AN AHP DECISION SUPPORT MODEL FOR THE HUB PORT CHOICE OF THE SHIPPING LINERS ON THE MEDITERRANEAN REGION

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ABSTRACT

This paper applies the Analytic Hierarchy Process (AHP) to analyse hub-port selection in the Mediterranean Sea. For the AHP, 5 main criteria and 16 sub-criteria are determined through the conducted studies in the literature review by taking consideration the characteristic features of the region. The comparison of criterion is conducted by service providers which are port users, ocean carrier operators and other service providers in the region. The obtained survey results are applied to pre-determined 3 candidate ports which are Piraeus Port (Greece), Candarli Port (Turkey) and Gioia Port (Italy). The AHP model gives the best score to Piraeus Port with Candarli Port facility taking second place.

1. INTRODUCTION

The Mediterranean Sea ports show a natural hub port characteristic because cargoes from various Asian countries such as China, India, Japan and Korea pass through Suez Canal; cargoes from Russia, Baltic and Black Sea pass through the Bosporus; and cargoes from America and Europe pass through Gibraltar and the cargoes are gathered in the Mediterranean and are distributed to other ports with hub ports in the Mediterranean Sea basin. However, there is limited number of hub ports in the Mediterranean Sea basin for modern-day mega container vessels, and so choosing optimum hub port has a pivotal role in the container sector to generate sustainable container operations for freights to/from or through the Mediterranean Sea. Recent developments in terms of growth in vessel sizes, container volume and trade raise the importance of hub port strategies of the container shipping companies and lines. However, some problems have been facing by determining the most optimum hub port from liner side, port side and shipper side as well. Some of the main obstacles could be described as obstacles while improving the efficiency of port operations. The obstacles are generally classified into three types: Infrastructural obstacles, also known as mismatch among port structure and operated vessel fleet size, maritime business, economic obstacles or sort of operational obstacles and environmental obstacles.

In the new global maritime economy, the hub port choice has become one of the central issues for the shipping liners. Because, the correct hub port choice provides operational flexibility and sustainability, and also brings economic and managerial advantages for the shipping liners from increase in profit to corporate reputation depending on the operational advantages of the hub port strategy. This paper attempts to show that the impacts of the effective hub port decision on a specific maritime container trade region.

2. BACKGROUND

Throughout the years, the port competition has not overreached the understanding of giving the best service at the lowest price. However, although the competition among ports continues for traffic from hinterlands, the competition has reached to a different level with the containerization. Initially the service quality has begun inadequate to take advantage in the competition, and afterwards strategic investments have brought ports into the forefront among others. These strategic investments differ from region to region. While long and depth berths have more strategic importance for Asian ports, the hinterland connection investments are more strategic in Europe; although they are also important for both. Within that period, while some weak links are smashed under the heavy rivalry conditions, the big port operator situated in this fierce competition such as PSA International, APM Terminals, DP World, so on.

Alongside the rivalry among ports, the port chose of the container liner companies is the other end of knife. The regular schedules in the liner shipping push the companies to choose the optimum port facility in terms of performance, price, connectivity etc. Ports in a region may offer different alternative routes for a destination at the hinterland. However, deserve to gain the highest benefit from economies of scale which is based to reduce vessel's port times, directs to find alternative liner strategies at the foreland. The increasing container volume, container shipping company partnerships which are appeared as slot sharing and alliances, may be noted as other factor to focus the transportation stakeholders on hub ports. Veldman and Bückmann (2003) emphasized the increasing number of routing options between two regions are directed companies to deploy hub port strategy. Figure 1 presents a demonstration of hub-and-spoke network.

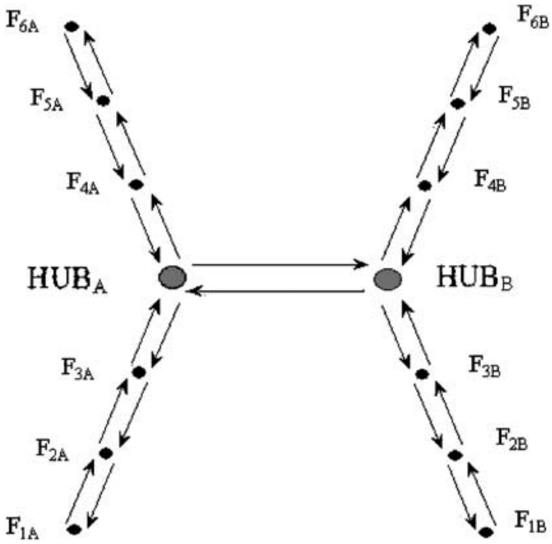

Figure 1: A hub-and-spoke network Source: Aversa et al. (2005)

Hub ports have a task to connect liner services and are an intermodal transfer point for a container flow. There are several factors in the choice decision of a hub port, and these factors vary by the perspective of the components in a transportation activity. Three components may play an active role in the hub port decision mechanism for the liner shipping. These are shippers, liner companies and ports (Zan, 1999). The main purpose of all components is to lead a reduction in transportation cost and increase in service quality by taken a hub port decision. As can be seen from Figure 2, the relationship between port administration, carrier and shipper depends on various factors.

