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Port Choice by Intra-Regional Container Service Operators: An Application of Decision-Making Techniques to Liner Services Between Malaysian and Other Asian Ports

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ABSTRACT

Intra-regional container service operators are challenged to design regular and reliable liner services connecting regional ports at the lowest cost and shortest transit time while considering customer demand. This paper focuses on the selection of ports of call in regular intra-regional container services, an under-researched part of the container shipping market. A combination of decision-making techniques (i.e. Analytical Hierarchy Process, fuzzy link-based and Evidential Reasoning) are presented to assist intra-regional container service operators in selecting ports of call. The proposed methodology is empirically applied to container services between Malaysian and other nearby Asian ports. While Port Klang is the main gateway to Malaysia, the results show that other Malaysian ports should play a more prominent role in accommodating intra-Asian container services. This research can assist maritime stakeholders in evaluating intra-regional port-to-port liner service configurations. Furthermore, the novel mix of decision-making techniques complements and enriches existing academic literature on port choice and liner service configuration.

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1. Introduction

Intra-regional container liner services are part of short sea shipping business activities. These services involve the deployment of container vessels between major or minor ports located in the same geographical area. The unit capacity of these vessels typically ranges between 100 and

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2500 TEU (Rudic and Hlaca, 2005; Gorski and Giernalczyk, 2011; Varbanova, 2011; Doderer, 2011), although some bigger units are occasionally used in some larger markets, such as East Asia (e.g. Busan-Japan), the Mediterranean and North Europe. The vast majority of vessels used in intra-Asian services ranges between 500 and 2000 TEU (Ng and Kee, 2008). However, Polat (2013) observed that the carrying capacity of some vessels used on cargo-rich regional routes can reach up to 4300 TEU.

Intra-regional container service operators are challenged to design regular and reliable liner services connecting regional ports at the lowest cost and shortest transit time. Designing a liner schedule can be considered as a strategic planning problem (Fagerholt, 2004). Notteboom and Vernimmen (2009) provide insight on the key elements in the liner service design process. After the service planner has analysed the potential market demand and the existing supply of intra-regional liner services, he or she has to decide on a number of key inter-related design variables, such as the liner service frequency, the fleet size (i.e. number of vessels deployed), the vessel size, the fleet mix (i.e. vessel size distribution), vessel speed, and the number of port of calls including the specification of the ports of call which will be included in the intra-regional liner service.

This paper focuses on the selection of ports of call in regular intra-regional container services. We present a combination of decision-making techniques (i.e. Analytical Hierarchy Process, fuzzy link-based and Evidential Reasoning) to assist intra-regional container service operators in selecting ports of call.

The mix of decision-making techniques is empirically applied to intra-regional container services between Malaysian and other nearby Asian ports. The government of Malaysia is actively implementing the Eleventh Malaysia Plan (2016-2020). An important component of this plan is the aim to increase the efficiency of all ports and jetties by streamlining their functions and expanding their operations (Economic Planning Unit, 2015). In addition, Malaysia is in the process of structuring an integrated demand-oriented transport system for enhancing connectivity across transport modes and regions, as well as expanding port capacity, access and operations (Economic Planning Unit, 2015). With the Eleventh Malaysia Plan (2016-2020) in mind, the empirical section of this paper intends to study the mix-matching of port choices between seven Malaysian seaports (i.e. Bintulu Port; Penang Port; Port Klang; Port Tanjung Pelepas; Kuantan Port; Kuching Port; and Johor Port/Pasir Gudang Port) and five other Asian seaports (i.e. Ho Chi Minh Port - Vietnam; Laem Chabang Port - Thailand; Jakarta/Tanjung Priok Port - Indonesia); Chittagong Port, Bangladesh; and Yangon Port - Myanmar).

The paper is structured as follows. The next section provides a short overview of the extant literature on port choice/selection and identifies five port selection criteria. In section 3, these five criteria are integrated in a comprehensive decision-making methodology. The components and techniques of this methodology are fully discussed. In part 4, the presented methodology is applied to the Malaysian port context. The final section places the results in a wider policy and managerial context and draws conclusions on scope, relevance and practical and academic contribution of the presented research.

2. Literature Review on Port Selection/Choice

Port selection/choice is a much-studied topic in port studies (Pallis et al., 2011). The extant literature analyses port choice from the perspective of the shippers or their appointed third-party logistics service providers, as well as from the perspective of ship operators. In the first case, the focus is very much on modal choice and carrier selection, instead of port selection (Lam and Dai, 2012). Lirn et al. (2004), Tongzon and Sawant (2007), Wiegmans et al. (2008) and Chang et al. (2008) provide a structured discussion on port choice by ship operators. In summarizing the port choice literature, Notteboom (2009) points out that port choice criteria used by ship operators relate to the demand profile of the port or terminal (e.g. cargo-generating power of the port), the supply profile (i.e. the capacity, costs and quality/reliability of nautical access, terminal operations and hinterland access), the market profile (i.e. the market structure in the port, the logistics focus of the port and port reputation) and carrier dynamics linked to carrier operations and cooperation. The latter group of port choice factors mainly relates to the role of the terminal involvement of shipping lines or their affiliate terminal operating companies (Notteboom et al., 2017) and strategic alliance formation among shipping lines in port selection processes. Salem and El-Sakty (2014) focused on the role of port performance on competition between Mediterranean ports. Malchow (2001) argued that the provision of efficient services is more important than the port charges, but there is no consensus as to which factors are most important.

Port choice is also dependent on the operational characteristics of the route to be served. In studying port choice in Southern China, Wong (2007) pointed to the lowest transportation cost or shortest transit time as key elements in the selection of ports of call on either side of a shipping route. However, customer needs and the location of cargo-generating industrial premises also influence port choice. Thus, ship operators might prefer ports which give them operational advantages in terms of operating costs and or transit time, but at the same time they also must take into account commercial considerations related to the preferences and specific demand of their customers.

Abdul Rahman and Ahmad Najib (2017) narrowed down the main determinants of port choice by ship operators to five parameters, i.e. 1) port facilities in terms of equipment used for container handling; 2) the distance between the port of origin and the port of destination; 3) the total sailing time which has an impact on the number of ships needed to guarantee a desired liner service frequency, 4) the distribution centre functions of the port; and 5) the bunker cost of the vessel for a single trip. These five port selection factors are further discussed in the next paragraphs.

Port facilities. The facilities provided by a port should allow ship operators to offer efficient liner services (Zarei, 2015). This requires a high-quality port and terminal infrastructure to achieve a fast ship turnaround time, competitive port charges, and the provision of value-added activities (Salem and El-Sakty, 2014). Port terminal operators try to boost the number of ship calls by expanding and improving the port infrastructure (Haralambides, 2002; Malchow and Kanafani, 2004). Port operators typically focus on the port infrastructure mainly because of their perception that other port selection factors, such as hinterland transport connectivity, are largely beyond their control (Sanchez et al., 2011).

Distance. The geographical position of a port of call is important in view of delivering a fast connection to other ports of call (Ducruet and Notteboom, 2012). A short distance between shipment ports reduces the operational cost as it involves less sailing time and less vessels are needed to offer a desired service frequency (Fagerholt, 2004).

Sailing Time. The ship steaming time is one of the important factors that need to be considered by shipping lines. Ship operators are challenged to offer a short transit time following a fixed sailing schedule and offering a high schedule reliability (Notteboom, 2006). The ship master creates the ship passage plan based on the shipping schedule. Shippers demand fast and on-time delivery. One of the factors influencing the sailing time is vessel speed which can be increased or decreased depending on the loading or discharge schedule in the next port of call (Abdul Rahman, 2012).

