Air Cargo Service Competitiveness of Major Asian Airports⁺

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ABSTRACT

This paper evaluates and assesses the competitiveness of airports by analyzing the efficiency of those in Northeast Asia. This research implemented Data Envelopment Analysis (DEA) to compare the competitiveness of airport efficiency and Decision Making Unit (DMU), which was selected by the top ranking freight operations among the airports in this region. Due to the lack of previous research with regard to the competitiveness of hub concentrated airports in air cargo volume, the variables have been screened for selection through referential documents and records related to air freight. Finally, aviation freight experts assisted in the final selection of the relevant variables for this research. The result of the analysis show that the larger airports in Northeast Asia are positively correlated with higher efficiency. In contrast, inefficient airports have suffered from over capacity or insufficient input.

Keywords : air cargo terminal, DEA, Asian airports, competitiveness

1. INTRODUCTION

Predictably, the Northeast Asian region has gradually become positioned as a hub of

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global economic activity so that multinational companies with capital investment and large generators of freight in the region will centralize their activities there. This prediction is especially true for air cargo since it has now been expanding and increasing annually in Asia more than in any other region worldwide. However, the logistics of moving freight is becoming more complicated since it involves packing, preparing documentation, arranging insurance, collecting freight from the shipper, facilitating customs clearance at origin and destination, and completing final delivery (Ohashi *et al.*, 2003:5).

In addition, it is essential to install efficient and effective container device loading equipment in appropriate areas such as the loading and unloading decks as well as relevant entrances for the freight movement due to the fact that most freight consists of import and export trade. Unlike airlines, the primary benefit of hubs is not to increase the number of cities served but to reduce the amount of time a driver must transport the cargo on land, which in turn reduces annual driver turnover rates and the accompanying hiring and training costs (Abdinnour-Helm, 2001:203).

This paper finds that transshipment volume is more sensitive to time and monetary costs: the reduction in aircraft turnaround time by one hour is worth more than \$1,000 in airport charges. This implies that it would be more effective to encourage the airports to reduce aircraft and air cargo turnaround time, rather than increasing airport usage by reducing airport user charges such as landing fees (Ohashi 2003: 325). In choosing between routes the forwarder's principal concern is the time duration of shipping. For this reason, competition has increased among air freighters and airports. From an airports' perspective, the installation of key facilities is essential to entice efficient freight forwarders because it creates a more competitive atmosphere.

As early as 1975, the International Air Transport Association (IATA) concluded that air cargo is at the airport "waiting" for transportation, for 78% of its total travel time, there are no clear signs that there have been significant improvements since then. According to IATA, this inefficiency was caused mainly by the lack of communication and integration of administrative processes on the ground (Christiaanse *et al.* 2003:513). It follows that an international air cargo hub requires an appropriately sized airfreight terminal setting and efficient site assurance to consider speediness of airfreight movement procedures. At this time, the airfreight terminals' efficiency survey of airports in the Northeast Asian region merits attention for the strategic development to cope with airfreight environmental changes.

The DEA (Data Envelopment Analysis) methodology was adopted and implemented to analyze the efficiency of airfreight facilities among airports in the Northeast Asia

region. The primary reason for adopting this methodology is to make objective comparisons between the input and the output variables. Using the DMU (Decision Making Unit) for the airport comparison study, seven Asian airports were selected as the highest ranked airports in the region among 100 international airports worldwide in terms of the world air freight throughput rankings in year 2002 by the Airport Council International. A preliminary list of input and output variables was broadly chosen from a literature review, and the variables finally selected were defined by aviation professionals and experts in academia and industry. The data collection for the implemented variables was from officially recognized international organizations and agencies such as IATA, Airport Council International (ACI) and International Civil Aviation Organization (ICAO).

2. REVIEW OF DATA ENVELOPMENT ANALYSIS (DEA)

Efficiency is most simply defined as the rate of input in relation to the rate of output. The method used to gauge relative efficiency is the DEA model based on Charnes, Cooper & Rhodes' (1978) original non-parameter version. Using the DEA's DMU estimate level is analogous to gauging an organization's input and output efficiency, a method for comparing different organizations and their relative technical efficiency. There are many advantages in using this method of comparing input and output: cost information is unnecessary; and ex post facto experiential data can be employed since the assumptions necessary for estimating parameters are not needed. The input factors' portion is increased, so the output's different portions can not be increased without decreasing the DMU's output.

