AIR TRANSPORT POLICY ANALYSIS FOR FUTURE NETWORK IN JAPAN

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INTRODUCTION

International and domestic air transport network are just on a turning point due to the policy change and three major airport projects. The purposes of this paper are to develop the analytical tools for air transport policies and to discuss the influences of policies to the future air network using newly developed demand models. The results of analyses indicate us that additional policies and strategies for the desirable air network pattern are necessary.

1. CURRENT SITUATION OF JAPANESE AIR TRANSPORT

1.1 International transport

The government started "Ten Million Plan" that is a set of policies in 1987 to increase the travelers to foreign countries partly because the reduction of foreign exchange reserves is required to balance the international economy. The number of travelers have been increasing from 5.5 million in 1986, 6.8 million in 1987 to 8.4 million in 1988 by this policies and high rate of yen(Fig.-1), but the difference between metropolitan and local areas has also increased. It means that this latent demand in local prefectures may be future large market.

Another problem is over-concentration of traffic to Narita Airport(Fig.-2). The additional runway and terminal of Narita Airport, and New Kansai Airport are under construction. 60 percent of international travelers depart from Narita Airport. It is difficult not only to expand Narita Airport again but also to find new location of third Tokyo Airport. Kansai Airport owned by private sector has to be profitable, getting enough flights. Governers of most prefectures strongly desire to introduce international airlines to their local airports for regional economic development. The policy to decentralize the demand to New Kansai Airport and the local airports is necessary for the above reasons, but most international airlines want to use Narita Airport than local airports.

1.2 Domestic transport

80 percent of domestic air passengers have their origin or/and destination at Haneda (Tokyo) Airport or/and Osaka Airport, and more than 55 percent have their origin or destination at Haneda Airport(Fig.-3 or (1)). The competition between airlines to keep the slots is so hard that the government has to assign them at two hub airports. Each airline prefers large airplanes to use the limited slots efficiently and to keep the major market of both cities. Large sizes of airplanes make the frequency of

flights very low comparing the number of passengers at each local airport. And the airlines have opened the routes between local airports in spite of advantages of hub and spoke network. The 4th Comprehensive National Development Plan by the government recommends the expansion of local to local routes to adjust the concentration of land use in Tokyo metropolitan area.

The other hand, deregulation policy makes airlines entry to their competitors' routes from Haneda or Osaka Airport when the slots become available by the expansion of capacities. The government decided the principle, that is, double trucking for the routes with more than 700 thousand annual passengers and triple trucking for the routes with more than 1 million passengers.

The capacity of Haneda Airport will be expanded after the on-going re-construction. For Osaka airport more slots may be able to assign to domestic air routes after the relocation of international airlines to New Kansai Airport. These projects and deregulation policy will bring more concentration of traffic at Haneda and Osaka Airport. And the competition of the two airports will be also accelerated. To match the air transport policies with 4th Comprehensive National Development Plan additional decentralized policies are necessary.

Another new policy is deregulation for commuter airlines under which new services using small planes and helicopters in two regions were started, but the airline industries and local governments are watching these leading businesses which have not become profitable. The future possibility of commuter airlines belongs to their success.

2. DEMAND ANALYSIS OF INTERNATIONAL PASSENGERS

In this section, 3 kinds of models for international demand were developed which were available to analyze the above mentioned policies. The major topics are prediction of future travel demand and the possibility of the increase of international flights at local airports.

2.1 Trip production model

As there exist some difficulties in explaining recent increase of international passengers demand with conventional cross-sectional models, we employed a new model formulation, that is, one of the variable coefficient model which can trace time series variation of demand structure. By the model, we analyzed trip attraction volume in 19 countries(Table-1) from the year '76 to '85 that is 76% of total Japanese travelers. The model structures are as follows;

$$T_j = \sum_k \beta_t^k X_{jt}^k \qquad (1)$$

$$\beta_t^k = \sum_l \gamma^l Z_{jt}^l \; (= \gamma^1(time) + \gamma^0) ,$$

where, T_j is attraction volume of country j , X, Z are exogenous variables, β, γ are parameters, and time variable equals 1 in '76. Table-2 shows estimated parameters using Generalized Least Square method (2), and Fig.-4 shows prediction results of total volume which we call productiuon volume. The predicted volume with the variable coefficient model was improved than that with conventional models,