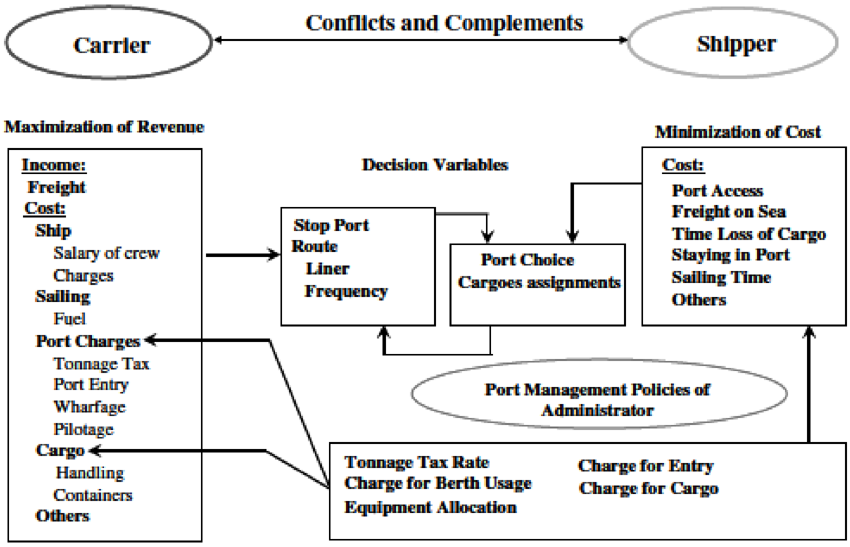

Figure 2: Relationship between port administration, carrier and shipper Source: Zan (1999)

3. LITERATURE

In previous studies, the port choice decision handled by different perspectives. Veldman and Bückmann (2003) assess the port decision from the shipper perspective and the study has been conducted depending upon three main factors which are listed as i) production-attraction, ii) distribution and iii) routing. They are described as purchasing or selling decision for a specific type and amount of goods; to get transportation service from a certain supplier and to decision for a specific transportation alternative. While the shipper perspective covers all sections in a transportation activity, the hub port location, service quality, and capacity, connectivity to hinterland and other ports and the provided priority for a certain ocean liner company/ies are some main criteria for the carrier perspective at the hub port choice decision. Location is a key factor for the most efficient hub port performance. Aversa et al. (2005) applies a P-HM (P-hub median) model among five types of discrete problems regarding the location of a hub. Other discrete problems are discussed by (Campbell, 1994). P-hub median problem (P-HM), incapacitated hub location problem (IHLP), capacitated hub location problem (CHLP), P-hub centre problem (P-HC), hub covering problem (HCV)

Aversa et al. (2005) argues the problem models in two sub categories regarding their applicability. The applicability of P-HM, IHLP and CHLP models is more suitable for terminal locations problem, while P-HC and HCV models are more applicable for the problems of emergency service facilities or vehicle base location at a hub port.

Studies show that hub-and-spoke strategy is more favorable for some region or routes while to design shipping network through multi-port strategy provides more effective container shipping. In this perspective, Imai et al. (2009) examines multi-port calling network for conventional ship size and hub-and-spoke network for mega-ships in consideration of the container management cost. Imai et al. (2009) defines the result as MPC is superior to H&S network in terms of container management costs in both European and North American lines. However, the significant result for the European shipping line is that H&S network provides cost-reduced and more profitable container shipping. In a study conducted by Wu (1988), it was shown that multi-port calling strategy is more applicable for Taiwan Ports. Although there is not yet any certain cost optimisation model, a general cost model is formulated by Notteboom (2010) to compare multi-port calling and hub-and-spoke alternatives and the model is applied to the South-African container port system to show transition from multi-porting to a hub-port configuration.

Hsu and Hsieh (2007) generates a two-objective model to solve container carriers` problems on the determination of optimal liner routing, ship size and sailing frequency for Trans-Pacific service of a container carrier. The formulated two-objective model aims to minimize shipping and inventory costs for a maritime hub-and-spoke container network. In their study, the optimal routing to minimize costs depends to make shipping activity through a hub port with together optimal ship choice and sailing frequency (Hsu and Hsieh, 2007). Thus, it can be noted that the optimum hub decision may provide remarkable cost advantage for container carriers, and the idea on extend the network with a hub port is strengthened.

