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Analyzing Capacity Competition among the Airports in the Pearl River Delta

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ABSTRACT

Pearl River Delta (PRD) is one of the busiest manufacturing regions in the world. Logistics industry is crucial in this area in both importing raw material and exporting finished products. Since many logistics activities are subject to tight time constraints and involve high value products, air transportation is highly preferable by many companies in the region. Although the amount of air cargo available in the PRD area is enormous, the five PRD airports are trying their best to obtain a larger market share. These airports are called A5 group, including airports in Hong Kong, Guangzhou, Shenzhen, Zhuhai and Macau. The PRD airports competition is unique as the five airports are located within a 200km radius area, there are three different legal systems and borderlines between the two Special Administration Regions (Hong Kong and Macau) and the Mainland China. In this paper we focus on the three larger airports, Hong Kong, Guangzhou and Shenzhen, and study their capacity competition. The model proposed in this paper matches the current situation, and it can be used to predict the future market shares of the three airports under different scenarios. It can also be used to study the capacity expansions of the airports. According to our study, we conclude that Hong Kong airport will remain its leading position in the A5 group. However, its market share will drop and airports in Guangzhou and Shenzhen will steadily increase their market shares in the future. Moreover, if all three airports expand their capacities as they planned and the air cargo in the PRD area does not increase significantly fast, all three airports will likely have large excessive capacities in the future, which may result in more serious competition, and eventually hurt all members in the A5 group.

Keywords: Airport Competition, Air Logistics, Capacity Expansion

1. INTRODUCTION

According to the statistics of 2005 (Table 1), there was about five million tons of air cargo transporting inbound and outbound of the pearl river delta (PRD) area. Although the amount of air cargo is huge, competitions amongst the five PRD airports are excessive. Among them, Hong Kong International Airport (HKIA) handled around 70% of the total amount of cargo in the five airports. Although HKIA is continually setting new record in handling 3.4 million tons of air cargo in 2005, its position as Southern China's gateway is threatened by the newly opened Guangzhou Baiyun International Airport (GBIA) in August 2004. The new GBIA has the state-of-the-art facilities, and it was recently declared as one of the three key airports by the Chinese central government. Not long after its opening, GBIA is now conducting its phase II construction with a budget of RMB$10 billion (US$1.25 billion). The logistics giant FedEx is also building its new Asia Pacific hub in GBIA which will start operating in 2008 (FedEx Press Releases, 2005-07-13; Nanfang Daily**,** 2006-02-12). There is no doubt that GBIA will become a serious competitor of HKIA. Shenzhen Baoan International Airport (SBIA) is less competitive than HKIA and GBIA. However, it is striving in its own way to survive in this fierce competition. By aiming to transform its major operation into handling air-cargo by 2015, Shenzhen airport invests RMB$11 billion (US$1.37 billion) on a major expansion that includes building of a second runway (Nanfang Daily**,** 2005-12-21; Shenzhen International Airport Midia Report, 2005-07-21). Even though Macau airport is small compared to other airports, it is one of the most fast growing airports in the world. To solve the saturation that it is experiencing, Macau airport will also invest MOP$6 billion (US$0.78 billion) on its capacity expansion (China Business**,** 2006-03-06). The usage of Zhuhai airport is still far below its capacity. However, it can be used as a supplementary airport for the main PRD players. For instance, Hong Kong Airport Authority is planning to invest in Zhuhai airport, but there is still no further decision has been made yet (People**,** 2005-09-08; China Business**,** 2006-03-06). Besides of this planning, HKIA also announces in early 2006 investing $HK4.5 billion (US$0.58 billion) for expansion to ensure its leading role in PRD area (Hong Kong Commercial Newspaper**,** 2006-01-27).

However, this scale of capacity expansion in the PRD area is dangerous, since the future air cargo growth rate in the PRD area is uncertain and there is little coordination among the airports in capacity expansion. Capacity planning is a very important topic for the five airports in the PRD area. In this paper, we develop a simple model to analyze the market shares of the three major airports (Hong Kong, Guangzhou, and Shenzhen), and we use the model to study the market shares of the airports in the future under different capacity scenarios.

