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환적화물 유치를 위한 동북아 항만간 경쟁에 게임이론의 응용

On the Application of Game Theory to the Competition among Major Ports in NE Asia for T/S Cargos

한욱*.박계각*†.안태영**
Xu Han, Gyei-Kark Park†, and Tae-Young Ahn

*목포해양대학교 해상운송시스템학부
**한서대학교 국제통상학과

요 약

동북아시아 경제의 급성장으로 인한 지역 물동량 및 해운시장 환경 변화에 따라서 부산항과 상해항은 동북아 물류 중심 허브가 되기 위하여 항만개발 및 항만 경쟁력을 강화해 왔으며, 최근에는 환적 컨테이너 화물 유치경쟁이 더욱 심화되고 있다. 따라서 본 연구에서는 동북아 주요 컨테이너 항만중 경쟁관계에 있는 부산항과 상해항을 대상으로 이 두 항만이 피더항의 환적화물을 유치하기 위한 경쟁의 게임모형을 수립하여 경쟁상황을 분석하였다.

키워드 : 동북아, 주요항만, 환적컨테이너, 게임이론, 경쟁모형

Abstract

Due to rapid growth of East Asian economy, some changes are being made in trade volume and shipping market of this area. Busan port in Korea and Shanghai port in China are continually increasing their investment in port development and competitiveness in order to become the logistics hub of Northeast Asia. Especially the competition for transshipment containers becomes more and more fierce. So in this study, we set a goal of increasing the port competitiveness on transshipment cargo by an analysis of competition strategies. We choose the Busan port and the Shanghai port as the research objects, game competition model and real data is used to analyze the two ports′ price strategies and market share. According to the results, some advices will be put forward to enhance competitiveness of the two ports.

Key Words : NE Asia, Major Ports, T/S Containers, Game Theory, Competition Model.

1. Introduction

Due to scale effect trunk container ships have tended to be large-sized over the past few years. Taking economy and efficiency of shipping operations at sea into account, major shipping companies usually call at a small number of ports in a certain region. As a result, a transportation network system of HUB AND SPOKE, which centers on hubs and carries out multi-branch lines to cover surrounding feeder ports, has taken shape gradually[1]. The hub port provides transshipment and ocean transportation services primarily, while the feeder ports generally gather cargo into the hub port by small-sized container vessels of 500-1,000 TEUs. Compared with general containers, the T/S container is characterized with high additional value which can not only increase the port throughput and create huge revenue, but also improve port's function as a maritime logistics center and thus advance the port's attraction and its international reputation. In Northeast Asia, recently, with the rapid development of economy, many ports obtain a chance to develop and to expand quickly. In order to become the logistics central hub of Northeast Asia, each port authorities has taken great efforts on port infrastructure upgrading and policy support, also, we can see the competition among major ports is becoming fiercer[14].

Therefore, this paper aims at improving the transshipment competitiveness of ports to adopt to the changes of marine market in Northeast Asia. We take an analysis of strategies of port price and service and make recommendations for the port policy setting and

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†교신저자

corresponding strategies by using game theory[6-8].

This paper consists of the following sections, for further details: In second section, based on game theory and the Hotelling method, we build a competition model for Busan port and Shanghai port; The third section deals with analysis of port price strategies and influence factors; In the fourth section, real data is adopted to the competition model to analyze the market share; In the last part, we take a conclusion of our research and give a plan for future study.

2. Game Model on the Competition between Busan and Shanghai Ports

2.1. Competition for T/S containers among major ports in NE Asia

Japan, South Korea and China in the Northeast Asia have achieved a rapid economic growth since the mid-20th century. Nowadays, Northeast Asia accounts for 25% of the world's GDP. Rapid economic development has led to more demands for international trade and logistics, which has accelerated the development of ocean transportation and port industry in the meantime. Many countries have been making great efforts in the development and expansion of ports, in order to build the maritime logistics center of Northeast Asia, the competition among major ports also appears to be fiercer.