As noted, this research deals with efficiency for air freight terminal operations which can be measured by correlating an output variable such as freight transaction volume with input data, notably terminal space available, total freight handling capacity, and number of serviced airlines at an airport.

The DEA concept will be elaborated later in the following sections. First, input and output factors need to be used to express the efficiency of the estimated level.

$$Efficiency = \frac{Output(O)}{Input(I)}$$

However, this expression is insufficient enough to explain the efficiencies of the respective different multiple input and output factors.

$$\text{Efficiency} = \frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}}$$

In the following formula transformation is possible. If estimate level j is derived from efficiency, then the efficiency of estimate level j is as follows.

$$E = u_1 y_{1j} + u_2 y_{2j} + \cdots / v_1 x_{1j} + v_2 x_{2j} + \cdots$$

u_r = the weight given to output r

y_{rj} = the amount of output r from object j

v_i = the weight given to input i

x_{ij} = the amount of input i from object j

However, the previous assumptions for each factor exist due to the weight of an organization's attributes, therefore it is problematic to use one commonality to weigh the efficiency of all estimated measurements satisfactorily. To solve this problem, Charnes, Cooper & Rhodes (1978) developed the CCR (Charnes, Cooper & Rhodes) model which permits each DMU to have different weightings (Equation 1). Additionally, this is the same as (Equation 2) when rearranging the decision making unit form.

$$\begin{aligned} \text{MAX } h_0 &= \frac{\sum_{r=1}^t u_r y_{rj0}}{\sum_{i=1}^m v_i x_{ij0}} \dots\dots\dots (\text{Eq. 1}) \\ \text{subject to : } &\frac{\sum_{r=1}^t u_r y_{rj0}}{\sum_{i=1}^m v_i x_{ij0}} = \leq, j = 1, \dots, n, \\ &u_r, v_i \geq \varepsilon, \forall \text{ rand } i \end{aligned}$$

$$\begin{aligned}
MAX \ h_0 &= \sum_{r=1}^t u_r y_{rj0} \dots\dots\dots (Eq. 2) \\
subject \ to : \quad &\sum_{i=1}^m v_i x_{ij0} = 1 \\
&\sum_{r=1}^t u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, \ j = 1, \dots, n, \\
&-u \leq -\varepsilon, \ r = 1, \dots, t, \\
&-v \leq -\varepsilon, \ i = 1, \dots, m,
\end{aligned}$$

However, the CCR method assumes away the difficulties of estimating the efficiency of the weightings of each DMU's scale returns. Therefore, this method preserves the advantage of not needing to differentiate between an efficiency scale and pure technical efficiencies. In 1984, Banker, Charnes & Cooper introduced the BCC method so that the rates of scale efficiencies could be understood. What distinguishes the BCC model from the established CCR model is the variable u_0 , which measures the return results of scale (Banker, Charnes and Cooper, 1984).

$$\begin{aligned}
MAX \ h_0 &= \sum_{r=1}^t u_r y_{rj0} - u_0 \dots\dots\dots (Eq. 3) \\
subject \ to : \quad &\sum_{i=1}^m v_i x_{ij0} = 1 \\
&\sum_{r=1}^t u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, \ j = 1, \dots, n, \\
&-u \leq -\varepsilon, \ r = 1, \dots, t, \\
&-v \leq -\varepsilon, \ i = 1, \dots, m, \\
&u_0 = \text{urs}(\text{free}) \text{ Variable}
\end{aligned}$$

Thus, the research goal of the DEA model is embodied in the CCR and BCC models, which are the foundations of this study.

