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Analysis of the Efficiency of Chinese Repair Shipbuilding Industry

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Abstract

The purpose of this research is to analyze the efficiency of the Chinese repair shipbuilding industry using a DEA model with 12 Chinese repair shipbuilding companies. Unlike preceding studies, this study has different research subjects as well as selected input and output variables. The research was conducted with competitive Chinese companies in the market. For the efficiency analysis, input variables included the number of technicians as well as facilities, and output variables were diversified with relevant factors using the number of repaired ships and service ranges as well as sales. The differences were analyzed by including only facilities as an input variable for the DEA model, and then both facilities and technicians. For inefficient DMUs, the strengths and weaknesses were analyzed by finding the causes through a reference group, which was developed into an efficient DMU. Moreover, public and private companies were separated to develop improvement measures.

Key words: China repair shipbuilding industry, efficiency analysis, DEA, reference set, improvement plan

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Ⅰ. Introduction

The shipbuilding industry has played an important role in the development of the national economy. Development of the industry has critical impacts on the national economy and brings advancement to surrounding regions of the area. It makes the structure of the national economic industry to be upgraded, improves the overall national competitiveness, and influences a direct and indirect area, employment. Moreover, the industry is also important for national defense, as it protects national safety and national territory and improves the weapons equipment technology level. That is, the shipbuilding industry consists of both national factors and corporate factors.

In particular, the repair shipbuilding market in which labor, technology and capital are concentrated has the characteristics. The more vessel traffic there is due to booming global economy, the higher the bottoms(the total weight of cargo to load); which leads to an expansion of the market scale including demand for extending the service life of ship owners' ships. This is similar to the characteristics of the new shipbuilding market. Ship repair is to minimize waste of ship manufacturing resources for normal ship operations and conduct ship maintenance through quick development of the shipbuilding industry(China Ship Network, 2007). The annual aggregate value of the global repair shipbuilding market reaches 20-25 billion dollars(China Industry Information Network, 2016). As for the development process of the repair shipbuilding industry, it started in Europe, the center of repair shipbuilding, and then transferred to the U.S., Singapore and the Middle East, as well as China and Southeast Asia. This is attributable to rising labor costs, the development of ship manufacturing, the expansion of international trade, and the development of the marine transport and logistics industry. The global repair shipbuilding industry has lowered labor costs to improve productivity and accelerated M&As to realize added values by making the most use of resources. As the cycle of the marine transport industry has quickened, the importance of the repair shipbuilding market has also increased. Thus, major shipbuilding nations have integrated resources to expand the share of repair shipbuilding companies and maintained much higher competitiveness by diversifying, specializing and grouping them with strategic management operations (Forward Business Information Co., Ltd, 2017).

China has accounted for 30% of the global repair shipbuilding market since its economic reform. Its repair shipbuilding industry is distributed in the Bohai Economic Rim region mostly centering around Dalian, the Yangtze River Delta region centering around Zhoushan, and the Pearl River Delta region centering around Guangzhou. As of 2015, there were 1,452 shipbuilding companies with over 20 million yuan of sales in China, and the total sales increased 1.3% year-on-year and recorded 789.3billion yuan(Korea International Trade Association, 2016). In 2010~2013, the Chinese repair shipbuilding industry continued to develop, showing an increasing trend in total production. For GDP, the proportion of the industry increased from 0.028%

in 2010 to 0.045% in 2013. By 2022, the market scale is expected to reach 26.555billion yuan (Forward Business Information Co., Ltd, 2017). According to the 2016～2021 global repair shipbuilding analysis data published by SINA Corp., however, although the Chinese repair shipbuilding process rate(number of completed ships) accounts for 40% of the world, the value cannot reach 20%(Sina Finance, 2017). Moreover, due to the global economic recession in 2014, the total production of repair shipbuilding decreased to 25.847 billion yuan, constituting 0.041% of GDP. In 2016, the total production kept declining to 197.16 billion yuan, making up 0.026% of GDP. Although China' s share of GDP has declined, China' s share of global markets is increasing. Therefore, it is necessary to examine the current status and actual condition of the repair and shipbuilding industry in China. This resulted from the worsening environment of international trade and economy. However, since bottoms have already exceeded the marine cargo volume due to ship supply, it is expected that demand for ship repair would continuously increase rather than new shipbuilding. In the short run, the repair shipbuilding industry has grown thanks to low oil prices, but demand for large marine process equipment and special shipbuilding is not still enough; for this, long-term countermeasures are required.

