THE DEVELOPMENT OF A CONTAINER PORT SELECTION INDEX IN EAST MEDITERRANEAN USING A FUZZY AHP APPROACH

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ABSTRACT

Competition between ports receiving container ships has started to attract more clients such as freight forwarders, importers, exporters, shipping lines, ship owners and logistics service providers. Container terminals play a substantial role in global cargo transportation by serving as an intermodal between the maritime entities and by a variety of carriers. This paper aims to investigate those criteria that can be applied by port clients (shipping lines only) when they select their calling ports. A questionnaire has been developed to identify those criteria that are currently applied by shipping lines in the container market in calling at seven ports located in the East Mediterranean region. Data and answers were collected for this questionnaire and were then compared with those criteria discussed in the available literature. Several interviews have been conducted with different shipping lines working in the east Mediterranean region in order to select the most important criteria from their perspective. The most important criteria identified by shipping lines are grouped into seven categories. The Fuzzy AHP approach was applied to weight each criterion. The results were distributed again in a second questionnaire to the experts and academics in the field, to highlight the basic criteria from their perspective. Finally, the results of both questionnaires were given weight for each criterion through the AHP method of analysis and K-firm concentration ratio. A ranking index of ports was developed based on the criteria identified by the shipping lines. It is concluded that the port charges criterion has the highest degree of importance as perceived by the shipping lines served by the East Mediterranean container market.

***Keywords**: East Mediterranean Ports, Port selection index, fuzzy AHP, K-firm concentration ratio*

บทคัดย่อ

การแข่งขันระหว่างท่าเรือที่รองรับเรือบรรทุกตู้คอนเทนเนอร์ เริ่มจะดึงดูดลูกค้ามากขึ้น อาทิเช่น ตัวแทนของผู้ส่งสินค้า ผู้นำเข้า ผู้ส่งออก ตัวแทนของผู้นำเข้าและส่งออก เจ้าของเรือ และผู้ให้บริการโลจิสติกส์

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ทั้งนี้ท่าเทียบเรือมีบทบาทอย่างมากในการขนส่งสินค้าทั่วโลก โดยทำหน้าที่เป็นช่องทางเชื่อมการค้าการขนส่งทางทะเล บทความนี้มีวัตถุประสงค์เพื่อศึกษาเกณฑ์ที่สามารถนำไปใช้โดยลูกค้าของท่าเรือ (ตัวแทนของผู้นำเข้าและส่งออกเท่านั้น) เมื่อพวกเขาทำการเลือกท่าเรือที่จะจอดเพื่อนำสินค้าขึ้นหรือลงเรือ ผู้วิจัยได้พัฒนาแบบสอบถามชุดที่ 1 เพื่อหาเกณฑ์ที่ลูกค้านำมาใช้ในการเลือกท่าเรือในภาคตะวันออกของทะเลเมดิเตอร์เรเนียน ทั้ง 7 ท่า จากนั้นผู้วิจัยได้นำข้อมูลและคำตอบที่ได้จากแบบสอบถามมาเปรียบเทียบกับเกณฑ์ที่ระบุในงานวิจัยอื่น ๆ แล้วจึงทำการสัมภาษณ์ตัวแทนของผู้นำเข้าและส่งออกหลายราย เพื่อเลือกเกณฑ์ที่คิดว่าสำคัญที่สุด โดยผลที่ได้สามารถจัดกลุ่มเกณฑ์ที่สำคัญที่สุดได้ 7 กลุ่ม แล้วนำแต่ละเกณฑ์มาทำการถ่วงน้ำหนักด้วยวิธี Fuzzy AHP จากนั้นจึงนำผลลัพท์ที่ได้ไปเผยแพร่อีกครั้งในแบบสอบถามชุดที่ 2 ให้กับผู้เชี่ยวชาญและนักวิชาการทำการตอบ เพื่อให้ได้เกณฑ์จากมุมมองของคนกลุ่มนี้ ในที่สุดผลลัพท์จากแบบสอบถามทั้ง 2 ชุด ได้ถูกทำการถ่วงน้ำหนักในแต่ละเกณฑ์ ผ่านวิธีวิเคราะห์ AHP และ K-firm concentration ratio ดัชนีการจัดอันดับท่าเรือได้ถูกพัฒนาขึ้น โดยอิงจากเกณฑ์ที่ระบุโดยตัวแทนของผู้นำเข้าและส่งออก ซึ่งสามารถสรุปได้ว่าเกณฑ์เกี่ยวกับค่าธรรมเนียมของท่าเรือมีระดับความสำคัญสูงสุดตามมุมมองของตัวแทนของผู้นำเข้าและส่งออก