Distribution Centre functions of the port. Seaports are increasingly functioning not as individual places that handle ships but as turntables within global supply chains and global production networks (Notteboom and Winkelmans, 2001), which brings the perspective of port development to a higher geographical scale, i.e. the phase of port regionalization (Notteboom and Rodrigue, 2005). The increasing importance of integrating ports and terminals in value-driven supply chains (Robinson 2002) has increased the focus on the creation of value-added linked to cargo passing through the port. A well-coordinated logistic and distribution function of seaports with cooperation of various service providers facilitates the integration of ports in advanced logistical and distributional networks through a new range of high-quality value-adding services (Jakomin, 2003; Montwill, 2014) which can have a positive impact on the port selection decisions of carriers (Malchow, 2001; Zarei, 2015).

Bunker Cost. Depending on the cost per ton of ship fuel, a very substantial part of ship operating cost is derived from bunker consumption (Ducruet and Notteboom, 2012). A ship normally sails at a constant speed. Moreover, the fuel price is different at different ports, which can influence the choices made at the level of vessel speed on the route (Hsu and Hsieh, 2007). The main fuel and auxiliary fuel prices are also important in view of optimising the sailing schedule. The bunker costs are further influenced by operational and commercial factors such as the distance to the port of call, the weight and dimensions of the cargo, and the customer's demand in terms of transit time (Polat, 2013).

While some of the above determinants are related to each other, no fixed relations exist between them at a liner service and fleet level. For example, the distance between ports of calls for a given ship is directly proportional to the sailing time and the associated bunker fuel consumption and cost (Hsu and Hsieh, 2007), but these relations might be different for each ship and liner service. Notteboom and Vernimmen (2009) demonstrate that the bunker cost is dependent on the sailing time and to a lesser extent port time (use of auxiliary engines), but much depends on the sailing speed adopted by the vessel operator and the bunker cost at the time and location of bunkering. These elements can also differ per ship and liner service and even per individual trip within a specific liner service. Therefore, we include distance, sailing time and bunker cost as separate port selection factors.

3. Methodology

3.1. *Main research methods*

We propose a combination of decision-making techniques to select ports of call in regular intra-regional container services. The five port selection factors introduced in the previous section serve as input for shaping the decision-making framework. Two decision making techniques are used, i.e. Analytical Hierarchy Process (AHP) and Evidential Reasoning (ER). These methods are linked using the Fuzzy Link Based technique.

3.2. *Data collection using an expert panel*

The application of the mix of decision-making techniques to a specific empirical setting requires the identification of relevant decision makers. As the empirical section will be focusing on intra-regional container services between Malaysian and other Asian ports, discussion sessions were held with eight industrial experts of intra-regional container service operators. The profile and affiliation of these experts are presented in Table 1. The sessions were aimed at applying the methodology to identify the most appropriate route combinations of Malaysian and other Asian ports. The experts were asked to fill out the pair-wise comparison matrix for calculating the weight values of each of the five parameters. They were also asked to provide the belief degree values of the Evidential Reasoning method for determining the mix-matching of both Malaysian and other Asian Ports. In the next section, we elaborate further on the mix of decision-making techniques used in this paper.

Table 1
Information on the eight industrial experts

No.	Feeder Service Providers	Level of Position	Year of Experience	Routes
1.	Malaysia Trade & Transport (MTT) Shipping	Operation Manager	17 years in shipping operation	Malaysian Peninsular to Sabah and Sarawak
2.	Perkapalan Dai Zhun Lines (PDZ)	Operation Manager	12 years sailing and 10 years in shipping operation	Malaysian Peninsular to Sabah and Sarawak
3.	Regional Container Lines (RCL)	Manager of Operational Support Division	20 years in shipping operation and logistics	East Asia, South East Asia, and Middle East
4.	Evergreen Marine Corp (MALAYSIA) Sdn Bhd	Deputy Manager Operation	16 years in shipping operation	East Asia, South East Asia, Southern Asia
5.	X-Press feeder (Sea Consortium Sdn. Bhd)	Senior Executive Operations	11 years in shipping operation	East Asia, South East Asia, East Asia, Southern Asia and Oceania
6.	Bengal Tiger Line (M) Sdn Bhd	General Manager	16 years in logistics and shipping operation	Southern Asia and South East Asia
7.	Q-Express Line (QEL)	Operation Manager	19 years in shipping operation	South East Asia and Oceania
8.	Harbour-Link Group Berhad	Operation Manager	22 years in shipping operation	South East Asia and East Asia

3.3. *Analytical Hierarchy Process (AHP)*

The pair-wise comparison approach (Saaty, 2008) was used to determine the relative weights of the five port selection factors. First, the experts were informed on how to evaluate the port selection criteria by referring to Table 2. Then, the pair-wise matrix was established.

Table 2
Fundamental scale of pair-wise comparison

Intensity of assessment scale	Assessment scale meaning	Intensity of assessment scale	Assessment scale meaning
1	Equally important	1	Equally unimportant
3	Moderately important	1/3	Moderately unimportant
5	Important	1/5	Unimportant
7	Very important	1/7	Very unimportant
9	Extremely important	1/9	Extremely unimportant
2,4,6, and 8	Intermediate values of important	1/2, 1/4, 1/6, and 1/8	Intermediate values of unimportant

Source: Saaty (2008)

The pair-wise matrix is arranged in the form of an (n x n) matrix. The criterion C_{ij} is obtained from expert judgments using the intensity of assessment scale (Saaty, 2008). The lower triangular matrix; C_{21}, C_{ji}, C_{j2} can be calculated using the reciprocal values of the upper diagonal; C_{12}, C_{ij} , C_{2j}.

$$A=\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}=\begin{bmatrix} 1 & C_{12} & C_{ij} \\ C_{21}=\frac{1}{C_{12}} & 1 & C_{2j} \\ C_{ji}=\frac{1}{C_{ij}} & C_{j2}=\frac{1}{C_{2j}} & 1 \end{bmatrix} \quad (1)$$

Where, C_{ij} = pairwise comparison scale between criterion, i = row of matrix, j = column of matrix. Rule 1 =C_{11}, C_{22}, C_{33} = 1 $\neq 0$.

Then, the weight value of the pair wise comparison between attributes can be calculated as follows (Abdul Rahman, 2012):

$$w_k=\frac{1}{n}\sum_{j=1}^{n}\left(\frac{C_{kj}}{\sum_{i=1}^{n} C_{ij}}\right) \qquad (k = 1, 2, 3,\ldots, n) \quad (2)$$

Where C_{ij} stand for the entry of row i and column j in a comparison matrix of order n. The validity of the analysis is checked using the Consistency Ratio (CR) obtained from IDS software. The consistency ratio must be equal or less than 0.10 (Yang and Xu, 2002).

The Consistency Index, CI is calculated as follows:

$$CI = \frac{\lambda \max - n}{n - 1} \quad (3)$$

After CI is calculated, the Consistency Ratio, CR can be obtaining by using Equation 4:

$$CR= \frac{CI}{RI} \quad (4)$$

The random consistency index, RI can be obtained from Table 3.

