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A Study on the Classification of Chinese Major Ports based on Competitiveness Level

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Abstract : *Since the beginning of open-door policy, China has been making rapid annual growth with an average 10% economic development. And due to this rapid growth, cargo volumes via ports have been also rapidly increased, and accordingly, current China government has intensively invested in port development. Further, this development project is significantly big scale, compared with those projects which Korea and Japan have. Thus, China is beginning to threaten Korean ports, especially Busan port which try to be a hub port in Northeast Asia. For this reason, it has been very important issue for Korea and Busan port to investigate or analyze Chinese ports based on empirical data. Especially, although various studies related to Shanghai and Hong Kong have been conducted, the competitiveness of overall Chinese major ports has been little studied. In this paper, we analyzed competitiveness level of eight Chinese ports with capabilities as container terminal, based on reliable sources. From data analysis, eight Chinese ports were classified into four groups according to competitiveness level. Rankings among four clusters based on competitiveness level are cluster B(Hong Kong), cluster C(Shanghai), cluster A(,Qingdao, Tianjin, and Yantian) and cluster D(Dalian, Shekou, and Xiamen).*

Key words : *Northeast Asia, Chinese Container Ports, FCM(Fuzzy C-means), Hub-port, Port competitiveness*

1. Introduction

Port has been an area where ships load and unload goods or passengers. However, today's port is recognized as multi-functional area for leisure, information and business as well as for logistics service(Lee, 2000). Further, due to the rapid changes in world trade and shipping environment, today's ports face ever-increasing competition, from adjacent competing ports -especially container ports or terminals.

To maintain the competitiveness of a port, each country spurs its port industry to meet more diversified demands in the era of logistics through the expansion and improvement of port facilities and services. Especially, it is well known that competition among countries in Northeast Asia is a most striking phenomenon. To be a hub port in Northeast Asia, Korea spurs development of new container terminal, and at the same time, builds various strategies to promote port logistics related industries. However, other adjacent countries, such as China and Japan, also progress big projects for hub port.

In particular, since the beginning of open-door policy, China has been making rapid annual growth with an average 10% economic development. And due to this rapid growth, cargo volumes via ports have been also rapidly increased, and accordingly, China government have recognized the importance of a container port. In order to be a hub-port in Northeast Asia, current China government has intensively invested in port development. Further, this development project is significantly big scale, compared with those projects which Korea and Japan have. Thus, China is beginning to threaten Korean ports, especially Busan port which try to be a hub port in Northeast Asia.

For this reason, it has been very important issue for Korea and Busan port to investigate or analyze Chinese ports based on empirical data. However, although studies on analysis of Shanghai and Hong Kong port have been much reported, other container ports which have competitiveness in China have been little investigated. Moreover, overall competitiveness level of Chinese container ports including Shanhai and Hong Kong port have not been investigated. In fact, it is not well known that China has more two container ports except Shanghai and Hong Kong in the world's top 30 in terms of TEUs handled per annum. That is, in order to face competition among adjacent ports, it is surely necessary to have enough informations about adjacent ports. However, because the most of previous studies have only dealt with parts of all, it is still unknown overall competition level of Chinese container ports. That is, there has been no research to classify and analyzed overall

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Chinese container ports, based on competitiveness level. Due to the lack of this research, Busan port may have simple strategies to face compete with only both two ports, Hong Kong and Shanghai, without consideration for development of the other Chinese major ports. Current Chinese government spurs development of various container ports such as Qingtao and Tiangin as well as Hong Kong and Shianhai. Thus, in this time, to build more various strategies for hub port. it is necessary for Busan port to classify and analyze overall Chinese major ports, based on their competitiveness.

The aim of this paper is to classify Chinese container ports, based on competitiveness level. Through this classification, overall competitiveness of Chinese container ports can be easily investigated. All of target ports are in world's top 100 in terms of TEUs handled per annum, and thus, it can be considered as major ports which have somewhat competitiveness in China.