INTRODUCTION

Containerization plays an indispensable role in reducing transport costs of international trade. Hence, shipyards have started to produce new designs, which are technically better in terms of their adaptability to the new market conditions, more economical and above all highly competitive compared to the existing ships. On the other hand, ports play an important role in accommodating new designed ships with larger volumes of cargo. The quality of facilities inside ports can achieve faster ship turn-around time, less unit cost, and provide added value activities. This helps in enhancing port competitiveness. Furthermore, those facilities are represented as criteria that are used by port clients (shipping lines) for selecting a calling port. It is obvious that the market for maritime container transport is quite oligopolistic, where substantial volume is being carried by a small number of "Mega Carriers-Top ten" such as Maersk Line, MSC, and CMA–CGM (Elsayeh et al., 2011). In 2014, these three operators have deployed 1265 vessels out of 6175 vessels for the 50 leading liner companies (UNCTAD, 2014). Hence, different shipping lines apply different criteria in selecting their calling ports. This paper is designed as follows. Section one starts with an introduction to the paper regarding the nature of the container market, research problem, research methodology and research structure. Section two discusses the development of container terminals and liner shipping companies in the East Mediterranean region, and critically reviews the literature of service quality criteria and attributes used in selecting the calling container terminals. Section

three describes the Fuzzy AHP (FAHP) technique, data analysis phase and rating scale for selected ports. Section four provides conclusions.

LITERATURE REVIEW

A huge amount of research has been conducted to study port selection criteria for quality services from different perspectives. Many of them have focused on the selection criteria for mode and carrier from the shipper's point of view. These studies are mainly based on cost factors and qualitative evaluation. Other studies have based their methodology on an Analytic Hierarchy Process (Bagchi, 1989). Chang et al. (2008) has listed those factors that affect port selection. D'Este et al. (1992) and Chang et al. (2008) have studied the port/ferry choice. Both studies have been carried out using surveys and focusing on factors such as quality service level, frequency of service, price, facilities etc. Lagoudis et al. (2006) developed a Generic System Model which assisted in the identification of a number of variables that affect the port selection in the total supply chain for international trade. They also adopted the Soft Systems Methodology as a more holistic approach in order to identify the wider possible variety of factors that determine and affect the port selection in the modern business environment. Chang et al. (2008) focused on port choice models made by shippers rather than by other stakeholders. Tjong Kim Sang and De Meulder (2003) distinguished external factors of using a port from internal factors relevant to major port arena, and attempted to check if these factors changed over time. Using container transhipment in Northern Europe as a case study, Chang et al. (2008) applied an analytic hierarchical process (AHP) method to reveal liners' transhipment port selection. Their empirical test showed that both container liners carriers and port service providers have a similar perception about the most important service attributes for port selection. Other factors, notably, time efficiency, geographical location and service quality, should also be taken into consideration. On the other hand, using a revealed preference approach, Tongzon and Sawant (2007) concluded that port costs and range of port services are the only significant factors in shipping lines' port choice.

For East Mediterranean ports, they are experiencing a period of revival, and now offer the same number of departures both towards the West and the Far East as do northern European ports (Tiwari et al., 2003). The forecasts concur in predicting that transhipment will continue to grow in the main countries bordering on the Mediterranean. As defined by the east Mediterranean region (Egypt, Cyprus, Turkey, Syria, Lebanon and Israel) these countries are competing in the Maritime transport market within the region, with a total number of 22 commercial ports, where 15 of them include at least one container terminal. Those container terminals were selected from the Group of the Eastern Mediterranean and convergence in size to compete with each other and thus show how difficult is the

selection process due to the convergence of the distances between those terminals as well as the volume of containers handled per year. Port Said, Ashdod, Haifa, Damietta, Mersin, Piraeus and Alexandria are selected for the case study in this paper. A questionnaire was sent to most of the container shipping carriers that serve the container market in the study area (Eastern Mediterranean ports), in order to identify the most important criteria and related attributes from their perspectives. The shipping carriers selected are the top container carriers serving the Eastern Mediterranean ports (Alphaliner, 2016). Most quality criteria in the available literature at port container terminals include Port Features (5 attributes), Port Charges (3 attributes), Operations Management (3 attributes), Cargo Handling (3 attributes), Customer Service Levels (6 attributes), Information Technology (4 attributes) and External Factors (4 attributes).

