BEHAVIOR ANALYSIS OF AIR CARRIER UNDER THE PASSENGERS' EQUILIBRIUM FLOW IN THE ASIAN-PACIFIC AVIATION NETWORK

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Abstract: The present paper aims to analyze the carriers' and the passengers' behavior under the policy of " open sky ", which means the air transportation market is perfectly competitive. Under this assumption, the air carriers' and passengers' behaviors are formulated, respectively, and the Nash type equilibrium conditions of both behavior in the market are given. The model is applied to the East Asian air market in 2010, and the impact of the construction of international hub-airports in the region on the equilibrium solution is numerically discussed.

1. INTRODUCTION

Deregulation of the international air transportation market is the recent global trend as called as " the Open Sky Policy ". Especially, in the East Asian region, it will be very much concerned corresponding to the rapid growth of air transportation demand, because the market will be expected to become much more competitive and it may give much influence on the airport policy of the countries.

In East Asia, some countries are making efforts to develop the big international hub-airport capable to accept the Boeing 747 type or the much larger aircraft. According to the newspaper, five or six new big airports will be opened until the year of 2010. Those airports are expected to be an international hub-airport. Then, this rush of construction of big airport in East Asian region will invite a significant influence on the air carriers' strategy such as routing, service frequency, air fare and so forth as well as on the route choice behavior of passengers.

Many researches on air demand forecast have been seen in the past, but researches on air carriers' behavior are limited. Kanafani *et al* (1985) showed that ,in the competitive air market, the air carriers will make the hub-and spokes shaped aviation network in order to minimize their total operation cost. Kobayashi *et al* (1998) also discuss the impact of airport fee on the structure of aviation network. They showed that air carrier's service network changes from a hub and spokes type to a direct connecting type depending on the relative amount of the marginal link cost to the airport fee. These researches are successful in the sense of giving logical bases to consider the network formulation by air carriers. However, they do not take into account of the airport capacity.

Other researches, which treat both behavior of the air carriers and the passengers, are seen in Furuichi *et al* (1993), Morichi *et al* (1993) and Yai *et al* (1998). Most of these researches discuss the interaction of the carriers' behavior and the passengers' behavior and some of them focus on the benefit of airline alliance. However, they disregard the equilibrium in the market of the air carrier's behavior and the passengers behavior.

On the other hand, Kuroda and Takebayashi (1996, 1997 and 1998) treat this equilibrium in the domestic air transportation market as the "Stackelberg Problem" taking the asymmetric information in the market into consideration. Their model, however, does not consider the air fare as a variable. In many researches conducted in the past, the air fare has been treated as a externally given value. The present paper, however, formulates the international air transportation market as the " perfectly competitive market" , which will be appeared in the near future when deregulation is progressed. The paper also applies the model to the international air transportation market in the year of 2010, and discusses the influence of the construction of big international airport in the East Asian region.

2. THE MODEL FORMULATION

2.1 Premises and Assumptions

In the present paper, the air transportation market is regarded as the perfectly competitive one. In formulation of the market structure, following premises and assumptions are introduced;

1) There are potentially so many competitive carriers in each service route as to make the market perfectly competitive.
2) There is no sunk cost for air carriers in each service route.
3) The same quality of service is provided in the same service route.
4) The flight length of each service route is a priori given and fixed.
5) The flight capacity of each airport is given, and airport charges such as landing fee, navigational aids facility fee, terminal cost and so forth are a priori given.
6) The fuel cost per gallon is the same price at any airport, and given a priori.
7) Only one type aircraft can be served at all service routes. In the present paper, the Boeing 747-400 type aircraft is considered.
8) Passengers are assumed to choose the route which gives the minimal generalized cost.
9) The O.D. passenger's volume is a priori given, and the carriers are not allowed to shut out from shipment of any passenger.
10) All passengers make a round trip by using same route. Then, the flight frequency of a certain route is same as that of the return route.

In the present paper, since the air transportation market is regarded as the perfectly competitive one, the equilibrium solution between carriers and air passengers is given by the Nash type equilibrium.

2.2 Air Carriers' Behavior

The air carriers aims to maximize their net revenue through their strategic behavior in the market. However, since the perfectly competitive market is assumed, the air carrier can not take any surplus, that is, their net revenue may become infinitely equal to zero even if they make efforts to minimize their operation cost. This means the air fare of each service route is realized by the carriers' operation cost which is determined from the equilibrium of the carriers' operational strategy and the passengers' route choice behavior. The carriers' operation cost is consisted of the aircraft operational cost (henceforth, called as the linehaul cost) and airport charge which includes the landing fee, the navigational aids facility fee, the terminal operation cost and so forth. Therefore, in the perfectly competitive market, the air carriers' behavior can be formulated as follows;