We should notice there are limitations in collecting freight data of the airports in Table 1. The data of the Mainland China's airports are more difficult to collect compared to the freight data of Hong Kong and Macau. Also, we observe some of these data of the Mainland's airports include air cargo and mail only, but the others contain air cargo, mail and luggage due to different sources from China. Although there are inconsistencies among the data, we consider them as acceptable since these data typically do not vary significantly.

Table 1. Freight handling by the five airports in PRD from 1995 to 2005 (tons)

Year	Hong Kong	Guangzhou	Shenzhen	Zhuhai	Macau
1995	1,457,680	278,797	78,623	3,098	134
1996	1,563,493	320,951	90,435	9,815	25,043
1997	1,786,487	351,770	98,882	10,354	45,540
1998	1,628,742	407,570	114,725	11,695	65,167
1999	1,974,291	448,117	154,639	9,995	53,118
2000	2,240,586	489,427	202,246	8,809	68,084
2001	2,074,333	531,565	247,655	11,134	76,076
2002	2,478,818	592,559	334,100	12,499	111,267
2003	2,642,103	543,987	406,600	10,729	141,223
2004	3,089,911	632,000	495,400	13,705	220,828
2005	3,402,250	752,100	550,500	11,254	227,233

Sources: Hong Kong Civil Aviation Department; Macau International Airport; Bureau of Statisitcs of Guangdong Province; Bureau of Statistics of Guangzhou; Shenzhen Statistics; ZhuHai Statiscal Information Net; Yearbooks of Guangdong, Guangzhou, and Hong Kong; Statistical Yearbooks of Guangzhou, and Shenzhen; Statistics of Guangzhou (1995-1996), Shenzhen (1995-1996), Zhuhai (1995-1996) ~ Zhang, A., 2003. Analysis of an international air-cargo hub: the case of Hong Kong. Journal of Air Transport Management 9 (2003), pp. 123-138.

Airport competition has been studied in the transportation literature. Barrett (2000) studies the airport competition in Europe after the deregulation. Pels et al. (2003) use a two-level nested logit model to study the airport competition in the San Francisco Bay area. The HKIA has also been studied in the literature. Zhang (2003) analyzes HKIA's role as an international air-cargo hub and studies its competition with other major airports in Asia. Hui et al. (2004) study China's air cargo flows and data and mention the relationship between HKIA and PRD cities. Loo et al. (2005) use the continuously equilibrium approach to model the passenger flows in the PRD area and to forecast the traffic distributions under different scenarios.

The issue of capacity competition has been studied in the operations management literature. Li and Lee (1994) developed a model to study this topic with considering price, service level, and processing rate. The authors found that firms with greater capacity enjoy greater market shares and profits when the service qualities are the same for all firms. As Keavency (1995) stated that "core service failures" was the most important reason for customers to switch to another service provider, Hall and Porteus

(2000) suggest that this kind of failures could be driven by the system capacity, such as service rate. Therefore, increasing the system capacity can decrease the waiting time and it is considered an effective method in retention of customers. In addition, they also point out that price and quality of service are other important elements in studying of market shares in a competition.

In this paper we use an M/M/1 queue to represent each airport and calculate the market shares of the airports under the waiting time equilibrium. We use this model to study the capacity competitions among the airports. In the rest of the paper, section 2 provides discussion about the theoretical analysis behind the model, and section 3 gives numerical observations of the model based on different stages of capacity expansion plans of the three airports. Section 4 presents some ideas that would extend the model into more realistic situations, and the paper is concluded in section 5.