Research Problem

This paper aims to address the question of how do shipping lines select their calling container terminals in the East Mediterranean? What are the criteria and attributes currently applied by the shipping lines? How can ports in the East Mediterranean be ranked according to the shipping lines' criteria?

METHODOLOGY

The methodology in this paper is an empirical enquiry that investigates a contemporary phenomenon within its real-life context. The paper will make use of multiple methods of collecting data, which will be both qualitative and quantitative in nature. The methods used in this paper mainly include a literature review, structured interviews, and an administered questionnaire. Also, the Analytic Hierarchy Process (AHP), and the K-Firm Concentration (KCR) tools will be used for data analysis. Fuzzy AHP is a widespread multi criteria decision-making tool and has been used widely in the literature (Chang, 1996; Bashiri & Hosseininezhad, 2009; Cinar & Ahiska, 2010). A set of structured interviews with a group composes of 20 interviewees has been conducted to confirm the validity and appropriateness of the quality criteria in port container terminals discussed in the literature. An administered questionnaire has been distributed to seven out of the most important 25 operating shipping lines in the world, where they constitute about 56% of total shares (Alphaliner, 2016).

Container Port Selection Criteria

Analysis of the data provided by the first questionnaires which had been sent to the shipping lines, shows that the category of "Port Charges" constitutes the most important factor with a percentage of 57%, followed by "Information Technology" with a percentage of 43%. The "Operation Management" category has the lowest weight at 14 %. This reveals that the shipping lines are interested

more in the outcome of the management decisions related to the port fees and associated charges.

Each selection criterion is a set of different attributes. Analysing the questionnaire results, Port Depth is the most important attribute in the Port Features category, followed by the Location attribute. Handling Fees and Operating Costs are the more important attributes in Port Charges. Relations with Staff became the most important in the Operations Management category, whereas Cargo Volumes was the highest attribute in the Cargo Handling category. Planning Movements was the highest attribute in the Customer Service Levels category, while Gate Automation and Service Efficiency were the highest attributes in the Information Technology category. Finally, Competitor Ports was the highest attribute in the External Factors category.

An AHP questionnaire was developed and posted to four groups, each of five respondents with a total of twenty respondents. The first group represents ports management, the second represents maritime experts, and the third group represents academic experts, while the fourth group represents the terminal professional operators. The responses were analyzed by the AHP approach to obtain the relative degree of importance of each category and attributes, and the performance of each port on these seven categories.

Fuzzy Analytic Hierarchy Process

The AHP of Saaty (1977) only makes use of the pair-wise comparison matrix to evaluate the ambiguity in multi-criteria decision-making problems, as in the following formula (1). First, let C1, C2, Cn denote the set of elements, while (aij) represents a quantified judgment on a pair of elements Ci, Cj. The relative importance of the two elements is rated using a scale with the values 1, 3, 5, 7, and 9, where 1 denotes equally important, 3 for slightly more important, 5 for strongly more important, 7 for demonstrably more important, and 9 for absolutely more important. An n-by-n matrix A can be expressed as follows:

$$A = [aij] = \begin{array}{c} \\ C1 \\ C2 \\ \vdots \\ Cn \end{array} \begin{array}{c} \begin{array}{cccc} C1 & C2 & \dots & Cn \end{array} \\ \begin{bmatrix} 1 & a12 & \dots & a1n \\ \frac{1}{a12} & 1 & \dots & a2n \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{a1n} & \frac{1}{a2n} & \dots & 1 \end{bmatrix} \end{array} \quad (1)$$

Where C_1, C_2,…, C_n denote the set of elements, aij = 1/aji and aij =$\frac{1}{aij}$ i, j= 1, 2,…,n