3. DEFINING THE MODEL AND VARIABLES

A key attribute of freight movement is its sensitivity to time. Further, a large portion of the freight shipping time elapses in the airport's ground operations. It follows that airlines consider facility capacities as an important factors when selecting strategic

airports for handling of freight. Accordingly, research from model studies has shown that airlines and their owners can be manipulated as inter-terminal freight competitive is fierce. This consideration was incorporated in measurements designed to obtain the best strategy. Using the DMU methodology to make comparisons among current top 30 airfreight handled airports, nine airports in Asia in Table 1: New Hong Kong Airport (HKG), Narita Airport (NRT), Singapore Changi Airport (SIN), Taipei Chiang Kai Shek Airport (TPE), Shanghai Pudong Airport (PVG), Bangkok Airport (BKK), Kansai Airport (KIX), Beijing Capital Airport (PEK), Guangzhou Airport (CAN), and Incheon Airport (ICN), were chosen by using DMU.

Table 1. Asian airports among the top 30 international freight managing airports

Rank (2004)	Airport	JAN 2004		AUG 2003		OCT 2002	
		Cargo (tons)	Change %	Cargo (tons)	Change %	Cargo (tons)	Change %
3	Hong Kong, CN (HKG)	264,000	5	2,504,584	19.3	2,100,276	-7.4
5	Tokyo, JP (NRT)	204,265	-3.2	2,001,822	19.1	1,680,937	-13
6	Seoul, KR (ICN)	177,777	10.8	1,705,880	43.2	1,196,843	n.a.
9	Singapore, SG (SIN)	152,407	2.1	1,660,404	8.5	1,529,930	-10.3
13	Taipei, TW (TPE)	137,990	1	1,380,748	16	1,189,874	-1.6
17	Shanghai, CN (PUG)	115,953	75.2	634,966	80.1	n.a.	n.a.
19	Bangkok, TH (BKK)	86,453	2.3	956,790	13.7	841,150	-3.1
22	Osaka, JP (KIX)	78,475	-8.3	805,430	-7.5	871,161	-12.9
24	Beijing, CN (PEK)	74,544	27.1	669,347	13.2	591,195	6.1
25	Tokyo, JP (HND)	66,968	8.2	707,301	-2.5	725,124	-5.8
30	Guangzhou, CN (CAN)	53,698	2.4	592,559	11.5	n.a.	n.a.

Note: Haneda International Airport (HND) was excluded due to the fact that the volume of its domestic airfreight was much higher than international airfreight volume.

Source: Airport Council International (2004), <http://www.airports.org>

Previous research led to the use of input variables, including freight terminal handling capacity, national airport freight volume, airport facility usage volume, support area development, distance between bonded warehouses and airports, airport grounds area, runway operational ability and acreage, periodic mooring ability, parking capacity, freight terminal size of commissioned airline acreage, service city and the size of the country of origin. However, variable selection in DEA is the most important step in

obtaining efficient outcome. Consequently, airfreight terminal efficiency is not included in the analysis of existing research because the final input and output variables selection was decided by using a panel of experts.

This expert survey to determine the inclusion of final input and output variables was based on the opinions of academicians, airline employees, airport operators, and industrial experts. Figure 1 shows a total of 35 experts, eight from airlines, ten from airport operations, six from research institutes, six from education, and five from transportation and logistics companies.

Figure 1. Distribution chart of participating experts in the survey

Figure 2 shows the ranked input factor derived from the survey: freight terminal area, capability of apron parking, number of serviced airlines, commissioned nations and cities, and freight terminal throughput.

Figure 2. Survey result of input variable selection by aviation affiliated experts

The survey results show that the most meaningful factor is the comparison between total annual freight volume and freight terminal efficiency. Accordingly, the freight terminal efficiency of airports in Northeast Asia was selected as the primary determinant to analyze the input variables of freight terminal handling volume, periodic mooring capacity, size of the freight terminal, national flag airlines, and size of the city while the output variable is annual freight handling throughput. However, there was some difficulty in collecting a set of essential data for all selected airports. As collecting data from Beijing Capital Airport (PEK) and Guangzhou Airport (CAN), in particular were extremely difficult, only seven airports were considered in the final DMU analysis.