$$MinC(f_l) = \sum_{l \in L} f_l (AC_l + \delta_h^l LC_h) \tag{1}$$

Sub. to

$$\sum_{l \in L} \delta_h^l f_l \leq CA_h \tag{2}$$

$$p_l (x_l + x_{l'}) = f_l (AC_l + \delta_h^l LC_h) + f_{l'} (AC_{l'} + \delta_h^{l'} LC_h) \tag{3}$$

$$x_l \leq \omega_l CP_l f_l \tag{4}$$

$$f_l = f_{l'} \tag{5}$$

$$f_l \geq 0 \tag{6}$$

where,

$C(f_l)$; total operation cost (US$ per week).
l ; a service route with a direction.
l' ; same service route as l with opposite direction.
f_l ; flight frequency at the service route l (flights per week).
AC_l ; linehaul cost at the service route l (US$ per flight).
LC_h ;airport charge at the airport h (US$ per flight per carft).
δ^l_h ; Cronecker's delta (=1.0 when the airport is included in the route l, otherwise zero).
CA_h ; flight capacity of the airport h (flights per week).
x_l ; air passengers' volume using the route l (person per week).
p_l ;air fare of the route l (US$ per person per flight).
CP_l ; load capacity of the aircraft on the route l (person per flight).
ω_l ; average load factor on the route l.
L ; a set of service routes.

In the above, Eq.(1) means the objective function of air carriers and f_l is the optional variable for the air carriers. Eq.(2) is the constraint for the airport capacity, and Eq.(3) gives the necessary condition for the equilibrium price of air fare. Eq.(4) is the constraint for the load capacity of each service route and Eq.(5) means the symmetric condition of the the flight frequency of a route based on the assumption (10).

2.3 Air Passengers' Behavior

Most of air passengers may hope to minimize the total travel cost and the travel time when they choose their travel route. Then, in the present model, the generalized cost is introduced to consider the value of travel time. Only air fare is considered as the travel cost, but the access and egress travel costs are not considered in the present model because the O.D. passengers volume is a priori given for each combination of two airports. The travel time is consisted of the line-hall flight time and the average waiting time at the departure airport and the transit airport if necessary. Denoting the generalized cost for the passenger travelling on the route l by u_l, it is given by

$$u_l = p_l + \alpha(t_l + \delta_l^h OT_h / 2f_l) \tag{7}$$

and the air passengers' behavior can be formulated as

$$\underset{x_{ij}^k}{Min} \sum_l \sum_k \delta_k^l u_l \tag{8}$$

Subject to

$$\sum_k x_{ij}^k = X_{ij} \tag{9}$$

$$x_l = \sum_i \sum_j \sum_k \delta_k^l x_{ij}^k \tag{10}$$

$$x_l \le \omega_l f_l CP_l \tag{11}$$

$$x_{ij}^k \ge 0 \tag{12}$$

in which

δ_k^l ; Cronecker's delta (=1.0 when the route l is included the k th path, otherwise zero).

t_l ; linehaul time of the route l (minutes).

OT_h ; service time at the airport h (minutes).

δ_{h2}^l ; Cronecker's delta (=1.0 when the airport h_2 is the departure airport of the route l, otherwise, zero).

α ; value of travel time (US$ per minute).

x_{ij}^k ; passengers' volume at kth path (person).

X_{ij} ; passengers' O.D. volume from zone i to zone j (person).

In the present paper, it is assumed that each air passenger chooses his optimal (minimal generalized cost) route deterministically, but not probabilistically. Therefore, when there are more than two routes between a certain pair of origin and destination, a rule of passenger's route choice behavior is necessary. For this passengers' behavior, the equal generalized cost principle is introduced, that is, " the generalized costs of all routes for each pair of O.D. are same and equal to the minimal generalized cost of the route if and only if those routes are chosen by passengers, but the generalized costs of the routes are greater than the minimum if they are not chosen." This principle is given by J.G. Wardrop as the user optimizing assignment rule in traffic engineering. This can be mathematically expressed as

$$if \quad x_{ij}^k > 0 \qquad then \qquad \sum_k \delta_k^l u_l = u_{ij}^* \tag{13}$$

$$if \quad x_{ij}^{k} = 0 \quad then \quad \sum_{k} \delta_{k}^{l} u_{l} > u_{ij}^{*} \tag{14}$$

where u^*_{ij} is the minimum generalized cost of the route l connecting the zone i with the zone j.

3. APPLICATION TO EAST ASIAN AVIATION NETWORK IN THE YEAR OF 2010

According to the discussion in Introduction, it is thought that "the open sky " deregulation policy is the global tendency as well as in East Asian countries. Then, if the perfectly competitive market will be appeared in the near future, it is necessary, for the effective management of international airports of each country, to predict which airport will be used as the international hub-airport. And most of airport planners may have great interest in the necessary conditions for the international hub-airport.

In this chapter, numerical applications of the present model to the international aviation network in the year of 2010 are carried out in order to know the necessary conditions for the international hub-airport focussing on the East Asian region.

