data collection.

Appendix B. Importance of 25 competitiveness criteria in transhipment port choice

	Mean	S.D.	Min	Max
Maximum connectivity	***6.08***			
M1. Accessibility of the port	6.25	1.41	2	7
M2. Feeder shipping network	6.35	0.59	5	7
M3. Connectivity with the main navigation route	6.40	0.60	5	7
M4. Proximity to Bangladesh	5.30	0.98	4	7
Port facilities	***6.03***			
F1. Quality of port infrastructure	5.95	1.15	3	7
F2. Quality of port superstructure	6.20	1.01	4	7
F3. Dedicated terminals and facilities for transhipment	5.95	1.23	4	7
Port efficiency	***6.41***			
E1. Time efficiency	6.85	0.37	6	7
E2. Technical efficiency	6.15	0.88	4	7
E3. Congestion	6.35	0.81	4	7
E4. Reliability of port services	6.30	0.66	5	7
Cost factor	***5.58***			
C1. Handling cost at TS port	6.05	0.69	5	7
C2. Feeder freight from CGP to TS port	5.90	0.72	5	7
C3. Incentives and other monetary benefits from TS ports	4.80	1.28	1	7
Port policy and management	***5.46***			
P1. Port authority policy and regulations	5.70	1.13	4	7
P2. Custom procedures	5.75	1.29	3	7
P3. Relations between port operator and shipping lines	5.75	1.02	3	7
P4. Efforts of marketing on the port by port authority	4.60	1.57	1	7
P5. Reputation of port within the region	5.50	0.89	4	7
Information systems	***6.13***			
I1. I.T. and advanced technology	6.25	0.91	4	7
I2. Common information sharing platform	5.70	0.73	4	7
I3. Online container tracking system	6.45	0.83	4	7
Green port management	***4.63***			
G1. Sustainable port management system	4.90	1.48	1	7
G2. Environmental incentive tool	4.50	1.00	2	6
G3. Environmental performance of port operators	4.50	1.15	2	6

Transhipment port choice criteria importance scores are on a 7-point Likert scale where 1 is 'do not consider' and 7 is 'very important'. Number of observation is 20, TS port. Transhipment port, CGP Chittagong port, S.D. Standard Deviation.

Appendix C. Unweighted supermatrix matrix

	Colombo	Port Klang	Singapore	Tanjung Pelepas	Connectivity	Facilities	Efficiency	Cost	Policy	Information systems	Green management
Colombo	0.000	0.000	0.000	0.000	0.214	0.173	0.173	0.291	0.172	0.155	0.156
Port Klang	0.000	0.000	0.000	0.000	0.211	0.190	0.190	0.336	0.188	0.184	0.195
Singapore	0.000	0.000	0.000	0.000	0.454	0.516	0.520	0.195	0.518	0.545	0.508
Tanjung Pelepas	0.000	0.000	0.000	0.000	0.121	0.121	0.116	0.178	0.121	0.116	0.141
Connectivity	0.145	0.141	0.101	0.116	0.000	0.000	0.000	0.233	0.000	0.000	0.000
Facilities	0.141	0.158	0.178	0.168	0.000	0.000	0.428	0.262	0.000	0.000	0.000
Efficiency	0.197	0.239	0.123	0.213	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cost	0.146	0.137	0.181	0.175	0.000	0.000	0.000	0.269	0.000	0.000	0.000
Policy	0.144	0.122	0.144	0.110	0.000	**0.466**	0.303	0.236	0.000	0.000	0.771
Information systems	0.155	0.124	0.190	0.139	0.000	**0.381**	0.268	0.000	0.000	0.000	0.229
Green management	0.072	0.078	0.082	0.079	0.000	**0.153**	0.000	0.000	0.000	0.000	0.000

Bold values would be the outcomes of Step 5 (Tables 6–8) when done on the aggregated judgment level.

Appendix D. Cluster matrix

	TS port alternatives	Competitiveness criteria*
TS port alternatives	0	1/2
Competitiveness criteria	1	1/2

*Weights apply to only the inner dependency associations shown in Table 2.

Appendix E. Weighted supermatrix matrix

	Colombo	Port Klang	Singapore	Tanjung Pelepas	Connectivity	Facilities	Efficiency	Cost	Policy	Information systems	Green management
Colombo	0.000	0.000	0.000	0.000	0.214	0.086	0.087	0.145	0.172	0.155	0.078
Port Klang	0.000	0.000	0.000	0.000	0.211	0.095	0.095	0.168	0.188	0.184	0.098
Singapore	0.000	0.000	0.000	0.000	0.454	0.258	0.260	0.098	0.518	0.545	0.254
Tanjung Pelepas	0.000	0.000	0.000	0.000	0.121	0.061	0.058	0.089	0.121	0.116	0.070

(continued on next page)

(*continued*)

	Colombo	Port Klang	Singapore	Tanjung Pelepas	Connectivity	Facilities	Efficiency	Cost	Policy	Information systems	Green management
Connectivity	0.145	0.141	0.101	0.116	0.000	0.000	0.000	0.116	0.000	0.000	0.000
Facilities	0.141	0.158	0.178	0.168	0.000	0.000	0.214	0.131	0.000	0.000	0.000
Efficiency	0.146	0.137	0.181	0.175	0.000	0.000	0.000	0.135	0.000	0.000	0.000
Cost	0.197	0.239	0.123	0.213	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Policy	0.144	0.122	0.144	0.110	0.000	0.233	0.152	0.118	0.000	0.000	0.386
Information systems	0.155	0.124	0.190	0.139	0.000	0.191	0.134	0.000	0.000	0.000	0.114
Green management	0.072	0.078	0.082	0.079	0.000	0.076	0.000	0.000	0.000	0.000	0.000

Appendix F. Limit matrix

	Colombo	Port Klang	Singapore	Tanjung Pelepas	Connectivity	Facilities	Efficiency	Cost	Policy	Information systems	Green management
Colombo	**0.078**	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
Port Klang	**0.087**	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
Singapore	**0.208**	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208
Tanjung Pelepas	**0.054**	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
Connectivity	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Facilities	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
Efficiency	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Cost	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073
Policy	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117
Information systems	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
Green management	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041

Bold values are raw synthesised scores of the corresponding alternatives.

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