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Study of the Competitiveness of Quanzhou Port on the Belt and Road in China Based on a Fuzzy-AHP and ELECTRE III Model

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Abstract: With the establishment of the Belt and Road national strategy, Quanzhou Port is a significant development opportunity. Quanzhou Port is the origin of the 21st century Maritime Silk Road and part of the Belt and Road, but as a pioneer project of the Maritime Silk Road and the main port in the Belt and Road strategy, its development has encountered some challenges and problems. Hence, this paper aims to evaluate the competitiveness of Quanzhou Port based on the criteria selected by experts and corresponding improvement suggestions are put forward for its weaknesses. Using fuzzy-AHP and ELECTRE III, port competitiveness is evaluated according to the total weights obtained based on the different criteria used. The key criteria consist of six factors (port size, port location, hinterland economy, port costs, operations management and growth potential) that are divided into 18 sub-criteria. Five competing ports were selected with respect to geographical proximity. The order of ranking according to ELECTRE III are as follows: Kaohsiung Port, Xiamen Port, Fuzhou Port, Taichug Port and Quanzhou Port. The findings show that the port of Quanzhou appears last in the ordering sequence, resulting in a need for integrative approaches to promote its competitiveness. Compared with competitive ports, Quanzhou Port has relatively weak overall infrastructure and relatively high port costs, which leads to a lack of obvious flow of port materials and a decrease in professional unloading services. Particularly in hinterland port economies, the industrial structure is extensive and backward. Hence, the question of how to achieve a green transformation of the manufacturing industry will be important for Quanzhou Port. This paper points out directions for the future development of Quanzhou Port and applies comprehensive evaluation methods, namely fuzzy-AHP and ELECTRE III.

Keywords: port competitiveness; fuzzy-AHP; ELECTRE III; Belt and Road; Quanzhou Port

1. Introduction

Ports are not only fundamental transport links in supply chain networks, but also important links for the development of the national economy and for changing the structure of world shipping. Hence, evaluating the competitiveness of ports has become an important issue related to their survival and development [1]. Hence, ports are considered to be an important factor in the development of national industries and the economic vitality of the country and need the strong support of national policy [2].

Proposed and led by China, the Belt and Road initiative involves massive infrastructure investments and ambitious plans to reduce non-tariff barriers to trade in Eurasia and Africa. The initiative consists of two parts: the land-based Silk Road Economic Belt and the Maritime Silk Road, covering areas with more than 60 countries, generating 55% of the world's GNP(Gross National

Product), affecting 70% of the global population, and transporting 75% of known energy reserves. Involving new roads, rail lines, ports and pipelines, it aims to boost connectivity and commerce across the region, with China as the hub. China's total financial commitment to the project is expected to reach 1.4 trillion dollars. Beijing has already committed around 300 billion dollars for infrastructure and trade financing in the coming years, including 40 billion dollars for the "Silk Road Fund" and initial capital of 50 billion dollars for the Asian Infrastructure Investment Bank (AIIB), initiated by China [3].

With the establishment of the Belt and Road national strategy, Quanzhou Port is a significant development opportunity. In 2015, with the release of the "Vision and Action to Promote the Silk Road Economic Belt and the 21st Century Maritime Silk Road", the construction of the Belt and Road shifted from strategy formulation to the implementation of enhanced planning and the promotion of specific projects [4]. China's Belt and Road initiative will impact the shipping industry in the future. China's Belt and Road global initiative is set to build land and ocean infrastructure to connect the country with Central and South Asia, Europe, the Middle East and Africa. Although known across the globe, the initiative seems so far to have slipped largely under the radar of the shipping community, and will have great impact on trade and shipping in the years ahead [5].

The interconnection of infrastructure as part of the construction of the Belt and Road is a strategic priority area. Quanzhou Port serves as a connecting point for the land-based Silk Road Economic Belt and the 21st Century Maritime Silk Road, and its strategic position is prominent. Focusing on key ports as a node, building an unimpeded and safe transport corridor is an important part of implementing the national strategy [6]. Quanzhou Port is the origin of the 21st Century Maritime Silk Road based on the Belt and Road, but as an important port on the southeast coast of China, its development has encountered some challenges and problems [7].

Most previous research has used the analytic hierarchy process (AHP) as the preferred analysis method to evaluate the competitiveness of the port. However, AHP is a subjective and qualitative analysis method, it is lacking with regard to sensitive issues such as identifying the exact tradeoffs and relative size of tradeoffs [8,9]. As opposed to methods that refer to all kinds of research materials and considering language fuzziness as well as the preference incomparability of qualitative methods, this study used multi-criteria methods combined with fuzzy-AHP and ELECTRE III. This approach can effectively eliminate personal biases in the choice of alternatives and can measure decision-makers' preferences regarding each decision criterion and balance conflicting criteria [10–12]. Additionally, other more comprehensive factors are also taken into account to make decisions more scientific and reasonable [13]. The main purpose of this paper is to establish how to improve the competitiveness of Quanzhou Port through an evaluation of the port's competitiveness. Adopting an evaluation model that combines quantitative and qualitative method not only provides a scientific basis for the future development of Quanzhou Port, but also provides a theoretical reference for other ports.