There are so many major ports in East Asia such as Shanghai, Yantian, Busan, Hongkong and so on, and they serve as transshipment and hub ports. Therefore it is seen that a great number of hub-port choice analysis focus on this region. Tai and HWANG (2005) conducted a hub-port choice analysis in East Asia region. The analysis is generated from 3 steps and contains a performance analysis of hub ports, influential factors of hub port decision and a decision model to choose the optimum hub port from the viewpoint of container carriers by taking consideration of rivalry among major ports. The conducted questionnaire survey indicates that 18 influential factors play critical role on hub port choice (Tai and HWANG, 2005).

An optimum hub port decision can be a very complex problem in some cases. The complexity of this problem can be linked that there are so many influential factors in decision process. Some main factors are mostly related to: i) location (distance to other ports), ii) connectivity (good foreland and hinterland connections), iii) operation performance (productivity, capacity, comfort and so on), iv) infrastructure (berthing, terminal space etc.) and v) other integrant services (Chou, 2010). In different studies several criteria is assessed and found important for hub-port selection. Chou (2010) discusses all possible factors which are used in various cases, are affecting the choice of a container port by a stakeholder. Several factors are described and used in the studies of Slack (1985), James and Gail (1988) and (Jansson, 2012).

As can be seen in literature, factors are elaborated as expediently for a specific case. Therefore, the selection case of hub-port has its own specific decision factors. The key factors for a successful hub-port decision are suggested by Thomson (1998) as: (i) berthing time, (ii) loading/discharge rate, (iii) number of berths, (iv) containerized cargo, (v) port facility, (vi) connectivity to major consumers market, (vii) operation hours of ports. The conducted study, which is worthwhile due to its application region –Italy ports-, notes that the key factors by selecting a hub-port are: (i) geographical location, (ii) knowledge of market of marine container operators, (iii) operation flexibility, (iv) investment opportunities and potential in the infrastructure and facility, (v) operation of related business (Stemberg, 2000). The carriers' hub-port decision is influenced depending upon the above-mentioned factors.

4. THE HUB PORT ALTERNATIVES

The hub alternatives decision is made among large and small 145 container ports from 23 countries. These ports cover the Mediterranean Sea and the Black Sea countries' container ports. The hub port decision process involves identification, classification, analysis and selection steps. The assessment of ports has started by dividing the Mediterranean Sea into sub-regions according to hinterland connectivity. The sub-regions have been identified as follows:

- West (Europe) Mediterranean – the area covers the Mediterranean coast ports of Spain, France, Italy, Malta,
- Adriatic – the determined area presents Adriatic connected ports of countries that Italy, Slovenia, Croatia, and Albania,
- Black Sea – Bulgaria, Romania, Ukraine, Russia and Georgia are the countries of region.
- Greece and Turkey – the region is known as the Aegean Sea but the region also covers the ports in Mediterranean, Aegean and Marmara sections of Turkey as well as Greece ports,
- Levant – Cyprus, Syria, Lebanon, Israel and Egypt's ports on the Mediterranean Sea Coast,
- North Africa – the region covers Algeria, Morocco, Tunisia and Libya ports.

All districts may be demonstrated as in Figure 3. The districts are determined through the detailed investigation on hinterland, connectivity and geostrategic characteristic for shipping.

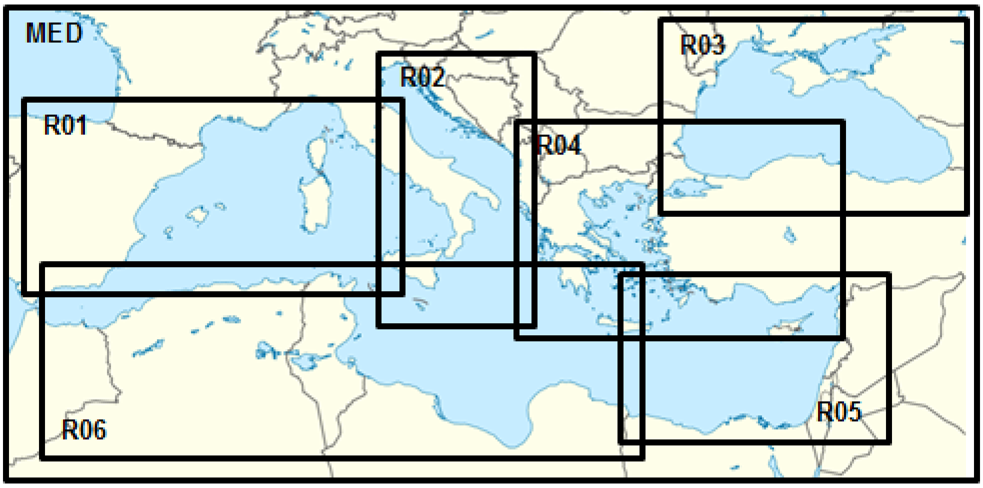

Figure 3: The Mediterranean Sea Districts

The characteristics of 145 ports in identified 6 sub-regions are investigated according to their availability to serve a hub port. Typical hub port characteristics are defined by Notteboom (2011) as in Table 1. When each characteristic is analysed, it is seen that some ports have more than one typical hub port characteristic.