In this paper, FCM(Fuzzy C-means) is used as research methodology for effective classification. FCM is well known as a flexible clustering method that add fuzzy algorithm to previous clustering method. The validity of FCM for this classification was verified from previous research (Keum, 2000).

This paper is organized as follows. Elements selection relevant to port competitiveness and FCM algorithm are made in Chapter two. Actual condition of Chinese ports are presented in Chapter three. And in Chapter four, Chinese ports is classified by using FCM, and then the competitiveness levels of the classified port-groups are discussed. Finally, conclusion of this research and future research are presented in Chapter five.

2. Research Methodology

2.1 Element selection relevant to port competitiveness

In respect of port competitiveness analysis, studies have mainly focused on the port selection criteria, in which a wide rage of dimensions and factors have been listed and examined. Port selection criteria investigated by French (1979) include terminal facilities, tariffs, port congestion, service level, connectivity of hinterland, etc. Willingale (1981) surveyed decision-making process for port selection. According to his research, port selection process consists of available port locating stage, the judgement and examination stage, the approach, visit and evaluation stage, the preliminary discussion stage, the negotiation stage, and selection stage. Foster (1978) identified four important factors for port selection, cost of transportation, port charge, container cranes, and scheduled conference liner service, based on results of two surveys. According to UNCTAD report (1990), important factors for port selection are geographical location of port, connectivity of hinterland, and safety. And Chung and Kwak (2001) used five criteria, TEUs handled per annum, number of berth, berth length, yard space, and GNP, for classification of container ports.

However, the above previous studies are biased and there are significant differences among researcher's viewpoint in port selection criteria. Especially, as the quality for port services is constantly changing according to the change of environment, factors related to port service should be re-assessed, and new factors based on new dimensions should be identified. And for these reasons, it is not reasonable approach to select elements relevant to port competitiveness, based on some related literatures.

Thus, to select elements relevant to port competitiveness, data related to port competitiveness were collected through surveys of experts including ship owners, shipping companies, terminal operators, and researchers and graduate students majoring port and logistics. These surveys were conducted over two months between April and May 2001. The interviewees were requested to freely describe any intrinsic factors which might be related to port competitiveness. Throughout this process, 73 detailed elements for port competitiveness were extracted. However, in those extracted elements, there were some duplicated and correlated items. To adjust those items, elements were grouped by researchers and graduate students majoring port and logistics. Through this process, five most important criteria such as port location, port facility, cargo volume, port expenses, and service level were identified. And, to confirm the validity of grouping, we reviewed some literatures related to port selection criteria and port evaluation. From this review, we confirmed that some previous studies(Yeo and Song, 2003: Lee, 2003: Lee and Lee, 1993) have the same grouping process and selected the same elements, for port selection criteria and port evaluation.

In the mean time, port expense includes various aspects, such as navigation costs, berth service fees, cargo handling charges, etc. And moreover, as port expense deeply depends on traditional custom, it is very difficult to acquire exact data related to port expense. In addition, although port expense is an important element for evaluation of port competitiveness among different countries, when evaluation of competitiveness among domestic ports, this item is little important. Hence, in this paper, port expense item excepts from important criteria about port competitiveness.

In order to calculate the empirical values of these criteria, it is necessary to define identifiable and representative attributes of each criteria. Attributes for port location include service frequency of liners, hinterland economy, and geographical location. And, of these attributes, service frequency of liners have merit that can be easily calculated(Yeo and Song, 2003). For this reason, in some previous studies(Roh et al, 1996: Yeo, 2002: Yeo and Song, 2003), service frequency of liners was used as an representative attribute of port location. Thus, in this paper, the service frequency of liners was adopted as a representative attributes for this criteria, port location. Port facility generally includes berth, handling equipments, such as container crane and yard tractor, and storage facility. Especially, berth length of these attributes is a representative attribute since most of other attributes are usually dependent on the berth length.

Cargo volume itself is quantitative data, and this item is always used as a typical criteria for annual world's ports ranking. Thus, cargo volume- TEUs handled per annum, was adopted as an attribute for cargo volume. Finally, the related information system was selected as a representative attribute for service level. IT can be regarded as a key service item that port users are looking for in the current business trend. And as today's IT supports most of service activities in the container terminal, it is an item enough to describe overall service level.