When evaluating port competitiveness, there are many factors that influence port competitiveness, such as the hinterland economy, geographic location, port infrastructure, transportation, information systems, etc., but few scholars have studied the growth potential of Quanzhou Port, especially the investment trend of the port and investment risk management. Due to the policy of China's Belt and Road initiative, the port will surely experience unprecedented development, with consequent huge investment [14]. Therefore, the growth potential of the port is an important evaluation index when evaluating port competitiveness.

Hence, the establishment of a plan to improve competitiveness by identifying the factors impeding the development of Quanzhou Port in accordance with rapid economic growth and the development of foreign trade [15]. At the same time, there is fierce competition among ports in the coastal areas of Fujian province, especially Xiamen Port and Fuzhou Port, to be the hub port of the Silk Road. In this context, strategy alternatives are sought for the continuous improvement of port competitiveness in the fierce competition among ports in the southeast. For this reason, the paper aims to firstly investigate the main factors for the evaluation of port competitiveness through a literature review; secondly, use the fuzzy-AHP and ELECTRE III methodologies to compare port competitiveness among ports in the southeast coastal areas; and finally, find ways to improve port competitiveness.

The rest of this article is organized as follows. The relevant literatures on the topic is outlined in Section 2. The research method and model of this paper are described in Section 3. The empirical analysis is provided in Section 4. Finally, conclusions are drawn, suggestions are made and future research is suggested in Section 5.

2. Literature Review and Evaluating Indicators

High harbor competitiveness means that a particular port has a comparative advantage in comparison with other ports when a port is being chosen by a ship or shippers. Van De Voorde et al. defined port competitiveness as a competitiveness of the logistics system in order to create port trade volume and to enhance the efficient operation of port operations and supplementary services [16].

Yi-Chih Yang and Shu-Ling Chen explored global logistics hub port assessment criteria and compared the competitiveness of three major international hub ports in Northeast Asia, namely the ports of Busan, Tokyo, and Kaohsiung, using the AHP and GRA (gray relational analysis) methods. A total of 20 assessment criteria were obtained under the five dimensions of political–economic environment, operating environment, cost environment, infrastructure facilities environment, and preferential incentive environment [17]. Kim divided the main relevant criteria into three major categories—port throughput, physical and financial criteria—in a competitiveness analysis of ports in Korea and China by entropy weight TOPSIS (technique for order preference by similarity to ideal solution) [18].

With changes to port environments, the service quality and hinterland conditions, landside accessibility, strategy differentiation, port (terminal) operational efficiency level, reliability, cargo handling charges, and the port selection preference of carriers and shippers have become the major factors that influence port competitiveness [19–21].

Imai indicated that the handling efficiency of mega ships is evaluated by the handling time, while other ships' handling efficiency is determined by handling time plus waiting time [22]. They argued that an efficient ship handling service in a port is particularly important to avoid the complexities of berthing small ships in terms of total service time, because mega ships have priority at the berth [23].

Guangqi Sun analyzed six aspects of the port competitiveness of Dalian Port, namely hinterland economy, geographical location, port infrastructure, traffic linkage, information system and policy support. The large industrial complex and efficient information system in the harbor hinterland were evaluated as factors that maintain high competitiveness [24].

Xiangyang Ma applied the AHP technique to analyze the competitiveness of Nantong Port by using four factors: the hinterland economy, port location, port size, and development potential. As a result, it was confirmed that the scale of the hinterland economy and the port location were the main factors for securing port competitiveness [25].

Peng Zhang applied the fuzzy-AHP technique for the evaluation of the competitiveness of Tianjin Port in relation to six aspects: hinterland economy, cargo capacity, infrastructure, transportation linkage, operation management, and geographical location. For comparison, Shanghai Port, Busan Port, and Zhoushan Port were selected, and Tianjin Port was analyzed as having the best infrastructure and traffic connectivity [26].

Yang identified key assessment criteria for the development of FTZs (free trade zones), including the integration of customs clearance and port logistics information systems, operational efficiency, exemption from customs duties, market economies of scale, incentives for business investment, labor costs, transportation and distribution costs, efficiency of the intermodal transportation network, land cost, and port logistics facilities [27].

From a systems perspective, Zhang found that the port logistics system assessment criteria can include geographic and natural environmental factors, infrastructure factors, port logistics support factors, operational status, port logistics management, and the service level [28].

Gordon et al. analyzed the port of Singapore in terms of infrastructure, government policy, port operation, information systems, and geographical location. In particular, it has a significant impact on competitiveness [29]. Tongzon applied factors to port choice and found via the existing literature, including high port efficiency, good geographical location, low port charges, adequate infrastructure, wide range of port services, and connectivity to other ports. Among these factors, adequate infrastructure was important for port selection [30].

Jeong used five factors and 14 indicators: port location, port facility, port cost, operation management, and the hinterland economy [31]. Yeo et al. pointed out that crucial elements of port competitiveness are shifting from hardware port expansion to software technology, and that efficient port-linked logistics systems are particularly important for ports with competitive power [32].