2. THE MODEL

The airport terminal is a complicated, multiple-server queueing network, it is difficult to study. In this paper, our goal is to obtain a rough estimate of the airport's market share, we approximate each airport as a single-serve queue. Suppose that the air cargo arrives to the airport according to a Poisson process with rate λ_i, the cargo processing time in the airport follows an exponential distribution with rate μ_i, and the airports' total capacity exceeds the total demand. Then according to Bocharov et al. (2004), the average waiting time in the queue of the cargo is

$$Wq_i = \frac{P_i}{\mu_i(1-P_i)} = \frac{\lambda_i}{\mu_i(\mu_i-\lambda_i)} . \qquad (1)$$

Suppose that there are N airports, then the equilibrium would be achieved when the queueing times in all N queues are the same, i.e.

$$Wq_1 = Wq_2 = \ldots = Wq_i = \ldots = Wq_N . \qquad (2)$$

In such a case, there is no difference for a customer to choose whichever queue to line up. This idea has also been used in other contexts, e.g., Mendelson (1985) and Mendelson and Whang (1990).

Since the service rate $\{\mu_i, i = 1, 2,\ldots, N\}$ of each queue is different, the arrival rate $\{\lambda_i, i = 1, 2,\ldots, N\}$ for each queue must be adjusted in order to satisfy the condition in Equation (2) where the summation of λ_i is defined as

$$\lambda = \Sigma \lambda_i = \lambda_1 + \lambda_2 + \ldots \lambda_i + \ldots \lambda_N . \qquad (3)$$

To determine the market shares of the airports in competition, we use their capacities as their service rates and we use the total amount of air cargo per annum as the total arrival rate λ. Then the arrival rates (λ_i) under the waiting-time equilibrium can be calculated. Then the market share of airport is

$$\text{Market share of airport i} = \frac{\lambda_i}{\lambda} \quad . \qquad (4)$$

3. OBSERVATIONS

Determining the airports' current capacities is crucial in this research. However, this piece of information is various from different sources. For example, Hong Kong Civil Aviation Department states the capacity of HKIA is 3 million tons, but HKIA handled 3.4 million tons of cargo in 2005. A recent article released by Hong Kong Airport Authority states that the airport handling capacity will be about 5 million tons after the expansion of Asia Airfreight Terminal (AAT) at the end of 2006. Considering all these factors, we use a value of 4 million tons. For other airports, we also have some adjustments on their capacity value. There are a number of reasons why the capacities of the airports are various. First, the airport capacity is determined by the peak season and the capacity value is affected by the demand pattern which gives the relative weight of peak and off-peak season. But the demand pattern may change every year, resulting in various capacity values. Second, all the five airports are continuously improving their cargo handling processes, identifying potential bottlenecks, and investing in critical resources. All these improvements make the airport capacities difficult to identify. Fortunately, we only need rough capacity values. We believe that the capacity values we provide in Table 2 are reasonable. In addition, we also provide the planned capacities in 2010 and the ultimate capacities (according to the current planning horizon) of the three airports (Table 2). This information is obtained through different resources including ultimate capacity of HKIA and Guangzhou airport are 9 and 2.5 million tons respectively, but the capacity in 2010 and ultimate capacity we use for Shenzhen airport is actually the capacity in 2008 and 2015 respectively (Dragon's Sky; Hong Kong International Airport website; Shenzhen Special Zone Daily, 2006-02-15).

Table 2. Capacities of the main three PRD airports

Capacity (million tons / year)	Year 2005	Year 2010	Ultimate
Hong Kong International Airport	4	4.3	9
Guangzhou Baiyun International Airport	1	1.8	2.5
Shenzhen Baoan International Airport	0.7	1.5	2.5
Total	5.7	7.6	14

Source: Hong Kong Civil Aviation Department; Hong Kong Airport Authority; Hong Kong Commercial Newspaper (2006-01-27); Nanfang Daily (2005-12-21, 2006-02-12); Shenzhen Special Zone Daily (2006-02-15); Shenzhen International Airport website; Dragon's Sky.