3.1 Numerical Conditions

O.D. Zones and O.D. Volume

In numerical application in the year of 2010, O.D. zones are defined with following rules:
1) East Asian region except Japan is divided into ten zones as listed in Table 1. Japan is divided into five zones. Others are Oceania, North America, West Europe and East Europe.
2) West Asia, Africa and South America are not taken into consideration because of small demand comparing with the other zones.
3) The international airports in Eastern Asia considered in the numerical application are shown in Figure 1.
4) Each zone has its representative airport as shown as Table 1. Therefore, the access and the egress to or from the airport are neglected.
5) Los Angels Airport represents North America.
6) West Europe and East Europe are represented by London Airport and Frankfurt Airport, representatively.

The O.D. air passenger volume in 2010 is estimated based on a gravity type model as shown in Eq. (15), but the detail is omitted because of limited pages.

$$V_{ij} = K \frac{(G_i G_j)^{\alpha} (p_i p_j)^{\beta} D_1^{d} \; D_2^{d_2} \cdots D_n^{d_n}}{R_{ij}^{\gamma}} \tag{15}$$

where
G_i, G_j ; GDP of the zone i and j, respectively (1,000US$/ person/ year).
P_i, P_j ; population of the zone i and j, respectively (1,000 person).
R_{ij} ; distance between the representative airport of the zone i and j (*km*).
$D.$; dummy variables
K, α, β, γ, $d.$; regression coefficients.

The regression coefficients of Eq.(15) are shown in Table 2. Using Eq.(15), the O.D. passengers' volume in 2010 are estimated. This is shown in Table3. The air carriers can serve any route linked with two airports, but they can not serve between Japanese airports.

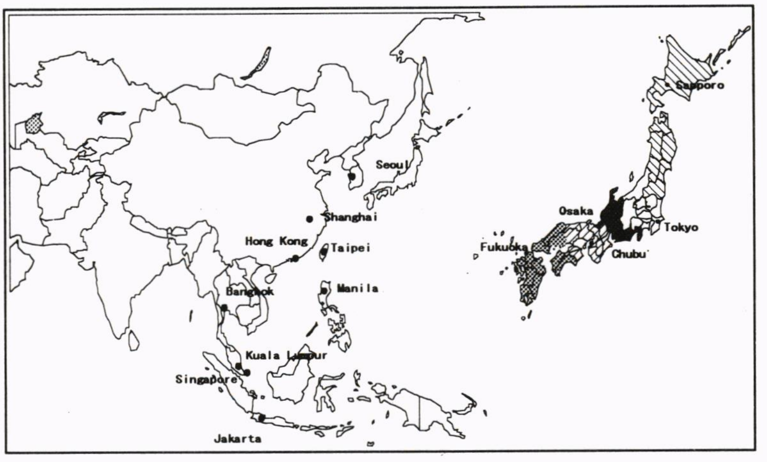

Figure 1 Airports in Eastern Asia in 2010

Table 1 O.D. Zones and Their Representative Airports

Airport	**Hinterland Zones**
1. Sapporo	Hokkaido (Japan)
2. Tokyo	Kanto, Tohoku and Hokuriku (Japan)
3. Chubu	Chubu and Hokuriku (Japan)
4. Osaka	Kinki ,Chugoku and Sikoku (Japan)
5. Fukuoka	Chugoku, Shikoku and Kyushu (Japan)
6. Seoul	Korea and North China
7. Shanghai	Central China
8. Hong Kong	South China
9. Taipei	Taiwan
10. Manila	Philippines
11. Bangkok	Thailand,
12. Kuala Lumpur	Malaysia
13. Singapore	Singapore
14. Jakarta	Indonesia
15. Oceania	Australia and New Zealand
16. Los Angels	U.S.A. and Canada
17. London	West Europe
18. Frankfurt	East Europe and Russia

Table 2 Regression Coefficients of Eq.(15)

	LnA	α	β	γ	d_1	d_2	d_3	d_4	d_5	d_6	r^2	sample
Intra-Asia	2.49	0.46	0.85	0.88	0.23	-0.56	0.15	0.52	0.16	0.70	0.877	33
Asia-N.A Europe. Oceania	18.11	0.41	0.12	1.08	0.84	-0.43	1.01	-1.29	0.30	-----	0.839	31