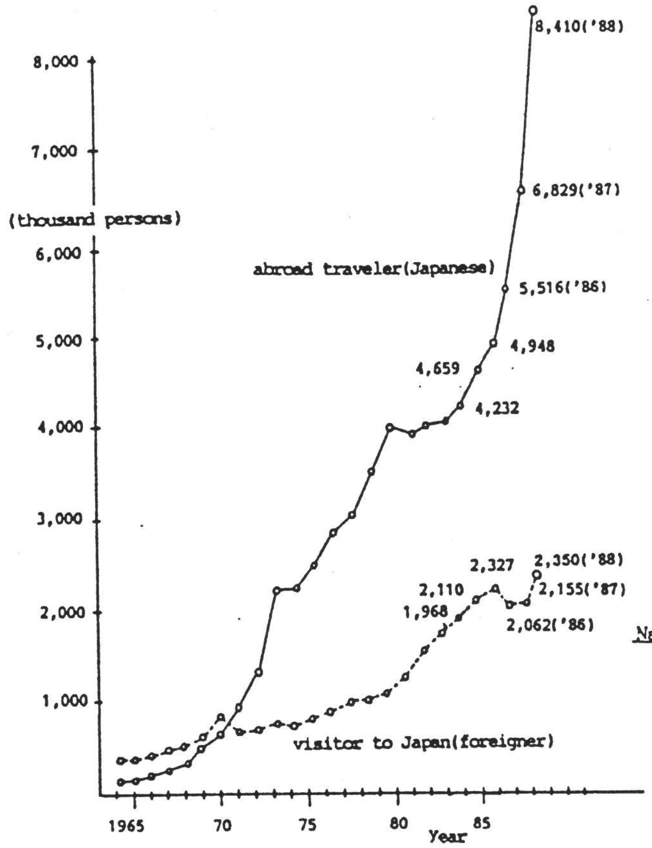

Fig.-1 The number of abroad trips

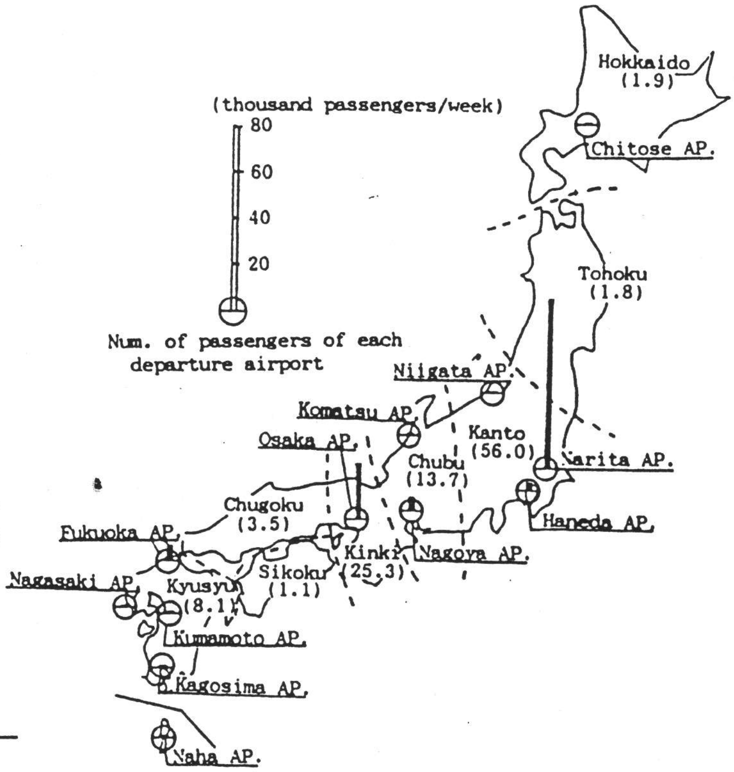

Fig.-2 12 International Airport and 8 area in Japan (trip generation volume in each area in parentheses (thousand/week))

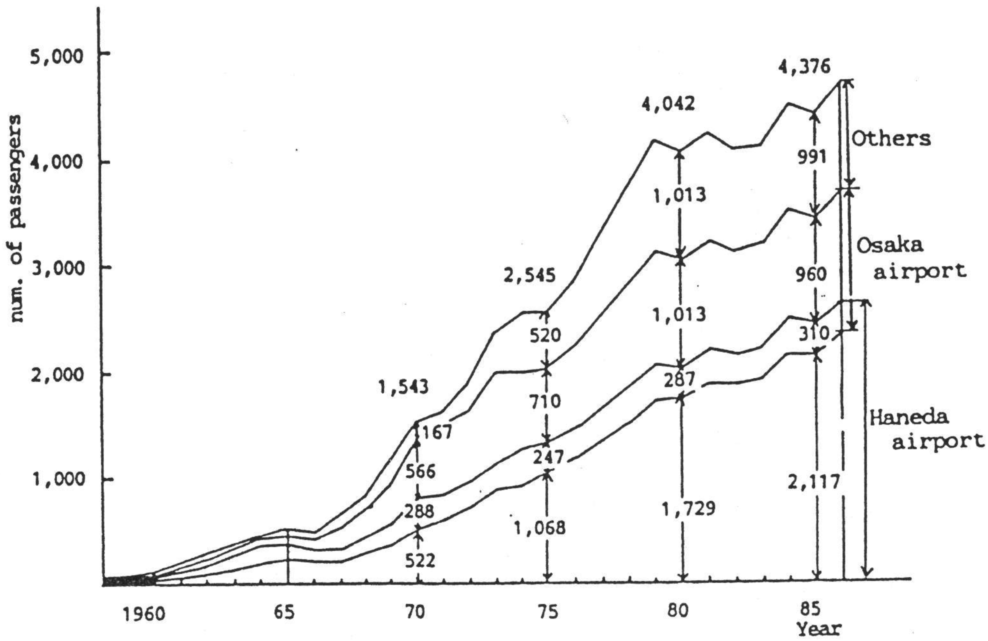

Fig.-3 The number of domestic air passengers (10 thousand persons) because the model can explain the change of demand structure. But observed volume excess the prediction in '86 and '87. The dramatic increase in this two years was caused by the "Ten Million Plan" and drastic high rate of yen.

