

## **THE HIERARCHICAL ANALYSIS OF PERCEIVED COMPETITIVENESS: An Application to Korean Container Ports**

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**Abstract:** The competitiveness of a port provides ship owners, operators and shippers with a significant basis in selecting a calling-port. Port operators can utilize the competitive advantage as a parameter for counter measures by grasping the advantages and disadvantages of the ports and be a prime factor of opportunities and threats of the ports. The determinants of port competitiveness are, however, subject to various sources, which do again depend on the elements of judged subjects, businesses, circumstances, the degree of knowledge or know-hows accumulated and the level of information exposure, and so on. Moreover, the components are mixed with quantitative and qualitative factors, and have a inter-active and complex relationship. Keeping this complicated nature of the business in mind, this paper will establish the fuzzy structuring method and apply it to the port industry so as to identify the subordinate and hierarchical relationships among the factors having an impact on port competitiveness and to draw a structural model that those involved in port logistics should consider.

**Key Words:** Fuzzy Structuring Model, Port Competitiveness, Container Port, Korea.

### **1. INTRODUCTION**

Compared with general industries or service activities, port competition was comparatively minimal in the past. Each port secured its own customers depending on the port situation. A variety of activities for these customers and industries were limited within a port area or its neighboring hinterland. Most of today's ports, however, share the hinterland and conduct a severe competition to secure cargo volume, depending on their circumstances (Baudelaire,1986). Examining types of port competition first, Goss (1990) categorized them systematically into five classifications of ports. That is, the competitive forces may be analysed more systematically as follows: 1) competition between whole ranges of ports or coastlines, 2) competition between ports in different countries, 3) competition between individual ports in the same country, 4) possible competition between the operators or providers of facilities within the same port, and 5) competition between different modes of transport. In the case of UNCTAD(1993), types of port competition were largely classified into inter-port competition, inter-modal transportation competition, and intra-port competition. Matsbashi(1997) classified port competition largely into both inter-port competition within a country, and international port competition. The latter competes with competition factors such as terms of price, time and technology. Meanwhile, the former competes with terms of price, time, safety, and information functions. In this respects, it is essential for port to have a power of competition which is to defeat other ports. The competitive power of ports presents ship owners or shippers with the standard of selecting ports. Port operators can utilize that power as a guide necessary for counter measures, by

grasping the advantages and disadvantages of ports, and the prime factors of opportunities and threats of ports with environments changing (Yang, 1999).

However, the elements of port competitive power are to be different depending on the elements of judging subjects, circumstances, the degree of knowledge, etc. Also, their degree of strength is to be changed as per the different ways of thinking in depth. Moreover, Components mixed with quantitative components and qualitative components, and have reciprocal organic and complex relationships each other. These many components have the problems of complex and organic relationships. It has been studied that the structuring system study quantitatively analyses the problems (Derano, 1985). That is, the structuralization of system extracts the components which are thought to consist the target system by the KJ method, developed by Kawakita, J., Brain Storming method, and DEMATEL method. (Kawakita, 1967) These extracted components are classified, and determine subordinate relationships among components belonging to the hierarchy, which can be represented by the graphic theory. The hierarchical methods were suggested e.g. Interpretive Structural Modeling (ISM) method and Modified ISM method. (Warfield, 1972; Gabus and Fontela, 1975). However, the series of ISM method had major drawback. That was used mainly to obtain the graphic structure through the subordinate matrix by a binary relation among components (Warfield, 1976). However, the subordinate matrix is a usually fuzzy binary relation rather than a binary relation. Therefore, we use the Fuzzy Structural Modeling (FSM) method, which is one extension of ISM (Tazaki and Amagasa, 1979; Ohuchi et al, 1986). In FSM, the entries in the subordinate matrix are taken to values on the interval [0,1] by virtue of a binary fuzzy relation (Ichimura et al, 1999).

The purpose of this study is to classify the port logistics experts' perception for the port competitive power in Korea to avoid the vagueness on the above port competitive power, and to seek the answers to the following detailed items:

- What elements are composed of port competitive power?
- What subordinate relationships have among the components of port competitive power?
- Can the subordinate relationships among components be classified?
- Can the most important components of port competitive power be extracted through the classified components in the subordinate relationships?

## 2. RESEARCH METHODOLOGY - FSM

Target system represents  $S = S_1, S_2, \dots, S_n$  and fuzzy subordinate relation of the extracted components represents  $A = [a_{ij}]$   $i, j = 1, 2, \dots, n$ . Here,  $A$  is square matrix of  $n \times n$ , the element of  $A$ ,  $a_{ij}$  is given by fuzzy binary relation.  $a_{ij} = f_r(S_i, S_j)$ ,  $0 \leq a_{ij} < 1$  ( $f_r : S \times S \rightarrow [0, 1]$ ), that is,  $a_{ij}$  is to represent the grade that elements  $S_i$  subordinate  $S_j$ , The procedure of Algorithm of the FSM method is as follows:

*Step 1:* Fuzzy subordinate matrix  $A (= [a_{ij}])$  given,  $A$  is used to form  $A'$  which satisfies fuzzy semi-transitive law.