Table 3 O.D. Volume of Air Passengers in 2010

	Sapporo	Tokyo	Chubu	Kansai	Fkuoka	Seoul	Shnghi	H.K.	Taipei	Manila
Sapporo	-	-	-	-	-	4741	8013	6623	3573	1369
Tokyo	-	-	-	-	-	37929	64104	52980	28299	10955
Chubu	-	-	-	-	-	16120	27244	22517	12027	4656
Kansai	-	-	-	-	-	28,446	48,078	39,735	21,224	8,217
Fukuoka	-	-	-	-	-	7,586	12,821	10,596	5,660	2,191
Seoul	4,741	37,929	16,120	28,446	7,586	-	50,921	35,113	17,122	5,730
Shanghai	8,013	64,104	27,244	48,078	12,821	50,921	-	72,941	42,453	6,336
Hong Kong	6,623	52,980	22,517	39,735	10,596	35,113	72,941	-	99,221	28,228
Taipei	3,537	28,299	12,027	21,224	5,660	17,122	42,453	99,221	-	20,069
Manila	1,369	10,955	4,656	8,217	2,191	5,730	6,336	28,228	20,069	-
Bangkok	3,510	28,080	11,934	21,060	5,616	14,295	18,711	49,449	45,325	7,495
Jakarta	1,869	14,956	6,356	11,217	2,991	6,957	8,346	22,797	17,332	4,096
KuraLmpr	1,394	11,156	4,741	8,367	2,231	5,415	6,745	18,200	14,939	3,112
Sngpore	2,439	19,516	8,294	14,637	3,903	8,700	21,513	29,434	23,760	10,515
Oceania	2,078	16,624	7,065	12,468	3,325	6,906	4,897	15,542	7,878	1,559
N.Amrca	4,498	35,982	15,293	26,987	7,196	14,531	15,098	23,377	12,536	1,553
W.Erope	2,286	18,289	7,773	13,717	3,658	8,895	7,511	16,516	7,917	931
E.Europe	1,966	15,731	6,686	11,798	3,146	7,749	6,608	14,183	7,098	818
TOTAL	44,323	354,601	150,706	265,951	70,920	277,156	422,340	557,452	386,397	117,830

	Bangkok	Jakarta	KraLmpr	Sngpor	Oceana	N.Amrca	W.Erpe	E.Erpe	TOTAL
Sapporo	3,510	1,869	1,394	2,439	2,078	4,498	2,286	1,966	44,323
Tokyo	28,080	14,956	11,156	19,516	16,624	35,982	18,289	15,731	354,601
Chubu	11,934	6,356	4,741	8,294	7,065	15,293	7,773	6,686	150,706
Kansai	21,060	11,217	8,367	14,637	12,468	26,987	13,717	11,798	265,951
Fukuoka	5,616	2,991	2,231	3,903	3,325	7,196	3,658	3,146	70,920
Seoul	14,295	6,957	5,415	8,700	6,906	14,531	8,895	7,749	277,156
Shanghai	18,711	8,346	6,745	21,513	4,897	15,098	7,511	6,608	422,340
Hong Kong	49,449	22,797	18,200	29,434	15,542	23,377	16,516	14,183	557,452
Taipei	45,325	17,332	14,939	23,760	7,878	12,536	7,917	7,098	386,397
Manila	7,495	4,096	3,112	10,515	1,559	1,553	931	818	117,830
Bangkok	-	16,421	20,547	56,751	23,338	31,417	24,967	22,325	401,241
Jakarta	16,421	-	13,553	57,219	1,991	1,792	1,374	1,224	190,491
KuraLmpr	20,547	13,553	-	95,039	2,277	2,736	1,914	1,706	214,072
Sngpore	56,751	57,219	95,039	-	20,570	23,416	15,868	14,112	425,686
Oceania	23,338	1,991	2,277	20,570	-	-	-	-	126,518
N.Amrca	31,417	1,792	2,736	23,416	-	-	-	-	216,412
W.Erope	24,967	1,374	1,914	15,868	-	-	-	-	131,616
E.Europe	22,325	1,224	1,706	14,112	-	-	-	-	115,150
TOTAL	401,241	190,491	214,072	425,686	126,518	216,412	131,616	115,150	4,468,862

Airport Capacity and Airport Charge

The flight capacity of each airport is listed in Table 4. Most of these capacities are based on the data of the airport plan in 2010, which has been published by their related authorities. In Table 4, it should be notified that the airports of Sydney, Los Angels (LSA),, London(LND), Frankfurt(FKF) are the virtual ones, and their capacities are assumed to be infinite in light of the present purpose of analysis, but their airport charges are employed as the representative airports of zones. Those airport charges are referred to the data of the Airport Statistics by ICAO (1996).

Table 4 Airport Capacity and Charge

	SAP	TKY	NCB	KIX	FUK	SEL	SHA	HKG	TPE
Capacity (Flights/Week)	700	2600	2148	2820	700	700	6062	7288	5754
Charge (US$/Flight)	7338	8954	8654	8654	7338	1992	1594	2826	1962

	MNL	BKK	JKT	KLP	SIN	SDN	LSA	LND	FRF
Capacity (Flights/Week)	2000	5931	1500	8746	11088	+∞	+∞	+∞	+∞
Charge (US$/Flight)	1615	1962	1569	2123	3077	5254	3246	4846	7408

The line-hall cost of aircraft is statistically estimated based on the Financial Data of ICAO (1995). The line-hall cost of aircraft is strongly correlated to the flight distance as shown in Figure 2. Thus, in the present numerical computation, the estimated equation of the line-hall cost shown in Figure 2 is employed. In the succeeding analysis, all the costs are used as the present value but not the future value. It is again notified that the aircraft type used in the computation is assumed as Boeing 747-400.