Although preceding research evaluated the efficiency of the shipbuilding industry and the Korean repair shipbuilding industry, none has conducted a study on the efficiency of the Chinese repair shipbuilding industry. As such, this research utilized the DEA model to analyze the efficiency of 12 companies with top sales records in the Chinese repair shipbuilding industry in 2015. It aims to provide not only Chinese but also Korean repair shipbuilding workers with implications.

II. The DEA model

The Data Envelopment Analysis(DEA) model is a non-parametric analysis method to evaluate the relative efficiency of decision-making units(DMUs) that input the least and create as many outputs as possible with a homogeneous group using linear programming(Park, 2008). The DEA-CCR model, which presumes Constant Returns to Scale(CRS), was first suggested by Charnes, et al.(1978). Returns to Scale(RTS) means the increasing rates of output when proportionally increasing input factors. The DEA model is a radial model that reduces input and output at the same proportion when finding the efficiency point. As it has directivity called "input standard" that fixes outputs and reduces inputs and "output standard" that fixes inputs and increases outputs, it is called an oriented model. The CCR model measures technological efficiency of DMU with DMU(Decision Making Unit), which uses minimum production input factors to produce outputs, and relative ratio with remaining DMUs. The input-oriented CCR model that presumes CRS(Constant Returns to Scale) based on input factors uses the equation(1).

$$Max \quad Eo = u_1 y_{10} + u_2 y_{10} + \cdots u_a y_{ao}$$

$$s.t \quad \sum_{i=1}^{m} v_i x_{i0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} \le \sum_{i=1}^{m} v_i x_{ij} (j = 1, 2, \cdots, s)$$

$$\text{and} \quad u_i \ge 0 (i = 1, 2, \cdots, s) \qquad (equation 1)$$

If the optimal solution of the CCR input-oriented model described above is $(v_1^*, v_2^*, \cdots, v_s^*; u_1^*, u_2^*, \cdots, u_m^*)$, $v_i^* x_{i0}$ is the virtual input of the input factor i of DMU_o, $u_r^* y_{ro}$ is objective function of DMU_o, and E_o^* is DEA efficiency score. In the equation, if $E_o^* = 1$, DMU_o is efficient; while if $E_o^* < 1$, DMU_o is inefficient.

In the CCR model, if the value of efficient DMU becomes or gets closer to "1," it is regarded to have efficiency. If it becomes an efficient frontier, both the input and output factors' slack will become "0" (Kim and Park, 2016).

Use lots of input variables and output variables in the DEA model to evaluate the efficiency, and then analyze right away without having to decide their weights. Moreover, if the units of the input and output variable data match each other, the efficiency of DMU does not affect the analysis results at all. Based on the analysis results, efficient DMU and inefficient DMU can be identified. The person in charge may identify problems of inefficient DMU and prepare benchmarking measures to see proper input and output. The the DEA model has so far been applied to various areas.

Ⅲ. Literature review

Zhang and Xu(2010) used the business data of 19 domestic and overseas shipbuilding companies as of 2006 and included total facility area, production rate, electrical consumption for production and average labor costs for input variables, and completion rate and production rate for output variables. Chen and He(2015), with the PCA-the DEA model, used total prime costs, total assets and number of employees for input variables, and operating profit and total earnings for output variables to analyze the efficiency of the Chinese shipbuilding industry. Zhang, *et al.*(2011) utilized the DEA model and included capital input level, personnel input level and technology input level for input variables; the rate for major parts to be determined 1st class, number of days with decreased vessel cycle, rate of using facilities, and variety flexibility for output variables in order to evaluate and analyze the optimal efficiency of production process for 10 Shipbuilding companies in Taizhou, Zhejiang. However, there has been no research analyzing the efficiency of Chinese repair shipbuilding.

Park and Kim(2012), based on the 2004～2010 data of 7 shipbuilding companies, used the number of employees, inner wall length and dock area for input variables, and shipbuilding tonnage for output variables to study using the DEA-Malmquist production index and panel analysis. Park(2010) utilized 7 shipbuilding companies' 2004-2009 data and analyzed DEA, Super-efficiency, DEA/Window and Malmquist production by using the number of employees as an input variable and shipbuilding tonnage as an output variable.

