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PREDICTION OF DOMESTIC AIR TRAFFIC PASSENGERS

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Abstract

A model of passenger's selection of travel means is introduced after analyzing the ratio of the air traffic passengers to the total passenger's transportation between major prefectures in Japan. The effects of transportation fares and travel times on passenger's preference are investigated.

The trend of railway fare and reduction of travel time by the extension of super express train in the future are considered. Microscopic predictions of domestic air traffic passengers on each route are accumulated to compare with the macroscopic prediction of the total domestic air passengers.

The macroscopic prediction or the forecast of the total air passengers is based on the correlation analysis with the gross national product. The number of local air routes which will be operated in the future are also estimated.

The present work is applied for the operations research of the new jet transport plane which will be constructed in the future.

Introduction

The amount of air transportation is expanding at a large scale in

recent years. The prediction of its trend in the future furnishes the foundation of policy-making for managements of air line companies as well as aircraft industries. The method of prediction based on the time series analysis has been extensively applied to obtain the forecast of air transportations. On the other hand, the correlation between air passenger and national income has been investigated and the total air passenger can be predicted from the trend of national income. A large number of investigations have been published concerning the macroscopic prediction of total air transportation. [1]-[3]

Although these methods are providing sufficiently accurate forecasts of the total air passengers, they are not adequate to furnish the microscopic prediction of the air traffic on each route, since it is influenced by the local conditions of the transportation affairs. Furthermore, the prediction of air traffic density on each route of the future network rather than the overall traffic trend is important in the course of policy-making in air transportation business.

For this purpose we shall introduce a model of passenger's selection of travel means reflecting the local traffic affairs. It is characteristic for the present study that the number of passengers carried by air transportation is obtained as a product of the total passengers multiplied by the share of the air transportation in the total amount of traffic between prefectures. We noticed the share of the air passengers in the total traffic quantity instead of the air traffic quantity itself. Fares and travel times are considered as the major factors influencing upon the share. On the other hand, the total amount of transportation between prefectures is estimated independently, taking account of the growth of local economy as well as population and the tendency of concentration of population in urban districts.

The variation of the carried passengers per day on the trunk lines, Tokyo-Osaka and Tokyo-Nagoya, are indicated in Fig. 1. We observe that the increasing tendency of air passengers are restricted a great deal by the opening of the super express train connecting Tokyo and Osaka

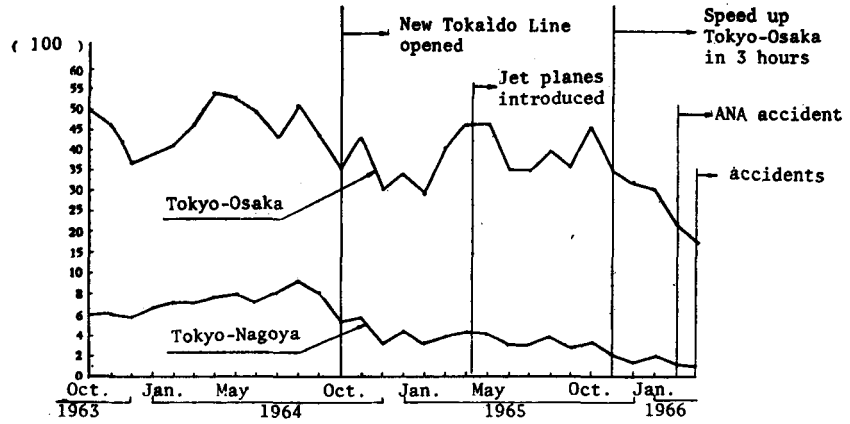

Fig. 1. Carried Passengers per Day (Monthly Average)

via Nagoya. In the meanwhile the increasing rate of domestic air passengers in this period has shown a considerable high value, *i.e.*, 17%-20% per year. Since in Japan a considerable development of railway is achieved in recent years, we can not underestimate the influence of the development of express railway on the increasing tendency of air traffic.

Model of Passenger's Selection

The opening of a super express railway connecting two major cities of Japan, Tokyo and Osaka, in 1964 has indicated a considerable impact on the increasing tendency of the air traffic on this trunk line. The authorities of the national railroad announced the longterm schedule of development of railway in the near future.

Obviously, fare and travel time affect the passenger's choice of travel means. In Fig. 2, the share of air passengers among the total (air plus railway) passengers on each route is plotted against the ratio of the fare increase to the time reduction of the air transportation in comparison to the railway trip between several combinations of prefectures.