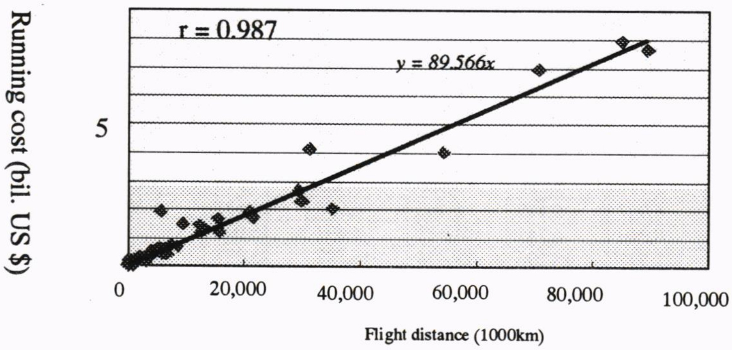

Figure 2 Linehaul Cost of Aircraft

3.2 Equilibrium of Eastern Asian Aviation Market in 2010

The computed equilibrium of the Eastern Asian aviation market in 2010 is discussed in this section. Henceforth this is called as "the basic case". As discussed previously, the equilibrium state is obtained as the Nash type equilibrium in the market between air carriers' behavior and air passengers' behavior.

The computed total volume of passengers at each airport in Eastern Asia is shown in Figure 3. In this figure, the total volume of transit passengers of all the airports is about 8 percent of the total O.D. passengers. Comparing with Table 3 and Figure3, it can be understood that the volume of the direct flight passengers of each airport is proportional to the O.D. volume of its hinterland, but the volume of transit passengers is not proportional. This is understandable to see Figure 4 which shows the detail of the transit passengers of each airport. The remarks in this figure, for example, the transit passengers named "Asia" means the passengers who move intra- Asian countries, while "Europe" means the passengers who travel to Europe from Asian of the vice-versa.

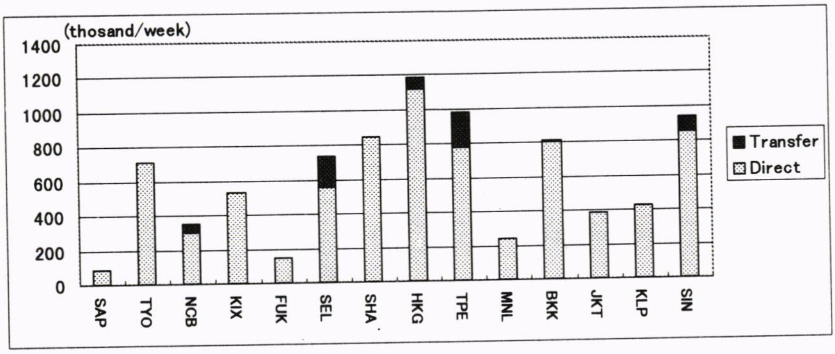

Figure 3 Passengers' Volume of Airport

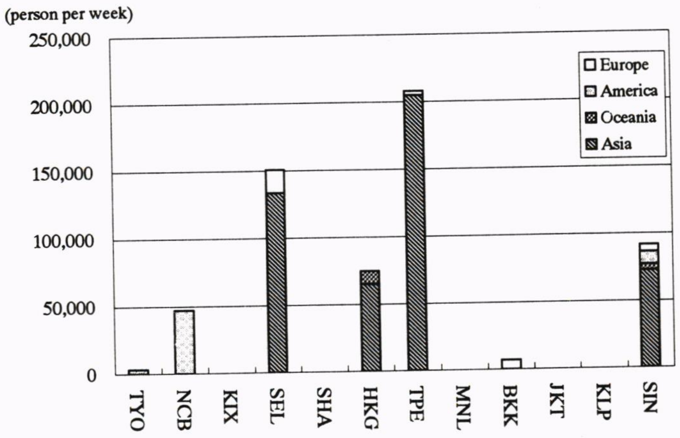

Figure 4 Transit Passengers at Each Airport

As can be understood from Figure 4, the passengers who travel intra-Asian countries use the airport of Taipei, Seoul Singapore, and Hong Kong as the transit airport, while those of "Oceania" use the airport of Hong Kong or Singapore. It should be noticed that the transit passengers of "Oceania" do not include the passengers from or to Europe and North America. The passengers bound for or from Europe use the airport of Seoul, Singapore and Taipei, respectively. However, the passengers to or from North America use the airport of New Chubu, Singapore or Tokyo as the transit airport. These passengers flow largely depends upon the passengers volume from or to Japan because the O.D. passengers' volume of Japan is relatively quite large comparing with those of other Asian countries as shown in Table 3. Thus it may be easily understood that the management policy of Japanese airports will give a great influence on the equilibrium passengers' flow and the air carrier's behavior. This is also anticipated from Figure 5 which shows the flight occupancy ratio of each airport which is defined as the ratio of the service flight's number per week at each airport provided by the air carriers to its flight capacity per week. As can be seen in this figure, the occupancy ratio of Japanese airports is much larger than that of other Asian airports.