Table 1. T/S Container Handling Capacity of Major Ports in NE Asia

(Unit: million TEUs, %)

Port		Shang hai	Busan	Ning bo	Qing dao	Tokyo	Kobe	Guang yang
2007	C	26.15	13.26	9.36	9.46	4.12	-	1.73
	T/S	5.75	5.81	0.94	0.95	0.36	-	0.31
	%	22	43.8	10	10	8.8	-	18.1
2008	C	27.88	13.43	11.2 2	10.32	4.27	2.4	1.81
	T/S	6.13	5.81	1.68	1.55	0.54	0.49	0.36
	%	22	43.2	15	15	12.7	20.2	20
2009	C	25.00	11.98	10.5	10.26	3.38	4.09	1.83
	T/S	-	5.37	-	-	-	-	0.30
	%	-	44.8	-	-	-	-	16.7

Note: PDAC data

From Table 1 we know that in Northeast Asia's main ports, Busan port has a obvious advantage on international transshipment, keeping more than 40% transshipment rate over years. The earthquake in 1995 destroyed Kobe, Busan Port seized the opportunity and grew quickly. It became the largest transit port in Northeast Asia. On the contrary, overall international transit decreased in recent year, the T/S containers of Japan's four largest port is less than 1million TEUs. Shanghai port has more than 20% of the conversion rate, where most of the boxes come from Changjiang River and coastal transshipment while International transshipment is small. However, Shanghai port has lots penitential in attracting T/S cargos with government support, water depth conditions, capacity, and operation efficiency. Ningbo port, as a newer port, is a competitor of competing to be a center harbor in Northeast Asia with its natural condition of deep water and first-class facilities[2].

According to SP-IDC's data, as the biggest foreign trade port in Korea, the port of Busan handles some 90% of the international T/S containers of the nation's share, which mostly from China's mainland and Japan. These boxes are transported to Busan by branch lines, and are then transferred to large container ships serving on the trunk route, towards the final destination (North America and Europe mostly). The following table shows container throughput and T/S container throughput between the port of Busan and some major ports in China[3].

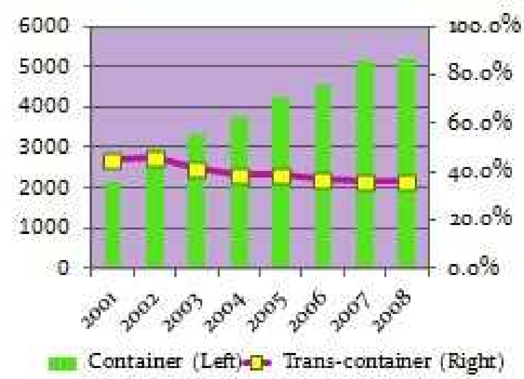

Figure. 1. T/S container volume of Korea-China

We should note that, as shown in Fig. 1, the transshipment rate between Korea and China shows a downward trend. On one hand, with the rapid rise of Chinese ports, major global shipping companies like Maersk has strengthened the cooperation with them. In addition, ports of Tianjin, Dalian, etc. have launched direct routes gradually since 2002[4]. On the other hand, the new transshipment pattern in Chinese coastal region, which takes Shanghai and Ningbo in the central region, Qingdao in the northern region as intermediate points, has reduce the attractiveness of Busan port for transshipment source from northern China[5].

2.2. Building A Game Competition Model for Busan port and Shanghai port

From the view of port condition and policy support, in Northeast Aisa, the most international competitiveness two ports are the Busan port of Korea and Shanghai port of China. So in our study, these two ports are chosen as the research objects and the competition model for the T/S cargo between them are described as Fig. 2.

Qingdao Port, after Tianjin, is the second largest port among ports, which transits containers between Busan port. Cargo of Qingdao is mainly transported through Busan to Europe and the United States. The volume of T/S containers increased significantly especially after an alliance had been formed among Busan and major ports in Shandong Province. On the other side, the Chinese government also actively promotes the establishment of a transportation network with Shanghai as a hub port. In addition to facing huge hinterland, Shanghai Port also increases the intensity of competition in the international T/S cargos.