Representative attributes for each element relevant to port competitiveness are shown in Table 1.

In the mean time, in order to decide object ports for classification, from a reliable source, major ports which have competitiveness as container terminal in China were selected with a reliable source. These ports - Dalian, Qingdao, Shanghai, Shekou, Tianjin, Xiamen, Yangtian, and Hong Kong - are among the world's top 100 in terms of TEUs handled per annum (Containerization International Yearbook, 2001).

Table 1 Port competitiveness elements and attributes

Element	Port Location	Port Facility	Cargo Volume	Service Level
Attribute	Service frequency of liners	Berth length	TEUs handled per annum	Information system

2.2 FCM (Fuzzy C-Means)

The well-known FCM algorithm by Bezdeck (1981) is an objective function based fuzzy clustering technique that extends the classical k-means method to fuzzy partitions. By replacing the Euclidean distance in the objective function other cluster shapes than the simple (hyper-)spheres of the fuzzy c-means algorithm can be detected, for instance ellipsoids, lines or shells of circles and ellipses.

That is, although classical hard clustering method(HCM) only identifies whether certain x_k(here, x_k means each port) belongs into a cluster S_i, FCM allows certain x_k belongs into multi clusters, and shows how degree x_k belongs to each cluster(see Fig. 1).

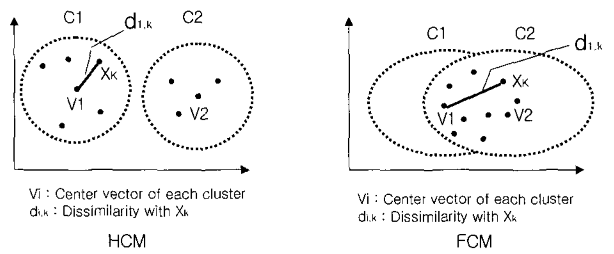

Fig. 1 The concept of HCM and FCM

Thus, through this FCM, it can analyze membership degree of each port for clusters without HCM, and thus, it is possible to acquire more various informations, such as the detailed membership tendencies of ports belonged into port-groups and possibilities ports get out of certain port-group, compare to previous clustering method.

FCM is an algorithm that calculate cluster center and membership grade of each entity to optimize objective function like (1) for data, x_k.

$$Minimize J(U, v) = \sum_{i=1}^{c} \sum_{k=1}^{n} (u_{ik})^m \; \|x_k - v_i\|^2 \qquad (1)$$

where,

$u_{ik} \in [0,1]$: $1 \le i \le c$, $1 \le k \le n$

$\sum_{i=1}^{c} u_{ik} = 1$: $1 \le k \le n$

$0 < \sum_{k=1}^{n} u_{ik} < n$: $1 \le i \le c$

Values of v_i and u_{ik} are calculated by (2) and (3).

$$v_i = \frac{1}{\sum_{k=1}^{n} (u_{ik})^m} \sum_{k=1}^{n} (u_{ik})^m x_k, \quad 1 \le i \le c \qquad (2)$$

$$u_{ik} = 1 / \sum_{j=1}^{c} (d_{ik}/d_{jk})^{2/(m-1)} \qquad (3)$$

where,

$$d_{ik} = d(x_k, v_i) = \|x_k - v_i\| = \sum_{j=1}^{p} (x_{kj} - v_i)^{2\,(1/2)}$$

On the other hand, FCM algorithm add routine that update U(membership grade) and v(cluster center) to previous HCM algorithm (Keum et al., 2000). Calculation procedures of FCM are as follows.