*Step 2:*  $L_t(s)$ ,  $L_i(s)$ ,  $L_{is}(s)$ , and  $L_b(s)$  are solved at  $A'$ ,  $L_t(s)$  and  $L_b(s)$  are used to determine  $B(S_i)$  (But,  $S_i \in L_b(S)$ ) and  $Q_j$ .

*Step 3:* Row of  $L_t(s)$  and row of  $L_b(s)$ , and row and column of  $L_{is}(s)$  are eliminated, and the



speedy and safe handling of special cargoes, etc. Major container liners are also seeking economy of scale by calling at only big harbors, while small ports are connected via feeder ships.

The following are some reviews of previous foreign studies on the extraction of the components of port competitive power. Murphy *et. al.* (1992) focused on port detention, port size, port accessibility, and calling frequency; French (1979) suggested terminal facilities, tariffs, port congestion, service level, connectivity, and port operators as internal components, while considering the economy of hinterland, the economic status of the nation, trade policy, and the world economic trend external components. Peters (1990) put emphasis on the service level, available facility capacity, status of the facility, and port operation policy, calling them internal factors. As external factors he took the examples of international politics, change of social environment, trade market, economic factors, features of competitive ports, functional changes of transportation, and materials handling. Calling frequency, tariffs, accessibility to the port, port congestion, and inter-linked transportation network were considered affecting factors by Slack (1985). Willingale (1981) surveyed the selection standards of port as well as the decision making process of the calling port, for the 20 liners in 1982. His study reveals that the selecting process consists of the following stages: the available port locating stage, judgment and examination stage, approach, visit and evaluation stage, preliminary discussion stage, negotiation stage, and selection stage. In the process of selecting a particular port, shipping lines consider the location factor, technical factor, operational factor, fiscal factor, and manpower factor. Kim(1993) analyzed the decision factors of port selection for Korean shippers, consignees, and liners. Distance between origin and destination, annual cargo handling volume, loading hours, average detention hours at port, goods value per tonnage, and inland trucking cost per kilometer affect exporting from higher to lower influencing order. Meanwhile, sea transportation distance, number of liners for calling-in, annual volume by import, inland transportation cost are the major factors for import port selection. In Jun's study in 1993, important decision factors of port selection contained navigation facilities and equipment holding status, port productivity, price competition, and port service quality. Based upon literature survey, this study conducted the survey on the attributes which should be put into the port competitive power. Since port logistics has some barriers to the general public in terms of expert knowledge, the surveys were catered to the understanding of the group of expertise. The group was selected from ship owners, shippers, terminal operators, national research institutes, and local government level research centers, consisting of 350 persons.

The surveying period covered April and May 2002, a two-month period. Both face-to-face interviews and telephone inquiries were conducted. The interviewed were encouraged to freely describe any intrinsic factors to be involved in the port competitiveness. Throughout the survey, 73 detailed elements of competition factors were extracted.

Table 1. List of the Elements of Port Competitiveness

- 
- application of EDI system
  - average hours of port congestion
  - berth/terminal availability
  - building Port MIS
  - capacity of transportation connectivity
  - capacity/status of facilities available
  - cargo volume of handling transshipment
  - changes in social environments
  - changes in transport and cargo function
  - complete preparation of multimodal transport
  - concentration of volume by export/import
  - customs clearance system
  - dredging: yes or no
  - easy access to port
  - economic scale of hinterland
  - effectiveness of terminal operations
  - existence of cargo tracing system
  - existence of port hinterland road
  - existence of terminal operating system
  - existing pattern of navigation routes
  - extent of port EDI
  - financial factors of port
  - free time of container freight station
  - frequency of ships calling
  - handling charge per TEU
  - handling volume of export/import cargo
  - inland transportation cost
  - inter-linked transportation network
  - internal politics
  - loading time
  - location factors of the port concerned
  - market position within the area
  - mutual agreement of port users
  - navigation distance
  - nearness to hinterland
  - nearness to main trunk
  - number of liners calling at ports
  - ability of port personnel
  - port accessibility
  - port congestion
  - port facilities
  - port marketing
  - port operation
  - port operation by government
  - port operation by local autonomous entity
  - port operation by private sectors
  - port operation strategies
  - port operation time
  - port ownership
  - port productivity
  - port service
  - port size
  - port tariff
  - possibility of mutual reference of electronic computation network
  - price competitiveness
  - response of port authorities concerned
  - road network to be fully equipped
  - sea transportation distance
  - securing deep draft
  - securing exclusive use of equipment
  - securing fairway
  - securing navigation facilities/equipment
  - securing railroad connection
  - status of national economy
  - sufficiency of berth
  - sufficiency of securing information equipment
  - technical factors of port
  - terminal facilities
  - trade market
  - trade/commerce policy
  - transportation distance
  - types of port operation/management
  - world business
- 

However, there were some duplicate and/or co-related items in the extracted elements to be adjusted. Therefore, this study can extract 12 important components on the basis of private firms related with port operations/ocean shipping/logistics, policy makers for port construction and management and academics.