Kim et al. analyzed the structure of competitiveness between hub ports in the multipolar northeast Asia and used exploratory factor analysis underpinning 19 measurement scales and a four-factor model incorporating availability, operational efficiency, port costs and service quality [33]. Sayaneh and Alizmini, using TOPSIS and AHP, found that the working time, stevedoring rate, safety, port entrance, sufficient draft, capacity of port facilities, operating cost, number of berths, ship channeling, and international policies are critical factors for selecting a container seaport in the Persian Gulf [34]. Table 1 provides a literature review on port competitiveness.

Table 1. Literature review on port competitiveness.

Authors	Main Relevant Criteria	Research Methods
Yang and Chen	Political–economic, operating, cost, infrastructure facilities, and preferential incentive	AHP and GRA
Kim	Port throughput, physical and financial criteria	Entropy Weight TOPSIS
Ahn et al.	Port location, port costs, port service, port facility port marketing	IPA(Importance-Performance Analysis)
Cho et al.	The cognitive service quality of ports, customer satisfaction, and post-behaviour	
Guangqi Sun	Hinterland economy, geographic location, port infrastructure, traffic linkage, information system, policy support	AHP
Xiangyang Ma	Hinterland economy, port location, port size, development potential	AHP
Peng Zhang	Hinterland economy, cargo capacity, infrastructure, transportation linkage, operation management, geographic location	Fuzzy-AHP
Yang	Port logistics information systems, operational efficiency, incentives for business investment, port costs, efficiency of the intermodal transportation network, and port logistics facilities	Fuzzy-AHP
Gordon et al.	Infrastructure, government policy, port operation, information system, geographic location	
Tongzon	Port efficiency, geographic location, port charges, infrastructure, port services, connectivity to other ports	
Jeong	Port location, port facility, port cost, operation management, and hinterland economy	AHP
Kim et al.	Availability, operational efficiency, port costs, service quality	Exploratory Factor Analysis
Sayaneh and Alizmini	Working time, stevedoring rate, safety, port entrance, sufficient draft, capacity of port facilities, operating cost, number of berths, ship channeling, international policies	TOPSIS and AHP

3. Methods

3.1. Study Area

In March 2015, the National Development and Reform Commission, Ministry of Foreign Affairs, and Ministry of Commerce of the People's Republic of China, with the authorization of the State

Council, issued the vision and actions for jointly building Silk Road Economic Belt and 21st Century Maritime Silk Road. The vision and actions make it clear that the central government supports Fujian in becoming the core area of the 21st Century Maritime Silk Road. This is a great historical development opportunity for the port of Quanzhou, which has had the most economic development of the coastal ports of Fujian province and has a long history of maritime trade.

However, the competition with nearby ports has become increasingly fierce. Quanzhou Port, Xiamen Port, and Fuzhou Port have also been selected as important cities for the Belt and Road initiative. They proposed the idea of establishing a hub of the Maritime Silk Road and intensified the competition for becoming the international hub of the Maritime Silk Road. Xiamen Port and Fuzhou Port are the main hub ports in China. However, compared with Xiamen Port and Fuzhou Port, Quanzhou Port is at a disadvantage in the port competition.

Due to different national policies and geographic advantages, Quanzhou Port has not developed as well as Xiamen and Fuzhou, and is squeezed by Xiamen and Fuzhou.

Xiamen is a special economic zone and Fuzhou is a provincial capital city. They have unparalleled advantages in terms of policies, funds, and talents. As a result, nearly 70% of the cargo in Quanzhou Port flows to ports such as Xiamen and Fuzhou. At the same time, Kaohsiung Port and Taichung Port across the strait have perfect port services and location advantages. Kaohsiung Port is the largest and most powerful port in the vicinity. The Chinese mainland and Taiwan are vigorously promoting maritime transport across the Taiwan Strait. This has seriously affected and restricted the development of Quanzhou Port.

Hence, in this study, Quanzhou Port (A1), Xiamen Port (A2) and Fuzhou Port (A3) in Fujian province, and Kaohsiung Port (A4) and Taichung Port (A5) in Taiwan were selected for comparative analysis, as shown in Figure 1.

Figure 1. The main ports around Quanzhou.

3.2. Assessment Variables

The core evaluation items are based on previous research, such as cargo volume, port facility, port location, port cost, service level, cargo capacity, port cost, port reputation, frequency, preference, logistics infrastructure, information communication, investment environment, accessibility, position on the main route, berth availability, port vessels, depth, inland transportation fares, entrance and exit costs, port labor stability, and backward transportation. Next, panelists were grouped according to six criteria through panel consensus. Port size, port location, hinterland economy, port cost, operation management, and growth potential were selected, and 18 items were selected by setting three detailed evaluation items constituting each evaluation criteria. These are port size (port throughput, container throughput, infrastructure), port location (geographic location, channel depth, number of working days throughout the year), hinterland economy (size of industry, import/export scale, industrial structure), port costs (inbound and outbound costs, loading costs, storage transportation costs), operational management (traffic connectivity, customs clearance, loading capacity), growth potential (government policy, investment trend, investment risk management). In this study, the growth potential was taken into account, especially in the activation of ports. Based on the selected finite number of alternatives and evaluation criteria, the hierarchical structure of the problem is shown in Table 2. The port service level is an important criterion for measuring the competitiveness of the port. The level of service directly affects the preference and loyalty of the shipping companies for the port and plays an important role in the development of the port. In this paper, port operation management involves a part of the level of port services, but we did not use port service levels as an evaluation criterion in the evaluation index system of port competitiveness, and future studies should strengthen the evaluation of port service levels.