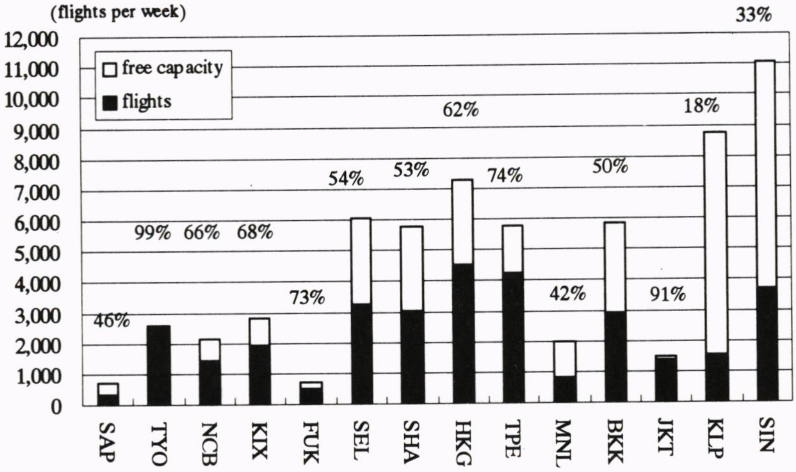

Figure 5 Occupancy Ratio of Each Airport

Surveying Figure 3 and Figure 5, it is understood that the Japanese airports are mainly used by the direct flight which is served for the passengers from or to Japan. This is the reason why the Japanese airports can not invite the enough number of flights for the transit passengers. This will be further discussed in the succeeding sections.

3.3 Impact of Super Hub-Airport Construction in Eastern Asia

It is expected that the next age aircraft will be introduced into the air transportation market in the beginning of the 21st century, and that the airport used by such aircraft will become the "*Super Hub Airport*". It is also said that one or two super hub airport will be probable in one continent. If so, it is anticipated that the location of the super hub airport will make a significant influence on the social and economic system of the region through the great change of air passenger's flow and the airline network. Therefore, it is very much interesting to predict the future equilibrium of air transportation market when a super hub airport available for the next age aircraft is on service. A super hub airport is ,in this paper, defined as the airport only for which the inter-continental flight can be served, but, at other airports in the region, only feeder service flights are available.

Assumptions

In this section, the equilibrium of the air transportation market is discussed when one or two super hub airport is located in the Eastern Asian region to connect with other hub airports in America and Europe. In computation, followings are assumed about the next age aircraft and the super hub airport;

(1)The O.D. volume of passengers is same as that of the basic case in 2010.
(2)The capacity of next age craft is 622 sheets.
(3)The average navigational speed is Mach 1.0 (1.2 times faster than the present jumbo-type craft).
(4)The linehaul operational cost is 1.5 times than that of the existing jumbo-type craft.
(5)The airport cost for the next age aircraft is as the same price as that for the existing

jumbo-type craft.

(6) The capacity of all the airport in the Eastern Asia is enough large so as to accept all flights. This condition is necessary to find the equilibrium solution because it is supposed that the flight capacity of the super hub airport may not be overflowed in computation process when it invites many feeder service flights.

The Case of One Super Hub Airport

Concerning with the super hub airport, a question "where is the most probable for its location from the viewpoint of air carriers' strategy?" is very much interesting. Figure 6 shows the answer for this question. This figure shows the computed results of carriers' operational cost when the location of the super hub airports is changed. It should be noticed in this figure that the carriers' operation cost is normalized by the case that the super hub airport is located at Seoul. From Figure 6 it is observed that Seoul is most preferable for the carriers as the super hub airport because it gives minimum operation cost. This comes from the advantage of Seoul than the others in order to connect the Eastern Asian countries with Europe and America because of its location and the O.D. passengers' volume. Therefore, if the O.D. volume of the air passengers is changed from the assumed the pattern, the optimal location of the super hub airport will be changed.