Table 1: Typical Characteristics of Hub Ports

	Typical characteristics of a hub port
Single or near single-user facility	Most of the pure transhipment hubs are used largely, or even exclusively by a single carrier (dedicated terminal)
Way-port	A pure hub maximizes the port pair combinations that can be generated by interlining of mainline service
Minimal deviation	It is important for mainline vessels serving the hubs that the deviation sailing time from the main maritime route is kept to a minimum
Avoidance of a major operational cost	Hub ports have emerged near the Panama Canal and Suez Canal because they enable carriers to reduce the number of canal transits and to make considerable cost savings
Small Islands	Small local gateway cargo on islands makes transhipment traffic a high percentage of the container throughput see e.g. Marsaxlokk (Malta), Limassol (Cyprus) and Famagusta (Turkey)
Low cost	Many hubs are located in countries or regions with lower labour costs compared to the countries/regions they serve via feeder. This is particularly the case for the role of many hubs in the West Mediterranean
Ability to serve a large number of small markets	This is a defining characteristic of some regional hub ports.

Source: Notteboom (2011), (Aversa et al., 2005)

The location and the hub port characteristic of a port are key factors for hub port decision. Therefore, most of the ports eliminated due to location criterion to be a hub port. For example, Black Sea ports are automatically excluded, because they have very long distance to other ports in region. Port characteristics and other factors have been investigated for an optimum hub-port selection. Finally, it is decided to extend the investigation on Aegean and Ionian Sea ports which are located on Greece, Turkey and Italy. Another criterion is decided that one port form one selected country. So, in the Mediterranean Sea, three ports come into prominence among 145 ports from 23 countries geographically. They are Gioia Tauro, Piraeus and Izmir Candarlı ports from Italy, Greece and Turkey, respectively. The location importance of these ports has been supported by that they provide the top three shortest connections to other ports in the subject. The main characteristic features of the ports are given in Table 2.

Table 2: Basic data of Gioia Toura port, Piraeus port and Candarlı port

	Gioia Toura[1]	Piraeus Port[2]	Candarli Port[3]
Total port area (decare)	4,400	764	6,000
Container yard area (m2)	1,800,000	72,400	800,000
Container capacity (TEU)	3,087,395	3,700,000	4,000,000
Depth of berth (m)	18	16	18
Number of container crane	27	21	
Terminal operator	Private	Private/State	BOT

Source: Port related data is received from port authority webpages and governmental sources as indicated in footnotes

[1] Gioia Toura Port Authority
[2] Piraeus Port Authority
[3] The Republic of Turkey Prime Ministry Investment Support and Promotion Agency

Gioia Toura port is the largest container port of Italy with its annual throughput more than 3 million TEU. The Port of Gioia Toura is located in Reggio Calabria, southern Italy. It is situated along the route connecting Suez to Gibraltar which is one of the busiest maritime corridors in the world and the port is specialised in transhipment activities (Gioia Toura Port Authority, 2015)

Other hub-port alternative is the Port of Piraeus as the largest Greek seaport that is located in the Mediterranean Sea basin. The port served as the port of Athens since the ancient times. Piraeus port is a strategic location for Europe-China trade. It is a good transhipment location for goods to be destined to Central and Eastern Europe. This could save from four to ten days than using alternative ports such as Hamburg, Rotterdam and Antwerp. Cosco's investment since 2009 has considerably improved the capacity at pier II and containers throughput markedly augmented. Piraeus port became one of the fastest growing ports in the world, with an increase of handling from 1.7 million TEU (twenty feet container unit) in 2011 to 2.7 million TEU in 2012. Its throughput reached 3.7 million TEU in 2014, a fold of nine times when it handled 433,000 TEU before the Cosco's involvement in 2008. The growth could continue as Cosco expanded its investment to increase the annual capacity to 6.2 million TEU by 2020. Chinese investment in Piraeus Port has helped modernize the terminal equipment, bring in businesses from shipping companies which are close partners of Cosco and notably enhance operating efficiency (Pong, 2015).

As a last hub-port alternative, Candarli port is located in the Northern Aegean region and it already has a breakwater of 1.800 metres built two years ago. Except the breakwater, the port has no backyard facilities or infrastructure. The plan of Turkish government was to attract private investors and have them build all infra and superstructures in return for the operation right of the port. The project was planned as BOT and the operation term was more than 40 years. The bid would take place in 2013. Although six big companies showed interest in buying the bid file, none of them made a proposal. The main aim of this project is to have a transhipment port in the Aegean region, in order to capture some cargo from the other competitor T/S ports. Candarli port was expected to assume a central role in the naval trade between Asia and Europe. It is planned as an alternative to Greece's Piraeus port on the other side of the Aegean. According to authorities, the port was going to be among the top ten ports in Europe. However, as mentioned above, the construction of the port could not be realized except its breakwater. Despite the Turkish government's strategic decision about Candarli port, there are some missing points in building such a big port in the region in terms of logistics.