Table 2. Hierarchy for the competitiveness assessment.

Level I	Level II
Port Size	Port throughput (S1) Container throughput (S2) Infrastructure (S3)
Port Location	Geographical location (L1) Channel depth (L2) Number of working days (L3)
Hinterland Economy	Size of industry (H1) Import/export scale (H2) Industrial structure (H3)
Port Cost	Inbound/outbound costs (C1) Loading costs (C2) Storage transportation costs (C3)
Operation Management	Traffic connectivity (O1) Customs clearance (O2) Loading capacity (O3)
Growth Potential	Government policy (G1) Investment trend (G2) Investment risk management (G3)

A detailed description of the evaluation items is as follows. Port size refers to the harbor handling volume and infrastructure status. Port location refers to the geographic location in which the port is located and includes water depth and working conditions. The hinterland economy refers to the size and structure of the port hinterland industrial complex and the volume of import and export transactions. The port cost refers to the costs related to the use of the port, such as inbound and outbound costs, and loading costs. Operational management is a factor that shows the expertise of port logistics services such as cargo capacity and traffic connection. Growth potential includes government policy support, investment trends, and investment risk management.

3.3. Multi-Criteria Decision Making: Fuzzy AHP-ELECTRE III

In this study, we used fuzzy-AHP and ELECTRE III, which are used in multi-criteria decision-making models, to evaluate the importance of harbor competitiveness evaluation factors hierarchically. This model can be used to derive the weight of the evaluation factors by using AHP and apply the ranking preference of alternatives in ELECTRE III to obtain reliable results using a number of questionnaires. Fuzzy-AHP was initiated by Laarhoven and Pedrycz by combining Satty's theory with fuzzy theory, and Chang proposed a technique using trigonometric fuzzy numbers through the extent analysis method (EAM) [35,36]. In this study, Chang's EAM was applied, which is a technique for expressing the degree of satisfaction with regard to a set of objects with an extent for a goal set.

Recently, some evaluation models have been developed, each with certain constraints. AHP and fuzzy models can only handle ordinal data. ELECTRE III can analyze different criteria without converting them into a single scale as GAs (genetic algorithms) do [37]. ELECTRE III uses various mathematical functions to indicate the degree of dominance of one alternative or group of alternatives over the remaining ones. It also facilitates comparisons between alternative schemes by assigning weights to the decision criteria. The outranking relationships between alternatives are constructed and eventually exploited [38,39].

In this paper, the fuzzy-AHP and ELECTRE III method is proposed for solving the alternative selection problems for the following reasons:

(1) This is a scientific and systematic approach for decision-making.
(2) This approach can effectively eliminate personal biases in the choice of alternatives.
(3) The method can measure decision makers' preferences towards each decision criterion and balance the conflicting criteria.

ELECTRE III is adopted in this study because this method involves some aspects that are often neglected by the other methods and to yield relatively stable results [40]. The use of ELECTRE III can systematically analyze expert judgments on the decision factors and alternatives that can rationalize the selection process. The outranking relation represents the decision-makers' preferences, which are established in their minds. The outranking method facilitates comparison between alternatives by ascribing initial weights as part of a sensitivity analysis, if their exact value is not known. The comparison between alternatives is carried out on a pairwise basis and then the degree of dominance or outranking of one option over another is established [41,42].

ELECTRE III compares the two alternatives (a, b) based on the assumption of a preference's non-transitivity and the incomparability of alternatives. Hence, if the decision-maker judges that alternative a is the alternative that is not less than alternative b, even if there is no mathematically dominant relation between the two alternatives a and b, the subjective preference of the decision-maker who chooses alternative a is defined as the ranking preference.

Based on this ranking preference relation, systematically eliminating inferior alternatives to determine the ranking of comparison alternatives, the ranking preference relation of the compared alternatives is measured by the concordance and the discordance index. The concordance index shows a trend where decision-makers choose alternative a, considering the weight of the evaluation items and determining that alternative a is superior to alternative b. The discordance index shows that alternative a is generally superior to alternative b, but the decision-makers tend to choose alternative b by giving a very high score to b. In this study, ELECTRE III is used to rank alternatives [43].