Kim(2010) conducted an efficiency analysis using DEA with 50 Korean shipbuilding companies, with capital and number of employees as input variables, and sales and net income as output variables.

Kim(2017) used DEA to analyze multilevel production for measurement of shipbuilding performance. For input variables, capital production performance and design performance considered with labor productivity were used, and shipping charges, which is a financial variable directly related to sales of shipbuilding companies, were used for output variables. As a result of a Tobit regression analysis for indices related to production performance, automatic welding was the most influential performance variable on productivity.

Using the DEA-Window and Malmquist productivity index analysis, Koo *et al.* (2014) analyzed 12 private and public ship-manufacturing companies in China by including the number of employees, inner wall length and area in input variables, and number of ships, shipbuilding tonnage and sales in output variables.

Ecorys Research and Consulting(2009) analyzed the characteristics and development process of the shipbuilding industry in Europe. It also identified the current competitive status and competitors, and developed a strategy to develop the European shipbuilding industry by using the SWOT analysis technique.

Jiang *et al.*(2013) evaluated the measurement factors of competitiveness for the global shipbuilding industry with profit rates; they revealed that the Chinese shipbuilding industry has competitiveness due to the cost, while Japanese and Korean shipbuilding has competitiveness when it comes to contract price deviation. For building bulk carriers and tankships, China has higher competitiveness than Japan, and its gap between Korea has decreased since 2000.

Lee *et al.*(2015) studied the changes of ship import and export structure in Korea and China based on the comparative advantage theory of international trade using time series data of market share ratio, relevant comparative advantage index and trade specialization index.

When it comes to research on repair shipbuilding, Lee and Jang(2012) focused on 24 repair shipbuilding companies specialized for organizations in Yeongdo-gu, Busan by setting the number of technicians, factory scale, labor costs and material costs as input variables, and annual sales as an output variable. Song *et al.*(2010) compared and analyzed global competitiveness among major repair shipbuilding nations based on the major indices for competitiveness of repair shipbuilding yard: location condition, repair costs and technological competitiveness. Kim and Park(2016) analyzed the DEA and Malmquist productivity index for nine ship repair companies in Busan, Gyeongsangnam-do and Jeollanam-do by including tangible fixed assets and the number of employees in input variables, and sales and operating profit in output variables.

In addition, Park *et al.*(2003) investigated the current status of the repair shipbuilding industry in Busan and prospected the future of the industry by studying the management conditions and business environment of 54 major repair shipbuilding companies in Busan. Oh *et al.*(2007) explored measures to establish a development model for the new port of Busan with the repair shipbuilding industry in the city. Most of the existing literature identified the current status and condition of the repair shipbuilding industry and suggested the industry as an alternative industry or local development industry for new shipbuilding(Lee and Jang, 2012).

Dev and Saha(2015) estimated multiple regression models by the least squares method so as to develop a model on ship repair time with 600 cargo ships dealt with at a single yard. The analysis results showed that ship type, age of vessel, loadage, and major hull repair tasks including coating, piping, structural steel and tank coating had effects on repair shipbuilding time.

Despite the studies and evaluations on the efficiency of the shipbuilding industry, further research on the repair shipbuilding industry is required. Accordingly, this research analyzed the efficiency of the top 12 Chinese repair shipbuilding companies in sales in 2015 using the DEA model. Regarding the strengthened competitiveness of the Chinese industry, it identified decision-making units of the companies and analyzed efficiency levels. Based on the results, this research aims to provide officials from the Korean government and those who are involved in Korean repair shipbuilding companies with various implications for competitiveness and development of the Korean industry.

Ⅳ. Empirical analysis

1) Selection of analysis subjects and variables

This research analyzed 12 companies efficiency out of the top 14 Chinese repair shipbuilding companies in sales as of 2015, whose data were available. The data were collected from the 2016 China Shipbuilding Industry Yearbook, the China Association of the national Shipbuilding Industry Repair Branch, the companies' official sites, phone calls and e-mails with persons in charge of operations, and 'Report on the demand and supply and investment prospect and analysis on the Chinese repair shipbuilding industry' by Forward Business Information Co., Ltd. (2017).