Based on the capacity values, we predict the market shares of the three airports under different total amount of air cargo per annum using their current capacities (Figure 1), 2010 capacities (Figure 2), and ultimate capacities (Figure 3). We use a vertical line to mark the 5 million tons total arrivals in the figures since it is the arrival rate in 2005. This allows us to make comparisons to the current situation. Based on the model, current capacities of the airport and the total arrival in 2005, we predict the market shares in 2005. We compare them to the actual 2005 market shares (Table 3). It is clear that our predictions are accurate.

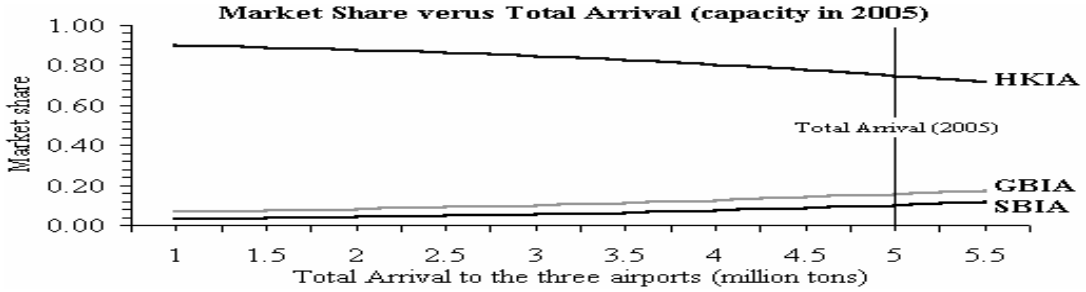

Figure 1. The market shares of the airports versus the total amount of air cargos in 2005

Table 3. Market Share Comparison of the result obtained in the model and actual statistics

	Predicted Market Share in 2005	Actual Market Share in 2005*
Hong Kong International Airport	0.75	0.72
Guangzhou Baiyun International Airport	0.15	0.16
Shenzhen Baoan International Airport	0.10	0.12

*Data from Table 1 are normalized where the summation of the actual market shares of the three airports in 2005 is 0.95 in PRD.

The results shown in Figures 2 and 3 indicate the market shares of the airports after their capacity expansions in two different scenarios. Both figures show similar trend as Figure 1. In spite of HKIA will continuously handle most of the air cargo in PRD, its market share will decrease. On the other hand, both GBIA and SBIA will obtain larger market demands when more air cargos are available. The market shares of GBIA and SBIA grow in the same rate in Figure 3 because they have the same ultimate capacities.

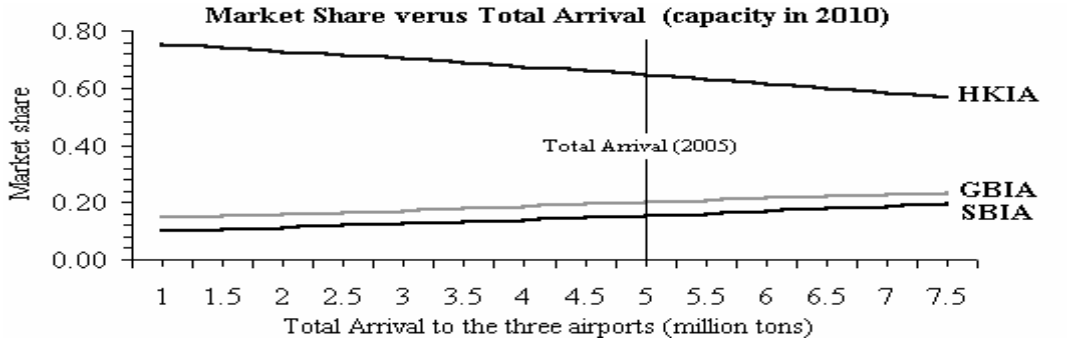

Figure 2. The market shares of the airports versus the total amount of air cargos in 2010