Second, the structuring of the pair-wise ratio matrix is with the triangular fuzzy numbers. The ratings are converted into the following scale including triangular fuzzy numbers (Bozbura & Beskese, 2007). The geometric mean accurately

highlights the consensus of experts, and is the most widely used in practical applications. Here, geometric mean (which represents the consensus of experts) is used as the model for triangular fuzzy numbers, that is the mean of membership is expressed by equation (1). A fuzzy pair-wise comparison matrix based on triangular fuzzy numbers is established as follows:

$$\tilde{u}ij = (Lij, Mij, Uij), Lij \leq Mij \text{ and } Lij, Mij \epsilon [1/9, 1] \cup [1,9] \quad (2)$$

$$Lij = \min(Bijk), \quad (3)$$

$$Uij = \max(Bijk). \quad (4)$$

Where Bijk represents a judgement of expert k for the relative importance of two criteria i-j.

$$\tilde{A} = [aij] = \begin{array}{c} \\ C1 \\ C2 \\ \vdots \\ Cn \end{array} \begin{array}{c} \begin{array}{cccc} C1 & C2 & \dots & Cn \end{array} \\ \begin{bmatrix} 1 & a12 & \dots & \tilde{a}1n \\ \frac{1}{a12} & 1 & \dots & \tilde{a}2n \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{a1n} & \frac{1}{a2n} & \dots & 1 \end{bmatrix} \end{array} \quad (5)$$

Third, the value of synthetic extent is calculated with Equation (6), as the preferences of experts are relatively subjective opinions, and their responses could differ depending on the degree of environmental uncertainty and depending on whether the experts adopt a conservative or optimistic attitude when determining their preferences. Therefore, the degree of environmental uncertainty and the degree of experts' confidence in their preference have been taken into consideration.

For the questionnaire responses:

$$(a_{ij}^{a})^{\lambda} = \left[\lambda . L_{ij}^{a} + (1 - \lambda) . U_{ij}^{a}\right], 0 \leq \lambda \leq 1, 0 \leq a \leq 1 \quad (6)$$

Consistency Test

Table 1: Consistency

Test of consistency					
Selection Criteria	EIGENVALUE	N	CI	RI	CR
Port Features	5.204506644	5	0.05112666	1.12	0.0456488
Port Charges	3.08969393	3	0.04484697	0.58	0.07732235
Operation Management	3.1	3	0.05	0.58	0.0862069
Cargo Handling	3.037285906	3	0.01864295	0.58	0.03214302
Customer Service level	6.303668115	6	0.06073362	1.24	0.04897873
Information Technology	6.353508	6	0.0707016	1.24	0.05701742
External Factors	4.148487771	4	0.04949592	0.9	0.05499547

Table 1 shows that the consistency is perfect, since the CR is less than 0.1. This means that the results are consistent and the test is valid.

Rating Scale for Selected Ports

Decision makers associate different importance weights with different criteria at different levels. Then, the weights of criteria of different levels are aggregated to obtain final weights of the decision alternatives. Many approaches have been developed to aggregate the performance from multi-criteria expressions; such as the weighted mean aggregation operator, to handle hierarchical links, the port terminal operator, for taking interactions into account, and the AHP technique, to quantify the weights and the performance elementary expression (Berrah & Clivillé, 2007).

In the proposed FAHP technique, the weighted average aggregation method is used to aggregate the performance of all the selection criteria performance measurement attributes. After determining the performance rate (R) and the relative weight (W) of each attribute, the weighted rate (WR) of each attribute is calculated by multiplying the relative weight of each attribute by its performance rate.

$$WR = W * R \quad (7)$$

Where W = the weight of the attribute and

R = the assigned performance rate for the attribute

Then, the weighted rates of all performance measurement attributes are aggregated for each selected port in this paper in order to obtain the overall SC operations' performance in terms of the SC Index (SCI). This index reveals the overall SC performance according to an interval based performance scale:

$$[0.0<R<=0.3], [0.3<R<=0.7], [0.7<R<=1]; \quad (8)$$

Where R denotes value of the SCI,

[0.0<R<=0.3] denotes poor performance,

[0.3<R<=0.7] denotes good performance,

[0.7<R<=1] denotes excellent performance.