Based on existing research, this research selected total length and area of dock, total weight of dock and floating dock and number of technicians, which are factors that have the most direct influence on company efficiency, as input variables; and number of repaired ships, national and local scope that used repair shipbuilding service as well as 2015 sales as output variables. This research employed the DEA model and used the DEAP2.1 program.

Table 1. Preceding research on the efficien cy evaluation shipbuilding and repair shipbuilding industry

Source	Evaluation targets	Variables		Applied model
		Input variables	Output variables	
Kim(2010)	with 50 Korean shipbuilding companies	· capital · number of employees	· sales · net profits	DEA-BBC DEA-CCR
Park(2010)	7 companies: Hyundai, Samsung, Daewoo, Hyundai Samho, Hanjin, Hyundai Mipo, STX, etc.	· number of employees	· shipbuilding tonnage	DEA-BBC Super-efficiency DEA/Window Malmquist
Zhang and Xu (2010)	19 shipbuilding companies at home and abroad	· facility total area · production rate · electricity used · average labor costs	· completion rate · production rate	DEA-CCR
Zhang *et al.*(2011)	production process optimization efficiency of 10 shipbuilding companies' in Taizhou, Zhejiang	· capital input · personnel input · technology input	· rate of parts to be determined 1st class · number of days with decreased vessel cycle · rate of using facility · variety flexibility	DEA-CCR
Lee and Jang (2012)	24 repair companies specialized for the region, Yeongdo-gu, Busan	· number of technicians · plant scale · labor costs · material costs	· annual sales	DEA-BBC
Park and Kim (2012)	7 companies: Hyundai, Samsung, Daewoo, Hyundai Samho, Hanjin, Hyundai Mipo, STX, etc.	· number of employees · inner wall length · dock area	· shipbuilding tonnage	Malmquist panel analysis
Koo *et al.*(2014)	12 private and public shipbuilding companies in China	· number of employees · area · coastal length	· number of ships · shipbuilding tonnage · sales	DEA-Window Malmquist
Chen and He (2015)	7 shipbuilding companies listed in China	· total prime costs · total assets · number of employees	· operating revenue · total operating revenue	PCA-DEA
Kim and Park (2016)	9 ship repair companies in Busan, Gyeongsangnam-do and Jeollanam-do	· tangible fixed assets · number of employees	· sales · operational profits	DEA-BBC Malmquist
Kim(2017)	data on 123 medium product carrier built at M shipyard in 2011~2015	· man hour · number of blocks equipped with air at dock rate of automatic welding · rate of design error · rate of process compliance	· shipping charges · shipbuilding tonnage	DEA-BBC DEA-CCR Tobit analysis

Table 2. output and input variables

	Variable name	Measurement unit
Output	sales in 2015	10,000 yuan
	number of repaired ships	
	service scope (nation and region)	
Input	total dock length	m
	total area of dock	10,000 ㎡
	dock and floating dock total weight	10,000 tons
	number of technicians	

2) Efficiency analysis

For efficiency analysis, the descriptive statistics of the input and output factors is as follows:

Table 3. Descriptive statistics of selected input and output variables

	Max.	Min.	Avg.	SD.
Sales in 2015	286,000	37,900	95,783	71,288
Number of repaired ships	786	163	270	169
Service scope (nation and region)	50	9	27	11
Total dock length	8,858	774	2,855	2,466
Area	600	21	146	166
Dock and floating dock total weight	252	27	69	60
Number of technicians	1,666	119	729	465

The total dock length was calculated by summing dock lengths owned by each DMU. As for groups, length of docks only for repair shipbuilding was used. The total weight of dock and floating dock was also used by summing up. For service scope, an integral was used for cases not described exactly. Due to a lack information on three companies, the number of technicians was presumed using the ratio of sales and estimated average number of repaired ships, and service scope was presumed with sales and estimated average number of repaired ships.

The maximum value, minimum value, average and standard deviation of the input variables – total length and area of dock, total weight of dock and floating dock and number of technicians – showed differences among the repair shipbuilding companies.