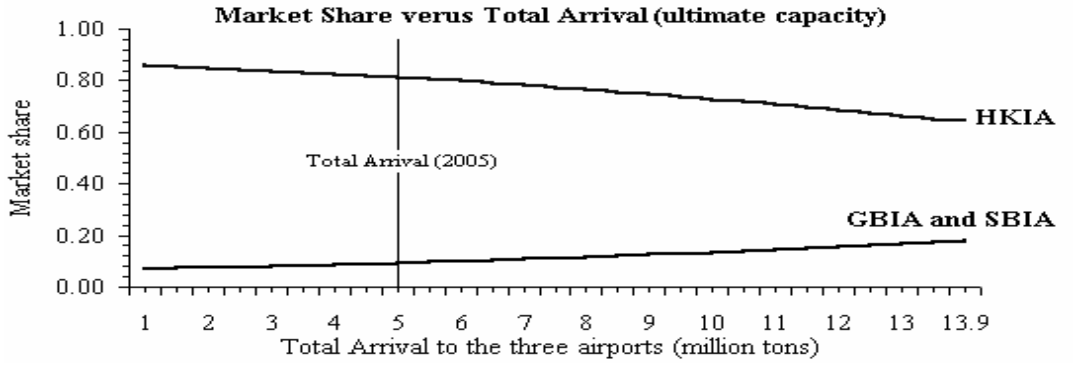

Figure 3. Market shares of the airports versus the total amount of air cargos (ultimate capacities)

Although there are some predictions of the future market shares of the PRD airports, they can be significantly different. It is difficult to judge the accuracy of these predictions since the data and the methodology used for prediction are generally confidential and are not available for comparison. For instance, GHK predicts that HKIA in 2020 will handle 47% of the exporting air cargo of Guangdong province, and GBIA and SBIA will obtain 29% and 17% of these cargo respectively (www.skyscrapercity.com; HK Standard, 2004-05-15), but an article from Capital Magazine predicts that HKIA will handle 7.5 million tons and GBIA will handle 12 million tons of cargo in 2020 (www.business.gov.hk; Capital).

Since none of the airports have fully utilized their capacities after the expansions in the two scenarios, it is interesting to investigate their excessive capacities under various total amounts of air cargos with their 2010 capacities (Figure 4) and ultimate capacities (Figure 5). We find that the capacities utilizations of these airports in 2010 would meet the current situation when the total amount of air cargo per annum reaches about 6.5 million tons. However, this amount of cargo is almost doubled in order to meet the current capacities utilizations if the airports are expanded into their ultimate capacities. Therefore, we conclude that in case the growth rate of the total amount of air cargo does not increase significantly in the future, a large portion of capacity will be wasted in every airport. Again, capacity planning is an inevitable topic for the five PRD airports.

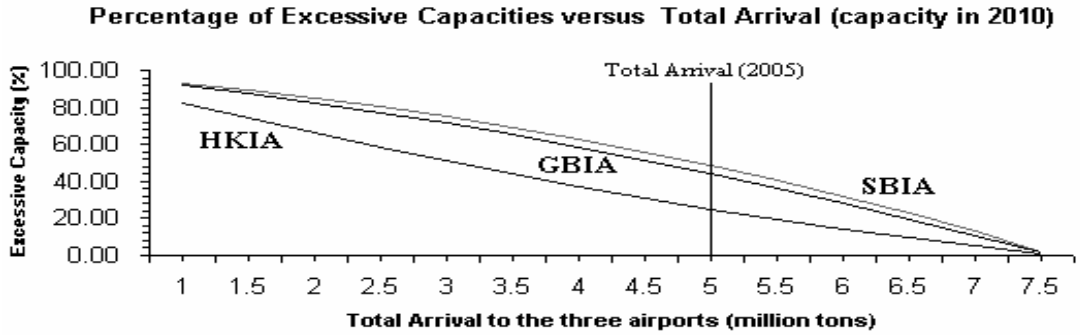

Figure 4. Excessive capacities (%) of the airports versus the total amount of air cargos in 2010

