한국항해항만학회지 제37권 제2호
J. Navig. Port Res. Vol. 37, No. 2 : 187-193, April 2013 (ISSN:1598-5725(Print)/ISSN:2093-8470(Online))
DOI : http://dx.doi.org/10.5394/KINPR.2013.37.2.187

A Study on Measuring the Efficiency of Korea-China Car Ferry Routes by using Data Envelopment Analysis

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Abstract : *In this prolonged economic recession, the countries in Northeast Asia play a crucial role in the global market and the relationship between Korea and China gets more attention due to its significant achievement during the past 20 years after the establishment of diplomatic ties in 1992. In this regards, this study presents general overview of Korea-China Car Ferry Route and evaluates the efficiency level of each operating route using DEA model. Incheon-Yingkou, Incheon-Lianyungang, Pyeong Taek-Lianyungang are analyzed as efficent routes, while from the view point of passenger efficiency, 4 routes i.e, Incheon-Dalian, Incheon-Dandong, Pyeong Taek- Weihai, Gunsan-Shidao are also noted as efficient routes. Consequently, other inefficient routes can benchmark these efficient routes by increasing cargo volume and passengers.*

Key words : *Korea-China route, Car Ferry, DEA, BCC-O*

1. Introduction

Since Korea and China established diplomatic ties in 1992, bilateral trade volume has grown 35-folds and exceeded 200 billion dollars in 2011 which accounts for more than 20% of Korea's overseas trade. 24% of Korea's exports are to China and the ratio has increased on average by 23% annually, rising twice as fast as exports to other areas.

As the trade between the two countries expands, so does the cargo volume. For the past two decades, shipping cargo volume has increased 57-folds and number of passengers also grown 38 times bigger so that more than 4 million TEUs and 12 million passengers have been carried out by Korea-China Car Ferry Routes. After opening the initial car ferry route in 1990, which is 2 years before the establishment of Korea-China diplomatic ties, 15 car ferry routes are currently being operated in this area.

Due to this remarkable quantitative growth, Korea-China corridor, currently a closed system, gets more attention, especially this year which marks the 20th anniversary of 'Korea-China Maritime Consultative Meeting' by which all the maritime issues in this area are handled and decided. Different from other normal shipping routes, Korea-China shipping routes have been well-protected and controlled with restrictions by the two nations' governments to prevent fiercely destructive competition. However, in this severe economic downturn and prolonged shipping industry slump, problems like nowadays' oversupply of tonnage and low freight rate in this routes become so serious that it is expected to be changed according to the current global market situation.

In this regard, the purpose of this research is to understand the current situation in Korea-China Car Ferry Routes and evaluate the efficiency of each operating route using financial and operational data. Even though there have been vast researches and papers using DEA in logistics and transport fields to assess the performance such as transit systems, ports or logistics companies, ferry service has not been a many scholars' choice to investigate. Therefore, there is no preceding study of the efficiency of Korea-China Ferry Routes using DEA model. By conducting DEA(Data Envelope Analysis) with 3 input variables(vessel size, passenger capacity, container capacity, and 2 output variables(average cargo volume, number of passengers), this study presents empirical result for estimating the competitiveness of each car ferry route.

2. Literature Review

Like many other research areas, DEA has been applied for the assesment of efficiency of transportation and logistics sector. In maritime sector, especially for assessing

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the global competitiveness or production efficiency of container ports, numerous researches can be found using DEA model. Wang et al.(2003) used both DEA and FDH(Free Disposal Model) approaches to study the efficiency of 28 world's leading container ports and compared the results for the first time within container terminal industry. Culliane et al.(2006) assessed effectiveness of the world's top 30 container ports applying DEA and SFA(Stochastic Frontier Analysis) to the same set of data and compared the results. Tongzon (2001) selcted 16 ports as DMUs. The number of crane/berth/tug/terminal, delay time and labor were used as input variables. Output variable selection consists of cargo throughput and ship working rate. Valentine et al.(2002) assessed the efficiency of 12 container ports, as DMUs, in Europe and Northeast Asia. A number of containers, total length of berths, and total length of berths only for container ship were selected for input variables. Total cargo throughput (ton) was the only output variable of the research. Oh et al.(2001) used both CCR and BCC model for assessing the production efficiency among 28 container ports. Total length of berths, a number of gantry cranes, total area of CY and total area of CFS were the input variables. Output variables were total throughput and port usage.