A graphical representation of the problem is developed in terms of the overall goal, criteria, sub-criteria and decision alternatives. Such a graph depicts the hierarchy for the problem. Figure 4 shows the hierarchy for the hub-port selection problem. Note that the first level of the hierarchy shows that the overall goal is to select the optimum hub-port. At the second and third level, we see that the criteria and sub-criteria will contribute to the achievement of the overall goal.

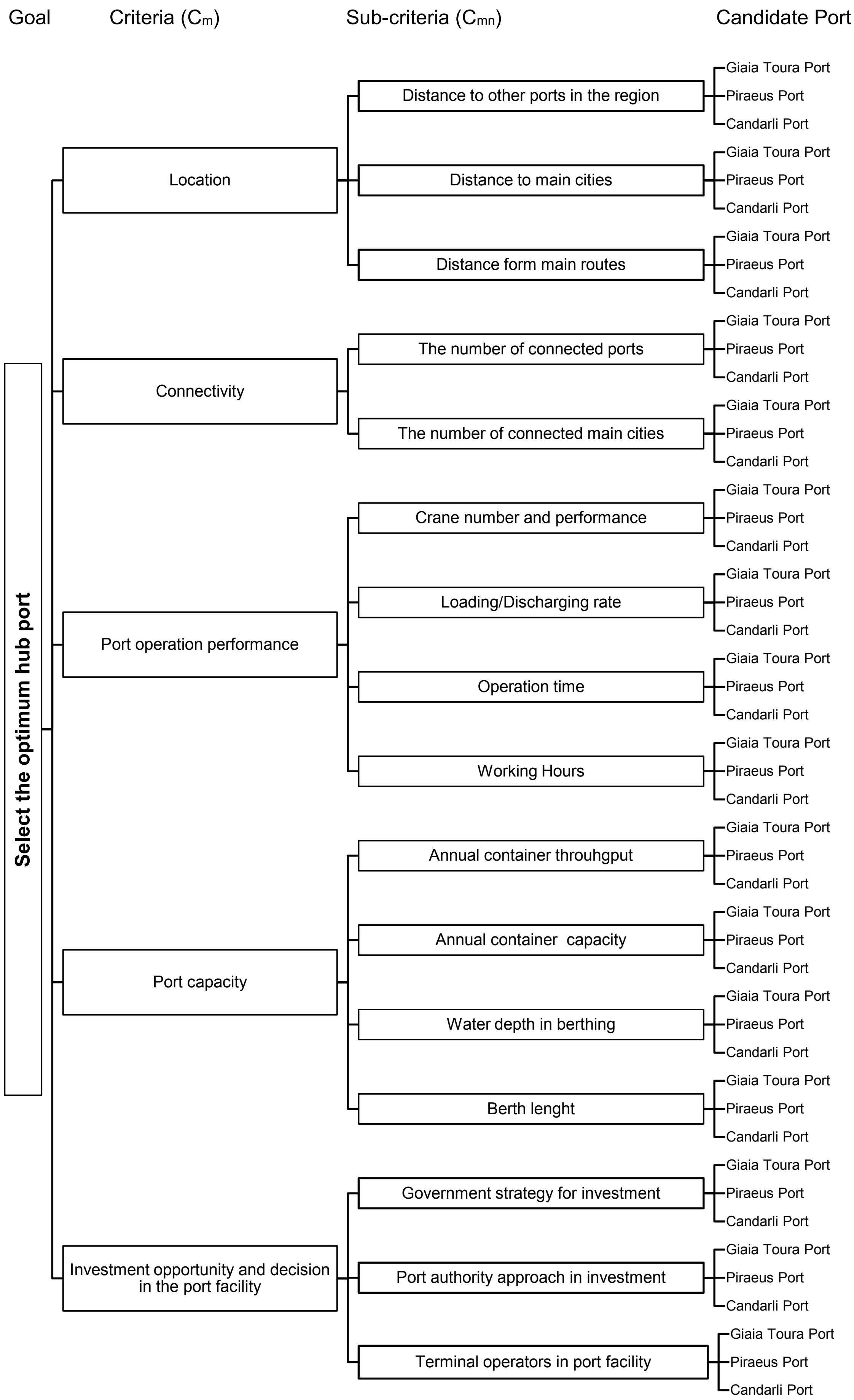

Figure 4: Hierarchy for the hub-port selection problem

Using a systematic hierarchy structure, the complex estimation criteria can be represented clearly and definitely. Ratio scales can be utilized to make reciprocal comparisons for each element and layer. After completing the reciprocal matrix, one can obtain comparative weights for each element as seen in Table 3 and 4 for main and sub criteria, respectively.