Table 3
Random consistency index, RI of matrix size

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Source: Saaty (2008)

3.4. *Application of Fuzzy Link Based Technique*

According to Yang et. al. (2009) and Abdul Rahman (2012) different criteria use different grades of assessment, which need to be standardized by using a transformation of belief degree from fuzzy input to fuzzy output. The transformation processes followed by the parent of Lower Level Criteria (LLC) then convert to Upper Level Criteria (ULC). The mathematical formulation is as follows, also referring to Figure 1 (Abdul Rahman, 2012):

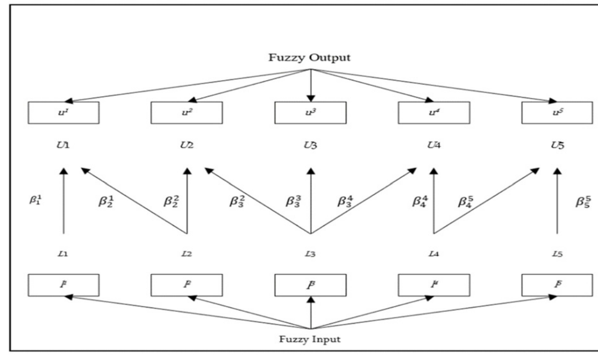

Fig. 1. Conversion of fuzzy input to fuzzy output values
Source: Abdul Rahman (2012)

$$u^j=\sum_{i=1}^{5} l^i\beta_i^j \quad (5)$$

$$\sum_{i=1}^{5} l^i\leq 1 \quad (6)$$

$$\sum_{j=1}^{5}\beta_1^j=1,\ \sum_{j=1}^{5}\beta_2^j=1,\ \sum_{j=1}^{5}\beta_3^j=1,\ \sum_{j=1}^{5}\beta_4^j=1,\ \sum_{j=1}^{5}\beta_5^j=1 \quad (7)$$

Where u^j is fuzzy output; l^i = fuzzy input; β_i^j = belief degree assigned by experts, (j, i =1, 2, 3, 4 and 5) and sum of $\sum u^j$ = 1; $\sum l^i$ = 1.

3.5. *Evidential Reasoning (ER)*

ER is used to solve problems dealing with an aggregate of Multiple Attribute Decision Analysis (MADA) (Zhou et al., 2013). There are top level and lower level attributes also known as main criteria and sub criteria with L basic criterion $e_i(i = 1, 2, \ldots, L)$ linked with a general criterion y (Yang and Xu, 2002; Abdul Rahman, 2012). The weight values of criteria or attributes are denoted as $w_i(i = 1, 2, \ldots, L)$, where w_i is the relative weight of the i^{th} basic attribute (e_i) with$0 \leq w_i \leq 1$. The AHP algorithms for obtaining weight values were discussed earlier. The assessment of attribute $e_i(i = 1,2, \ldots, L)$ is denoted in Equation 8 (Yang and Xu, 2002; Abdul Rahman, 2012; Zhou et al., 2013).

$$S(e_i)=\left\{\left(H_n,\beta_{n,i}\right), n = 1, 2,\ldots,N\right\},\ i = 1, 2,\ldots,L, \quad (8)$$

Where H_n is the n^{th} assumed to be collectively comprehensive of evaluation grade. $\beta_{n,i}$ denotes the degree of belief satisfying $\beta_{n,i} \geq 0$ and $\sum_{n=1}^{N} \beta_{n,i} \leq 1$. Then, an assessment of $S(e_i)$ is complete if $\sum_{n=1}^{N} \beta_{n,i} = 1$ (respectively, $\sum_{n=1}^{N} \beta_{n,i} \leq 1$). Otherwise it is incomplete (Zhou et al., 2013). According to Abdul Rahman (2012), $m_{n,i}$ is a basic probability mass indicating the degree to which the i^{th} basic criterion e_i supports the hypothesis that criterion y is assessed to the n th grade H_n . $m_{n,i}$ is calculated as follows (Yang and Xu, 2002; Abdul Rahman, 2012; Abdul Rahman and Ahmad Najib, 2017):

$$m_{n,i}= w_i\beta_{n,i} \qquad n = 1,2,\ldots,N, \qquad i = 1, 2,\ldots,L \quad (9)$$

Then, w_i needs to be normalised. $m_{H,i}$ is denoted as:

$$m_{H,i}=1 - \sum_{n=1}^{N} m_{n,i} \qquad i = 1, 2,\ldots,L \quad (10)$$

The residual of probability mass $m_{H,i}$ is divided in two parts, $\bar{m}_{H,i}$ and $\tilde{m}_{H,i}$, see Equations 11 and 12 (Yang and Xu, 2002; Abdul Rahman, 2012; Abdul Rahman et al., 2018; Zhou et al., 2013).

$$\bar{m}_{H,i} = 1 - w_i \qquad i = 1,2,\ldots,L \tag{11}$$

$$\tilde{m}_{H,i} = w_i \left(1 - \sum_{n=1}^{N} \beta_{n,i}\right) \qquad i=1,2,\ldots,L \tag{12}$$

Then, $m_{H,i} = \bar{m}_{H,i} + \tilde{m}_{H,i}$. $\bar{m}_{H,i}$ is a fundamental probability mass representing the belief degree of the basic attributes e_i, while $\tilde{m}_{H,i}$ is the residual of the belief degree assessment. The recursive evidential reasoning algorithm can be summarised as follows (Yang and Xu, 2002; Abdul Rahman, 2012; Abdul Rahman et al., 2018; Zhou et al., 2013; Zhou et al., 2016):

$$K = \left[1 - \sum_{t=1}^{N} \sum_{\substack{j=1 \\ j \neq t}}^{N} m_{t,i} m_{j,i+1}\right]^{-1} \quad i = 1, 2, \ldots, L-1 \tag{13}$$

$$m_n = K\left[m_{n,i} m_{n+1,\,i} + m_{n,\,i} m_{H,i+1} + m_{H,i} m_{n+1,i}\right] \quad n = 1,2,\ldots,N \tag{14}$$

$$\tilde{m}_H = K\left[\tilde{m}_{H,i}\tilde{m}_{H,i+1} + \bar{m}_{H,i}\tilde{m}_{H,i+1} + \tilde{m}_{H,i}\bar{m}_{H,i+1}\right] \tag{15}$$

Where K is a normalised factor. Then, the normalisation of the probability $\bar{m}_H$ can be computed as follows:

$$\bar{m}_H = K\left[\bar{m}_{H,i}\bar{m}_{H,i+1}\right] \tag{16}$$

The degree of belief β_n for a specific grade can be stated as (Yang and Xu, 2002; Abdul Rahman, 2012):

$$\beta_n = \frac{m_n}{1 - \bar{m}_H} \quad n=1,2,\ldots,N \tag{17}$$

4. Application to port choice on intra-regional routes between Malaysian and other Asian ports

4.1. *Background on the ports of call included in the analysis*

The empirical section of this paper analyses the mix-matching of port choices between seven Malaysian seaports (i.e. Bintulu Port; Penang Port; Port Klang; Port Tanjung Pelepas; Kuantan Port; Kuching Port; and Johor Port/Pasir Gudang Port) and five other Asian seaports (i.e. Ho Chi Minh Port - Vietnam; Laem Chabang Port - Thailand; Jakarta/Tanjung Priok Port - Indonesia; Chittagong Port - Bangladesh; and Yangon Port - Myanmar). Intra-regional container services (both feeder and short sea services) play an important role in cargo transportation in Malaysia. These types of services constitute one of the key focus areas in enhancing the competitiveness and attractiveness of Malaysian ports (Khalid, 2007). Excellent intra-regional container service networks are important to achieve greater economies of scale and higher foreign trade container transportation efficiencies (Chang et al., 2008). In Malaysia, Port Klang is the most important port for intra-regional services in terms of container throughputs per annum (ASEAN Ports Association Malaysia (MAPA), 2017). In total, Malaysia counts seven container ports that accommodate intra-regional container services to other Asian ports (see Table 4).