The demand for each area and the average distance of international travels estimated by the model are shown in Fig.-5, 6. Long distance demand have been increasing by time. More demand of long distance trips could be developed by low air fare policy and by reducing the constraint of vacation.

Table-1 Analyzed countries

1. Indonesia	11. U.K.
2. Saudi Arabia	12. Switzerland
3. Thailand	13. Denmark
4. South Korea	14. West Germany
5. Philippines	15. France
6. Malaysia	16. Belgium
7. Australia	17. Canada
8. New Zealand	18. Taiwan
9. Italy	19. U.S.A.
10. Netherlands	

Table-2 Estimated parameters of variable coefficient model

β	γ	Coefficient	t-statistic
$log(GNP_j)$	Time	-0.027077	(1.44)
[million dollars]	Constant	1.1699	(9.60)
$log(distance)$	Time	0.076842	(2.18)
[mile]	Constant	-2.6283	(11.5)
Constant	Time	-0.23329	(0.86)
	Constant	18.691	(10.9)
Correlation coefficient		0.8888	

2.2 Departure airport choice model

One of the international airport problem is over concentration of traffic to Narita Airport(Table-3). The policy to decentralize the demand to New Kansai Airport (under construction) and other existing local airports is required. The following two modelling concepts can be considered, when airport capacity constraints are non-negligible.

a) the demand model which has parameters estimated using switching regression method (see section 3.1 in this paper)

b) the demand model which has supply conditions as endogenous service variables: congestion, waiting time or number of flights etc.

The applications of the above models to multinomial choices are further topics to be studied.

Here, the flight capacity and level of service at Narita Airport are fixed, and departure airport choice models based on formulation b) are calibrated to estimate the change of passenger demand by the number of flights chiefly for local airports. From "Japanese Overseas Travel Survey" in 1985, we can get several individual trip information; departure prefecture, departure airport, destination city. In this study, we selected 8 destination cities (Table-3), and 12 international airports (Table-4). Model formulation of aggregate logit model is as follows,

$$S_{jlik} = \frac{exp[\ \sum_{l} \alpha_l X_{jl}\ ]}{\sum_{j'} exp[\ \sum_{l} \alpha_l X_{j'l}\ ]}\ , \tag{2}$$

where, S_{jlik} is a share of j airport for origin i prefecture and destination k country. The level of access and line-haul services were introduced as X_{jl} . Table-5 shows the estimated parameters of each trip purpose. The models showed high fitness and the various parameters were estimated significantly.

Table-3 Selected 8 Cities

City	Number of passengers	Number of flights (per year)
Guam	269098	45
Hong Kong	331852	118
Honolulu	397347	60
Taipei	460911	105
Seoul	369097	101
Shanghai	136154	31
Los Angeles	195985	62
Pusan	183192	35

Table-4 Departure airport share of each area (%)

	Narita	Osaka	Chitose	Niigata	Haneda	Nagoya	Komatu	Fukuoka	Kumamoto	Nagasaki	Kagosima	Naha
Hokkaido	94.4	2.8	0.4	0.6	1.5	0.3	0	0	0	0	0	0
Tohoku	86.2	5.3	0	2.5	4.6	0.6	0	0.8	0	0.1	0	0
Kanto	93.8	1.8	0	0.2	3.8	0.1	0	0.3	0	0	0	0
Chubu	46.2	17.8	0	1.9	0.9	31.5	0.6	1.1	0	0.1	0	0
Kinki	33.3	64.7	0	0	0.2	1.5	0	0.3	0	0	0	0
Chugoku	26.6	48.0	0	0	0.3	0.3	0	24.3	0	0.4	0	0
Sikoku	39.6	54.4	0	0	0.5	0	0	5.4	0	0	0	0
Kyushu	28.0	6.5	0	0.2	0.5	0.3	0	55.3	1.2	2.4	2.4	3.2
Total	66.6	20.4	0.1	0.4	2.2	4.3	0.1	5.2	0.1	0.2	0.2	0.3

The demand elasticity of share for flight frequency at each airport was calculated from the model. Fig.-7 for Taipei routes shows that the flights are concentrated at Narita and that the elasticity for Narita was not highest. The elasticities of Osaka, Fukuoka and Naha were so low because most passengers in the service areas departed not from Narita but from their local airports. Haneda and Nagoya airport have latent demand. Such analysis makes it clear that there is possibility to introduce more international air routes to local airports.

Table-5 Estimated parameters of departure airport choice model ( ):t-statistic

Trip purpose	All		Recreation		Business	
Variable	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Access time	-8.168	-7.834	-8.653	-9.256	-7.799	-7.801
(1000 min.)	(2.51)	(2.40)	(2.13)	(2.15)	(1.74)	(3.34)
Access cost	-1.465	-1.671	-1.241	-1.345	-1.055	-1.154
(10000 yen)	(7.20)	(6.93)	(5.25)	(5.09)	(3.80)	(3.34)
Line-haul cost		-0.2563		-0.2034		-0.08857
(10000 yen)		(2.19)		(1.58)		(0.50)
Num. of flights	0.9936	0.9957	0.9537	0.9402	0.9277	0.9519
(logarithm)	(6.82)	(6.78)	(6.04)	(5.87)	(3.48)	(3.51)
Correlation coefficient	0.980	0.984	0.967	0.969	0.978	0.978
Num. of samples	210		130		84	

2.3 Trip generation model considering induced demand

The increase of flights at a local airport brings the demand from other airports and also induces demand generation by the improved service. We analyzed this effects by introducing "accessibility variable" that was calculated by departure airport choice model in section 2.2. The attributes are defined as

$$AV_i = \sum_{k=1}^{K} \frac{1}{K} log(\sum_j exp[V_{jik}]) \quad (3)$$

$$V_{jik} = \sum_l \alpha_l X_{jl} \quad (\textit{same as equation } (2)),$$

And the model is formulated as equation (4).

$$log(T_i) = \beta_1 log(GDP_i) + \beta_2 AV_i + \beta_0 \quad (4)$$

T_i is trip generation volume in i area. The estimated results are shown in Table-6. It is indicated that the attribute of accessibility was significant.