The results of the DEA analysis for the Chinese companies that only facility was used as an input variable are as follows:

Table 4. Efficiency analysis on each DMU (input variable: facility)

DMU	Efficiency score	Ranking
DMU1	1.000	1
DMU2	0.819	5
DMU3	0.839	4
DMU4	0.566	7
DMU5	1.000	1
DMU6	0.969	3
DMU7	0.434	9
DMU8	0.993	2
DMU9	0.454	8
DMU10	1.000	1
DMU11	1.000	1
DMU12	0.766	6

The analysis results show that four companies including DMU 1, 5, 10 and 11 were evaluated to be efficient, while the other eight companies including DMU 4 were analyzed to be inefficient. While most of existing literature considered variables for facility, this research conducted efficiency analysis considering number of technicians; this means a difference in the existing efficiency score. The analysis results revealed six efficient companies including DMU 1, 5, 6, 8, 10 and 11 and the other six inefficient companies including DMU 2. When number of technicians was used as an input variable, DMU8, a non-efficiency company, was converted into an efficient one. Moreover, the efficiency of DMU 2, 3, 4, 7, 9 and 12 was more improved than when only facility was input.

Table 5. Efficiency analysis on each DMU (input variables: facility and number of technicians)

DMU	Efficiency score	Ranking
DMU1	1.000	1
DMU2	0.907	3
DMU3	0.964	2
DMU4	0.690	6
DMU5	1.000	1
DMU6	1.000	1
DMU7	0.624	7
DMU8	1.000	1
DMU9	0.720	5
DMU10	1.000	1
DMU11	1.000	1
DMU12	0.857	4

To identify the cause of non-efficiency DMU, reference groups and improvement potential were suggested:

Table 6. Reference unit of inefficient DMU

DMU	Reference unit
DMU2	DMU5, DMU1, DMU11
DMU3	DMU5, DMU6, DMU11
DMU4	DMU1, DMU5, DMU10
DMU7	DMU1, DMU5
DMU9	DMU1, DMU5
DMU12	DMU5, DMU1, DMU10, DMU11

As for DMUs that are reference groups to each inefficient DMU, DMU1 and DMU5 relatively seemed to be representative. Compared to reference groups, DMU9 was more inefficient than DMU1 and DMU5. Compared to DMU1, DMU9 was revealed to be operating at just 72% efficiency.

Table 7. Average efficiency analysis on inefficient DMUs

Corporate charac-teristics	DMU	Average efficiency by input	
		Facility input	Facility+number of technicians
Public	DMU3	0.652	0.750
	DMU4		
	DMU7		
	DMU9		
Private	DMU2	0.860	0.882
	DMU12		

For the corporate characteristics, public enterprises and private enterprises, the average efficiency of inefficient DMU was compared by inputting facility and number of facilities and technicians, and private enterprises showed higher average efficiency. In general, unlike corporate characteristics, inputting both facility and number of technicians had higher average efficiency than inputting only facility.

Non-efficiency levels of each company were estimated with the goal values of input and output factors for optimized scale for efficient management and slack values of inefficient companies. Through this, it was possible to see which part of each DMU is inefficient. If the results of the analysis based on the CCR model shows (+) value for improvement levels, each company for each input and output factor need to increase this. On the other hand, (-) value means that each company needs to reduce each input and output factor. As shown in Table 8, inefficient DMUs – DMU2, DMU3, DMU4, DMU7, DMU9 and DMU12 – have improvement potential. For example, the efficiency value of DMU9 is 0.72; compared to DMU1 and DMU5, which is considered to have the same structure for input and output, the input factor of total length and area of dock shows 72% efficiency due to excessive input. Therefore, DMU9 wastes 28% of resources, operating inefficiently. For efficient management, it is necessary to develop improvement measures by referring to the DMU of reference groups and adjust the amount of input variables.

V. Inefficient DMU analysis and improvement measures

Table 8 shows that total length and area of dock, total weight of dock and floating dock and number of technicians were all input excessively in DMU2, DMU3, DMU4, DMU7, DMU9 and DMU12. While DMU2, DMU3, DMU7 and DMU9 showed proper output sales, they were less than DMU4 and DMU12. On the other hand, the other DMUs that repaired ships and service range had properly been output were underestimated; which implicates low profitability of products and service. Therefore, it is required for DMU2, DMU3, DMU7 and DMU9 to reduce input amount and expand the number of repaired ships and service range. As DMU4 and DMU12 estimated fewer sales compared to the input amount, it is necessary to reduce the input scale.