Table 4 reveals that ship operators do not seem to consider the Malaysian ports located in the Southern region of Malaysia (Port of Tanjung Pelepas and Johor Port/Pasir Gudang Port) as relevant choices for intra-regional container services. A similar condition is observed for the ports located at the east coast of the Malaysian Peninsula (Kuantan Port in particular). Meanwhile, Penang port which is located in the northern part of the Malaysian peninsula received the lowest number of vessel calls.

The Malaysian government has planned and enforced the Eleventh Malaysia Plan (2016-2020) to strengthen the networks between Malaysian ports and foreign ports (Economic Planning Unit, 2015). Table 5 presents the container throughput figures for five intra-Asian ports which are important to the Malaysian port system, namely Ho Chi Minh, Laem Chabang, Jakarta, Chittagong and Yangon.

Table 4
Vessel calls per year in Malaysian container ports (intra-regional container services to foreign Asian ports only)

No.	Malaysian Container Ports	Vessel calls /Year					
		2011	2012	2013	2014	2015	2016
1.	Bintulu Port	433	405	383	286	369	353
2.	Penang Port	0	0	1	1	3	6
3.	Port Klang	11,273	10,300	9,950	9,601	10,869	10,678
4.	Port Tanjung Pelepas	2,386	2,413	1,943	2,363	2,699	2,392
5.	Kuantan Port	426	413	315	293	295	307
6.	Kuching Port	188	190	219	257	300	231
7.	Johor Port/Pasir Gudang Port	1,320	0	0	0	66	0

Source: ASEAN Ports Association Malaysia (MAPA) (2017)

Table 5
Container throughput of a selection of Asian ports relevant to the Malaysian port system

No.	Port, Country	Years	Annual Container Throughput (TEU)	Sources
1.	Ho Chi Minh, Vietnam	2012	5,060,000	International Association of Ports and Harbors, 2016
		2013	5,542,000	
		2014	5,368,927	
		2015	5,788,084	
2.	Laem Chabang, Thailand	2012	5,830,000	
		2013	6,041,000	
		2014	6,583,168	
		2015	6,780,000	
3.	Jakarta, Indonesia	2012	6,200,000	
		2013	6,590,000	
		2014	5,900,000	
		2015	5,201,118	
4.	Chittagong, Bangladesh	2012	1,406,000	
		2013	1,540,000	
		2014	1,622,000	
		2015	2,024,207	
5.	Yangon, Myanmar	2012	413,377	Tun, 2016; Myanmar Port of Yangon, 2017
		2013	478,340	
		2014	617,169	
		2015	744,789	

4.2. *Stepwise application of the decision-making techniques*

4.2.1 Step 1: Identification of assessment criteria and alternatives

The selection and identification of assessment criteria and alternatives are proceeded by a comprehensive discussion and brainstorming with the experts. This was required to ensure that the five port selection factors obtained from extant academic literature are also perceived as relevant by the industrial practice. The proposed criteria were screened by the eight experts listed in table 1. The screening process relied on a six-point Likert Scale: *"Absolutely Important = 6"*, *"Important = 5"*, *"Reasonably*

Important = 4", "Reasonably Unimportant = 3", "Unimportant = 2", "Absolutely Unimportant = 1" (Gohomene et al., 2014). The screening process led to the withholding of the five criteria that will be used for further analysis: (1) Port Facilities '*PF*'; (2) Distance *'D'*; (3) Journey Time '*JT*'; (4) Container Cargo Distribution Centre *'DC'*; (5) Bunker Cost *'BC'*. The intra-regional container service operators are currently active in all seven Malaysian container ports of call listed earlier.

4.2.2 Step 2: Development of assessment model of criteria and alternatives

An analytical assessment model or decision-making model was developed by combining the information identified in Step 1. Figure 2 shows the assessment model consists of three tiers which are 'Goal' at the top position of the model, followed by 'Criterion' at the second stage, and alternatives at the bottom part of the model. All the assessment criteria are linked to the alternative ports to be assessed in the evaluation and calculation process.

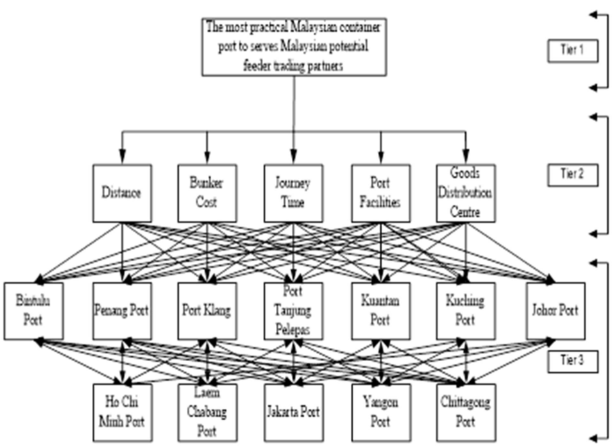

Fig. 2. Model structure for the selection of Malaysian container ports of call to serve other Asian Ports via intra-regional container liner services

4.2.3 Step 3: Data collection process

As indicated in section 3.2, a comprehensive data set was obtained from a panel of eight experts. The quantitative data set was extracted based of a questionnaire. Then, table 6 shows the parameters' assessment using pair-wise comparison (AHP) extracted from primary data. The experts gave their judgement on five main factors namely *'PF'; 'D'; 'JT'; 'DC'*; and *'BC'*.

Table 6
Pair-wise comparison matrix of assessment criteria

Criterion	*PF*	*D*	*JT*	*DC*	*BC*
PF	1.0000	1.6250	1.8570	0.6667	2.1250
D	0.6154	1.0000	2.7500	0.8889	2.2500
JT	0.5385	0.3636	1.0000	0.6667	1.5000
DC	1.5000	1.1250	1.5000	1.0000	1.7500
BC	0.4706	0.4444	0.6667	0.5714	1.0000
Sum	4.1245	4.5580	7.7737	3.7937	8.6250

4.2.4 Step 4: Establishment of weight values for each criterion using AHP approach

The process of obtaining the weight values of *A(PfDJtDcBc)* is calculated from Table 6 and summarised in Table 7.

Table 7
Values of normalized principal eigenvector of each main criterion

Criterion	*PF*	*D*	*JT*	*DC*	*BC*
PF	1.0000	1.6250	1.8570	0.6667	2.1250
D	0.6154	1.0000	2.7500	0.8889	2.2500
JT	0.5385	0.3636	1.0000	0.6667	1.5000
DC	1.5000 ÷ 4.1245 = 0.3637	1.1250 ÷ 4.5580 = 0.2468	1. 5000 ÷ 7.7737 = 0.1930	1.0000 ÷ 3.7937 = 0.2636	1.7500 ÷ 8.6250 = 0.2029
BC	0.4706	0.4444	0.6667	0.5714	1.0000

The weight values or normalized principal eigenvector of all criteria are determined using Equation 2. Given criterion '*DC*' as an example, the weight value is computed as follows: W_{DC}= (0.3637 + 0.2468 + 0.1930 + 0.2636 + 0.2029) ÷ 5 = 0.2540. Thus, the weight value of criterion '*DC*' is 0.2540. By using the same technique in Steps 3 and 4, the weight calculation algorithms are applied to all other criteria. Next, the weight values of the criteria are analysed using the Intelligent Decision Software (IDS). The weight values of the assessment criteria are summarised as follows: *A(PfDJtDcBc) = Pf (0.2520), D (0.2435), Jt (0.1377), Dc (0.2540), Bc (0.1128).* The weight value output is summarised in Table 8.