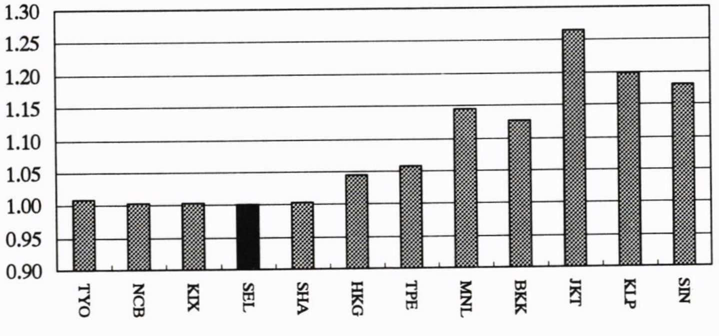

Figure 6 Comparison of Carrier's Total Operation Cost

When the super hub airport is located at Seoul, what will happen to passengers utility? The answer is shown in Table 5 in which the travel time and the travel cost mean the difference from the basic case discussed in the section 3.2.

As can be understood from Table 5, the travel time of the passengers from and for Japan, Shanghai and Taipei is reduced in spite of small increase of the travel cost. On the other hand, the travel time and the cost of the passengers from and for the ASEAN countries will be largely increased. From this case study, it can be concluded that the passengers of the country who has the super hub airport and of its adjacent countries will be much more beneficial than the others.

In this context, which airport in Eastern Asia is available for the super hub airport if the airport capacity is limited as same as the basic case in 2010? The answer is shown in Figure 7 which shows the total flight number (the least necessary capacity functioned as the super hub airport) and the planned capacity of each airport in 2010.

Table 5 Change of Passengers' Utility (Europe Bound)

Zone	Travel Time (min./person)	Travel Cost (US$/person)
Sapporo	-219	7
Tokyo	-79	98
Chubu	-312	61
Osaka	-161	12
Fukuoka	-240	4
Shanghai	-105	513
Hong Kong	1	155
Taipei	-144	394
Manila	61	232
Bangkok	148	1048
Jakarta	44	868
Kuala Lumpur	169	976
Singapore	81	973

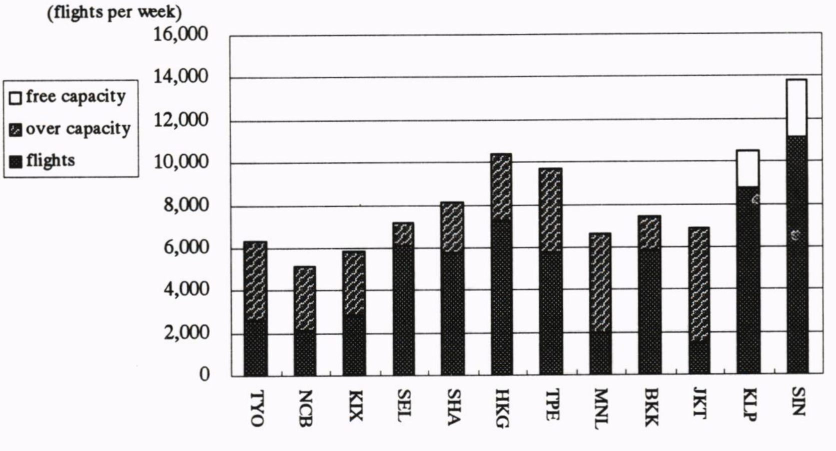

Figure 7 Total Flight Number and Capacity of Each Airport as Used as a Super Hub Airport

From this figure it is understood that only the Singapore and the Kuala Lumpur airports are the candidates for the super hub airport. Consulting with Figure 6 and Figure 7, the Singapore airport is the only one candidate for the super hub airport if the other airports have no plan of capacity extension because it has enough capacity to become the super hub airport and .the carriers' operation cost is less than the Kuala Lumpur.

The Case of Two Super Hub Airports

Another scenario of the super hub airport is the location of two super hub airports, each of which the service flight is specialized for a special continent. That is, one is for Europe and the other is for America. In this section, this scenario is discussed. In this scenario, a question "where is chosen for the specialized super hub airport? " is now interesting.

The answer is shown in the Figure 8 in which the total operational cost of carriers for each airport is shown when it becomes the specialized super hub airport. From this figure the Tokyo (Narita) International airport is most preferable for the carriers as the super hub airport specialized bound for America while the Seoul airport is most preferable for the carriers as the super hub airport specialized bound for Europe. This result again says that the ASEAN countries have the disadvantage to invite the specialized super hub airport.

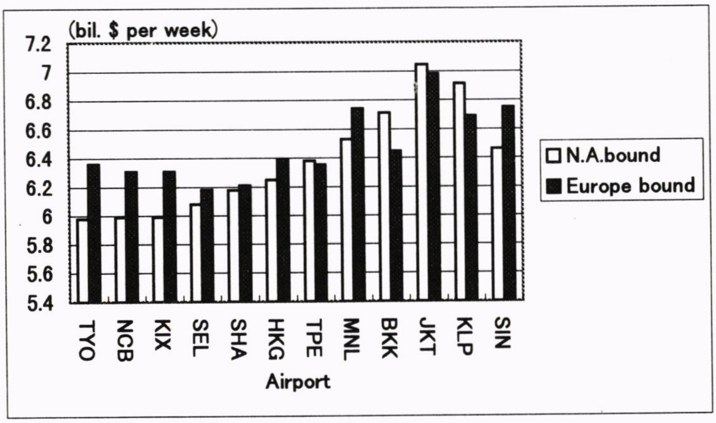

Figure 8 Comparison of Carriers' Operation Cost

Next question is again "what will happen to the passengers' utility if these two super hub airports are located? " The computed results of the travel cost and the generalized cost of a passenger from and to each airport are shown in Figure 9 in the case, in which these costs mean the difference from the basic case discussed in the section 3.2.