Table 3: Main criteria information for the hub port selection problem

Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria
C1:Location							X											C2:Connectivity
C1:Location								X										C3:Port Performance
C1:Location				X														C4:Port Capacity
C1:Location		X																C5:Investment Opportunity
C2:Connectivity								X										C3:Port Performance
C2:Connectivity							X											C4:Port Capacity
C2:Connectivity					X													C5:Investment Opportunity
C3:Port Performance							X											C4:Port Capacity
C3:Port Performance								X										C5:Investment Opportunity
C4:Port Capacity											X							C5:Investment Opportunity

Table 4: Sub-criteria information for the hub port selection problem

Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria
C11: Distance to other ports in the region							X											C12: Distance to main cities
C11: Distance to other ports in the region								X										C13: Distance from main routes
C12: Distance to main cities											X							C13: Distance from main routes
C21: The number of connected ports						X												C22: The number of connected main cities
C31: Crane number and performance												X						C32: Loading/Discharging rate
C31: Crane number and performance													X					C33: Operation time
C31: Crane number and performance											X							C34: Working hours
C32: Loading/Discharging rate												X						C33: Operation time
C32: Loading/Discharging rate											X							C34: Working hours
C33: Operation time								X										C34: Working hours
C41: Annual container throughput													X					C42: Container capacity
C41: Annual container throughput																X		C43: Water depth
C41: Annual container throughput																X		C44: Berth length
C42: Container capacity																X		C43: Water depth
C42: Container capacity																X		C44: Berth length
C43: Water depth								X										C44: Berth length
C51: Government investment strategy											X							C52: Port authority investment approach
C51: Government investment strategy								X										C53: Terminal operator
C52: Port authority investment approach						X												C53: Terminal operator

5. THE ANALYTIC HIERARCHY PROCESS (AHP) METHODOLOGY

The hub port decision has been made by using the analytic hierarchy process (AHP) which is designed to solve complex problems involving multi criteria (Saaty, 1990). The process requires the decision maker to provide judgments about the relative importance of each criterion and then specify a preference on each criterion for each decision alternative. The output of AHP is a prioritized ranking indicating the overall preference for each of the decision alternatives.

To introduce AHP, we consider the problem faced by container carriers, which is planning to choice the optimum hub port in the Mediterranean Sea. After a preliminary analysis of the ports available in the region, container carriers has narrowed the list of decision alternatives to three ports, which it will be referred as Gioia Toura Port, Piraeus Port and Candarlı Port . Table 2 provide a summary of the information container carriers have collected regarding these ports.

Based on the information in Table 2, there are several criteria that they needed to analyse in making the hub port selection decision. After the depth analysis, location, connectivity, port performance, port capacity and investment opportunity have selected as the five main criteria. Quantitative data regarding port infrastructures are provided directly in Table 2.

AHP has the decision maker specify the assessment about the relative importance of each criterion in terms of its contribution to the achievement of the overall goal. At the next level, AHP asks the decision maker to indicate a preference or priority for each decision alternative in terms of how it contributes to each criterion. For example, in the hub-port selection problem, container carriers need to specify the assessment about the relative importance of each of the five criteria. They also need to indicate their preference for each of the three ports relative to each criterion. Given the information on relative importance and preferences, a mathematical process is used to synthesize the information and provide a priority ranking of the three ports in terms of their overall preference.

AHP utilizes pairwise comparisons to establish priority measures for both criteria and the decision alternatives. What need to be determined in the hub-port selection problem are the priorities of:

1. The five main criteria in terms of the overall goal
2. The three ports in terms of the location criterion
3. The three ports in terms of the connectivity criterion
4. The three ports in terms of the port performance criterion
5. The three ports in terms of the port capacity criterion
6. The three ports in terms of the investment opportunity criterion

In the following discussion, it is demonstrated how to establish priorities for the three ports in terms of the location criterion. The other sets of priorities can be determined in a similar fashion. Pairwise comparisons are fundamental building blocks of AHP. In establishing the priorities for the three ports in terms of location, it is ask container carriers to state a preference for the location of the ports when the ports are considered two at a time (comparison). That is the comparison of a criterion of Piraeus Port to Candarli Port, Piraeus Port to Gioia Toura Port, and Candarli Port to Gioia Toura Port in three separate comparisons.

AHP employs an underlying scale with values from 1 to 9 to rate the relative preferences for two items. Table 5 provides the numerical ratings recommended for the verbal preferences expressed by the decision maker. Research and experience have confirmed the nine-unit scale as a reasonable basis for discriminating between the preferences for two items.

To develop the priorities for the three ports in terms of the location criterion, it is needed to construct a matrix of the pairwise comparison ratings. Since three ports are being considered, the pairwise comparison matrix will consist of three rows and three columns. Using the numerical values of preference, the pairwise comparison matrix for the location criterion is shown in Table 6.