Table 8
The normalized principal eigenvectors of evaluation criteria

Criterion	*PF*	*D*	*JT*	*DC*	*BC*	*Sum*	*NPEV*
PF	0.2425	0.3565	0.2389	0.1757	0.2464	1.2600	0.2520
D	0.1492	0.2194	0.3538	0.2343	0.2609	1.2175	0.2435
JT	0.1306	0.0798	0.1286	0.1757	0.1739	0.6886	0.1377
DC	0.3637	0.2468	0.1930	0.2636	0.2029	1.2700	0.2540
BC	0.1141	0.0975	0.0858	0.1506	0.1159	0.5639	0.1128
SOEC	1.0000	1.0000	1.0000	1.0000	1.0000	*TNPEV*	1.0000

Notes: SOEC= Sum of Each Column; TNPEV = Total of Normalized Principal Eigenvector; NPEV: Normalized Principal Eigenvector or Weight values of criterion

Next, the *'Consistency Measure', 'Maximum Eigenvalue', λmax and 'Consistency Ratio', CR* are calculated. The values of the pair-wise comparison in each column in Table 6 are multiplied with the criterion weight values in Table 8. Table 9 presents the results. An example calculation process for criterion *'DC'* in obtaining the 'Consistency Measure' value is shown below:

(1.5000 x 0.2520) + (1.1250 x 0.2435) + (1.5000 x 0.1377) + (1.0000 x 0.2540) + (1.7500 x 0.1128) = 1.3099"

1.3099 / 0.2540 = 5.1571

Table 9
Calculation process of maximum eigenvalues, λmax

Criterion	*PF*	*D*	*JT*	*DC*	*BC*	*Consistency Measure*
PF	1.0000 x 0.2520 = 0.2520	1.6250 x 0.2435 = 0.3957	1.8570 x 0.1377 = 0.2557	0.6667 x 0.2540 = 0.1694	2.1250 x 0.1128 = 0.2397	1.3125 ÷ 0.2520 = 5.2083
D	0.6154 x 0.2520 = 0.1551	1.0000 x 0.2435 = 0.2435	2.7500 x 0.1377 = 0.3787	0.8889 x 0.2540 = 0.2258	2.2500 x 0.1128 = 0.2538	1.2569 ÷ 0.2435 = 5.1618
JT	0.5385 x 0.2520 = 0.1357	0.3636 x 0.2435 = 0.0885	1.0000 x 0.1377 = 0.1377	0.6667 x 0.2540 = 0.1693	1.5000 x 0.1128 = 0.1692	0.7004 ÷ 0.1377 = 5.0860
DC	1.5000 x 0.2520 = 0.3780	1.1250 x 0.2435 = 0.2739	1.5000 x 0.1377 = 0.2066	1.0000 x 0.2540 = 0.2540	1.7500 x 0.1128 = 0.1974	1.3099 ÷ 0.2540 = 5.1571
BC	0.4706 x 0.2520 = 0.1186	0.4444 x 0.2435 = 0.1082	0.6667 x 0.1377 = 0.0919	0.5714 x 0.2540 = 0.1451	1.0000 x 0.1128 = 0.1128	0.5766 ÷ 0.1128 = 5.1117

Next, we sum all the 'Consistency Measure' of each criterion from each row in Table 9 and divide with the number of criteria. The value of λ max is obtained as follows:

$$\frac{5.2083+5.1618+5.0860+5.1571+5.1117}{5}=5.1450$$

The consistency index, CI was obtained by applying Equation 3:

$$CI=\frac{\lambda\max-n}{n-1}=\frac{5.1450-5}{5-1}=0.0363$$

The suitable value of the Random Consistency Ratio, RI is obtained from Table 3; RI = 1.12, matrix size of five pair-wise criteria. The calculation of the consistency ratio, CR, referring to Equation 4 is shown as follows:

CI/RI = CR then applies to calculate: 0.0363/1.12 = 0.0324 < 0.1, which is consistent

4.2.5 Step 5: Determination of assessment grade values of criteria

Next, we determine the assessment grades of the criteria. The qualitative data with five numbers of grades and the utility value of each grade are shown in Table 10.

Table 10
The values of criterion assessment grades for criteria and alternative

Criteria	**Assessment grades**					
	Excellent	*Good*	*Average*	*Poor*	*Worst*	*Measurement unit*
Distance	500	900	1300	1700	2100	Nautical miles
Journey time	1.40	2.50	3.60	4.70	5.80	Days
Bunker cost	14,000	25,000	36,000	47,000	58,000	USD$
Port facilities	1.0	0.75	0.5	0.25	0.0	Level
Distribution centre	1.0	0.75	0.5	0.25	0.0	Level
Alternative						
The most practical Malaysian port	*Practical*	*Reasonably Practical*	*Average*	*Reasonably impractical*	*Impractical*	*Measurement unit*
	100%	75%	50%	25%	0%	%

The quantitative datasets have been used for determining the input of the five criteria. The excellent, good, average, poor and worst values of each criterion are set up together with the measurement unit as described in Table 10. The best, average, and worst values for the criteria distance, bunker cost, and journey time have been obtained using the following calculations:

(a) Distance

The distances highlighted in bold refer to the five shortest distances for 35 possible port-to-port routes (i.e. 7 Malaysian ports x 5 other Asian ports).

Table 11
Distance comparison of seven Malaysian ports to five other Asian ports

Malaysian ports	***Other Asian Ports / Distance (Nautical miles)***				
	Ho Chi Minh	*Laem Chabang*	*Jakarta*	*Yangon*	*Chittagong*
Bintulu	*(5)* 803	*(4)* 969	*(5)* 749	*(7)* 1685	*(7)* 2079
Penang	*(7)* 1108	*(7)* 1201	*(7)* 955	*(1)* ***724***	*(1)* ***1114***
Kelang	*(6)* 969	*(5)* 1007	*(6)* 763	*(2)* 913	*(2)* 1341
Tanjung Pelepas	*(4)* 795	*(3)* 832	*(2)* 589	*(3)* 1103	*(3)* 1488
Kuantan	*(1)* ***601***	*(1)* ***603***	*(4)* 663	*(5)* 1337	*(5)* 1731
Kuching	*(2)* 710	*(6)* 1154	*(3)* 615	*(6)* 1530	*(6)* 1924
Pasir Gudang	*(3)* 752	*(2)* 790	*(1)* ***527***	*(4)* 1135	*(4)* 1529

Notes: Numbers between brackets indicate the ranking starting from the Malaysian port to the nearest potential port of call.

(b) Journey time

According to Notteboom and Vernimmen (2009) journey time can be calculated as follows:

$$Journey\ time=\frac{D}{V\times 24} \tag{18}$$

Where,
D = Distance between two ports (in nautical miles)
V = Actual steaming speed (in knots)

For example, the journey time from Bintulu Port to Ho Chi Minh Port can be determined as follows: steaming speed is 15 knots, time at sea = 803 ÷ (15 × 24) = 2.23 days. A similar calculation process is applied to other ports and shown in Table 12.

Table 12
Journey time of seven Malaysian ports to five other Asian ports

Malaysian ports	***Other Asian Ports / Journey Time (Days)***				
	Ho Chi Minh	*Laem Chabang*	*Jakarta*	*Yangon*	*Chittagong*
Bintulu	*(5)* 2.23	*(4)* 2.69	*(5)* 2.08	*(7)* 4.68	*(7)* 5.78
Penang	*(7)* 3.08	*(7)* 3.34	*(7)* 2.65	***(1) 2.01***	***(1) 3.09***
Kelang	*(6)* 2.69	*(5)* 2.80	*(6)* 2.12	*(2)* 2.54	*(2)* 3.73
Tanjung Pelepas	*(4)* 2.21	*(3)* 2.31	*(2)* 1.64	*(3)* 3.06	*(3)* 4.13
Kuantan	***(1) 1.67***	***(1) 1.68***	*(4)* 1.84	*(5)* 3.71	*(5)* 4.81
Kuching	*(2)* 1.97	*(6)* 3.21	*(3)* 1.71	*(6)* 4.25	*(6)* 5.34
Pasir Gudang	*(3)* 2.09	*(2)* 2.19	***(1) 1.46***	*(4)* 3.15	*(4)* 4.25

Notes: Numbers in brackets refer to the ranking starting from a Malaysian port to the nearest potential port of call.