Table 2. The adopted variable for DEA analysis

Input Data		Output Data	
V1	Scale of freight terminal	U1	Air cargo throughput
V2	Apron capacity of cargo terminal		
V3	Freight handling capacity		
V4	Commissioned nations		
V5	Number of serviced airlines		

4. RESULTS OF ANALYSIS

The CCR model, depending on the classification by routes in Asia's leading freight terminal competitive efficiency, is shown in Table 3. If one examines the relative efficiency of Asia's regional airports by using the CCR model's breakdown by the defined variables, and regarding the average efficiencies at seven airports. According to the CCR model's analysis, three airports; Hong Kong, Incheon, and Changi were evaluated as efficient airports in 2001, three efficient airports in 2002 and four in 2003. These efficient or inefficient airports' criteria can be measured by relative performance concerning the concept of efficiency frontier. Inefficient airport ($CCR < 1.0$), therefore, means that its performance can be defined as relatively inferior compared to the other selected airports.

Using data from 2002, Incheon Airport was compared with Hong Kong Airport as

the standard reference airport which refers as a best practical performance airport considering network connected cities, operated airlines, airfreight volume and lack of freight terminal capacity. As a result, excess input in moorings portions can be known. Other freight handling capacities show low productivity. Therefore, the DEA model was used so that another interpretation could be made of the analysis regarding the standard representative. The DEA model's efficiency rating, inefficiency class, level of inefficiency and other factors allow for all these variables to be compared against standard representative measurements. Although every airport can be measured as efficient or inefficient using the CCR model, it is very difficult to find out which variables (inputs) have impacted on this performance (output) transparently.

Table 3. Results of the CCR model

Airport	Year	CCR		Standard Referred Group
HONG KONG, CN (HKG)	2001	1	E	-
	2002	1	E	-
	2003	1	E	-
TOKYO, JP (NRT)	2001	1	E	-
	2002	1	E	-
	2003	1	E	-
SEOUL, KR (ICN)	2001	0.55	INE	NRT
	2002	0.96	INE	HKG
	2003	0.67	INE	HKG,NRT, TPE
SINGAPORE, SG (SIN)	2001	1	E	-
	2002	1	E	-
	2003	1	E	-
TAIPEI, TW (TPE)	2001	n.a.	n.a.	-
	2002	n.a.	n.a.	-
	2003	1	E	-
SHANGHAI, CN (PVG)	2001	0.55	INE	NRT
	2002	0.84	INE	NRT
	2003	0.81	INE	NRT
OSAKA, JP (KIX)	2001	0.74	INE	NRT
	2002	0.59	INE	HKG, NRT
	2003	0.42	INE	NRT, TPE

Note: E : Efficient DMU, INE : Inefficient DMU

Figure 3. Excess or deficient investment of Incheon compared with Hong Kong

The efficiencies of Kansai Airport, Narita Airport and New Hong Kong International Airport (HKG) were compared using information from 2002. Among them, the most important DMU was Hong Kong. At that time, Hong Kong recorded the following statistics: freight terminal dimensions (80%), apron capacity (78%), air freight handling capacity (79%), launched airlines (82%), commissioned nations (80%), and annual airfreight throughput (80%). Accordingly, Kansai Airport's administrators have adopted a strategy that uses Hong Kong as a benchmark to improve the efficiency of Kansai Airport's freight terminal operations.

Figure 4. Comparison of service capabilities

As applied the BCC model, Table 4 shows relative efficiencies of Asia's major air freight terminals which had assumed the variable returns to scale rather than the constant return to scale of the CCR's assumption. According to the BCC model's analysis, five airports; HKG, NRT, SIN, PVG, and KIX, among seven selected airports were assessed as an efficient group in 2001, five efficient airports; HKG, NRT, ICN, SIN, and PVG in 2002 and five; HKG, NRT, SIN, TPE, and PVG in 2004.

Through inefficient airport and standard group comparisons, it is possible to define differences between an inefficient airports' real inputs and actual data and the calculated optimal inputs and output data applied to BCC model. However, in 2002, the reason for Kansai Airport's inefficiency was the DMU as shown when compared to Shanghai Airport in all areas of excess investments in freight terminal facilities and operating sections which caused relative inefficiencies.