Step 1: Define number of cluster, $c(2 \le c < n)$ and exponent m $(1 < m < \infty)$. In addition, initialize the membership values ($U^{(l)}$)

Step 2: Calculate the cluster center v_i using the membership values $U^{(l)}$

Step 3: If $x_k \neq v_i^{(l)}$, update $U^{(l)}$ to $U^{(l+1)}$, if not,

$$U_{ik}^{(l+1)} = \begin{cases} 1 & i=j \\ 0 & i \neq j \end{cases}$$

Step 4: If $|U^{(l+1)} - U^{(l)}|_G \le \varepsilon$, finish this step, if not, let $l = l+1$ and go to step 2

3. Actual Condition of Chinese Ports

3.1 Economic Growth of China

Since the beginning of open-door policy, growth rate of China has been rapidly increased. According to National Bureau of Statistics of China(NBS) (2003), the national economy maintained relatively fast growth. The GDP(Gross Domestic Product) of the 2002 topped the 10 trillion yuan level to reach 10,239.8 billion yuan, up by 8 percent over the previous year at comparable prices. The value-added of the primary industry was 1,488.3 billion yuan, up by 2.9 percent. The value-added of the secondary industry was 5,298.2 billion yuan, up by 9.9 percent. The value-added of the tertiary industry was 3,453.3 billion yuan, up by 7.3 percent. Especially, although since 1997, many countries in Asia have experienced serious economic depression, China have maintained fast growth. Thus, due to this growth in economy, China are beginning to threaten adjacent country's economic growth. Further, many researchers speculate that China becomes one of the biggest countries like today's US in economy as well as in military force, in near future.

3.2 Actual Condition of Chinese Ports

As the above mentioned paragraph, due to the rapid economic growth, cargo volume handled at Chinese ports also have been rapidly increased. Thus, to handle those cargos, China government spurs big port development project, and at the same time, they plans strategies to become hub-port in Northeast Asia. Actual conditions of Chinese ports are shown in Table 2.

In Table 2, we used verifying value to measure the level of information system. From a source(Containerization Year Book 2001), it was found that Hong Kong port had the best information systems(or software) of them the rest ports have. Thus, to describe level of information system, in this paper, verifying value was used to express level of information system of each port as percentage, when level of information system of Hong Kong port is 100.

Table 2 Actual condition of Chinese container ports

Attributes / Ports	Cargo volume (TEU)	Berth length (m)	Service frequency of liners	Information system (%)
Dalian	1,008,400	918	10	50
Qingdao	2,116,300	1,189	8	50
Shanghai	5,612,000	2,281	18	70
Shekou	720,000	650	13	80
Tianjin	1,708,400	397	14	60
Xiamen	1,080,000	142	4	70
Yantian	2,147,476	2,350	28	80
Hong Kong	18,098,000	5,319	50	100

Source: Containerization Year Book 2001

It were found that Hong Kong and Shanghai port were number one and two in most aspects. And Xiamen and Shekou less handled cargos than the rest ports did. However, Table 2 showed that levels of information systems of these two ports were not low.

4. Analysis and Discussion

4.1 Clustering using FCM

In order to decide the optimum number of cluster, changing number of cluster from two clusters to nine clusters, analysis were done. And, as values FCM users usually used, exponent m and ε for termination criterion set 2 and 0.0001. The Results of analysis are shown in Table 3.

Table 3 Results of analysis

Cluster / Ports	A	B	C	D
Dalian	0.0041	0.0000	0.0002	0.9957
Qingdao	0.9919	0.0000	0.0008	0.0073
Shanghai	0.0000	0.0000	1.0000	0.0000
Shekou	0.0288	0.0002	0.0020	0.9690
Tianjin	0.8560	0.0003	0.0053	0.1384
Xiamen	0.0208	0.0001	0.0009	0.9782
Yantian	0.9867	0.0001	0.0014	0.0118
Hong Kong	0.0000	1.0000	0.0000	0.0000

Center values of each clusters are shown in Table 4. From this data analysis, it was found that membership grades of all ports for a cluster were more than 0.5 (see Table 3). It implies that ports within the same cluster clearly have different characteristics that ports out of the same cluster does not have. Current Chinese ports were easily classified according to competitiveness level. And results of this analysis showed that competitiveness level of cluster B were the highest and that of cluster D was the lowest, in most aspects.