The inefficient DMU was divided according to eh characteristics and further investigation was conducted on the DMU. As seen in Table 9, the pros and cons of inefficient DMUs were analyzed according to the characteristics of DMUs (public and private) and improvement measures were suggested. Located in the Pearl River estuary, DMU3 is close to Hong Kong and Macau. There are many high-ranking managers and technicians who belong to public groups and have rich experience and research skills. DMU4 is affiliated to a public group, and its mother company has promoted market entrance. Technological and managerial competitiveness have continuously been developed to provide customers with satisfactory products. DMU7 is affiliated with the

Chinese State-Owned Shipping Company, and its facility scale and the production capacity of equipment have been expanding. It also has a research center on ships and marine engineering. Having branch offices across China and an internationally recognized large ship company, DMU9 is highly influential at home and abroad. Additionally, since branch offices affiliated to the group are included in the medium and long-term development plan of China's shipbuilding industry, they have advantages in utilizing resources.

However, public enterprises(DMU3, DMU4, DMU7, DMU9) have relatively larger liabilities and higher financial risks. Being a national company, it has to carry out systematic tasks, which makes it less flexible. Despite the proper scale, the level of integrated service is low and the service contents are too simple. Therefore, it is necessary to increase the turnover ratio of assets and change the operating system by converting the information system to input or decision-making methods. It is also necessary to nurture technicians through industry-academy cooperation projects and hire specialized technicians for the market. The R&D technological model is commercialized and developed in the market. It needs to provide differentiated and added-value services by linking with measures to motivate employees to promote aggressive marketing activities. On the other hand, a private enterprise, DMU2, is geologically favored thanks to the surrounding waters. Not only facilities are well equipped, but also, as a joint-stock company, related companies' resources are accessible. Preferentially, it established a comprehensive management system for quality, work safety and environment in Korea, and then acquired global certificates. Such characteristics have put the company in the number 3 position in China's repair shipbuilding market, increasing international awareness.

Table 8. Improvement level of inefficient DMUs

DMU	Improvement potential	Input variables				Output variables		
		Total dock length (m)	Area (10,000 ㎡)	Dock and floating dock total weight (10,000 tons)	Number of technicians	sales in 2015 (10,000 yuan)	Repaired ships	Service range (nation and region)
DMU2	Value of measured variable	2,290.00	102.00	90.00	1090.00	143,200.00	263.00	30
	Goal value	2,078.10	92.56	72.37	989.14	143,200.00	429.59	43.87
	Improvement level	0.09	0.09	0.20	0.09	0.00	-0.63	-0.46
DMU3	Value of measured variable	3,400.00	70.00	72.00	700.00	111,600.00	233.00	28.00
	Goal value	1,939.81	67.47	69.40	674.69	111,600.00	401.09	28.61
	Improvement level	0.43	0.04	0.04	0.04	0.00	-0.72	-0.02
DMU4	Value of measured variable	5,642.00	209.00	63.00	900.00	62,700.00	252.00	30.00
	Goal value	1,257.35	67.26	43.45	620.76	88,932.78	252.00	30.00
	Improvement level	0.78	0.68	0.31	0.31	-0.42	0.00	0.00
DMU7	Value of measured variable	5,000.00	330.00	55.00	787.00	72,000.00	163.00	20.00
	Goal value	953.74	49.47	34.32	491.15	72,000.00	193.00	23.88
	improvement level	0.81	0.85	0.38	0.38	0.00	-0.18	-0.19
DMU9	value of measured variable	8,858.00	600.00	252.00	1666.00	286,000.00	786.00	50.00
	goal value	4,001.94	225.61	181.44	1199.53	286,000.00	878.77	102.11
	improvement level	0.55	0.62	0.28	0.28	0.00	-0.12	-1.04
DMU12	value of measured variable	1,310.00	55.00	45.00	38.58	46,000.00	207.00	20.00
	goal value	953.91	47.16	38.58	300.09	60,443.75	207.00	20.00
	improvement level	0.27	0.14	0.14	-6.78	-0.31	0.00	0.00