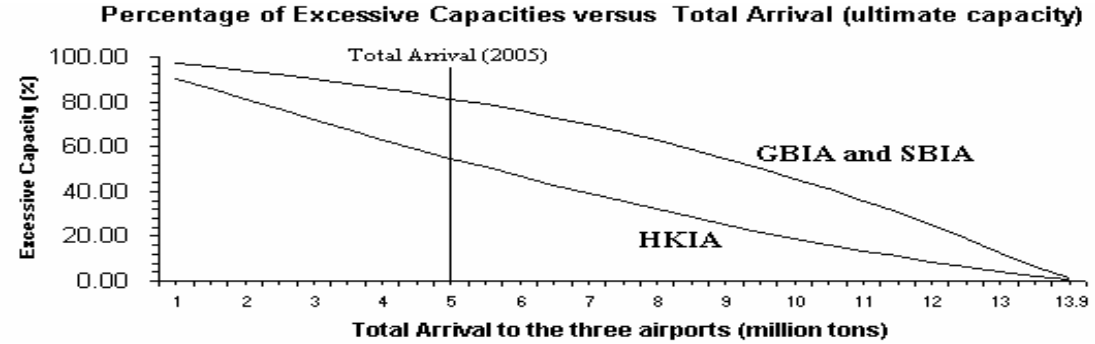

Figure 5. Excessive capacities (%) of the airports vs the total amount of air cargos (ultimate capacity)

4. EXTENSIONS OF THE MODEL

In the current model, capacity and arrival rate are the primary parameters used to determine the market shares of the airports. Though it captures main features of capacity competition, there is still much room to improve the model. First, priority queueing system can be adopted to classify air cargos into different classes by their types or values. For example, the air freights are designated into three classes where the highest priority class is for most valuable goods, the second priority class is for standard cargos, and the least priority class is for bulk cargos. Therefore, the amount of each class freights handled by airport i per year are denoted by the arrival rates ($\lambda_{i\_1st,}$ $\lambda_{i\_2nd,}$ λ_{i_3rd}, i = 1, 2,…, N), and the market share of airport i in handling each type of cargo can be determined by the existing model. The priority queueing system will enable us to study the market segmentation, which is another important long-term strategy of the different airports. For instance, due to the higher cost but better service of HKIA, HKIA may focus more on the valuable goods in the future. Second, service quality is another important parameter that can be employed into the model. For example, we can use M/G/1 queue instead of the M/M/1 queue. We may let the airports with better service quality have a service distribution with smaller coefficient of variation. Then with the same capacity and same cargo arrival rate, the airport with better service will have a shorter average waiting time. Third, the model could be revised to study cost equilibrium instead of waiting time equilibrium. The cost consists of a combination of cost actually charged to shippers (i.e., terminal cost, airline cost, land transportation cost and custom clearance cost if needed), cost of time, and even cost of service quality as described above. Since time and service qualities are important concerns for business, coefficients can be used to turn the total transportation time (i.e., waiting and processing time in an airport, and the shipping time) and service level into relative costs to the shippers. The summation of these costs is known as the 'total cost' for choosing an airport. Therefore the higher the total cost of an airport, the more reluctant

it will be a choice for shippers. To bring the research to the next level, game theory, including non-cooperative and cooperative games, can be used to study the game-based equilibriums. This would allow us to study the competitions and cooperation among the airports, and also study the necessities of the control and coordination from the regional governments.

5. CONCLUSIONS

In this paper we propose a simple queueing model to predict the market shares of the three airports in the PRD area under different capacity levels and different total amount of air cargo. This model enables us to analyze the market shares and the excessive capacities of the three airports, and study their capacity expansion plans. In summary, we find out that HKIA will still be the largest airport in the PRD region in the near future, and that the strategy of aggressive capacity expansion currently used by almost all PRD airports can be dangerous, especially if the total amount of air cargo cannot keep a significant growth rate.

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