The concordance index $c_j(a,b)$ in ELECTRE III indicates the tendency of the decision-maker to choose alternative a, considering the weight of the evaluation criterion where alternative a is judged to be superior to alternative b. The concordance index contains the membership value of the fuzzy theory, has a value between 0 and 1, and determines that alternative a is relatively more favorable than alternative b if the index is large. That is, when $c_j(a,b)$ is close to 1, the value belong to the fuzzy set, and when it is close to 0, it is low. The evaluation value $g_j(a)$ of alternative a is determined with respect to the evaluation criterion j, and the evaluation value $g_j(b)$ of alternative b is determined with respect to the evaluation criterion j. When we define the indifference threshold (q_j), the preferred threshold value (p_j), $c_j(a,b)$ is defined as follows.

$$c_j(a,b) = \begin{cases} 1, & if\ g_j(a) + q_j \geq g_j(b) \\ 0, & if\ g_j(a) + p_j < g_j(b) \\ \dfrac{p_j + q_j(a) - g_j(b)}{p_j - q_j}, & otherwise \end{cases} \quad (1)$$

Using the correspondence index, the correspondence relation $C(a,b)$ is defined as follows.

$$C(a,b) = \frac{1}{K}\sum_{j=1}^{n} k_j c_j(a,b) \tag{2}$$

$$K = \sum_{j=1}^{n} k_j \;\; j = 1, \ldots, n \tag{3}$$

The discordance index d_j shows the tendency of decision-makers to select alternative b by giving a very high score to alternative b, even though alternative a is an overall superior to alternative b. The discordance index has a value between 0 and 1, and the index increases as the difference between the performance of alternative b compared to alternative a becomes larger, so that alternative b is preferred to alternative a. That is, the ranking preference relationship is determined by the weight of the evaluation criteria and the difference of the evaluation scores of the comparison alternatives. Hence, for all evaluation criteria, when alternative a is defined as the opposite threshold (v_j) to avoid error and is at least a good an alternative to alternative b, d_j is defined as follows.

$$d_{\mathrm{j}}(a,b) = \begin{cases} 0, & if\ g_j(a) + p_j \geq g_j(b) \\ 1, & if\ g_j(a) + v_j \geq g_j(b) \\ \dfrac{g_j(b) - g_j(a) - p_j}{v_j - p_j}, & otherwise \end{cases} \tag{4}$$

The discordance relation, $D(a,b)$ is an index considering the correspondence due to the discordance and is defined as follows.

$$D(a,b) = \frac{1}{n}\sum_{j=1}^{n} f(d_j(a,b), c_j(a,b)) \tag{5}$$

$$f(d_j(a,b), c_j(a,b)) = \begin{cases} 1, & d(\bullet) \prec C(\bullet) \\ \dfrac{1 - d_j}{1 - C(\bullet)}, & d_j(\bullet) \succ C(\bullet) \end{cases} \tag{6}$$

Fuzzy outranking relations consider the relationship between the concordance and the discordance; the definition is as follows.

$$aSb = C(a,b) \bullet D(a,b) \tag{7}$$

Finally, the fuzzy dominance relation and the fuzzy non-dominance relation determine the ranking of alternatives and are defined as follows [44].

Fuzzy dominance relation:

$$R_D(a,b) = \begin{cases} aSb - bSa, & if\ aSb \succ bSa \\ 0, & otherwise \end{cases} \tag{8}$$

Fuzzy non-dominance relation:

$$R_{ND}(a,b) = 1 - R_D(a,b) \tag{9}$$

Set of dominant alternatives:

$$\begin{aligned} R^*(Alternative_a) &= \min[1 - R_D(a,b)] \\ &= 1 - \max R_D(a,b) \\ &= 1 - \max[bSa - aSb] \end{aligned} \tag{10}$$

The best alternative:

$$R^*(Alternative^{*a}) = \max R^*(Alternative_a) = 1 - \min\max[bSa - aSb] \quad (11)$$

3.4. Data Collection

In this study, we conducted a survey of universities, research institutes, enterprises and local governments affiliated with the port from 26 December 2017 to 10 February 2018, through email, telephone interviews and actual visits. A total of 150 questionnaires were received. Specifically, the collection of questionnaires included the port management department (20), university (30), research institutes (25) and enterprises (75). The organizations and positions of the respondents are listed in Table 3.

Table 3. Details of survey respondents.

Type	Organizations and Positions
Port management department (20)	Quanzhou Port (Manager), Fuzhou Port (Manager), Xiamen Port (Manager), Fujian Province (Director)
University (30)	Huaqiao University (Professor of Logistics), Xiamen University (Professor of Logistics)
Research institute (25)	Quanzhou Port Association, Maritime Silk Road Institute
Enterprise (75)	Port of Kaohsiung Taiwan International Ports Corporation (Employee), Port of Taichug Taiwan International Ports Corporation (Employee, Manager), Fujian All-Trans Port Development Company (Manager), COSCO Logistic, (Fuzhou), COSCO Logistic (Manager Quanzhou), COSCO Logistic (staff Xiamen), Fujian Xington Shipping Group (Employee, Manager, Manager), Quanzhou Ocean Shipping Agency (Employee, Manager), COSCO International Freight Company (Manager), Quanzhou Harbor Group (Manager), Xiamen Port Holding Group (Manager), Quanzhou Pacific Container Terminal (Employee)

4. Data Analysis and Results

After selecting the evaluation criteria and alternatives, the procedure of the integrated fuzzy-AHP and ELECTRE III model is as follows.