Table 9. Characteristics and improvement measures of inefficient DMU

<table>
<tr><th>DMU</th><th>Charact eristics</th><th>Advantages</th><th>Disadvantages</th><th>Improvement measures</th></tr>
<tr><td>DMU3</td><td rowspan="4">Public</td><td>· belong to a public group
· many high-level managers and technicians with abundant experience
· located in Pearl River estuary, and close to Hong Kong and Macau</td><td rowspan="4">· with relatively large liabilities, high financial risks
· public companies have lower flexibility toward systematic changes
· low integrated service level
· simple service contents</td><td rowspan="4">· improve turnover ratio of assets by strengthening management capability and adjusting the financial structure
· improve efficient operating system by utilizing information system or changing decision-making method
· optimizing resource arrangement
· providing all-in-one service
· nurturing talents and improving technological ability through academy-industry cooperation
· providing service and value-added service and promoting active marketing activities by utilizing advantages of public companies</td></tr>
<tr><td>DMU4</td><td>· affiliated to a public group, and its mother company promotes market entrance
· high utilization of resources thanks to national macroscopic political support
· consistent development of technological and managerial competitiveness</td></tr>
<tr><td>DMU7</td><td>· affiliated to Chinese State-Owned Shipping Company
· expanding facility scale and equipment production capability
· high utilization of resources thanks to national macroscopic political support
· operating a research center on ships and maritime engineering</td></tr>
<tr><td>DMU9</td><td>· has branch offices and large ship companies with high international awareness
· high utilization of resources thanks to national macroscopic political support
· a branch office affiliated to the group is included in medium and long-term development plan of China's shipbuilding industry
· high awareness at home and abroad</td></tr>
</table>

<table>
<tr><th>DMU</th><th>Characteristics</th><th>Advantages</th><th>Disadvantages</th><th>Improvement measures</th></tr>
<tr><td>DMU2</td><td rowspan="2">Private</td><td>· advantages location in terms of waters
· as a joint-stock company, related companies' resources are accessible
· high international awareness
· established a comprehensive management system for quality, work safety and environment in Korea, and then acquired global certificates</td><td rowspan="2">· low professionalism in corporate internal management
· low work capacity
· low market profits for product
· relatively narrow service market range</td><td rowspan="2">· prevent excessive investment and more focus on internal management
· improve work ability and provide various high-profit services
· secure competitive edge through economy of scale via merger and partnership among enterprises
· improve market share by designing the management activities for repair shipbuilding
. actively cooperate with marine transport companies by switching the management method and conclude long-term contracts
. retain customers by utilizing repair shipbuilding agencies</td></tr>
<tr><td>DMU12</td><td>· located in favorable location for waters
· as a joint-stock company of Korea, China and Japan, it is easy to secure the Korean, Chinese and Japanese market
· planning to expand its scale and facility production capacity</td></tr>
</table>

DMU12 is located in a prominent region of the global maritime route, Yangshan Deep-water Port, and the intersection of China North-South Water Path and Chang Jiang Golden Waterway. As a joint-stock company of Korea, China and Japan, it is easy to secure the Korean, Chinese and Japanese market and is planning to expand its scale and facility production capacity. However, DMU12 has faced the same problems as a private enterprise, DMU2.

Although the private enterprises of DMU2 and DMU12 have continued to expand their management scale, they lack professionalism for internal business management. Accordingly, their work abilities and market profits have decreased, and the service ranges are relatively narrow. Thus, DMU2 and DMU12 need to reduce corporate inputs, concentrate more, improve work abilities and provide various services with high profitability.

Merger and partnership between public and private enterprises can secure a competitive edge through economies of scale. As the scope of the service market is relatively small, market share can be improved by designing the management activities for repair shipbuilding from the viewpoint of customers, using all resources. Moreover, it is necessary to actively cooperate with marine transport companies by switching the management method and conclude long-term contracts. It is also necessary to retain customers by providing various services and utilizing repair shipbuilding agencies.

Both public and private enterprises need to perform continuous upgrades in technology, management and industry. In addition, strengthening global cooperation and convergence of industry and science technology are necessary to lower costs and adjust the industrial structure.

VI. Conclusion and discussion

The repair shipbuilding industry has been transferred to China as well as Southeast Asia due to increases in labor costs, development of ship manufacturing, and other reasons. Across the world, the speed of M&As in the industry has quickened, and the industry has developed through diversification, specialization and grouping to obtain high productivity and added value with cheaper labor costs. The recent generation of stable imports has developed China's repair shipbuilding industry, but growth is becoming sluggish due to deteriorated international trade and the economic environment. Although the Chinese repair shipbuilding process rate takes up a large proportion on the international stage, the value is low; furthermore, the recession of the marine transport industry, the ship owners' financial crisis and the trend of lowering age of ships have been unfavorable factors. On the other hand, China has narrowed the gap with Korea by keeping a competitive edge in workforce and labor costs and improving design ability and production technology. As such, it is expected that China would account for a large proportion in order quantity in the global repair shipbuilding market.