Using above model, a case study was examined. We calculated the airport demand by the increase of flight frequency of Fukuoka-Hong Kong route(Fig.-8). By equation (2)~(4), we can calibrate demand switched from other airports and induced demand separately. Fukuoka and Kagosima airport are in same region, Kyushu. The models shown in 2.2 and 2.3 are useful to describe the competitive relation

Table-6 Estimated parameters of trip generation model ( ):t-statistic

	Coefficient in each area						
Variable	Hokkaido,Tohoku	Kanto	Chubu	Kinki	Chugoku,Sikoku	Kyushu	National
GDP_i (million dollars)	1.035	0.9234	0.8214	0.7812	1.063	0.7849	0.9857
(logarithm)	(17.6)	(14.7)	(14.3)	(8.05)	(17.3)	(10.0)	(30.0)
AV_i	0.1895	0.7692	0.2188	0.6743	0.04686	0.8427	0.2323
	(4.12)	(7.13)	(3.14)	(2.26)	(0.75)	(5.93)	(8.60)
Constant	4.634	4.348	6.005	5.214	4.669	5.684	5.043
	(14.7)	(14.0)	(22.5)	(11.6)	(15.6)	(16.2)	(30.2)
Correlation coefficient	0.971	0.985	0.975	0.959	0.962	0.974	0.962
Num. of samples	21	21	27	21	27	21	141

between airports. The marginal demand of flight frequency seems not enough for getting profitable load factor. For such a market where the demand between two cities is too small for one flight, the connected route of more than one origin and destination both in Japan and in foreign countries is necessary to increase international flights from/to local airports at present stage. To decentralize the flights from Narita airport, other policies with which the airline industries get some advantages, such as lower landing fee at local airports or deregulation for "entry to" and "exit from" local airports, are required.

3. DEMAND ANALYSIS OF DOMESTIC PASSENGERS

As mentioned section one, the domestic air transport network is just on a turning point because of three kinds of policies; the expansion of the capacity of Haneda and Osaka Airport, deregulation policies for airline industries and cultivation policies for commuter airlines. For the analysis of the policies, a) modal split model under capacity constraints, b) passengers' route choice model and c) demand model for commuter airlines, were developed.

3.1 Modal split analysis considering seat-capacity

By the expansion of Haneda airport, each airline will increase the flights between Tokyo and local airports. We can not predict the impact of expansion of capacity with conventional demand models that are calibrated with existing demand data, because past demand related to Haneda airport are constrained by the supplied capacity. The demand models without supply constrains have biased parameters. We developed a new modal split models using disequilibrium estimation (3). Through the model, we can evaluate whether the airline is constrained or not, and the latent demand or the excess supply probability can be also calculated.

We defined the following demand and supply equations.

-Demand:

$$T_{j1} = T_j \frac{1}{1 + e^{g_d(X_{dj}) + \varepsilon_{dj}}}$$

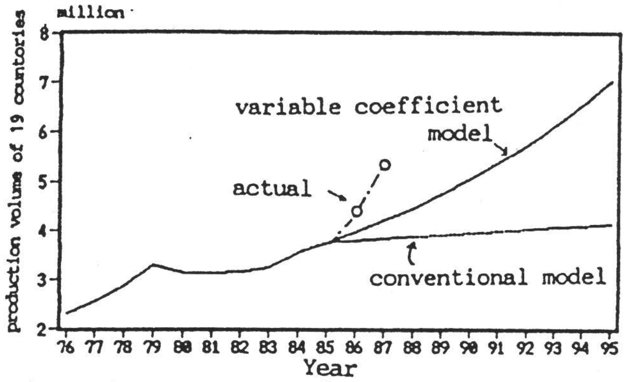

Fig.-4 Prediction result of variable coefficient model

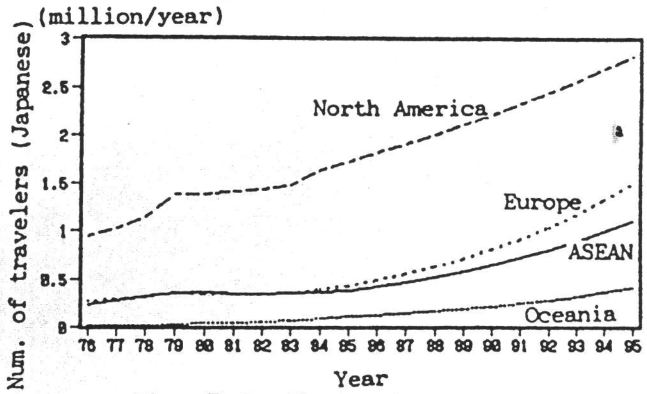

Fig.-5 Prediction in each area

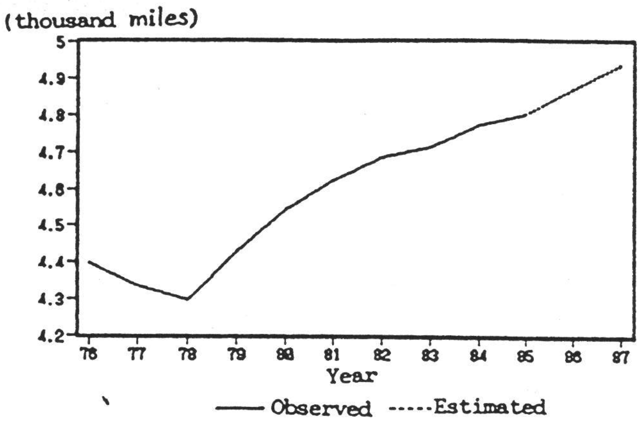

Fig.-6 Average travel distance of abroad trips

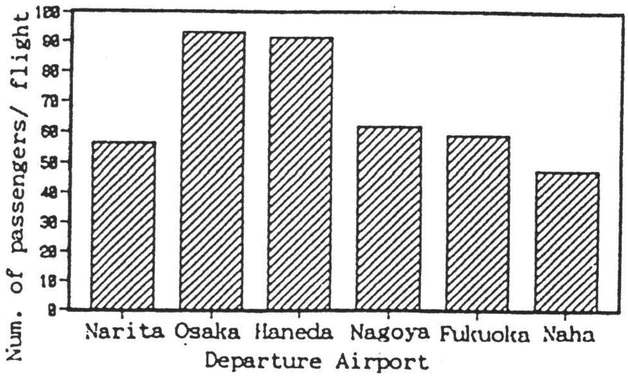

Fig.-7 (1) Number of passengers per one flight (for Taipei)

** The volume excludes the passengers for other destinations via Taipei

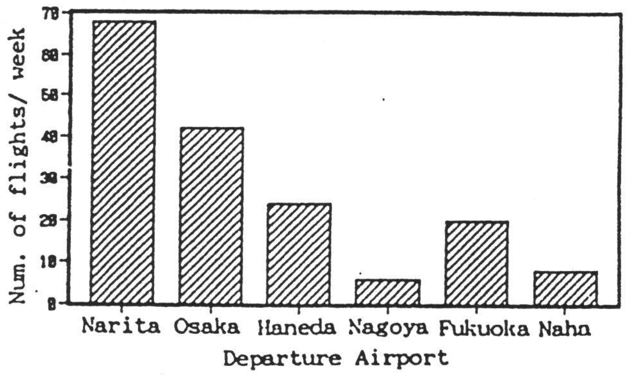

Fig.-7 (2) Flight frequency (for Taipei)

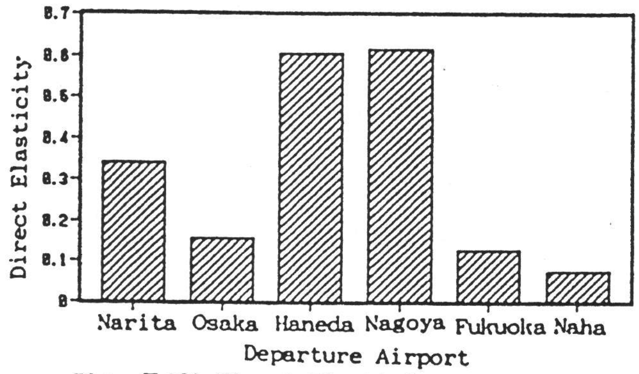

Fig.-7 (3) Direct Elasticity of each departure airport (for Taipei)

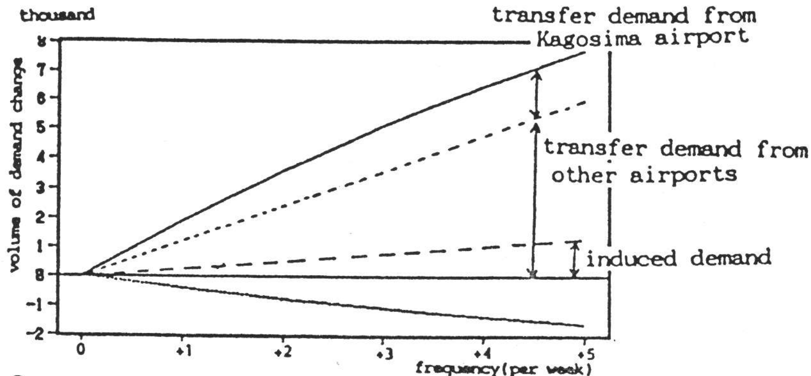

Fig.-8 Increasing demand of Fukuoka airport by additional one flight per week on Fukuoka-Hong Kong route

$$= T_j \frac{1}{1 + e^{g_d}(X_{dj})} + \eta_j \tag{5}$$

$$\varepsilon_{dj} \sim N(\,0\,,\,\sigma_d^2\,)\,,\ \ (\,T_j = T_{j1} + T_{j2}\,)$$

Here, T_j is total demand of jth OD pair, T_{j1} is airline demand and T_{j2} is demand of railway. ε_{dj} is a stochastic term distributed as normal, and η_j is a stochastic term transformed from ε_{dj} .