4.1. Fuzzy-AHP Analysis

The logical consistency of the survey respondents was examined and the consistency ratio (CR) was less than 10%. Fuzzy-AHP was applied based on the obtained responses to derive the weight of the evaluation criteria. The results of this study are as follows: the growth potential was 27.10%, the port location was 25.4%, the hinterland economy was 23.3%, the operation management was 16.2%, the port size was 6.7% and the port cost was 1.3%. In particular, the growth potential, port location, and hinterland economy were important (refer to Table 4). Due to the increasingly fierce competition from nearby ports, in order to attract more ships, these ports are reducing their own port costs, so the port cost factor is not very important in this area.

Table 4. Final weight of evaluation criteria.

Level I		Level II		Final Weight
Item	**Weight**	**Item**	**Weight**	
Port Size	0.067	Port throughput (S1)	0.301	0.020
		Container throughput (S2)	0.522	0.035
		Infrastructure (S3)	0.177	0.012
Port Location	0.254	Geographical location (L1)	0.571	0.145
		Channel depth (L2)	0.008	0.002
		Number of working days (L3)	0.421	0.107
Hinterland Economy	0.233	Size of industry (H1)	0.450	0.105
		Import/export scale (H2)	0.121	0.028
		Industrial structure (H3)	0.429	0.100
Port Cost	0.013	Inbound/outbound costs (C1)	0.420	0.005
		Loading costs (C2)	0.498	0.006
		Storage transportation costs (C3)	0.082	0.001
Operation Management	0.162	Traffic connectivity (O1)	0.591	0.096
		Customs clearance (O2)	0.153	0.025
		Loading capacity (O3)	0.256	0.042
Growth Potential	0.271	Government policy (G1)	0.516	0.140
		Investment trend (G2)	0.141	0.038
		Investment risk management (G3)	0.343	0.093

Derive the relative weight of the competitive port based on the evaluation criteria (refer to Table 5). Near the port of Quanzhou (A1), four competing ports were selected: Xiamen Port (A2), Fuzhou Port (A3), Kaohsiung Port (A4) and Taichung Port (A5). In this study, the preference for a competitive port according to the evaluation criteria was obtained using the triangular fuzzy number. As a result, the preference was expressed as a weighted value. The number of triangular fuzzy numbers is easily utilized because it is easy to express preferences intuitively by respondents using three points (lower limit, median, upper limit).

Table 5. Scores for evaluation criteria.

	A1	A2	A3	A4	A5
S1	4.15	5.93	3.79	6.27	3.49
S2	2.85	6.11	3.82	6.39	3.62
S3	2.92	6.19	4.15	6.23	4.59
L1	4.05	5.92	3.95	6.15	4.09
L2	5.32	5.92	4.69	6.15	4.89
L3	5.88	5.96	5.08	6.07	5.62
H1	5.3	6.12	4.62	6.01	4.39
H2	4.75	6.07	4.42	6.11	4.52
H3	3.25	5.89	4.59	6.03	4.52
C1	3.59	5.34	3.95	6.19	4.79
C2	3.79	5.28	4.15	6.13	4.92
C3	3.45	5.25	3.95	6.11	4.95
O1	3.12	6.1	5.16	6.36	4.65
O2	3.99	5.89	4.79	6.22	4.75
O3	3.69	6.15	5.03	6.19	4.85
G1	4.76	6.03	5.5	5.88	4.99
G2	4.79	6.07	5.43	6.1	4.76
G3	3.65	5.57	4.52	6.07	4.76

Overall, Table 5 shows that Kaohsiung Port and Xiamen Port are on the first level, and the overall competitiveness is at a high level. Fuzhou Port and Taichung Port are on the second level, and the overall competitiveness is average; Quanzhou Port is on the third level. With regard to the detailed evaluation items, 10 items for Quanzhou Port were low, among them, Quanzhou Port is at an absolute disadvantage in terms of infrastructure, container throughput, industrial structure, transportation connectivity, and port cost. While in terms of size of industry and port throughput, Quanzhou Port has an advantage.

4.2. ELECTRE III Analysis

Pseudo-criteria should be set to minimize the inaccuracies or uncertainties of survey respondents with regard to alternative preferences for the evaluation criteria. The most important feature of ELECTRE III is that the method for ranking alternatives uses pseudo-criteria, and uses an indiscriminate threshold (q_j), preference threshold (p_j), and reverse threshold (v_j). If there is no standard criterion set, it is determined by the subjective judgment of the decision-maker. However, according to Rogers and Bruen, it has been suggested that the preference threshold can be set at 2–3 times the indifference threshold and 5–6 times the opposite threshold [45].

The correspondence relation and inconsistency relation were calculated using Equations (1)–(4). Tables 6 and 7 summarize the correspondence relations and inconsistency relations, respectively. According to Equation (5), the fuzzy rank preference relation is derived by using the relation of concordance and discordance, and Table 8 summarizes this.