Table 5: Pairwise comparison scale for AHP preferences

Verbal Judgement of Preference	Numerical Rating
Extremely Preferred	9
Very strongly to extremely	8
Very strongly preferred	7
Strongly to very strongly	6
Strongly preferred	5
Moderately to strongly	4
Moderately preferred	3
Equally to moderately	2
Equally preferred	1

Table 6: The pairwise comparison matrix

	Main Criteria				
	C_1	C_2	C_3	C_4	C_5
C_1	1	3	2	6	8
C_2	1/3	1	2	3	5
C_3	1/2	1/2	1	3	2
C_4	1/6	1/3	1/3	1	1/3
C_5	1/8	1/5	1/2	3	1

In the pairwise comparison matrix, the value in row *i* and column *j* is the measure of preference of the port in row *i* when compared to the port in column *j*.

Once the matrix of pairwise comparisons has been developed, it can be calculated that is called the priority of each of the elements being compared. For example, the pairwise comparison information in Table 4 is to estimate the relative priority for each of the ports in terms of the location criterion. The exact mathematical procedure required to perform the synthesization involves the computation of eigenvalues and eigenvectors and is beyond the scope of this text. However, the following three-step procedure provides a good approximation of the synthesized priorities.

Step 1 – Sum the values in each column of the pairwise comparison matrix.
Step 2 – Divide each element in the pairwise comparison matrix by its column total; the resulting matrix is referred to as the normalized pairwise comparison matrix.
Step 3 – Compute the average of the elements in each row of the normalized matrix; there averages provide an estimate of the relative priorities of the elements being compared.

After completing the reciprocal matrix, one can obtain comparative weights for each element. Let's consider the criteria $C_1,\ldots,C_i,\ldots,C_j,\ldots,C_n$, some-one level in the hierarchy. One wishes to find their weights of importance, $W_1,\ldots,W_i,\ldots,W_j,\ldots,W_n$, on some elements in the next level. Allow a_{ij}, $i,j=1,2,\ldots,n$ to be the importance strength of C_i when compared with C_j. The following matrix represents A matrix which denotes all a_{ij}.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \vdots & & \vdots & & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}_{n\times n},$$

An obvious case of a consistent matrix A is its elements

$$a_{ij} = w_i / w_j,\ i, j = 1, 2, \ldots, n$$

Thus, when the matrix A is multiplied by the vector formed by each weighting $w = (w_1, w_2, \ldots, w_n)^T$

$$Aw =$$

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_j & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_j & \cdots & w_2/w_n \\ \vdots & \vdots & & \vdots & & \vdots \\ w_i/w_1 & w_i/w_2 & & w_i/w_j & & w_i/w_n \\ \vdots & \vdots & & \vdots & & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_j & \cdots & w_n/w_n \end{bmatrix}_{n\times n} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{bmatrix}_{n\times 1} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{bmatrix} = nw$$

A key step in AHP is the establishment of priorities through the use of the pairwise comparison procedure just described. An important consideration in terms of the quality of the ultimate decision relates to the consistency of judgments that the decision maker demonstrated during the series of pairwise comparisons. AHP provides a measure of the consistency of pairwise comparison judgments by computing a consistency ratio. This ratio is designed in such a way that values of the ratio exceeding 0.10 are indicative of inconsistent judgments; in such cases, the decision maker would probably want to revise the original values in the pairwise comparison matrix. Values of the consistency ratio of 0.10 or less are considered to be a reasonable level of consistency in the pairwise comparisons.

It is noted that a_{ij} is the subjective ratings given by decision-maker, there must be a distance between a_{ij} and w_i/w_j. Therefore, the following formulations are used to obtain the consistency ratio. Saaty (1990) suggests the maximum eigenvalue $\lambda_{\max} = \frac{1}{n}\left(\frac{w_1'}{w_1} + \frac{w_2'}{w_2} + \ldots\ldots + \frac{w_n'}{w_n}\right)$, the consistency index is defined as $CI = \frac{\lambda_{max} - n}{n-1}$, where n= the number of items being compared. The consistency ratio is defined as $CR = \frac{CI}{RI}$, where RI is the random index which is generated randomly. In our hub-port selection problem n=3, RI = 1.12 and CR = 0.09.

As mentioned previously, a consistency ratio of 0.10 or less is considered acceptable. Since our case shows a consistency ratio of 0.09, the degree of consistency exhibited in the pairwise comparison matrix is acceptable.

6. RESULTS

The obtained weights for criteria C_1, C_2, C_3, C_4 and C_5 are W_1 = 0.4548, W_2 = 0.2384, W_3 = 0.1632, W_4 = 0.0569, and W_5 = 0.0866, respectively. In similar fashion, according to the information in Table 4, the weights are computed for sub-criteria.