Table 4. Result of the feasibility study for the BCC model

Airport	Year	BCC		Change of scale	Standard Referred Group
HONG KONG (HKG)	2001	1	E	constant	-
	2002	1	E	constant	-
	2003	1	E	constant	-
TOKYO (NRT)	2001	1	E	constant	-
	2002	1	E	constant	-
	2003	1	E	constant	-
SEOUL (ICN)	2001	0.62	INE	increasing	HKG, NRT
	2002	1	E	constant	-
	2003	0.73	INE	increasing	HKG, NRT
SINGAPORE (SIN)	2001	1	E	constant	-
	2002	1	E	constant	-
	2003	1	E	constant	-
TAIPEI (TPE)	2001	n.a.	-	n.a.	-
	2002	n.a.	-	n.a.	
	2003	1	E	constant	
SHANGHAI (PVG)	2001	1	E	constant	-
	2002	1	E	constant	-
	2003	1	E	constant	-
OSAKA (KIX)	2001	1	E	constant	-
	2002	0.94	INE	increasing	ICN, PVG
	2003	0.67	INE	increasing	NRT, TPE

Note: E : efficient DMU, INE : inefficient DMU

5. CONCLUSIONS

The model research DEA test analyzed the relative efficiency of airfreight terminal operations at leading Asian airports. Realistically, analyzing absolute efficiency is difficult to accomplish, therefore relative measurements, such as airport freight terminal operation improvements, are the next best measurements. When inefficient airports fall below an airport's benchmarking considerations, it is understood that subsequent improvements will result in efficiency.

Findings derived from the model identify three important contributions concerning the efficiency of freight terminals. First, terminals managing freight analyzed in comparison to area dimensions and managing capacity showed that excess inputs are the cause for the inefficiencies. Second, the terminals managing freight found to have sufficient dimensions and managing capacity to absorb the holdings were concluded to be efficient. Third, when the two statements above are combined, the efficiency of terminals can be determined using the comparison of an inefficient one, which means a freight terminal that has a wide area and large managing capacity. Evaluating the efficiency of air freight terminal operations, is not an objective index since the model applied to evaluate the variable efficiencies in this research. Although many environmental factors need to be taken into consideration when measuring efficiency, the suggested kind of analysis in this paper can be used as a pre-diagnosis for future uncertainty situations.

The limitations of this research reflect those of the DEA model, which represents relative efficiency by comparing similar decision-making units. Although a DMU's relative efficiency results in "unity" as the highest efficiency, its marginal improvement can not be seen to contribute to absolute efficiency. Therefore, the DEA test is an effective substitute method for other discussions and measurements techniques. The second limitation is the use of air freight terminal data drawn from each airport and official international organizations such as IATA, ACI, and ICAO. Most resources have concentrated on passenger related data rather than air freight.

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Appendix : Data of Input and Output

2001	Warehouse space (square meters)	Input				Output
		Parking stand at cargo terminal	Cargo handling capacity (million tons)	Network connected city	Commissioned country	Total cargo throughput (metric tons)
Hong Kong (HKG)	210,000	21	300	140	69	2,100,276
Tokyo (NRT)	145,000	12	200	91	68	1,680,937
Seoul (ICN)	205,000	24	270	117	89	1,196,843
Singapore (SIN)	100,000	10	350	139	86	1,529,930
Shanghai (PVG)	222,000	8	75	84	60	352,541
Osaka (KIX)	264,000	14	139	64	67	871,161
2002	Warehouse space (square meters)	Input				Output
		Parking stand at cargo terminal	Cargo handling capacity (million tons)	Network connected city	Commissioned country	Total cargo throughput (metric tons)
Hong Kong (HKG)	210,000	21	300	58	96	2,504,584
Tokyo (NRT)	145,000	12	200	57	68	2,001,822
Seoul (ICN)	205,000	24	270	41	89	1,705,880
Singapore (SIN)	100,000	10	350	58	86	1,660,404
Shanghai (PVG)	222,000	8	75	36	60	634,966
Osaka (KIX)	264,000	14	139	37	67	805,430
2003	Warehouse space (square meters)	Input			Output	
		Parking stand at cargo terminal	Cargo handling capacity (million tons)	Network connected airport	Total cargo throughput (metric tons)	
Tokyo (NRT)	149,000	12	200	82	1,954,881	
Seoul (ICN)	205,000	24	270	102	1,678,467	
Singapore (SIN)	100,000	10	350	92	1,488,700	
Shanghai (PVG)	191,200	15	78	44	1,363,286	
Osaka (KIX)	222,000	8	185	78	1,068,038	
Hong Kong (HKG)	264,000	14	139	65	721,432	