Hahn et al.(2009) evaluated the efficiency of Seoul's exclusive bus routes using DEA and analyzed the factors by Tobit Regression that the most important element which has influence on the exclusive buses is the length of intervals.

In addition to these studies, numerous researches about Korea-China trade routes of various transportation modes can be found by Korean authors. Regarding shipping routes, Lee et al.(2008) stated the characteristics of Korea-China trade and present condition of Korea-China liner shipping. They claimed that the strategies of Korean-flag shipping lines for the up-coming complete opening of Korea-China shipping route should be prepared to predominate over Chinese-flag liner shipping companies and suggested specific solutions according to in-depth interview with major shipping lines.

Regarding Multi-modal transportation routes, Yoo (2007) studied multimodal transportation system between Korea and China such as Sea and Air System, explaining the characteristics and the present situation. He introduced the concept of new RFS(Road Feeder System) and estimated the expected effect of this new transportation system after implementing in Korea-China trade route. He concluded that the positive effects of RFS would be shorter lead time, price competitiveness, increase of cargo volume and creation of added value, less cargo damage, and increase of logistics effectiveness in the region.

Also, Cho et al.(2007) emphasized the importance of integrated intermodal transportation system in Northeast Asia due to rapid increase of trade volume. They introduced the concept of rail-ferry and explained the merits of it in logistics, in cost, and in service. In this research, the possibility of introduction of rail-ferry among Korea, China and Japan was examined and the possible routes was suggested.

Kim et al.(2007) studied the circumstances of Korea-Japan shipping environment including car ferry system and highlighted the strong merits of car ferry such as fast transit time and availability of transporting both cargo and passengers together at the same time but these merits are also the factors of higher rate compared to container ships. Park et al. (2011) pointed out the recent increase of car ferry routes between Korea and Japan and stated that international car ferry system has become more attractive for certain shippers who need door-to-door service to transport their special and expensive cargo, compared to bulk cargo which is more likely to cause claims for concealed damage. Moon (2011) showed the development of Korea-China car ferry routes since the first opening in 1990, summarizing agendas of all 18 'Korea-China Maritime Consultative Meeting' from 1993 to 2010 and took the focus on car ferry routes between Incheon port and Chinese ports. In spite of Korea-China trade routes' importance, scant research has been investigated regarding the efficiency of the car ferry routes between two countries. DEA can be considered as an appropriate methodology to reveal the efficiency of car ferry companies in a quantitative manner.

3. DEA Model

Since the basic model of DEA(Data Envelopment Analysis) was developed by Charnes, Cooper and Rhodes (CCR approach), it has been broadly applied for evaluating the relative efficiencies of a set of comparable DMUs(Decision Making Units).

There exists various kinds of DEA models but the most frequently used models are CCR model (by Charnes, Cooper and Rhodes) and BCC model which was developed by Banker, Charnes, Cooper. The big difference between CCR model and BCC model is whether returns to scale is constant or variable. CCR model allows the concept of constant returns to scale, while BCC model assumes returns to scale is variable. Also, DEA model can be described as input oriented model, or output oriented model, according to its character. Input oriented model has a purpose to minimize inputs while maintaining the levels of outputs, on the other hand, output oriented model aims to maximize outputs. Therefore, in this research, we apply output oriented DEA-CCR model to study the efficiency of car ferry routes between Korea and China. Unlike normal circumstances in other shipping routes, a situation in Korea-China ferry routes can be described as rather special. It is strictly controlled and operated by the annual 'Korea-China Maritime Consultative Meeting' and all the issues including opening a new ferry route, deploying additional ferry, or allowing container vessels into ferry route and other detailed issues concerning maritime affairs between the two nations. Consequently, in this area, to change or adjust input factors according to market economy in an aspect of efficiency is not as easy as it is for other areas. Therefore, with such given conditions, we apply output oriented DEA-BCC model to measure efficiency level of existing car ferry routes. BCC-model equation is as follows.