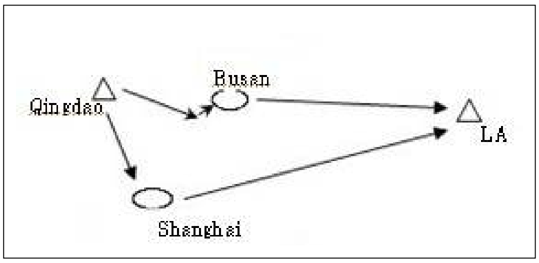

Figure. 2. Competition model of Busan port and Shanghai port

Assuming that shippers located in the feeder port want to send their cargo to the port of LA, and they should take a selection between Busan and Shanghai as their transit-port, See Fig. 2. In general, the shippers would think over factors like transport cost, port charges, service quality and time, ect. before making a decision on shipping route. We use utility function to measure the customer's satisfaction, referring to the utility function for port choice which was built by Park and Kim(2010)[10-13]. When customer chooses the Busan port or the Shanghai port, the utility of them can be expressed respectively as

$$U_{(p_B, q_B)} = J_i \cdot \lambda q_B - p_B - x_{Q-B} \cdot t_1 - x_{B-LA} \cdot t_2 \quad (1)$$

$$U_{(p_S, q_S)} = J_i \cdot \lambda q_S - p_S - x_{Q-S} \cdot t_1 - x_{S-LA} \cdot t_2 \quad (2)$$

whereas p_B ,p_S mean the port service prices of Busan and Shanghai and q_B, q_S mean the service quality of Busan and shanghai. x indicates the distance between two port, t_1,t_2 are the freight for unit cargo on unit distance in terms of near-sea transport and ocean transport respectively. $\lambda > 0$ is the value coefficient of port service.

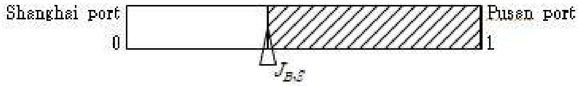

Figure. 3. Distribution of shippers' preference for port service

Suppose that shippers' preference to port service quality are in [0,1] and meeting uniform distribution, see Fig. 3, Busan port with relatively high service level is on the right side and shanghai is seated on the left. There will be a customer attaches the same utility whether when he chooses Busan or Shanghai, we call him limitation customer and his preference is defined as $J_{B,S}$. Let $U(q_B, q_B) = U(q_S, q_S)$, we have

$$J_{B,S} = \frac{p_B - p_S + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2}{\lambda(q_B - q_S)} \quad (3)$$

if $J_{B,S} \le 0$, all the users will choose Shanghai port;
if $J_{B,S} \ge 1$, all the customers will choose Busan port;
if $0 < J_{B,S} < 1$, the two ports will share the T/S cargos from the feeder port.

3. Analysis of Port Price Strategies

According to Formula (3), the shippers on the right side of $J_{B,S}$, with high preference to service quality, will choose Busan port and the others will choose Shanghai port. The demand functions of Busan and Shanghai can be written as Eq. (4) and Eq. (5)

$$D_{I,B} = 1 - \frac{p_B - p_S + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2}{\lambda(q_B - q_S)} \quad (4)$$

$$D_{I,S} = \frac{p_B - p_S + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2}{\lambda(q_B - q_S)} \quad (5)$$

Consider service cost and fixed cost for example, c_B, c_S refers to the service cost invested by Busan port and Shanghai port on one container. F_B, F_S refers to the fixed cost of Busan port and Shanghai port respectively. Using Formulas (4) and (5), the profit function of each port is defined as

$$\Pi_{I,B} = \left[1 - \frac{p_B - p_S + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2}{\lambda(q_B - q_S)}\right] \cdot (p_B - c_B) - F_B \quad (6)$$

$$\Pi_{I,S} = \left[\frac{p_B - p_S + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2}{\lambda(q_B - q_S)} \right] \cdot (p_S - c_S) - F_S \quad (7)$$

Under noncooperation game, Busan port and Shanghai port appear to be pursuing their own benefit maximization by making price decision. Nash Equilibrium Point is the optimal strategies set of port prices for two competing players. In order to calculate the optimal price of each port, take a derivative with respect to p_B, p_S separately by Eq. (6) and (7), the results are

$$P_B^* = \frac{1}{3}[2\lambda(q_B - q_S) - (x_{Q-B} - x_{Q-S})t_1 - (x_{B-LA} - x_{S-LA})t_2 + c_S - 2c_B] \quad (8)$$

$$P_S^* = \frac{1}{3}[\lambda(q_B - q_S) + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2 + 2c_S - c_B] \quad (9)$$

In order to understand how the difference between ports' service influence optimal prices, with the secondary derivative of p_B^*, p_S^*

$$\partial p_B^* / \partial(q_B - q_S) = \frac{2}{3}\lambda > 0 \quad (10)$$

$$\partial p_S^* / \partial(q_B - q_S) = \frac{1}{3}\lambda > 0 \quad (11)$$

Through Eq. (10) and (11), the answer is that, along with the increasing of service difference between two ports, both of the service prices of two ports will be larger too. In addition, the price rising rate of Busan is twice than Shanghai. It means if Busan port can enlarge the service difference, Busan port will obtain more price advantage and profit compared to shanghai.