The combination of each criterion for the priorities of each decision alternative can be shown in the following formula.

$$P_r = \sum_{m=1}^{M}\sum_{n=1}^{N} W_m \times W_{mn} \times P_{rmn}$$

Where; P_r represents the shipping company's preference rate for the r^{th} port. P_{rmn} represent the preference assigned to the r^{th} port by the decision maker under criteria Cm and sub-criteria C_{mn}.

The procedure used to compute the overall priorities for each decision alternative can best be understood if it is thought of the priority for each criterion as a weight that reflects its importance. The overall priority for each decision alternative is obtained by summing the products of the criterion priority times the priority of its decision alternative. Ranking these priority values are given in the following AHP ranking of the decision alternatives.

Table 7: AHP Model Overall Priority Ranking

Alternatives	Priority
Piraeus Port	0.554
Candarli Port	0.340
Gioia Toura Port	0.106
Total	1,000

According to the obtained priority rate for the candidate ports, it can be said that the optimum hub-port in the Mediterranean Sea is Piraeus Port with its 0.554 priority rate. The priority rate for Candarli port is 0.340 while it is 0.106 for Gioia Toura Port.

7. CONCLUSION

This study was undertaken to design a hub-port selection model and evaluate all relevant factors to decide for the optimum hub-port. An AHP model is developed for the selection of container ports which can be considered to serve as a hub-port in the Mediterranean Sea. The research has shown that Piraeus port has the highest priority among three candidate ports as a result of the investigation of the influential factors affecting carrier's hub-port choice. The investigation of all ports in the region has also shown that location is the key factor for the selection of hub-port, because three candidate ports are top three ports in terms of distance to main navigation routes and import/export areas in total among the assessed 145 ports in 23 countries. Although the location criterion may be the most important criterion, the characteristic of the region plays a key role for the selection of hub-port. Therefore, it can be said that in the global container terminal industry, 'Proximity to Main Routes, Cities and Ports', 'Liner Shipping Connectivity Index', ' Port Operation Performance', 'Sufficient Port Capacity', and 'Investment to Develop Infrastructure Condition' have the highest importance weight above the global mean value for all sub-criteria. The AHP survey is conducted through this global container terminal industry perspective. The present study makes several noteworthy contributions to support the idea that the centralized ports are more suitable to serve as hub-port if they have appropriate infrastructural features.

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REFERENCES

Aversa, R., Botter, R., Haralambides, H. & Yoshizaki, H. 2005. A mixed integer programming model on the location of a hub port in the east coast of South America. *Maritime Economics & Logistics,* 7**,** 1-18.

Campbell, J. F. 1994. Integer programming formulations of discrete hub location problems. *European Journal of Operational Research,* 72**,** 387-405.

Chou, C.-C. 2010. AHP model for the container port choice in the multiple-ports region. *Journal of Marine Science and Technology,* 18**,** 221-232.

Hsu, C.-I. & Hsieh, Y.-P. 2007. Routing, ship size, and sailing frequency decision-making for a maritime hub-and-spoke container network. *Mathematical and Computer Modelling,* 45**,** 899-916.

Imai, A., Shintani, K. & Papadimitriou, S. 2009. Multi-port vs. Hub-and-Spoke port calls by containerships. *Transportation Research Part E: Logistics and Transportation Review,* 45**,** 740-757.

James, B. & Gail, B. 1988. The perception of route competition via seaports in the European communities. *Maritime Policy and Management,* 15**,** 35-55.

Jansson, J. 2012. *Liner shipping economics*, Springer Science & Business Media.

Notteboom, T. 2010. From multi-porting to a hub port configuration: the South African container port system in transition. *International Journal of Shipping and Transport Logistics,* 2**,** 224-245.

Notteboom, T. 2011. An application of multi-criteria analysis to the location of a container hub port in South Africa. *Maritime policy & management,* 38**,** 51-79.

Saaty, T. L. 1990. How to make a decision: the analytic hierarchy process. *European journal of operational research,* 48**,** 9-26.

Slack, B. 1985. Containerization, inter-port competition, and port selection. *Maritime policy and management,* 12**,** 293-303.

Stemberg, R. 2000. The successful factors of an ocean transshipment center, the case study of one Italian Port. *The journal of Chinese Ports,* 16**,** 13-18.

Tai, H.-H. & HWANG, C.-c. 2005. Analysis of hub port choice for container trunk lines in East Asia. *Journal of the Eastern Asia Society for Transportation Studies,* 6**,** 907-919.

Thomson, B. Structure changes in the maritime industry's impact on the inter-port competition in container trade. International conference on shipping development and port management, 1998.
Veldman, S. J. & Bückmann, E. H. 2003. A model on container port competition: an application for the West European container hub-ports. *Maritime Economics & Logistics,* 5**,** 3-22.
Wu, Y. 1988. The economics of containership route deployment. *GeoJournal,* 16**,** 301-314.
Zan, Y. 1999. Analysis of container port policy by the reaction of an equilibrium shipping market. *Maritime Policy & Management,* 26**,** 369-381.