-Supply:

$$S_j = g_s(\,X_{sj}\,,\,\theta_s\,) + \varepsilon_{sj} \tag{6}$$

$$= \theta_s^1 W_j + \theta_s^0 + \varepsilon_{sj} \qquad \varepsilon_{sj} \sim N(\,0\,,\,\sigma_s^2\,)$$

W_j is number of annual supplied seats. Next, we assumed that the observed volume is decided by the demand function or supply function with the assumption so called "minimum condition" (4).

$$Q_j = min[\,T_{j1}\,,\,S_j\,] \tag{7}$$

Q_j is observed volume. Moreover, excess supply probability π_j is defined by the following equation.

$$\pi_j = pr[\,T_{j1} < S_j\,] \tag{8}$$

The domestic air and rail transportation demand data from the year '73 to '81 were used to calibrate the model, and the parameters were estimated by Maximum Likelihood method. And we assumed expected volume ($\bar{Q}_j$) by the model as follows,

$$\bar{Q}_j = \pi_j D_j + (1-\pi_j) S_j\,. \tag{9}$$

The estimated results are shown in Table-7. The disequilibrium model has higher goodness of fit than conventional models (Fig.-9). We can see that the dots for disequilibrium model in Fig.-9 correspond to the dots for supply or demand in Fig.-10, as presented equation (7).

The model is applied to Hiroshima-Haneda route to show the availability. The airline increase the supplied flights on this route from 1984, transferring the slots of Haneda airport for this route from closed routes where the bullet train was started the operation. The demand had increased remarkably from '84 (Fig.-11). Fig.-12 shows that the estimated demand is very similar to observed one and that latent demand had been existed before '84. Using this model we can predict the future concentration of flights at Haneda airport.

On the other hand, the deregulation policy allows the airlines to entry to busy routes most of which are connected to Haneda or Osaka airport. By the expansion of capacity and deregulation policy will cause more concentration of flights to hub airports as the experience in U.S.

3.2 Route choice model

Structuring the multi-hub air network is one of the policies to reduce the flights at Haneda. To examine the feasibility of this policy, we analyzed individual route choice behavior via Haneda or Osaka

Table-7 The results of model estimation ( ):t-statistic

	Demand model		Supply model	
Variable	Model 1 *	Model 2 **	Model 1 *	Model 2 **
Travel cost (1000 yen)	-0.1272 (2.70)	-0.2047		
Travel time (1000 min.)	-8.512 (6.07)	-16.50		
Constant	1.015 (3.07)	0.5021	37697 (0.599)	21632
Num. of supplied seats (annual)			0.6835 (28.1)	0.7885
Standard error	0.7068	0.07659	258001	194335
Num. of samples	45			

* *Model* 1: *Conventional model*
** *Model* 2: *Disequilibrium estimation*

airport by disaggregate logit models. Table-8 shows that demand share of two routes for each OD-pair. The frequency of Osaka-Sikoku route is so high that the demand share of the routes to/from Sikoku via Osaka Airport is greater than that of other OD-pairs (Table-8,Fig.-13).

Table-8 Number of passengers on each route
(via Haneda: via Osaka)

	Chugoku	Sikoku	Kyushu
Hokkaido	10 : 6 (183):(170)	41 : 23 (182):(156)	189 : 23 (197):(185)
Tohoku	19 : 1 (169):(189)	44 : 53 (168):(175)	226 : 15 (183):(204)

( ): average line-haul time

From the estimated parameters(Table-9), it is indicated that frequency is one of the significant factors for route choice behavior.

Using Model 2 in Table-9, we calculated elasticities of flight frequency in each area. The elasticity of flight frequency is described as follows;

$$\left\{\frac{dP_1}{P_1}\right\} / \left\{\frac{d(FF_1)}{(FF_1)}\right\} = \frac{dP_1}{d(FF_1)} \frac{FF_1}{P_1} = \theta_{FF}(1-P_1)$$

$$\left\{\frac{dP_2}{P_2}\right\} / \left\{\frac{d(FF_1)}{(FF_1)}\right\} = -\theta_{FF}P_1 \, .$$

Here,

$$P_1 = \frac{exp[V_1 + \theta_{FF}log(FF_1)]}{exp[V_1 + \theta_{FF}log(FF_1)] + exp[V_2 + \theta_{FF}log(FF_2)]},$$

where, FF_1 is flight frequency of route 1, θ_{FF} is its parameter and V_1 is utility of route 1 excluded flight frequency variable. Table-10 shows the direct elasticity of the route via Osaka Airport and the cross elasticity of that via Haneda airport. Elasticities of Kyushu area are high, because they include low frequent service routes, that is, Osaka-Hokkaido and Osaka-Tohoku. It is suggested that the increase of flight frequency for local hub airports may decentralize the demand.