Shipping cost on sea is usually relevant to transport distance and fuel rate. It was pointed out preciously that the rate for one TEU on one nautical mile is different between near-sea route and ocean route. In order to understand transport cost's impact on optimal prices, assume that $t_1 = 2t$, $t_2 = t$ for easy calculation, and then take a secondary derivative of p_B^*, p_S^*

$$\partial p_B^* / \partial t = -\frac{2}{3}(x_{Q-B} - x_{Q-S})t - \frac{1}{3}(x_{B-LA} - x_{S-LA})t \quad (12)$$

$$\partial p_S^* / \partial t = \frac{2}{3}(x_{Q-B} - x_{Q-S})t + \frac{1}{3}(x_{B-LA} - x_{S-LA})t \quad (13)$$

Since $2x_{Q-B} + x_{B-LA} < 2x_{Q-S} + x_{S-LA}$, seen Formula (12) and (13), when t increases, the price of Busan port also increase, but Shanghai port with higher shipping cost has to reduce price to keep its market share.

4. Application of Game Model and Discussion

Based on above formulas, let's have a look at the current situation of T/S competition between Busan and Shanghai by using actual data[9]. Shipping cost on sea is usually relevant to transport distance and fuel rates. Distances of Qingdao-Busan, Busan-LA and Qingdao-Shanghai, Shanghai-LA are shown in Table 2. Due to the scale effect, the charge for one TEU on one nautical mile appears different between the near-sea route and the ocean route. According to the shipping freight quotations provided by shipping companies and the data in table 2, we take a calculation on shipping costs of unit distance for one TEU, the results are some $t_1 = 0.55\ USD, t_2 = 0.27\ USD$.

Table 2. Transport Distance between the Ports of Busan, Shanghai, Qingdao, LA

Transit port	Qingdao (Feeder port)	LA (Destination)
Busan port	512 nm	5260 nm
Shanghai port	351 nm	5700 nm

The current transshipment prices used by Busan port and Shanghai are presented in Table 3, which was obtained by the interview of port officers and agents of shipping company.

Table 3. Transshipment price of Busan Port and Shanghai Port

Container / Port	TEU	FEU
Busan port	134.2 USD	203.2 USD
Shanghai port	147.6 USD	238.1 USD

Note: Price of Busan is from shipping companies in Busan port; Price of Shanghai is from Homepage of SIPG

Inserting the above data into Formula (3), since $\lambda(q_B - q_S) > 0$, so

$$J_{B,S} = \frac{134.2 - 147.6 + (512 - 351) \times 0.55 + (5260 - 5700) \times 0.27}{\lambda(q_B - q_S)} < 0$$

This means if only port transshipment price, transport distance and unit freight rate are taken into account, it's can estimated that Busan port can monopolize all of the transshipment containers from Qingdao port in reality. The reason is both from a view of price and from a view of service, Busan is more competitive than Shanghai, what is more, it costs smaller transport fee compared with Shanghai in case of Qingdao to LA.

In this case, what strategies should Shanghai take to attract transshipment cargo from Qingdao? Assuming $p_B^* = 134.2$ is the optimal price of Busan port, service investment of two ports are $c_B = 60, c_S = 40$, the value coefficient of port service λ can be deduced from Eq. (8) and shown as,

$$\lambda = \frac{3P_B^* + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2 - c_S + 2c_B}{2(q_B - q_S)} \qquad (14)$$

Before λ, the service difference between Busan port and Shanghai port$(q_B - q_S)$ should be calculated first, referring to Table 4.