#### **4. STRUCTURING ANALYSIS OF PORT COMPETITIVE POWER**

##### **4.1 Surveying the questionnaire**

The survey for asking the fuzzy relation of port competitiveness factors was conducted over two months between July and August 2002. Of the 80 interviewees, a total of 52 responses in three groups were successfully received and their business areas are illustrated in Table 3.

Table 2. Important Components of Port Competition

Important Components	Detailed Attributes
1. Hinterland Nearness	Hinterland Economy of Scale / National Economy Status / Social Environmental Changes / Foreign Trade Markets / Trade & Commerce Policy / International Politics / World Business / Hinterland Nearness
2. Port Facility	Terminal Facility / Facility Capacity Availability / Facility Condition / Transport & Cargo Work Function Changes / Port Technology Factor / Port Facility / Berth Terminal Usability / Loading Hours
3. Efficient Terminal Operation	Port Service / Types of Port Manager & Operator / Port Operation Strategy / Port Financial Factor / Efficient Terminal Operation / Port Production
4. Variety of Established Routes	Number of Port Calling / Market Position within the Region / Port Access / Pattern of Existing Routes
5. Port Ownership	Response of Port Authority / Agreement of Port Users / Port Ownership / Port Operation by Government / Port Operation by Private / Port Operation by Municipality
6. Position on Main Trunk	Transport Distance / Port Scale / Port Access Availability / Location Factor of the Port Concerned / Navigation Distance / Seaborne Transport Distance
7. Port Congestion	Port Congestion / Shortage of Navigation Facility & Equipment / Average Time of Port Delay / Excessive Concentration of Trade Volume by Export & Import / Berth Shortage / Shortage of Specialized Equipment
8. Combined Inter-link Transport	Inter-link Transport Ability / Inter-link Transport Network / Inland Transport Cost / Perfection of Intermodal Transportation / Establishment of Railroad Access / Possessing Road Network / Presence of Port Hinterland Road
9. Port Expense	Port Tariff / Price Competitive Power / Free Time Of Container Stock / Handling Charge per 1 TEU
10. Rapidity of Customs Clearance	Customs Clearance System / Port Service Quality / Personal Ability of Port / Establishment of Port MIS / Mutual Reference Possibility of Computer & Electronic Network
11. Entering Possibility of Large Ship	Fairway Security / Security of Deep Draft / Yes or No of Dredging
12. Providing Port Information	Port Marketing / Existence of Cargo Tracing System Operation / PDP Degree of Port Operation / Existence of Terminal Operating System / Sufficiency of Securing Information Equipment

For the 12 items extracted from the previous chapter, the subject of questionnaire was to be made a decision on how much  $S_i$  is more important than  $S_j$ . For example, if the subject felt that the component  $S_i$  was much more important than the component  $S_j$ , then he/she should write in brackets the following:

$$S_i [ \succ ] S_j \quad (80)$$

Table 3. Status of Questionnaire

Group	Total	No. of Collection (%)
Private Firm Group (Ship Owner, Shippers, Terminal Operators)	30	15 (50%)
Researcher Group (Researchers under Research Institutes and Universities)	30	25 (83%)
Policy Maker Group (Experts under central government and municipal government)	20	12 (60%)

If the subject felt that the component  $S_j$  was absolutely more important than the component  $S_i$ , then he should write the following:

$$S_i [ \prec ] S_j$$

(100)

These numbers on the interval [0,100] were converted to values on the interval [0,1](Yamashita, 1997). Then, subordinate matrix corresponding to the collected questionnaires can represent  $A^k = [a_{ij}^k]_{12 \times 12}$  ( $k = 1, 2, \dots, 52$ ). Equalizing it by  $A = [a_{ij}]_{12 \times 12} = [\sum_{k=1}^{52} a_{ij}^k / 52]_{12 \times 12}$  enables to obtain the representative fuzzy subordinate matrix such as Formula (1).