$$Max \quad h_o = \frac{\sum_{r=1}^{s} U_r Y_{r0} - U_0}{\sum_{i=1}^{m} V_i X_{i0}} \quad (1)$$

subject to:

$$\frac{\sum_{r=1} U_r Y_{rj} - U_o}{\sum_{i=1}^{m} V_i X_{ij}} \quad (2)$$

U_r , $Vi \geq \epsilon > 0 \quad j = 1, 2, \cdots, n$

h_0 = measuring DMU

U_r = the weight of output variable r, V_i = the weight of input variable i

X_{ij} = measured value of input variable i in DMU j

Y_{rj} = measured value of output variable r in DMU j

s = number of output variables, m = number of input variables

j = object DMU ($j = 1, 2, \cdots, n$)

U_0 represents the indicator of returns to scale. In case of increasing return is $U_0 < 0$, in case of being constant return is $U_0 = 0$, in case of decreasing return is $U_0 > 0$. Equation(1) is as follows when it changes dual problem.

$$Min \quad h_0 = \theta - \epsilon [\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+] \quad (3)$$

subject to: $\theta X_{i0} - \sum_{j=1}^{n} X_{ij}\lambda_j - S_i^- = 0$ (4)

$$\sum_{j=1}^{n} Y_{rj}\lambda_j - S_r^+ = Y_{ro} \ , \quad S_i^-, \ S_r^+, \ \lambda_j \geq 0, \quad \sum_{j=1}^{n} \lambda_j = 1$$

4. Selecting DMU and Analysis

4-1. Data and Selecting DMU

It is important to single out the DMUs and input/output variables because these can have an effect on the analysis results (Ryoo, 2005). Input/output variables have to be selected to meet the evaluation purpose in measuring the efficiency (Cullinane et al, 2005). In addition, it is strongly stressed that the efficiency measurement is valid if DMU's homogeneity remains high (Thanassoulis, 2001). The DMU of this study is car ferry route between Korea and China and there is a lot of similarity with the function and the business field.

Vessel size, passenger capacity and container capacity are selected as the input variables. The number of vessel has maintained to a similar extent in the Korea-China routes. For this reason, vessel size is more reflective characteristic of a car ferry than the number of vessel. Car ferry carries both passenger and container due to the nature of its purpose, which made to select passenger capacity and container capacity as the variables according to the routes respectively. Capacity is a general variable to be considered in measuring transport efficiency. In case of a car ferry, it plays both roles to transport cargo and passenger. Therefore capacity is divided into two variables as passenger capacity and container capacity. In the output variable selection, average cargo volume(TEU/service for once) and passenger (person/service for once) are selected according to car ferry itself purpose. Cargo volume and passenger are affected by the input variables to measure their efficiency.

Table 1 Input/output variables

Input/Output	Variable	Unit
Input	Vessel size(V1)	G/T
	Passenger capacity(V2)	Person
	Container capacity(V3)	TEU
Output	(Average) Cargo volume(U1)	TEU
	(Average) Passenger(U2)	Person

There are 15 Korea-China car ferry routes but the car ferry route from Pyeong-taek to Rizhao doesn't exist in the data in 2010. Therefore, 14 routes are selected except for the route from Pyeong-taek to Rizhao as the DMU. Data source as of 2010 is from Korea-China Car ferry Association. Also, cargo volume and passenger took an average based on round trip for one-time service.