(c) Bunker cost

The fuel consumption of a vessel can be calculated by using the equation presented by Stopford (2009):

$$msME=F^{*}\left(\frac{S}{S^{*}}\right)^{a} \tag{19}$$

Where,
msME = actual fuel consumption (tonnes/day)
F^{*} = design fuel consumption
S = actual speed
S^{*} = design speed

Exponent a has a value of 3 for diesel engine and 2 for steam turbine. We selected a container ship with a carrying capacity of 1,600 TEU and a designed fuel consumption of 40 tonnes with a design speed of 20 knots. Based on the expert from X-Press Feeder Company, such type of vessels is commonly used on the trade routes between Malaysian ports and other Asian ports. A container ship speed of 15 to 18 knots is categorized as super slow steaming (SSS), i.e. a vessel speed which minimizes fuel consumption while maintaining a competitive commercial service (Janic, 2014). Notteboom and Cariou (2013) pointed out that slow steaming leads to longer transit times and more vessels per liner service, but at the same considerably reduces fuel consumption of vessels deployed. A typical example of the fuel consumption of a ship deployed on an inter-regional container service:

msME = 40 tonnes per day (15 knots ÷ 20 knots) = 30 tonnes per day

Then, bunker cost can be calculated by using the following formulation (Magelssen, 2010):

$$Bunker\ cost = s \times msME \times P \quad (20)$$

Where,
s = total journey time
$msME$ = actual fuel consumption (tonnes/day)
P = bunker price per tonne

The bunker fuel costs from seven Malaysian ports to five other Asian Ports are calculated by using a ship operating at a sailing speed of 15 knots and a carrying capacity of 1,600 TEU. For example, the bunker cost from Bintulu Port to Ho Chi Minh Port amounts to:

if, s = 2.23 days; $msME$ = 30 tonnes per day; P = $330 per tonne
then, bunker cost = 2.23 days x 30 tonnes per day x $330 = $22,077

The lowest bunker costs between the Malaysian ports to the five other Asian ports, are highlighted in bold and italics as shown in Table 13.

Table 13
Bunker cost for a 1600 TEU vessel sailing at 15 knots

Malaysia ports	***Intra-Asian Ports / Bunker Cost in USD$***				
	Ho Chi Minh	*Laem Chabang*	*Jakarta*	*Yangon*	*Chittagong*
Bintulu	*(5)* $ 22, 077	(4) $ 26, 631	*(5)* $ 20, 592	*(7)* $ 46, 332	(7) $ 57, 522
Penang	*(7)* $ 30, 492	(7) $ 33, 066	*(7)* $ 26, 235	***(1) $ 19, 889***	***(1) $ 30, 591***
Kelang	*(6)* $ 26, 631	(5) $ 20, 592	*(6)* $ 20, 988	*(2)* $ 25, 146	*(2)* $ 36, 927
Tanjung Pelepas	*(4)* $ 21, 879	(3) $ 22, 869	*(2)* $ 16, 236	*(3)* $ 30, 294	*(3)* $ 40, 887
Kuantan	***(1) $ 16, 533***	***(1) $ 16, 632***	*(4)* $ 18, 216	*(5)* $ 36, 279	*(5)* $ 47, 617
Kuching	*(2)* $ 19, 503	(6) $ 31, 779	*(3)* $ 16, 929	*(6)* $ 42, 075	*(6)* $ 52, 866
Pasir Gudang	*(3)* $ 20, 691	(2) $ 21, 681	***(1) $ 14, 454***	*(4)* $ 31, 185	*(4)* $ 42, 075

Notes: (i) In January 2017, the average price of Intermediate Fuel Oil (IFO) 380 in Port Klang amounted to $ 330 per tonne.
(ii) The number in brackets refers to bunker cost from each Malaysian port to the other Asian ports, ranked from the lowest to the highest.

(d) Port facilities and distribution centre

The measurement unit of grade assessment is used, for which the total of assessment in each column must be equal to 1. The calculation is conducted to convert fuzzy input to fuzzy output. An example of fuzzy input data for ‘Distribution Centre’ with respect to alternative ‘Kuantan Port’ as referred to assessment grade in Table 10 is shown as follows:

Fuzzy input for criterion ‘DC’: (efficient = 0.20; reasonably efficient = 0.80; average = 0.00; reasonably inefficient = 0.00; inefficient = 0.00) = 1.00

The fuzzy input is converted to fuzzy output by using Equation (5), (6) and (7). An example of the calculation:

Short = (0.20 x 1.00) + (0.80 x 0.20) = 0.36
Reasonably Short = (0.80 x 0.80) + (0.00 x 0.20) = 0.64
Average = (0.00 x 0.60) = 0.00
Reasonably Long = (0.00 x 0.20) + (0.00 x 0.80) = 0.00
Long = (0.00 x 0.00) + (0.00 x 1.00) = 0.00

The fuzzy output for criterion ‘DC’ with respect to alternative ‘Kuantan Port’ is written as follows: (efficient = 0.36; reasonably efficient = 0.64; average = 0.00; reasonably inefficient = 0.00; inefficient = 0.00) = 1.00. Next, all fuzzy output values for ‘Distribution Centre and Port Facilities’ are summarised in Tables 14 and 15.

4.2.6 Step 6: Assessment of criteria using Evidential Reasoning (ER) approach

The assessment process can be performed by using manual calculation or analysis by intelligent decision software (IDS). Table 14 demonstrates the Evidential Reasoning method by using the fuzzy output value of ‘Distribution Centre’ with respect to the alternative ‘Kuantan Port’.

Table 14
Fuzzy output values of the criterion “Distribution Centre” with respect to seven alternative ports

Alternative ports	***Assessment grades / Belief degree (β) in level units***				
	Efficient	**Reasonably Efficient**	**Average**	**Reasonably Inefficient**	**Inefficient**
	(1.0)	(0.75)	(0.5)	(0.25)	(0.0)
Bintulu	0.08	0.44	0.36	0.12	
Penang	0.14	0.62	0.18	0.06	
Kelang	0.40	0.44	0.12	0.04	
Tanjung Pelepas	0.40	0.44	0.12	0.04	
Kuantan	0.36	0.64	0.00	0.00	
Kuching	0.08	0.44	0.36	0.12	
Pasir Gudang	0.28	0.40	0.24	0.08	

Table 15
Fuzzy output values of the criterion “Port Facilities” with respect to seven alternative ports

Alternative ports	***Assessment grades / Belief degree (β) in level units***				
	Excellent (1.0)	**Good (0.75)**	**Average (0.5)**	**Poor (0.25)**	**Worst (0.0)**
Bintulu	0.08	0.44	0.36	0.12	
Penang	0.12	0.56	0.24	0.08	
Kelang	0.40	0.44	0.12	0.04	
Tanjung Pelepas	0.40	0.44	0.12	0.04	
Kuantan	0.20	0.48	0.24	0.08	
Kuching	0.06	0.38	0.42	0.14	
Pasir Gudang	0.28	0.40	0.24	0.08	

By applying Equation 8, the belief degree value (ß) of ‘DC’ is arranged as follows:

S(DCD) = {(efficient, 0.36), (reasonably efficient, 0.64), (average, 0.00), (reasonably inefficient, 0.00), (inefficient, 0.00)}.