Table-9 Estimated parameters of route choice model ( ):t-statistic

Variable	Model 1	Model 2
Travel time (min.)	-0.02562	-0.02323
	(6.87)	(6.87)
Num. of flights	0.9218	
(logarithm)	(4.71)	
Num. of flights		0.6660
to hub-airport		(3.76)
(logarithm)		
Num. of flights		0.7725
from hub-airport		(4.55)
(logarithm)		
Constant	1.873	1.586
[Haneda]	(8.38)	(6.64)
Likelihood ratio index	0.224	0.237
Num. of samples	670	670

Table-10 Direct demand elasticity of flight frequency on the route via Osaka Airport

	Chugoku	Sikoku	Kyushu
Hokkaido	0.450	0.461	0.642
	(-0.270)	(-0.258)	(-0.078)
Tohoku	0.684	0.327	0.675
	(-0.036)	(-0.393)	(-0.045)

( ): cross elasticity for Haneda Airport

3.3 Demand analysis of commuter airline

For the expansion of the air network the government decided the construction of small airports and heliports, and policies to cultivate commuter airlines. As the tools for the feasibility study of commuter airlines we developed disaggregate logit models (5). The model for helicopter service is shown in this paper. In Japan, there is only one helicopter commuter line between Haneda and Narita airport. So, we can not get actual data sufficiently. In this study, we built the mode choice model using stated preference data. The model formulation is Nested Logit model (Fig.-14), and the results are shown in Table-11,12.

Table-11 Estimated parameters of NL model
(helicopter - taxi)

Variable		Coefficient	t-statistic
Travel cost (1000 yen)	[G]	-0.1226	2.11
Waiting time (min.)	[H]	-0.04101	4.06
Access distance to heli-port (km)	[H]	-0.0303	1.09
Num. of baggages	[H]	-0.9086	1.93
Constant	[H]		6.70
Likelihood ratio index		0.2453	
Num. of samples		187	

Table-12 Estimated parameters of NL model
(rail - bus - helicopter & taxi)

Variable		Coefficient	t-statistic
Inclusive price	[H,T]	0.7904	5.37
Age; over 40 = 1, others = 0	[R]	-1.098	2.73
Travel time (100 min.)	[R]	-0.6970	1.11
Income dummy; more than 10 million yen/year=1, others=0	[R]	-0.3742	0.86
	[B]	-1.429	6.48
Num. of mode changes	[B]	-0.8317	6.32
Constant	[H,T]	-1.070	5.27
	[R]	1.500	2.62
Likelihood ratio index		0.1104	
Num. of samples		517	

When the helicopter service does not exist, to improve the model estimated by the stated preference data, we assumed utility of helicopter to be minus infinite, and adjusted constant term by observed mode share. And we evaluated fitness of the model to the demand of Haneda-Narita heli-commuter line. The number of actual passengers from June to September in '88 was 796, and the calculated demand under the same condition was 1178. Although the model presented over-estimates, the error seems not so large considering that the modal share of helicopter is extremely small. Not only the existing demand of this route but also the predicted demand for other routes are too small to get good profitability. It suggests us the necessity of some kind of internal or external subsidy to establish the commuter network.

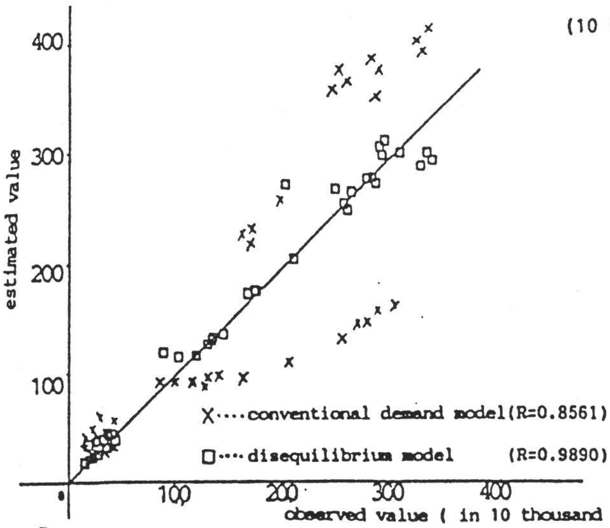

Fig.-9 Comparison between estimated values and observed ones (expectation by disequilibrium model, conventional model)