Table 4. Comparison of Service Quality for Busan Port and Shanghai Port

Factor	Busan port		Shanghai port	
Depth	-16m	10	-16m	10
Loading& Unloading efficiency	2.86 crane/berth	10	3.33 crane/berth	11.6
CY	89 thou-sand m^2/berth	10	137 thou-sand m^2/berth	15.4
Free time	14 days	10	4 days	2.85
Feeder network (e.g Qingdao)	69 lines	10	11 lines	1.59
Customs clearance speed	1-2 hours	10	3-4 hours	5
Quality	60		46.5	

Note: Shanghai International Port Co.Ltd & BPA
www.JCTRANS.com
Take Busan as benchmark.

Inserting data into Formula (14), we get

$$\lambda = 16.75$$

Based on the assumption above, according to Formula (9), Shanghai port's optimal price is

$$p_S^* = 71.95$$

In the case of $p_B^* = 134.2$ $p_S^* = 71.95$, the market share of the two competing ports is

$$J_{B,S} = \frac{p_B - p_S + (x_{Q-B} - x_{Q-S})t_1 + (x_{B-LA} - x_{S-LA})t_2}{\lambda(q_B - q_S)}$$

$$= 0.142$$

According to Formula (4),(5), only 14.2% of custom-ers in Qingdao port will choose Shanghai to transit their cargos though at very low transshipment charge, while Pusan have a clear advantage on transshipment to Qingdao port. Considering the investment and port interest, Shanghai has no room to reduce the price less than 71.95 USD, That's to say, the only two possible options for Shanghai port are increasing service level especially the feeder network and free time, or giving up the market of Qingdao but focusing on some ad-vantage lines[15-16].

5. Conclusions

Rich back-land resource and huge trade-flows in northeast Asia economic circle give birth to plenty of first-class ports in the world. Recent years, due to con-tainerization and large-scale shipping on sea, consider-ing economy and efficiency of shipping operations, major shipping companies usually call at a small number of ports in a certain region. As a result, a transportation network system of HUB AND SPOKE, which centers on hubs and carries out multi-branch lines to cover surrounding feeder ports, has taken shape gradually. Therefore, the competition among hubs for the T/S cargos became fiercer.

Transshipment is not only an important economic in-come source of Busan Port, but also highlights its im-portant statue in the Northeast Asia marine hub system. However, some major ports in China are active to expand and establish perfect transportation network to reduce transshipment share in other countries' port, for instance Shanghai, Ningbo, Qingdao. We choose Busan port and Shanghai port as the study objects, game competition model and real data is used to ana-lyze the two ports' price strategies and market share.

According to analysis results, Busan port has ad-vantage on transshipment price compared to Shanghai because it provides higher quality service and is posi-tioned near to trunk route. Especially on the route of Qingdao-North America, Busan port has absolute ad-vantage to monopolize all of the transshipment contain-ers from Qingdao port if just think about the factors of port charges. service quality and shipping cost. In this case, Shanghai can only get small market share even at a very low port price without interest. Therefore, the suggestions for Shanghai port are increasing service level especially the feeder network and free time, or giving up the market of Qingdao but focusing on some advantage lines.

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저 자 소 개

한욱(Xu Han)

2007년 : 중국대련해사대학교 항해기술학부 공학사
2009년 : 목포해양대학교 해상운송시스템학부 공학석사
2009년 ~ 현재 : 목포해양대학교 해상운송시스템학부 박사과정

관심분야 : Fuzzy, 게임 알고리즘, 지능형물류관리
Phone : 061-240-7550
E-mail : ddxboy@hotmail.com

박계각(Gyei-kark Park)

1982년 : 한국해양대학교 항해학과 공학사
1986년 : 동 대학원 수송공학과 공학석사
1983년 : 일본동경공업대학 시스템학과 공학박사
2010년 : 전남대학교 무역학과 경영학 박사
1995년 ~ 현재 : 목포해양대학교 교수

관심분야 : 지능형물류관리, 의사결정론
Phone : 061-240-7164
E-mail : gkpark@mmu.ac.kr

안태영(Tae-Young Ahn)

1983년 : 한국해양대학교 항해학과 공학사
1990년 : 성균관대학교 무역학과 경영학석사
2011년 : 목포해양대학교 해상운송시스템 학과 경영학 박사
2005년 ~ 현재 : 한서대학교 국제통상학과 겸임교수

관심분야 : 항만국제물류
E-mail : zenithmarine@kornet.net