This figure says that, if the super hub airport specialized bound for America is located at Tokyo, the travel cost and the generalized cost of the passengers to and from America through each airport are unchanged or slightly changed except those using the Shanghai airport. On the other hand, if the super hub airport specialized bound for Europe is located at Seoul, the travel cost and the generalized cost of the passengers through most of airports will be increased. Thus, the passengers may not use the specialized super hub because this case does not give any convenience to the travelers.

4. CONCLUSION

The present paper develops a model to obtain the Nash type equilibrium solution of the air transportation market when it is assumed as the completely competitive, and it is applied to the analysis of the Asian air transportation market in 2010 (basic case). Further, it is also applied to analyze the impact of the location of the super hub airport in the Eastern Asian region in the future considering the next age super-jumbo type aircraft.

The analytical results of the basic case say that, if the O.D volume in 2010 is increased by the present pattern, the Taipei, the Seoul, the Singapore and the Hong Kong airports will invite the inter-Asian passengers as the transit passengers. The travelers for and from Oceanian countries will use the Hong Kong and Singapore airports as the transit airport, and the transit passengers for and from America will use the New Chubu, the Singapore and the Tokyo (Narita) airports. The travelers for and from Europe will use the Seoul, the

Singapore and Taipei airports as the transit airport. In any case, the capacity of each airport except the Japanese airports and the Jakarta airport will be enough for the demand in 2010.

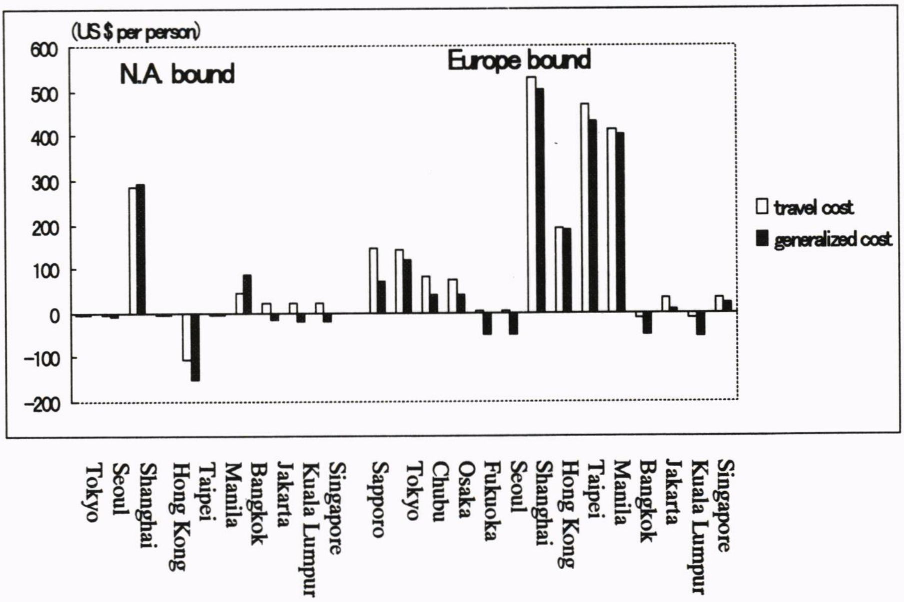

Figure 9 Impact on the Passengers' Utility

The analytical results of the scenario of appearance of the super hub airport in Eastern Asia region suggest that the location of super hub airport at Korea or Japan will be probable from the view point of carriers' strategic behavior if those airport have enough capacity to accept all the necessary flights, and it will result in the increase of the convenience of the passengers for and from Japan, Korea and Taiwan, but vice versa for and from the passengers of the ASEAN countries. However, the analytical results show that ,if those airports can not have enough capacity, the most probable location of the super hub airport will be at Singapore. If so, the passengers' convenience will be changed from the case of above mentioned.

The present paper can give many interesting suggestions for the future air transportation market. However, the present paper includes some uncertainties associated with the estimation of O.D. volume, and the model structure itself has a problem. That is, in the real world, the air transportation demand will be elastic to the travel cost, then its increase will result in the decrease of demand, which will influence on the behavior of the carriers, but the change of carriers' behavior will further influence on the passengers' behavior, and so forth. The improvement of the proposed model concerning with this problem is remained in the future.

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