$$A = \begin{matrix} & S_1 & S_2 & S_3 & S_4 & S_5 & S_6 & S_7 & S_8 & S_9 & S_{10} & S_{11} & S_{12} \\ \begin{matrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \\ S_7 \\ S_8 \\ S_9 \\ S_{10} \\ S_{11} \\ S_{12} \end{matrix} & \begin{bmatrix} 0.00 & 0.26 & 0.46 & 0.42 & 0.62 & 0.22 & 0.30 & 0.36 & 0.18 & 0.54 & 0.58 & 0.38 \\ 0.74 & 0.00 & 0.70 & 0.64 & 0.84 & 0.46 & 0.54 & 0.58 & 0.42 & 0.78 & 0.82 & 0.62 \\ 0.54 & 0.30 & 0.00 & 0.46 & 0.70 & 0.26 & 0.34 & 0.38 & 0.22 & 0.58 & 0.62 & 0.42 \\ 0.58 & 0.34 & 0.54 & 0.00 & 0.70 & 0.30 & 0.38 & 0.42 & 0.26 & 0.62 & 0.66 & 0.46 \\ 0.38 & 0.24 & 0.34 & 0.30 & 0.00 & 0.10 & 0.18 & 0.22 & 0.06 & 0.42 & 0.46 & 0.26 \\ 0.78 & 0.54 & 0.74 & 0.70 & 0.90 & 0.00 & 0.58 & 0.62 & 0.46 & 0.82 & 0.86 & 0.66 \\ 0.70 & 0.46 & 0.66 & 0.62 & 0.82 & 0.42 & 0.00 & 0.54 & 0.38 & 0.74 & 0.78 & 0.58 \\ 0.70 & 0.42 & 0.62 & 0.58 & 0.78 & 0.38 & 0.46 & 0.00 & 0.34 & 0.80 & 0.84 & 0.54 \\ 0.82 & 0.58 & 0.78 & 0.74 & 0.94 & 0.54 & 0.62 & 0.70 & 0.00 & 0.86 & 0.90 & 0.70 \\ 0.46 & 0.22 & 0.44 & 0.38 & 0.58 & 0.18 & 0.26 & 0.30 & 0.14 & 0.00 & 0.54 & 0.34 \\ 0.42 & 0.18 & 0.38 & 0.34 & 0.54 & 0.14 & 0.22 & 0.26 & 0.10 & 0.46 & 0.00 & 0.30 \\ 0.62 & 0.38 & 0.58 & 0.54 & 0.86 & 0.34 & 0.42 & 0.46 & 0.30 & 0.66 & 0.70 & 0.00 \end{bmatrix} \end{matrix} \quad (1)$$

## 4.2 Identification of System Structure

### 4.2.1 Structure of Level sets and Block sets

The threshold  $P$  should be decided to satisfy the fuzzy irreflexive law, and fuzzy asymmetric law for fuzzy matrix  $A$ . Then, the decided threshold  $P$  means that the value below the threshold is assumed that there is no subordinate relationships, and the number of level is changeable according to the threshold. It is shown that the scope is to be selected by the real number of semi-closed interval (0,1]. In the case of this study, when the threshold is adapted below 0.5 for representative fuzzy subordinate matrix,  $A$ , the fuzzy asymmetric law cannot be satisfied. Thus, Table 4 shows the most optimized inverse value,  $P$  should be decided, assuming a few cases over the threshold 0.5(Yamashita, 1995).

Table 4. Level Set and Block Set by Threshold

P value	Level set / Block set
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<b>P</b> <b>(0.5)</b>	<b>Level set</b>	$L_i(s)$	$S_5$
		$L_b(s)$	$S_9$
		$L_i(s)$	$S_1, S_2, S_3, S_4, S_6, S_7, S_8, S_{10}, S_{11}, S_{12}$
		$L_{is}(s)$	$\{\phi\}$
	<b>Block set</b>	$S_i \in L_b(s)$	$B(S_i) \subset L_i(s)$
<b>P</b> <b>(0.6)</b>	<b>Level set</b>	$L_i(s)$	$S_1, S_5, S_{10}, S_{11}$
		$L_b(s)$	$S_2, S_6, S_9$
		$L_i(s)$	$S_3, S_4, S_7, S_8, S_{12}$
		$L_{is}(s)$	$\{\phi\}$
	<b>Block set</b>	$S_i \in L_b(s)$	$B(S_i) \subset L_i(s)$
		$S_2$	$S_1, S_5, S_{10}, S_{11}$
		$S_6$	$S_1, S_5, S_{10}, S_{11}$
		$S_9$	$S_1, S_5, S_{10}, S_{11}$
		$Q_1 = S_1 S_5 S_{10} S_{11}$	
<b>P</b> <b>(0.7)</b>	<b>Level set</b>	$L_i(s)$	$S_1, S_5, S_{10}, S_{11}$
		$L_b(s)$	$S_2, S_6, S_7, S_9$
		$L_i(s)$	$S_3, S_4, S_8, S_{12}$
		$L_{is}(s)$	$\{\phi\}$
	<b>Block set</b>	$S_i \in L_b(s)$	$B(S_i) \subset L_i(s)$
		$S_2$	$S_1, S_5, S_{10}, S_{11}$
		$S_6$	$S_1, S_5, S_{10}, S_{11}$
		$S_9$	$S_1, S_5, S_{10}, S_{11}$
		$Q_1 = S_1, S_5, S_{10}, S_{11}$	
<b>P</b> <b>(0.8)</b>	<b>Level set</b>	$L_i(s)$	$S_1, S_5, S_{10}, S_{11}$
		$L_b(s)$	$S_2, S_6, S_7, S_8, S_9, S_{12}$
		$L_i(s)$	$S_3, S_4$
		$L_{is}(s)$	$\{\phi\}$
	<b>Block set</b>	$S_i \in L_b(s)$	$B(S_i) \subset L_i(s)$
		$S_2$	$S_5, S_{11}$
		$S_6$	$S_5, S_{10}, S_{11}$
		$S_7$	$S_5$
		$S_8$	$S_{10}, S_{11}$
		$S_9$	$S_1, S_5, S_{10}, S_{11}$
$S_{12} \quad S_5$			
$Q_1 = S_5, S_{11} \quad Q_2 = S_1, S_{10}$			