Table 6. Concordance relation.

	A1	A2	A3	A4	A5
A1	1	0.128	0.469	0.153	0.671
A2	1	1	1	0.849	1
A3	0.738	0.207	1	0.227	0.813
A4	1	1	1	1	1
A5	0.864	0.228	0.909	0.126	1

Table 7. Discordance relation.

	A1	A2	A3	A4	A5
A1	1	0.530	1	0.417	1
A2	1	1	1	1	1
A3	1	0.736	1	0.649	1
A4	1	1	1	1	1
A5	1	0.701	1	0.656	1

Table 8. Fuzzy outranking relation.

	A1	A2	A3	A4	A5
A1	1	0.068	0.469	0.064	0.671
A2	1	1	1	0.849	1
A3	0.738	0.152	1	0.147	0.813
A4	1	1	1	1	1
A5	0.864	0.159	0.909	0.083	1

In order to determine the ranking of the alternatives in descending order, the fuzzy dominant relation was derived by Equation (6). The fuzzy non-dominance relation is calculated by Equation (7). Tables 9 and 10 summarizes these.

Table 9. Fuzzy dominance relation.

	A1	A2	A3	A4	A5
A1	0	0	0	0	0
A2	0.931	0	0.847	0	0.84
A3	0.269	0	0	0	0
A4	0.935	0.15	0.852	0	0.916
A5	0.193	0	0.095	0	0

Table 10. Fuzzy non-dominance relation.

	A1	A2	A3	A4	A5
A1	1	1	1	1	1
A2	0.068	1	0.152	1	0.159
A3	0.73	1	1	1	1
A4	0.064	0.849	0.147	1	0.083
A5	0.806	1	0.904	1	1

Finally, using the Equations (8) and (9), the dominant index was derived for each alternative. Case I was analyzed using basic thresholds. The results show that A4 (Kaohsiung Port) was the most competitive, followed by A2 (Xiamen Port), A3 (Fuzhou Port), A5 (Taichung Port) and A1 (Quanzhou Port). In particular, there were three groups, A4 (1.000) and A2 (0.849), the second A3 (0.1476), the third A5 (0.0831) and A1 (0.0641). This can be interpreted as indicating that the port conditions are similar for each group. On the other hand, A1 (Quanzhou Port) is considered to have very low competitiveness compared to the other ports.

On the other hand, Case II and Case III show a priority change with regard to the alternative according to the change in the threshold. Case II increased the non-discrimination threshold of Case I two times, the preference and opposite thresholds were respectively applied at twice or five times the non-discrimination threshold, the result was A4 → A2 → A3 → A5 → A1. Case III set a higher pseudo-reference threshold at 2.5 times that of Case I, and the preference and opposite thresholds were two and four times greater, respectively. The results were A4 → A2 → A3 → A5 → A1. Hence, there was no change in the ranking of competitiveness according to the threshold changes, which means that there was some difference in the competitiveness of the port; Table 11 summarizes this.

Table 11. Degree of dominance.

Case	A1	A2	A3	A4	A5
I	0.064	0.849	0.147	1	0.083
II	0.293	0.895	0.544	1	0.500
III	0.470	0.944	0.680	1	0.637

4.3. Implications

Quanzhou Port ranks fifth among the five nearby ports in terms of overall competitiveness. According to the Belt and Road policy, Quanzhou was recently designated as the starting point of the Maritime Silk Road. It can be found that there is a high probability of growth, and a systematic growth strategy is required. So far, the port logistics in Fujian Province are developing, mainly centered in Xiamen Port and Fuzhou Port. Hence, the relatively distant Quanzhou Port inevitably faces fierce competition.

When Quanzhou Port is compared with the more competitive ports, it can be seen that its overall infrastructure is relatively weak and the port costs are relatively high. Hence, the port logistics volume is not obvious and the professional unloading service has also declined. In particular, in the port logistics system, the connection with roads and railways behind the port is very important and this will be an important issue for Quanzhou Port.

5. Conclusions and Discussion

5.1. Conclusions

China has been promoting the Belt and Road policy and selected Quanzhou Port in Fujian Province as the starting point for the 21st Century Maritime Silk Road. Quanzhou Port belonged to the four major ports of China in the Tang Dynasty, and it was the historical port that was responsible for sending china and tea all over the world. However, the port logistics system has been established centering on Xiamen Port and Fuzhou Port, currently located in the capital of Fujian Province and on the two sides of the Taiwan Strait. Hence, this study aimed to evaluate the factors affecting the development of Quanzhou Port, which is facing fierce competition from neighboring ports after the declaration of the Belt and Road policy of China.

In order to evaluate the port's competitiveness, we applied two decision-making techniques—fuzzy-AHP and ELECTRE III—to evaluate six major factors, namely port size, port location, hinterland economy, port cost, operations management, and growth potential. At the same time, we analyzed the importance of 18 subscales. The results were as follows.