Weight value of “*DC*” is 0.2540 as described in Step 5. The weight values of criterion or Normalized Principal Eigenvector have been obtained by applying the calculations in Steps 3 and 4. By using the information given in Table 14 and the weight values, the basic probability masses $m_{n,i}$ are calculated using Equation 9:

The $m_{n,i}$ of $DC =$

$m_{1,1}$= 0.2540 × 0.3600 = 0.0914,$m_{1,2}$= 0.2540 × 0.6400=0.1626 ,
$m_{1,3}$= 0.0000, $m_{1,4}$= 0.0000, $m_{1,5}$= 0.0000.

Then, the values for $m_{H,i}$ which refer to $m_{H,1}$ and $m_{H,2}$ are calculated using Equation 10. $\bar{m}_{H,i}$ can be computed using Equation 11, while $\tilde{m}_{H,i}$ can be calculated using Equation 12.

$$\bar{m}_{H,1} = 1 - 0.2540 = 0.7460$$
$$\tilde{m}_{H,1} = 0.2540\big(1 - (0.20 + 0.80 + 0.00)\big) = 0.0000$$
$$m_{H,1} = 1 - (0.0914 + 0.1626) = 0.7460$$
$$\bar{m}_{H,2} = 1 - 0.7460 = 0.2540$$
$$\tilde{m}_{H,2} = 0.2540\big(1 - (0.00)\big) = 0.2540$$
$$m_{H,2} = 1 - (0.00) = 1.0000$$

After that, the calculation proceeds with the application of Equation 13:

$$K=\{1 - (0.0000 + 0.0000)\}^{-1}= \{1 - 0.0000\}^{-1}= 1.0000$$

Then, the normalised factor (K) was computed using Equation 14:

$$m_1=K\big(m_{1,1}m_{2,1}+m_{1,1}m_{H,2}+m_{H,1}m_{2,1}\big)$$
$$= 1.0000(0.0000 + 0.0914 + 0.0000) = 0.0914$$

$$m_2=K(m_{1,2}m_{2,2}+m_{1,2}m_{H,2}+m_{H,1}m_{2,2})$$
$$= 1.0000(0.0000 + 0.1626 + 0.0000) = 0.1626$$

$$m_3=K(m_{1,3}m_{2,3}+m_{1,3}m_{H,2}+m_{H,1}m_{2,3})$$
$$= 1.0000(0.0000+ 0.0000 + 0.0000) = 0.0000$$

$$m_4 = K\big(m_{1,4}m_{2,4}+m_{1,4}m_{H,2}+m_{H,1}m_{2,4}\big)$$
$$=1.0000(0.0000+ 0.0000 + 0.0000) = 0.0000$$

$$m_5 = K(m_{1,5}m_{2,5}+m_{1,5}m_{H,2}+m_{H,1}m_{2,5})$$
$$=1.0000(0.0000+ 0.0000 + 0.0000) = 0.0000$$

Next, the normalisation of the probability $\tilde{m}_H$ is computed using Equation 15:

$$\tilde{m}_H = K(\tilde{m}_{H,1}\tilde{m}_{H,2}+\bar{m}_{H,1}\tilde{m}_{H,2}+\tilde{m}_{H,1}\bar{m}_{H,2})=1.0000(0 + 0 + 0) = 0.00000$$

Subsequently, we use Equation 16 to obtain the normalisation of the probability $\bar{m}_H$:

$$\bar{m}_H=K\big(\bar{m}_{H,1}\bar{m}_{H,2}\big)=1.0000(0.7460)= 0.7460$$

Then, Equation 17 is applied to obtain the belief degree values:

$$(Efficient)\beta_1=\frac{m_1}{1-\bar{m}_H}=\frac{0.0914}{1-0.7460}= 0.3598 \approx 0.36 \text{ x } 100 = 36.00\%$$

$$(Reasonably\ efficient)\beta_2=\frac{m_2}{1-\bar{m}_H}=\frac{0.1626}{1-0.7460}$$

$$= 0.6401 \approx 0.64 \text{ x } 100 = 64.00\%$$

$$(\text{Average})\beta_3=\frac{m_3}{1-\bar{m}_H}=\frac{0.0000}{1-0.7460}= 0.0000 \approx 0.00 \text{ x } 100 = 0.00\%$$

$$(Reasonably\ inefficient)\beta_4=\frac{m_4}{1-\bar{m}_H}=\frac{0.0000}{1-0.7460}$$

$$= 0.0000 \approx 0.00 \text{ x } 100 = 0.00\%$$

$$(Inefficient)\beta_5=\frac{m_5}{1-\bar{m}_H}=\frac{0.0000}{1-0.7460}= 0.0000 \approx 0.0000 \text{ x } 100 = 0.00\%$$

Therefore, the aggregated assessment of ‘Distribution Centre’ with respect to the alternative ‘Kuantan Port’ is summarised as follows:

S(Distribution Centre)
= S(DC)={(Efficient, 36.00%),(Reasonably efficient, 64.00%), (Average,0.00%), (Reasonably Ineffcient,0.00%), (Inefficient,0.00%)}

The belief degree assessment values referring to Kuantan Port on ‘Distribution Centre’ (*Efficient, 36%; Reasonably Efficient, 64%; Average, 0.00%; Reasonably Inefficient, 0.00%; Inefficient, 0.00%*) are illustrated in Figure 3 (see Appendix 1), which is computed using IDS software. The output of IDS corresponds to the results obtained via manual calculation.

Moreover, the aggregated assessment values of the other criteria can also be computed using the Intelligent Decision Making (IDS) software tool.

Figure 4 (see Appendix 2) describes the belief degree of five different evaluation grades with respect to the liner service connection Kuantan Port – Ho Chi Minh Port. The evaluation grade ‘Practical’ generates the highest percentage of belief degree (61.00%), followed by ‘Reasonably practical’ with belief degree of 32.10%.

All the percentage values of the evaluation grades on belief degree are used to calculate the overall ranking of alternatives. An example of the calculation for the routing alternative ‘Kuantan Port – Ho Chi Minh’ is shown below:

Practical: 61.00 % ÷ 100 x 1.00 = 0.6100
Reasonably practical: 32.10 % ÷ 100 x 0.75 = 0.2407
Average: 05.18 % ÷ 100 x 0.50 = 0.0259
Reasonably impractical: 01.73 % ÷ 100 x 0.25 = 0.0043
Impractical: 00.00 % ÷ 100x 0.00 = 0.0000

The average score of ‘Kuantan Port – Ho Chi Minh’ is linked between Figures 4 and 5 (see Appendix 2 and 3). The calculation process is as follows:

0.6100 + 0.2407 + 0.0259 + 0.0043 = 0.8809. Then, 0.8809 x 100% = 88.09% (see Appendix 3).

We applied the same steps for the other six Malaysian ports (Bintulu, Penang, Klang, Tanjung Pelepas, Kuantan, Kuching, and Pasir Gudang). Figure 5 reveals Kuantan Port is rated as the most practical Malaysian port to serve Ho Chi Minh Port, followed by Tanjung Pelepas and Pasir Gudang.