Then, taking into consideration each level set and block set, partition of the level of  $L_i(s)$  is incomplete for  $P$  value is 0.5, while it is difficult to grasp the structure for  $P$  value to be 0.8 because the existence of many levels of  $L_b(s)$ . Therefore, this study adopted  $P$  value, 0.7 for which the level of  $L_i(s)$  is best partitioned.

#### 4.2.2 Identification of system structure

Unnecessary rows and columns are eliminated in matrix  $A$ . That is, matrix  $A^2$  is composed by eliminating columns,  $S_1, S_5, S_{10}$  and  $S_{11}$  which are corresponding to top level set, and eliminating rows,  $S_2, S_6, S_7$  and  $S_9$ , which are corresponding to bottom level set.

$$A^2 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_8 & S_{10} & S_{11} & S_{12} \\ \begin{matrix} S_2 \\ S_3 \\ S_4 \\ S_6 \\ S_7 \\ S_8 \\ S_9 \\ S_{12} \end{matrix} & \begin{pmatrix} 0.74 & 0.70 & 0.64 & 0.84 & 0.58 & 0.78 & 0.82 & 0.62 \\ 0.54 & 0.00 & 0.46 & 0.70 & 0.38 & 0.58 & 0.62 & 0.42 \\ 0.58 & 0.54 & 0.00 & 0.70 & 0.42 & 0.62 & 0.66 & 0.46 \\ 0.78 & 0.74 & 0.70 & 0.90 & 0.62 & 0.82 & 0.86 & 0.66 \\ 0.70 & 0.66 & 0.62 & 0.82 & 0.54 & 0.74 & 0.78 & 0.58 \\ 0.70 & 0.62 & 0.58 & 0.78 & 0.00 & 0.80 & 0.84 & 0.54 \\ 0.82 & 0.78 & 0.74 & 0.94 & 0.70 & 0.86 & 0.90 & 0.70 \\ 0.62 & 0.58 & 0.54 & 0.86 & 0.46 & 0.66 & 0.70 & 0.00 \end{pmatrix} \end{matrix} \quad (2)$$

Generally, if rows or columns of matrix  $A^{(k)}$  includes a single element, the only  $a_{ij}^{(k)}$  that satisfies  $a_{ij}^{(k)} \geq P$ , it is called a regular row. Then, rows and columns can be eliminated if regular rows or columns place on the graph,  $S_3$  and  $S_4$  are called for regular rows for  $S_5$  in matrix  $A^2$ , so rows  $S_3$  and  $S_4$  are eliminated. The scope of  $\lambda$  is  $-1 < \lambda < \infty$ , and  $-0.3$  in this study. Then, Figure 2 shows the graph representing subordinate relationships

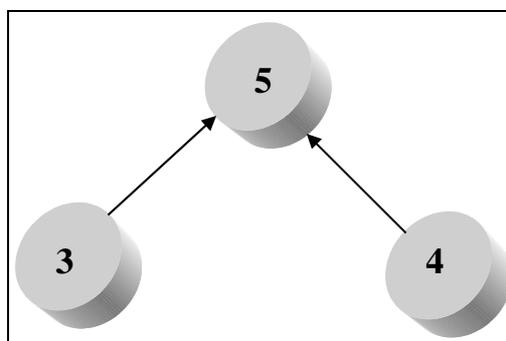


Figure 2. Structural Graph of  $A^2$

Also, Formula (3) shows completed matrix  $A^3$

$$A^3 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_8 & S_{10} & S_{11} & S_{12} \\ \begin{matrix} S_2 \\ S_6 \\ S_7 \\ S_8 \\ S_9 \\ S_{12} \end{matrix} & \begin{vmatrix} 0.74 & 0.70 & 0.64 & 0.38 & 0.58 & 0.78 & 0.82 & 0.62 \\ 0.78 & 0.74 & 0.70 & 0.33 & 0.62 & 0.82 & 0.86 & 0.66 \\ 0.70 & 0.66 & 0.62 & 0.43 & 0.54 & 0.74 & 0.78 & 0.58 \\ 0.70 & 0.62 & 0.58 & 0.47 & 0.00 & 0.80 & 0.84 & 0.54 \\ 0.82 & 0.78 & 0.74 & 0.29 & 0.70 & 0.86 & 0.90 & 0.70 \\ 0.62 & 0.58 & 0.54 & 0.64 & 0.46 & 0.66 & 0.70 & 0.00 \end{vmatrix} \end{matrix} \quad (3)$$