First of all, the ranking of the major factors was: growth potential 27.10%, port location 25.4%, hinterland economy 23.3%, operations management 16.2%, port size 6.7% and port cost 1.3%. Hence, it is necessary to develop policies to take the relative growth potential, port location and economic factors into account. In particular, it is essential to expand the infrastructure of the port and to activate the industrial complex using the wide hinterland.

Secondly, based on 18 detailed assessment criteria, the competitiveness of the five ports was analyzed. As a result, the ranking in terms of competitiveness was as follows: Kaohsiung Port, Xiamen Port, Fuzhou Port, Taichug Port, and Quanzhou Port. Quanzhou Port is the lowest ranked in the results. In particular, although ELECTRE III changed the threshold of the pseudo-standard, it was able to ascertain the order volatility of the alternatives, but there was no change in ranking preference.

Thirdly, of the 18 detailed evaluation items, 10 items for Quanzhou port were low, among them it was found that Quanzhou port was at an absolute disadvantage in terms of infrastructure, container throughput, industrial structure, transportation connectivity, and port cost. Thus, it is necessary to develop a strategy to strengthen the overall competitiveness. In particular, it is necessary to reduce the port cost through the expansion of the port infrastructure, and it is necessary to continuously secure the cargo volume.

5.2. Suggestions for Improvement

Judging by the disadvantaged and advantaged assessment items for Quanzhou Port, policy implications should be further improved as follow.

(1) Establishing a perfect system of distribution and transportation.

Quanzhou Port needs to improve cooperation with the railway system to develop combined sea–rail transport and to speed up the integration of dry-land resources, and moreover, to actively build a well-established and smooth network system for distribution and transport. The hinterland of the port must be expanded by vigorously developing multimodal transport and coastal feeder transport, and utilizing various transport modes to attract more cargo sources for port development. In particular, it is necessary to speed up the construction of the Quanzhou expressway network, Jiyongquan railway, Fuxia railway, and Changquan railway, and effectively strengthen the convergence and integration between different modes of transport to provide a more comprehensive and coordinated transport network for port development.

(2) Strengthening infrastructure construction and increasing container throughput.

The government should increase the investment in the construction of Quanzhou Port and increase the construction of large-scale, deep-water berths (especially large-scale, deep-water container berths) to enhance its comprehensive capacity. According to recent policy, during the 13th Five-Year Plan period, the government plans to invest 116.93 billion yuan in port construction. Under the guarantee of sufficient funds, Quanzhou Port should intensify its efforts to promote construction.

In order to increase port container volume, incentives can be granted to shipping companies, who will add the port to a new shipping route or increase the sailing frequency. For example, port authorities in Korea have provided incentives including a reduction of or exemption from dockage charges, wharf fees, and equipment usage fees, and even the provision of marketing assistance measures, to encourage such decisions. For instance, Busan port's "Transshipment Cargo Incentive Measures" have provided a total of 12 billion Korean won to shipping companies since 2006, which led to the growth of 20.52% in transshipment cargo from 2006 to 2010.

(3) Vigorously developing the private economy and striving to achieve the transformation and upgrading of the manufacturing industry.

Under the current situation, Quanzhou should focus on the first step in the internationalization of the private economy and strive to become a strategic highland for China to open up to Southeast Asia and the Middle East. Focus should be on the cultivation and expansion of private enterprises and the relyiance on pilot projects for comprehensive reform of the national-level private economy to create an institutional environment for investment trade facilitation and liberalization. Quanzhou should further enhance the international competitiveness of private enterprises and expand the two-way investment cooperation between Quanzhou and the Maritime Silk Road and adhere to the principle of "high-level introduction" and "large-scale global investment" and encourage private enterprises to "go global".

At the same time, Quanzhou should focus on the green transformation of the manufacturing industry. Quanzhou has currently formed five industrial clusters with output values exceeding 100 billion yuan in petrochemicals, textiles and garments, footwear, equipment manufacturing, construction and building materials. Quanzhou should further support the all-round innovation of enterprises, promote Quanzhou's "manufacturing" to "creation" and "intelligence making" in Quanzhou, and build a green manufacturing base for the Maritime Silk Road.

(4) Exerting the advantages of a "hometown of overseas Chinese" and building an international port.

By leveraging its strengths of deep connection with overseas Chinese, a dynamic private sector, and profound Islamic culture, Quanzhou should take the initiative to attract overseas Chinese to take part in the construction of the core area, encouraging private businesses to go global, promoting international exchanges, making international financial innovations, and transforming the manufacturing sector to be more environmentally friendly. Quanzhou should aim to open up to a new high level of cooperation with countries and regions in Southeast Asia, South Asia, West Asia and North Africa.

This study evaluates the current competitiveness of Quanzhou Port, which is a less well-known port in China. However, this study did have some limitations, for instance, it failed to conduct a full questionnaire survey of respondents in various fields; and safety was not taken into account in the assessment criteria for port competitiveness. However, the results of the study provide a direction for Quanzhou Port's development. In order to accurately diagnose Quanzhou Port's competitiveness and establish a growth strategy, it is important to periodically accumulate analytical data. Judging from the results of the current study, it is necessary to constantly seek ways to differentiate ports and cooperate with neighboring ports.

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