Table 2: Alexandria Port Index Example

Attribute	Min (2007 - 2011)	Max (2007 - 2011)	Current (2012)	Scale	Rate R	Weight W	WR
Location (Dev. Distains)(N.M)	32	32	32	Poor	0.3	0.371	0.1113
Port Depth (M)	14	14	14	Poor	0.3	0.109	0.0327
Storage Capacity (TEU)(No.)	31	39	54	Excellent	1	0.123	0.123
Berth length (M)	15.6	19.4	24.63	Excellent	1	0.153	0.153
Handling Equipment Availability (number of gantry cranes)	11	15	21	Excellent	1	0.245	0.245
						index	0.665

The seven indexes are represented in table 3 below in a descending order according to importance. Thus, a new ranking for the selected East Mediterranean container terminals is established.

Table 3: The East Mediterranean Container Port Selection Index

The port	W.R
Alexandria port	0.665
Port Said port	0.5054
Mersin port	0.5054
Haifa port	0.3983
Damietta port	0.3983
Piraeus port	0.3003
Ashdod port	0.3003

K-Firm Concentration Ratio

Chen et al. (2004) introduced a K-firm concentration ratio indicator for determining the market share as:

$$CR_m = s_1 + s_2 + ... + s_m \quad (9)$$

Where Sm is the market share and m defines the m^{th} firm

The previous equation was used to rank East Mediterranean container terminals in the Period from 2011 to 2012, as displayed in Table 4.

Table 4: East Mediterranean Container Terminals Rank

Port	Annual container throughput in TEUs - 2011	Market Share %	Port	2012	Share
Port Said	366,968	40.85	Port Saied	4,831,165	35.39%
Piraeus	680,133	12.79	Piraeus	2,745,012	20.11%
CR2		53.64	CR2		55.49%
Alexandria	1,490,000	11.34	Alexandria	1,500,000	10.99%
Haifa	1,235,000	9.40	Haifa	1,372,209	10.05%
Damietta	1,200,000	9.13	Mersin	1,263,495	9.25%
CR5		83.52	CR5		85.78%
Mersin	1,126,588	8.58	Ashdod	1,181,000	8.65%
Ashdod	1,038,950	7.91	Damietta	760,000	5.57%
Total	13,137,639	100	Total	13,652,881	100%

The researcher used the k-firm concentration in order to conduct an objective comparison between K-Firm Concentration Ratio method and the Fuzzy AHP, as shown in the table 5 below.

Table 5: Ranking for East Mediterranean Container Terminals

Rank	Ranking for East Mediterranean container terminals (K-Firm Concentration Ratio) (Past Performance)	Ranking for East Mediterranean container terminals (Fuzzy AHP) (Future Performance)
1	Port Said	Alexandria
2	Piraeus	Port Said
3	Alexandria	Mersin
4	Haifa	Haifa
5	Mersin	Damietta
6	Ashdod	Piraeus
7	Damietta	Ashdod

CONCLUSION

Container terminals can play an important role in attracting more clients and in enhancing port competitiveness. The availability and quality of facilities at the terminals are considered as criteria by many shipping lines when they select their calling ports. Different criteria are applied by different shipping lines for this purpose. Seven categories of criteria and their related attributes have been discussed, including Port Features, Port Charges, Operations Management, cargo Handling, Customer Service Levels, Information Technology and External Factors. Seven East Mediterranean container terminals were identified. Two questionnaires were developed, and structured interviews were conducted for collecting data in order to identify the most important criteria applied by the shipping lines for selecting their calling ports. It is concluded that the ‘port

charges' was the most important criterion, followed by 'information technology'. Two different methods were applied in this paper to rank the selected container terminals, including the Fuzzy AHP method of analysis and the K-firm concentration ratio. A ranking index was developed, where Alexandria port was ranked the highest when using the Fuzzy AHP method, while Port Said was ranked the highest when using the K-firm concentration ratio.

It is recommended to extend the study in the future to include other port clients, such as importers and exporters, stevedoring companies and freight forwarders, in order to identify the most important criteria for selecting the calling port from their perspectives. This may lead to changes in the ranking of the selected container terminals in East Mediterranean.

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