The regular row in matrix  $A^3$  becomes row  $S_{12}$  for  $S_{11}$ . Thus, matrix  $A^4$  can be obtained by eliminating row  $S_{12}$ , and operating column  $S_{11}$  by fuzzy complement set and replaced arrangement as in Formula (4). Figure 3 presents subordinate relationships on the graph.

$$A^4 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_8 & S_{10} & S_{11} & S_{12} \\ \begin{matrix} S_2 \\ S_6 \\ S_7 \\ S_8 \\ S_9 \end{matrix} & \begin{vmatrix} 0.74 & 0.70 & 0.64 & 0.38 & 0.58 & 0.78 & 0.77 & 0.62 \\ 0.78 & 0.74 & 0.70 & 0.33 & 0.62 & 0.82 & 0.83 & 0.66 \\ 0.70 & 0.66 & 0.62 & 0.43 & 0.54 & 0.74 & 0.70 & 0.58 \\ 0.70 & 0.62 & 0.58 & 0.47 & 0.00 & 0.80 & 0.64 & 0.54 \\ 0.82 & 0.78 & 0.74 & 0.29 & 0.70 & 0.86 & 0.89 & 0.70 \end{vmatrix} \end{matrix} \quad (4)$$

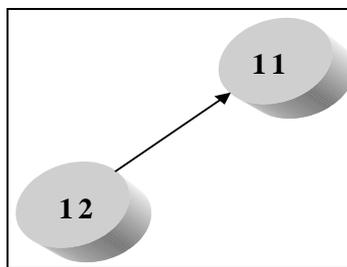


Figure 3. Structural Graph of  $A^3$

Regular rows and columns do not exist in matrix  $A^4$ . Thus,  $A^5$  can be formed with the value over the threshold selecting the least row and splitting the row.

$$A^5 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_8 & S_{10} & S_{11} & S_{12} \\ \begin{matrix} S_2 \\ S_6 \\ S_7 \\ S_9 \\ S_{8a} \\ S_{8b} \end{matrix} & \begin{vmatrix} 0.74 & 0.70 & 0.64 & 0.38 & 0.58 & 0.78 & 0.77 & 0.62 \\ 0.78 & 0.74 & 0.70 & 0.33 & 0.62 & 0.82 & 0.83 & 0.66 \\ 0.70 & 0.66 & 0.62 & 0.43 & 0.54 & 0.74 & 0.70 & 0.58 \\ 0.82 & 0.78 & 0.74 & 0.29 & 0.70 & 0.86 & 0.89 & 0.70 \\ 0.70 & 0.62 & 0.58 & 0.47 & 0.00 & 0.00 & 0.64 & 0.54 \\ 0.00 & 0.62 & 0.58 & 0.47 & 0.00 & 0.80 & 0.64 & 0.54 \end{vmatrix} \end{matrix} \quad (5)$$

Here,  $S_{8a}$  becomes regular row for  $S_1$ , and  $S_{8b}$  for  $S_{10}$ . Hence,  $A^6$  can be obtained by

eliminating regular rows, and replacing and arranging columns  $S_1$  and  $S_{10}$  by FSM. Figure 4 presents these relationships on the following graph.

$$A^6 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_8 & S_{10} & S_{11} & S_{12} \\ S_2 & 0.70 & 0.70 & 0.64 & 0.38 & 0.58 & 0.70 & 0.77 & 0.62 \\ S_6 & 0.77 & 0.74 & 0.70 & 0.33 & 0.62 & 0.77 & 0.83 & 0.66 \\ S_7 & 0.64 & 0.66 & 0.62 & 0.43 & 0.54 & 0.64 & 0.70 & 0.58 \\ S_9 & 0.82 & 0.78 & 0.74 & 0.29 & 0.70 & 0.86 & 0.89 & 0.70 \end{matrix} \quad (6)$$