Table 4 Centers of four clusters

Clusters \ Attributes	Cargo volume (TEU)	Berth length (m)	Service frequency of liners	Information system (%)
A	2,015,920	1,393	17	64
B	8,097,998	5,319	50	100
C	5,611,857	2,281	18	70
D	943,492	573	9	66

4.2 Discussion

Results of data analysis showed that Chinese ports consist of four groups, as following Table 5.

Cluster A(Qingdao, Tianjin, and Yantian) had lower competitiveness level than that of cluster B and C. And although they have higher competitiveness, compared to ports within the cluster D, it cannot say that they have capabilities enough to be mega port. Thus, it appears that Qingdao, Tianjin, and Yantian within Cluster A have capabilities that can mainly handled cargos generated in their regions.

Table 5 Classification of Chinese ports

Cluster	Ports
A	Qingdao, Tianjin, Yantian
B	Hong Kong
C	Shanghai
D	Dalian, Shekou, Xiamen

Cluster B(Hong Kong) was a group with the highest competitiveness in all aspects, compared to the rest clusters. Especially, Hong Kong port significantly much handled cargos, and service frequency of liners were significantly high, compared to the other ports. For these reasons, it seems that Hong Kong within cluster B have good capabilities for international port that can handle cargos of adjacent countries as well as regional cargos.

The competitiveness level of cluster C (Shanghai) comes to be number two in the above Table 5. Although there are much differences between cluster B(Hong Kong) and C(Shanghai) in all aspects, Shanghi port also much handled cargos. That is, it implies that, although port capabilities such as infrastructures is not high, due to regional economy growth, cargos via port is increased. Thus, although Shanghai port is in level that can mainly handle cargos generated in this region, it appears that Shanghai port has potential to become a port like Hong Kong, through the intensive port development.

Finally, cluster D(Dalian, Shekou, and Xiamen) showed the lowest level of competitiveness in most aspects. They handled only 11.7% cargos of cluster B(Hong Kong), and their service frequency of liners were 18% of Hong Kong port. It appears that, although Dalian, Shekou, and Xiamen within cluster D have somewhat capabilities, their capabilities are lower than those of ports (Qingdao, Tianjin, and Yantian) within cluster A.

Consequently, Chinese ports consist of four clusters with the different competitiveness level. And rankings among four clusters based on competitiveness level are cluster B(Hong Kong), cluster C(Shanghai), cluster A(,Qingdao, Tianjin, and Yantian) and cluster D(Dalian, Shekou, and Xiamen).

5. Conclusion

Today's Busan port faces severe competition from adjacent competing ports such as Shanghai, Hong Kong, Kaosung, and Kobe. Thus, to face this competition, Korea government spurs development of new port and building the various strategies. In relation to this, Chinese ports threaten Busan port. And further, they also progress big projects for port development. Thus, it is very important for Busan port to analyze and investigate overall competitiveness of Chinese ports. Especially, although various studies related to Shanghai and Hong Kong have been conducted, the competitiveness of overall Chinese container major ports have been little studied.

In this paper, we analyzed overall competitiveness level of eight Chinese ports with capabilities as container terminal, based on reliable source. From data analysis, eight Chinese ports were classified into four groups according to competitiveness level. And through this analysis, it was found that two groups including Shanghai and Hong Kong were leading towards international mega port, and that the other two groups including Qingdao and Xiamen have competitiveness regional main ports usually have. Thus, we believe that, when building the strategies for development of Busan port, results of this research can be used as available reference and resource to classify and analyze overall competitiveness level of Chinese major ports.

In the mean time, this research has some limitations. Although Chinese ports were successfully classified into some groups, we did not identify ranking of each ports within clusters, in detail. Thus, for this, hybrid approach mixed FCM with evaluation method is needed. In addition, although the aim of our research is to classify Chinese major ports, we didn't clearly identified types and characteristics of ports within each cluster, such as 'international mega port' and 'regional main port'. For those, additional studies are needed, and thus, it remains as future research.

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