Table 2 Selected DMUs and data

Year: 2010

Routes \ variable	(V1) Vessel size (G/T)	(V2) Passenger capacity (person)	(V3) Container capacity (TEU)	Cargo volume (TEU)	(U1) Average cargo Volume (TEU/ service for once: Round trip)	Passenger (person)	(U2) Average Passenger (person/ once service:Round trip)
Incheon/ Weihai	26,463	731	280	54,096	376	144,734	1005
Incheon/ Qingdao	29,554	660	325	55,500	385	118,520	823
Incheon/ Tianjin	26,463	800	274	36,496	380	83,128	866
Incheon/ Dalian	12,365	450	140	20,569	143	88,073	612
Incheon/ Dandong	16,,446	850	159	19,696	137	100,967	701
Incheon/ Yantai	16,071	392	293	37,122	258	92,514	642
Incheon/ Shidao	19,534	1000	253	38,710	269	127,286	884
Incheon/ Yingkou	12,304	290	228	17,444	182	47,608	496
Incheon/ Qinhuangdao	12,034	348	228	16,278	170	60,731	633
Incheon/ Lianyungang	16,071	392	293	43,435	452	58,519	610
Pyeong Taek/ Rongcheng	25,151	720	267	36,402	253	202,705	1,408
Pyeong Taek/ Lianyungang	8,577	668	170	30,643	319	76,668	799
Pyeong Taek Weihai	24,000	750	214	12,740	88	128,932	895
Gunsan/Shidao	17,022	750	203	14,582	101	151,249	1,050

Descriptive statistics is summarized as follows (Table 3).

It is essential to note a correlation, which means the degree of relationship connecting two variables. But, a scant of papers mentioned the proper range of correlation. Cho(2006) accepted 0.869 as a correlation and Ryoo(2005) also present 0.987 as a correlation between variables. In this paper, 0.74 is the highest score in correlation and it is acceptable score as compared with Cho and Ryoo's studies. Moreover, these variables are very essential in measuring the efficiency of car ferry routes so they can be considered as proper variables.

Table 3 Descriptive statistics on input/output data

	Vessel size	Passenger capacity	Container capacity	Cargo volume	Passenger
Max	29554	1000	325	452.44792	1407.6736
Min	8577	348	140	88.472222	495.91667
Average	18718.214	640	236.28571	250.92312	815.95288
SD	6315.543	188.39131	51.66987	113.67481	226.50757

Table 4 Correlation between variables

	Vessel size	Passenger capacity	Container capacity	Cargo volume	Passenger
Vessel size	1	0.4861946	0.551757	0.3518743	0.5907511
Passenger capacity	0.4861946	1	-0.130219	-0.0369608	0.5970191
Container capacity	0.551757	-0.130219	1	0.7410088	0.0292111
Cargo volume	0.3518743	-0.0369608	0.7410088	1	0.0378442
Passenger	0.5907511	0.5970191	0.0292111	0.0378442	1

Lastly, In order to present efficient routes, the reference sets are shown in Table5.

Table 5 Frequency in reference set

Reference	Frequency to other DMUs
Incheon/Dalian	2
Incheon/Yantai	5
Incheon/Yingko	0
Incheon/Qinhuangdao	0
Pyeong Taek/ Rongcheng	7
Pyeong Taek/ Lianyungang	0
Gunsan/Shidao	3

4-2. Efficiency analysis of BCC-O model

The result of relative efficiency among Korea-China car ferry routes, Incheon-Qinhuangao, Incheon-Dalian, Pyeong Taek- Lianyungang, Pyeong Taek-Rongcheng, Incheon-Weihai, Incheon-Lianyungang showed efficient routes.

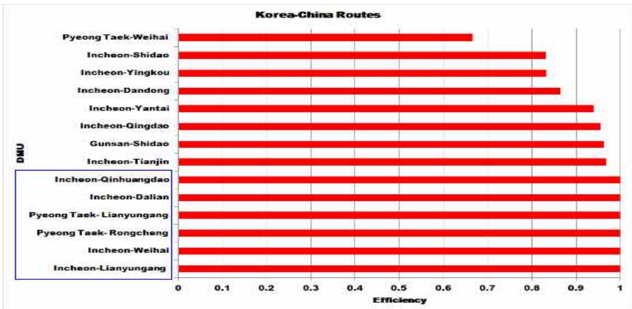

Fig. 1 Distribution of efficiency score

More specifically, the efficient routes in terms of cargo efficiency are Incheon-Yingkou, Incheon-Lianyungang, PyeongTaek-Lianyungang. And Incheon-Dalian, Incheon-Dandong, PyeongTaek- Weihai, Gunsan-Shidao are efficient Korea-China routes from a passenger perspective. As a result, inefficient routes are needed to benchmark for these efficient routes.