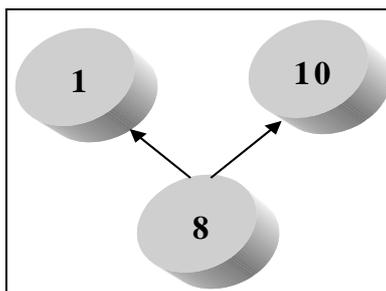


Figure 4. Structural Graph of  $A^5$

Regular row becomes row  $S_7$  for  $S_{11}$  in matrix  $A^6$  Therefore, matrix  $A^7$  can be obtained by eliminating row  $S_7$  and with column  $S_{11}$  operating by the fuzzy complement set of Formula (8), and replacing arrangement as in Formula (7). Figure 5 shows subordinate relationships on the graph.

$$A^7 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_8 & S_{10} & S_{11} & S_{12} \\ S_2 & 0.70 & 0.70 & 0.64 & 0.38 & 0.58 & 0.70 & 0.77 & 0.62 \\ S_6 & 0.77 & 0.74 & 0.70 & 0.33 & 0.62 & 0.77 & 0.83 & 0.66 \\ S_9 & 0.82 & 0.78 & 0.74 & 0.29 & 0.70 & 0.86 & 0.89 & 0.70 \end{matrix} \quad (7)$$

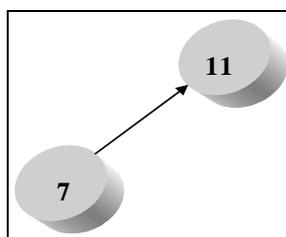


Figure 5. Structural Graph of  $A^6$

Since regular columns become  $S_8$  and  $S_{12}$  in  $A^7$  and rows do not exist corresponding to this, matrix  $A^8$  can be obtained by eliminating columns  $S_8$  and  $S_{12}$  and arranging it. This structural graph is shown in Figure 6.

$$A^8 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_{10} & S_{11} \\ \begin{matrix} S_2 \\ S_6 \\ S_9 \end{matrix} & \begin{vmatrix} 0.70 & 0.70 & 0.64 & 0.38 & 0.70 & 0.77 \\ 0.77 & 0.74 & 0.70 & 0.33 & 0.77 & 0.83 \\ 0.82 & 0.78 & 0.74 & 0.29 & 0.86 & 0.89 \end{vmatrix} \end{matrix} \quad (8)$$

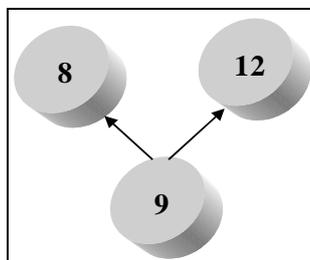


Figure 6. Structural Graph of  $A^7$

Regular rows and columns are not in the case of  $A^8$ ,  $A^9$  can be obtained by the splitting rows and arranging the matrix.

$$A^9 = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_{10} & S_{11} \\ \begin{matrix} S_6 \\ S_9 \\ S_{2a} \\ S_{2b} \\ S_{2c} \\ S_{2d} \end{matrix} & \begin{vmatrix} 0.77 & 0.74 & 0.70 & 0.33 & 0.77 & 0.70 \\ 0.82 & 0.78 & 0.74 & 0.29 & 0.86 & 0.77 \\ 0.70 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.70 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.70 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.77 \end{vmatrix} \end{matrix} \quad (9)$$

With  $A^9$  operating and arranging, matrix  $A^{10}$  like Formula (10) and structural graph of Figure 7 can be formed.

$$A^{10} = \begin{matrix} & S_1 & S_3 & S_4 & S_5 & S_{10} \\ \begin{matrix} S_6 \\ S_9 \end{matrix} & \begin{vmatrix} 0.77 & 0.74 & 0.70 & 0.33 & 0.77 \\ 0.82 & 0.78 & 0.74 & 0.29 & 0.86 \end{vmatrix} \end{matrix} \quad (10)$$

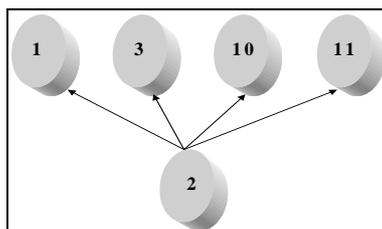


Figure 7. Structural Graph of  $A^9$

Since column  $S_5$  is a numerical value less than the threshold in matrix  $A^{10}$ , columns are eliminated. Here, since regular rows and columns are not in the remaining matrix, splitting the row is conducted in order for  $S_6$  and  $S_9$ . Here,  $S_{6a}$  becomes regular column for  $S_1$ ,  $S_{6b}$  for  $S_3$ ,  $S_{6c}$  for  $S_4$ , and  $S_{6d}$  for  $S_{10}$ , therefore,  $S_{6a}$ ,  $S_{6b}$ ,  $S_{6c}$ , and  $S_{6d}$  can be eliminated. Also, regular columns become  $S_1$ ,  $S_3$ ,  $S_4$ ,  $S_{10}$  in the arranged matrix for  $S_9$ , each can be eliminated. Doing it this way, all matrices are eliminated and the procedure is completed. Figure 8 represents the structural graph in the final stage.