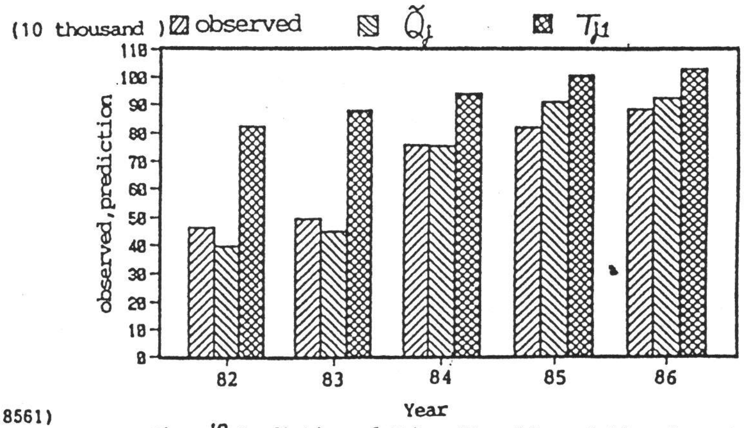

Fig.-12 Prediction of Tokyo-Hiroshima airline demand

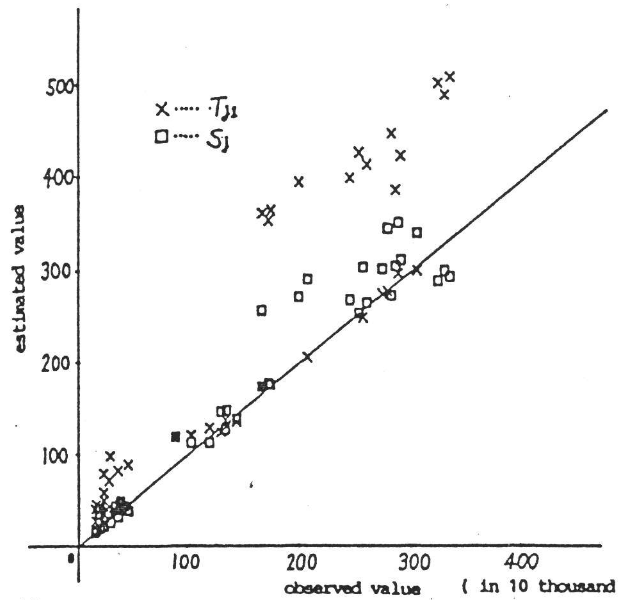

Fig.-10 Comparison between estimated values and observed ones (demand and supply estimation by disequilibrium model)

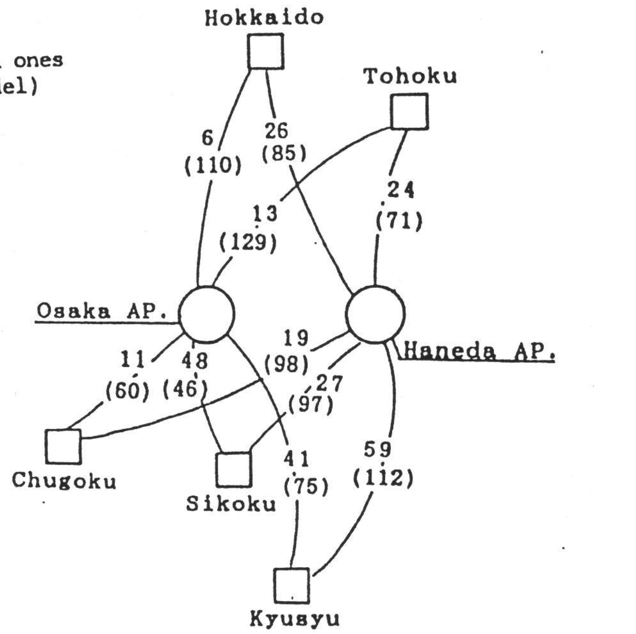

Fig.-13 Number of flights (per day) and on board time (in parentheses (min.)) of each route

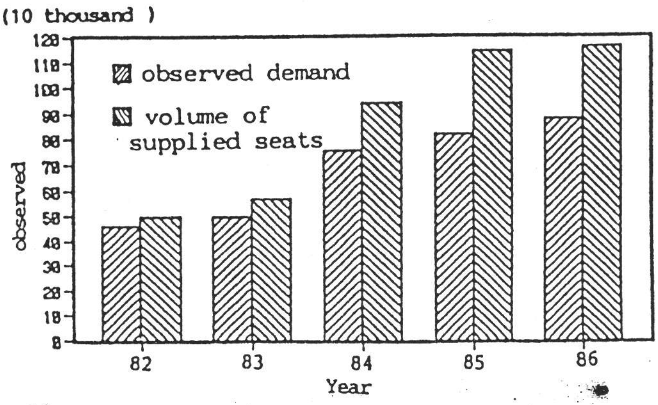

Fig.-11 Observed volume and num. of seats on Tokyo-Hiroshima airline

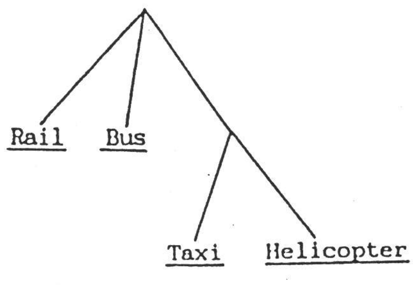

Fig.-14 The choice tree of the NL.model

4. CONCLUSION

The excessive concentration of population and economy in Tokyo Metropolitan Area is so serious social problem in Japan that the decentralization of routes and flights from Tokyo is requested in the national development plan and the regional development plans of every prefectures. For this background, the government having been constructed the local airports, the air network structure and air transport market have been expanded. But the recent diversified air transport policies which are necessary for various situations bring inconsistent impacts on the air transport market.

As mentioned in section 2 & 3, the series of current air transport policies seems to accelerate the concentration of air traffic to Tokyo. Additional air policies are desirable to change this trend, for example, decline of the landing fee of local airports, deregulation for entry of foreign airlines to local airport, deregulation for domestic airlines without the constraint of passenger volume, enlargement of air transport market in local cities, institutional support for commuter airlines and so on.

The result of the analysis also showed the possibility for airlines to expand their local services through the market mechanism. The feasibility has to be analyzed from the view point of not only demand but also cost aspect.

The models in this paper make it possible to analyze the impacts of air transport policies that are difficult to evaluate by conventional methods. Currently the air transport policies have been decided without enough quantitative analyses. As the analytical tools in this paper are only a part of considerable systems, the improvement of model system and analyses of more wide-range policies by such system are required to establish the comprehensive air transport policies.

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