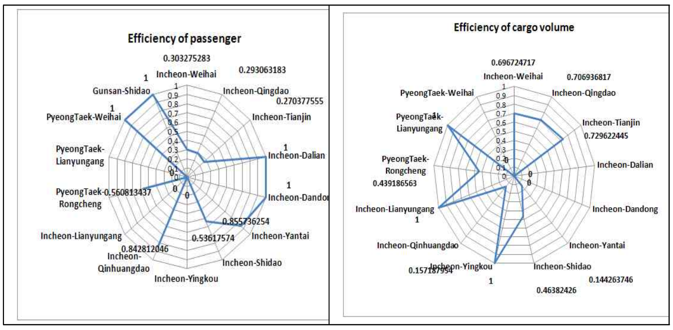

Fig. 2 Efficiency score of cargo volume and passenger

As for this analysis's result, to improve inefficiency DMU of 8 Korea-China routes, Pyeong Taek-Weihai route needs to handle 246.21 TEU and 1342.72 passengers more than what it handles now. In case of Incheon-Shidao, cargo volume has to increase 20.37%(323.57TEU) of cargo volume and 20.37% (1063.95) of passenger similarly. It needs to increase 20.05% of cargo volume and 29.48% of passenger in the route between Incheon and Yingkou. In the route of Incheon-Dandong, required cargo volume is 170.33(24.53) and required passenger is 810.64(15.61). 6.51% increase is required in the cargo volume and passenger of Incheon-Yantai route. Incheon-Qingdao route needs to increase 4.69% in cargo volume and passenger respectively. The cargo volume needs to increase 172.9% and passengers need 3.84% increasing in the route of Gunsan-Shidao. Lastly, the route between Incheon-Tianjin needs 3.30 % increasing of cargo volume and passengers in order to improve its inefficiency.

Table 6 Effective management of inefficient DMU

DMUs	Efficiency score	Output variables			Projection	Percentage
Pyeong Taek/ Weihai	0.667	Input	Vessel size	24000	24000	0
			Passenger capacity	750	707.71	-5.64
			Container capacity	214	214	0
		out put	Cargo volume	88	246.21	178.29
			Passenger	895	1342.72	49.97
Incheon/ Shidao	0.831	Input	Vessel size	19534	19534	0
			Passenger capacity	1000	613.83	-38.62
			Container capacity	253	236.62	-6.47
		out put	Cargo volume	269	323.57	20.37
			Passenger	884	1063.95	20.37
Incheon/ Yingkou	0.833	Input	Vessel size	12304	12304	0
			Passenger capacity	394	394	0
			Container capacity	228	228	0
		out put	Cargo volume	182	218.14	20.05
			Passenger	496	642.10	29.48
Incheon/ Dandong	0.965	Input	Vessel size	16446	15561.6	-5.38
			Passenger capacity	800	596.25	-25.47
			Container capacity	160	160	0
		out put	Cargo volume	137	170.33	24.53
			Passenger	701	810.64	15.61
Incheon/ Yantai	0.939	Input	Vessel size	16071	14451.88	-10.07
			Passenger capacityy	392	392	0
			Container capacity	293	150.04	-14.66
		out put	Cargo volume	258	274.59	6.51
			Passenger	642	684.30	6.51
Incheon/ Qingdao	0.955	Input	Vessel size	29554	22695.02	-23.21
			Passenger capacity	660	608.08	-7.87
			Container capacity	325	284.71	-12.40
		out put	Cargo volume	385	403.50	4.69
			Passenger	823	861.69	4.69
Gunsan/ Shidao	0.963	Input	Vessel size	17022	17022	0
			Passenger capacity	750	687.51	-8.33
			Container capacity	203	203	0
		out put	Cargo volume	101	276.35	172.90
			Passenger	1,050	1090.71	3.84
Incheon/ Tianjin	0.968	Input	Vessel size	26463	22378.2	-15.44
			Passenger capacity	800	600.90	-24.89
			Container capacity	279	284.71	0
		out put	Cargo volume	380	392.71	3.30
			Passenger	866	894.49	3.30