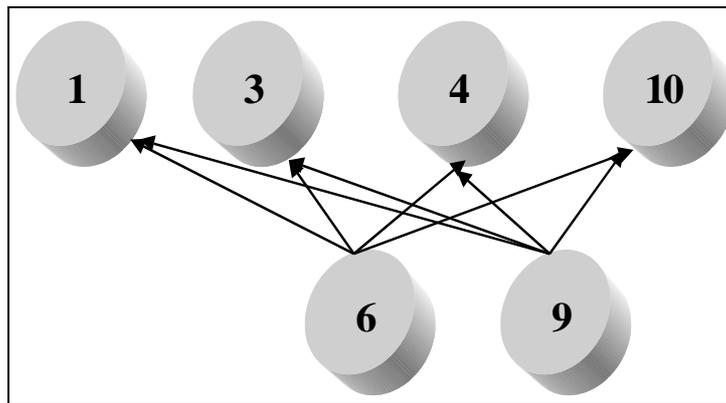


Figure 8. Structural Graph of the Final Stage

Figure 9 represents all the arrangement of structural graph from matrices  $A$  to  $A^{10}$ .

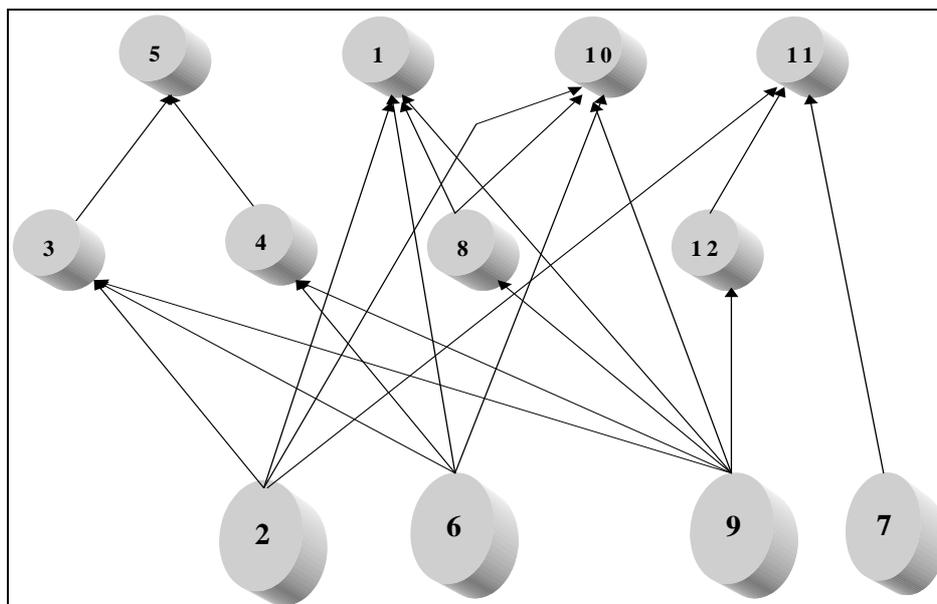


Figure 9. Schematization of Overall Structural Graph of Matrices  $A$  to  $A^{10}$

From the above figure, it can be seen that ‘port expense’, ‘location on main trunk routes’, ‘port congestion’ and ‘port facilities’ were the most important factors by the perceptions of

experts. These four factors located lower part of graph, and influenced the all other factors which located in the middle and top part of graph. This was explained by the facts that severe port competition exist in Northeast Asia, including Korea and China, and many choices could be possible from the perspective of port related experts. When this circumstance considered, lower port costs would be the most attractive factor. Moreover, sea port location in main trunk routes, e.g., Singapore, Hong Kong, Kaosung and Busan, was highly recognized to improve the port competitiveness. Finally 'no port congestion' and 'modern port facilities' were evaluated as other critical factors.

## 5. CONCLUSIONS

Ports use various strategies to increase port competitiveness. But port competitiveness can be different according to the subject of judgment, and the boundary also has vague characteristics. Therefore, this study aimed to grasp uncertain components of port competitiveness, their subordinate, and hierarchical relationships. The results of this study are as follows:

First, through the previous studies and questionnaire surveys of experts, 73 detailed elements of port competitiveness were extracted and 12 core criteria were grouped. The FSM method was applied to draw the subordinate relationships, hierarchical relationships, and the structural model which port logistics' experts consider. Second, according to the analysis of the structural model of the obtained experts' perception, the most significant components of the group included port expense, location on main trunk routes, port congestion, port facilities, etc. by the order of the grade of importance. Third, a relatively lower component group by grade of importance is the top component group. It was known that these components contained the access to hinterland nearness, the ownership of port, speediness of customs clearance, the possibility of entering port by large ships.

The results of this study will be able to be used effectively when port operators establish the competitive strategies, with relatively important components presented and port competitiveness considered.

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