Although the Chinese repair shipbuilding market is getting bigger, it is necessary to evaluate the industry at this point. In order to understand repair shipbuilding companies in China, this research analyzed the efficiency of 12 Chinese companies using the DEA model.

As for the characteristics of variables, input variables such as total length and area of dock, total weight of dock and floating dock and number of technicians show significant differences among the companies. Output variables including sales, repaired ships and service range also have significant differences among the companies.

As a result of the efficiency analysis, using only facility as an input variable and using both facility and number of technicians showed differences. As for inefficient DMU, after inputting the number of technicians, the efficient DMU is converted. Therefore, number of technicians is important to make decisions for running repair shipbuilding companies. Moreover, it is necessary to invest in the repair shipbuilding industry so as to develop employees' technological skills , research, development capacity and hire high-class technicians.

This research identified the input and output factors of inefficient DMU, and developed measures to improve efficiency based on improvement levels of inefficient companies. In particular, public companies among inefficient DMUs have relatively bigger liabilities and higher financial risks, causing additional financial expenses. The characteristics of public enterprises let enjoy the advantages, but at the same time, limits improvement of efficiency. While private enterprises have continuously expanded, they lack internal management skills and work professionalism, and have a relatively small service range. This requires M&A among companies in the repair shipbuilding industry, rearrangement of resources and upgrades of industrial structure. A win-win relationship between public and private enterprises is also necessary. Although public companies put an emphasis on liability scale and financial risks, private companies need to consider systematic internal management, nurturing talents, and others. As such, it is necessary to develop alternatives to secure a growth engine for sustainable development against strengthened environmental regulations, lack of manpower and China catching up with us in the repair shipbuilding industry.

In Korea, the repair shipbuilding industry has been considered only a part of the shipbuilding industry. However, the industry boosts production and creates employment opportunities; as it is a high value-added industry that expands the economy by being linked to other industries such as IT, people' s awareness of the industry needs to be changed. Since most Korean repair shipbuilding companies are small, political support is also necessary to promote the industry in Korea. Repair shipbuilding companies always hold financial risks and problems in internal management and nurturing talents. Through the analysis of the efficiency of the repair and shipbuilding industry in China, it will be necessary to make efforts to improve the staff capacity and R&D of the repair and shipbuilding industry in Korea. To solve such difficulties, they need to develop an industry-academia cooperation system.

The limitation of this research is that a non-parametric method including the DEA model was employed for analysis; it is necessary to further study using various methods including a parametric method. As there were a small number of repair shipbuilding companies that can be compared, and there were difficulties in investigating corporate internal financial conditions and collecting various evaluation data aside from service levels, it was difficult to conduct a comprehensive efficiency evaluation. Follow-up studies are required to select various variables and collect relevant data. Moreover, they need to use the suggested input and output variables for efficiency evaluation for Korea' s repair shipbuilding companies in order to compare with this research results and draw more abundant implications.

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중국 수리조선산업의 효율성 분석에 관한 연구

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국문요약

본 연구는 12개 중국 수리조선 업체를 대상으로 DEA모형을 활용해 중국 수리조선산업의 효율성을 분석하고자 하였다. 기존 연구들과 달리 본 연구에서는 연구대상 뿐만 아니라 선정된 투입과 산출변수도 차별성을 지닌다. 연구대상은 수리조선시장에서 경쟁우위를 보이고 있는 중국의 업체를 대상으로 진행하였다. 효율성 분석을 위한 투입변수는 시설 외에 기술자 수를 고려하였으며, 산출변수는 매출액 외에도 수리선 척수 및 서비스 범위를 사용하여 관련 변수들을 다양화하였다. 분석에는 DEA모형에 의하여 시설만 투입변수로 한 경우 및 시설과 기술자 수를 투입변수로 하여 차이점을 분석하였다. 비효율적인 DMU의 경우, 효율적인 DMU가 될 수 있도록 참조집합을 통해 비효율성의 원인을 찾아 장단점을 분석하였다. 또한 국영기업과 민영기업을 구분해서 개선방안을 도출하였다.

주제어: 중국 수리조선산업, 효율성 분석, DEA, 참조집합, 개선방안