5. Conclusions

For the past 20 years of mutual exchange in trade and culture since the establishment of diplomatic ties in 1992, Korea and China have developed such a remarkable achievement together and it is crucially important to strengthen this bond further for the two nations' future growth, especially in this severe global economic recession and prolonged shipping industry slump. In shipping, Korea-China corridor has been controlled by the two nations' governments through 'Korea-China Maritime Consultative Meeting' which is held every year since 1993. In this regard, this research provides some information about car ferry routes between Korea and China. We attempt to understand the actual state of this route and estimate the efficiency of every operating route with empirical data by conducting DEA. Among various kinds of DEA models, we chose output oriented DEA-BCC model by the nature of Korea-China car ferry routes which are being protected by the two countries, unlike other normal shipping routes. Currently, there are 15 car ferry routes that are actively working and in this research, this operating routes are the DMUs (we use 14 routes due to the unavailability of data 2010's Pyeong-taek to Rizhao route data). As for the input variables, vessel size, passenger capacity and container capacity are selected and cargo volume (TEU/service for once) and passenger (person/service for once) are used as the output variables.

As a result, among 14 car ferry routes, Incheon-Qinhuangao, Incheon-Dalian, Pyeong Taek-Lianyungang, PyeongTaek-Rongcheng, Incheon-Weihai, Incheon-Lianyungang are proven to be efficient routes. In the aspect of cargo efficiency, following 3 routes such as Incheon-Yingkou, Incheon-Lianyungang, Pyeong Taek-Lianyungang are analyzed as efficent routes, while from the view point of passenger efficiency, 4 routes i.e, Incheon-Dalian, Incheon-Dandong, PyeongTaek-Weihai, Gunsan-Shidao are also noted as efficient routes. Therefore, these efficient routes in terms of route itself, cargo efficiency or passenger efficiency, can be a benchmark against other routes. More specifically in the point of cargo volume and passenger, the inefficient 8 routes need to improve its efficiency level by increasing certain number of TEUs and passengers. In Pyeong Taek-Weihai route, 246.21 TEU and 1342.72 passengers are needed to increase its efficiency. Between Incheon and Shidao, 20.37%(323.57TEU) of more cargo volume and 20.37% (1063.95) of more passengers have to be transported. In the case of Incheon and Yingkou route, 20.05% of cargo volume and 29.48% of passengers have to be handled more. It is required to be increase 24.53% (170.33TEU) and 15.61%(810.64) passenger in Incheon-Dandong route, and 6.51% of both cargo volume and passengers(274.51 TEU/684.30 passengers) have to be raised in Incheon-Yentai route. Between Incheon-Qingdao, 4.69% on both cargo volume and passenger have to be increased (403.50 TEU/861.69 passengers). In Gunsan-Shidao route, 172% (276.35 TEU) and 3.84% (1090.71 passengers) are needed and lastly, in the route between Incheon and Tianjin, 3.30% on both cargo volume (392.71 TEU) and passenger (894.49 passengers) are required to be raised for improving its efficiency level. With this analysis, the efficiency of currently operating 14 car ferry routes between Korea and China can be estimated and evaluated. In the future, the decisions in 'Korea-China Maritime Consultative Meeting' have to be made on the basis of them for the upcoming change within Korea-China shipping routes according to a global market situation. This research can be useful for those who are offering car ferry services in unefficient routes. To improve their efficiency, aggressive marketing activity for prospective customers can be a good solution. Cooperation with related ports and other related associations, or with other ferry service companies are recommended to promote the routes. However, strengthening the ties between the two regions in industry, which can generate more exchange of people and cargo, is the most crucial and fundamental element for increasing efficiency in these routes and it is the thing which cannot be done by the effort of car ferry service operators or terminal operators alone.

This study has the limitations to show the dynamic changes in measuring efficiency and its productivity. In future research, the DEA-Window model and Malmquist analysis that can measure dynamic changes of efficiency will be conducted.

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Received 29 January 2013
Revised 9 April 2013
Accepted 9 April 2013