The same steps were followed to find the ranking of the seven Malaysian container ports to serve the other four Intra-Asian feeder ports (Laem Chabang Port, Jakarta Port, Yangon Port, and Chittagong Port). The results are shown in Figures 6 to 9 (see Appendices 4 to 7):

- ‘Kuantan Port’ (84.84%) is the most practical port to serve Laem Chabang, followed by ‘Port Tanjung Pelepas’ (83.24%) and ‘Pasir Gudang Port’ (80.41%), see Figure 6 (Appendix 4);
- ‘Tanjung Pelepas Port’ (89.12%) is the most practical port to serve Jakarta, followed by ‘Pasir Gudang Port’ (86.25%) and ‘Kuantan Port’ (84.84%), see Figure 7 (Appendix 5);
- ‘Penang Port’ (79.09%) is the most practical port to serve Yangon

Port, followed by 'Port Klang' (78.65%) and 'Port Tanjung Pelepas' (73.33%), see Figure 8 (Appendix 6);

- 'Penang Port' (68.01%) is the most practical port to serve Chittagong Port, followed by 'Port Klang' (64.42%) and 'Port Tanjung Pelepas' (58.78%), see Figure 9 (Appendix 7);

5. Discussion and conclusions

This paper addressed the selection problem of ports of call in regular intra-regional container services. The problem was analysed using a combination of decision-making techniques (i.e. Analytical Hierarchy Process, fuzzy link-based and Evidential Reasoning) and was empirically applied to intra-regional container services between Malaysian and other nearby Asian ports, using the assessment inputs of a panel of experts who are all active in intra-regional shipping companies.

Port Klang is the main gateway to Malaysia for both intercontinental mainline services as well as intra-regional container services. This study proposed a new mix-matching between Malaysian ports and other Asian ports, taking into consideration five port selection parameters described in the literature, i.e. 'Distribution Centre', 'Port Facilities', 'Distance', 'Journey time' and 'Bunker Cost'. The results in Figure 10 (Appendix 9) indicate that, next to Port Klang, also other Malaysian ports have a role to play in accommodating intra-Asian container services.

The results show that Laem Chabang Port and Ho Chi Minh Port can best be served by Kuantan Port, while Penang Port is the best choice to connect to Chittagong Port and Yangon Port. In fact, Penang Port and Kuantan Port are the nearest access points to respectively the Northern and Eastern regions of the intra-Asian market. When following this outcome, intra-regional container service operators can benefit from short ship sailing times, low bunker costs, and an increased service frequency or rotation between ports.

If Penang Port and Kuantan Port want to take up a more prominent role in intra-regional services, they have to improve their port facilities through expanding ship berthing capacity and adding container cranes and yard equipment. The development of the Malaysia-China Kuantan Industrial Park (MCKIP) project started in 2014. As Kuantan Port is located at the eastern coast of peninsular Malaysia, it should be able to benefit from its position as the nearest accessibility point for services to China. The South Malaysian ports of Tanjung Pelepas and Pasir Gudang can share the benefits and remain competitive in the industry. Pasir Gudang can also improve its port facilities, primarily in view of strengthening its position in relation to Jakarta Port and Indonesia as a whole.

In the future, the vessel traffic flows and the intensive use of the container yards in Port Klang and Port Tanjung Pelepas can be reduced by enhancing the market position in intra-regional services of potential alternative ports such as Penang Port, Kuantan Port, and Pasir Gudang.

This study provided a methodological framework that can assist maritime stakeholders such as shipping companies, terminal operators, port authorities and public policy planners to evaluate the feasibility and competitiveness of specific intra-regional port-to-port liner service configurations. While the method was empirically applied to the Malaysian context, the building blocks of the proposed methodology can be used in other regional contexts around the world, subject to the identification and surveying of a relevant panel of experts, and a regionally embedded reconfirmation of the relevant set of port selection parameters. The proposed mix of decision-making techniques enriches existing academic literature on port choice and liner service configuration in two ways. First, the presented methodological approach based on decision making techniques is novel and complements other more conventional approaches on vessel routing and port selection (such as optimization techniques in the OR field). Second, the focus is on intra-regional liner services which represent an under-researched part of the container shipping market.

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Appendix

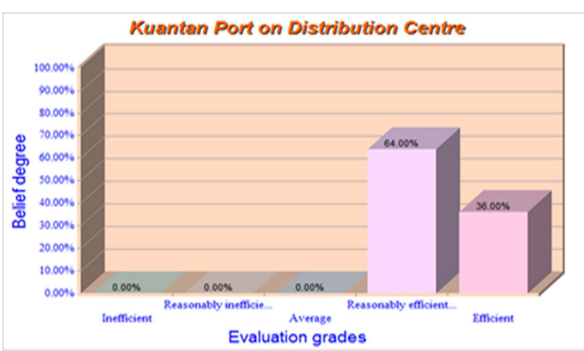

Fig. 3. The evaluation of belief degree assessment grade of 'Distribution Centre' for 'Kuantan Port'

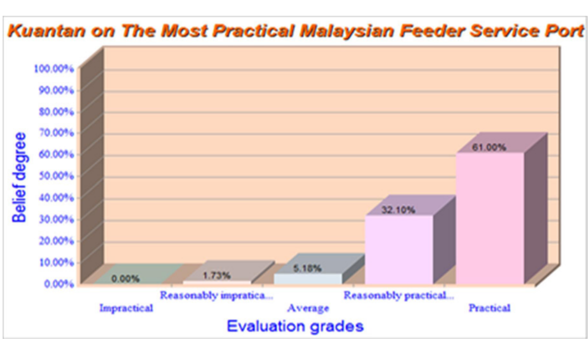

Fig. 4. The output values of 'Kuantan Port' to 'Ho Chi Minh Port'

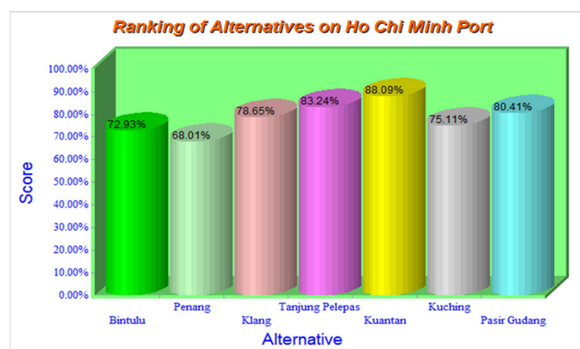

Fig. 5. The most practical Malaysian port for the route to 'Ho Chi Minh Port'

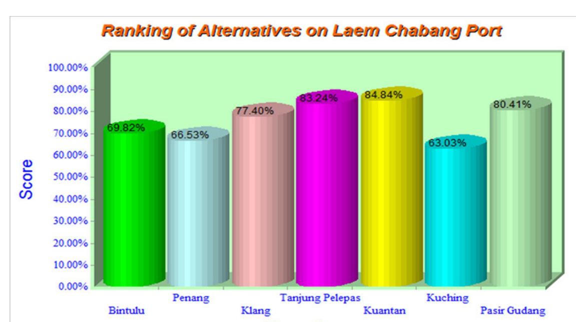

Fig. 6. The most practical Malaysian container port to serve 'Laem Chabang Port'

Fig. 7. The most practical Malaysian port to serve 'Jakarta Port'

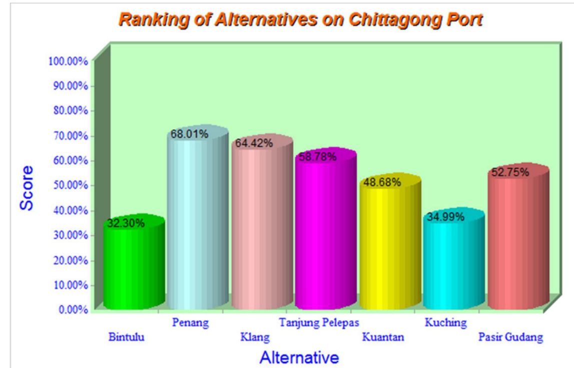

Fig. 9. The most practical Malaysian port to serve 'Chittagong Port'

Fig. 8. The most practical Malaysian port to serve 'Yangon Port'