The major advantage of the trip by air is the reduction of travel

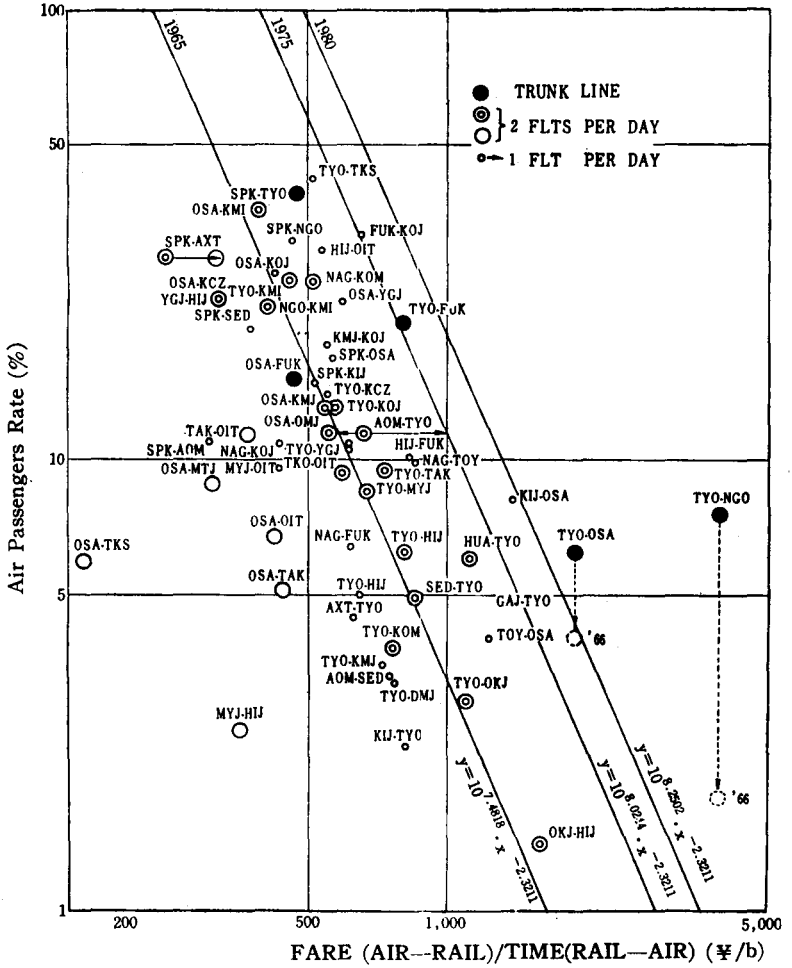

Fig. 2. Air Passenger Rate v.s. Cost of Travel Time Reduction

time, however the travel fare is generally expensive in comparison with that of railway. Therefore, the abscissa of the figure means the amount of money which one would willingly to pay for unit reduction of travel time.

The statistical data of passenger transport on each routes in 1965 is indicated on the figure. The points are scattered around the straight line

$$y=10^{7.4818}\ x^{-2.3211},$$

where x and y stand for the ratio of the fare increase (air-railway) to the time reduction (railway-air) in yen/hour and the share of the air passengers (the ratio of the air passenger to the total traffic quantity on each route) in percentage, respectively. Therefore, x means simply the cost for unit reduction of travel time. As the basis of comparison, the fare of the economy class and the travel time of the special express train, have been used for the fare and the time of railway. The approach time from down-town to an airport is estimated 0.5 hours on each end of an air route, therefore the travel time for air is determined as the sum of the block time of airplane plus one hour. We notice that the elasticity of the cost of the travel time reduction is about -2.32.

The trunk lines are indicated by black circles in Fig. 2. For the Tokyo-Osaka route and the Tokyo-Nagoya route in 1965 represent a considerable difference from the straight line but these rates decrease a great deal indicating a better agreement in 1966 (dotted circles). This fact and also the curve of Fig. 1 seem to indicate the existence of a lead time of the passengers' behavior or in other words, it seems to take some time before passengers accommodate themselves to a changed circumstance.

The other exceptions are the routes connecting Osaka and major cities in the Shikoku island. For these routes, since the difference of the travel time (boat-air) is large, the fare/time ratio yields a lower value in comparison with the block distance. At any rate, we understand that the straight line is representing the preference of passengers or the competition between air and railway.

The competition between air and boat should be investigated by establishing an appropriate model. However, the project of the construction of a bridge connecting the main island and the Shikoku island has

been undertaken, therefore, we can expect that the passenger rates on these routes will approach more or less to the standard case of the air to rail competition in the future. We presume that the elasticity of the cost of the travel time reduction to the air passenger will remain unchanged in the future.

The value of abscissa corresponding to the intersection of the straight line with the 100% share line or the horizontal line $y=100$, is denoted by x_*. We expect that the whole passenger will travel by air at this cost x_*. Presumably this x_* will be increased when travelers' income is raised.

On the other hand, the correlation between the air passenger P and the real national income I is given by

$$\log P=5.638+2.1155 \log I$$

as is indicated on Fig. 3. The reliable prediction of national income has been announced officially, and we assume that the total cost of the travel time reduction x_*, corresponding to the 100% share, is proportional to $\log I$, *i.e.*,

$$x_* \propto \log I.$$

Since it was found that $x_*=230$ yen/hour for $I=19513{,}400$ mill. yen in 1965. We can calculate the expected values of x_* as shown in Table 1.

Table 1.

year	real national income	x_*
1961	14, 138, 100 mill. yen	186
1965	19, 513, 400	230
1975	43, 332, 300	394
1980	60, 246, 900	493
1985	81, 064, 500	600

After determining x_* for each year, we presume that the share of air

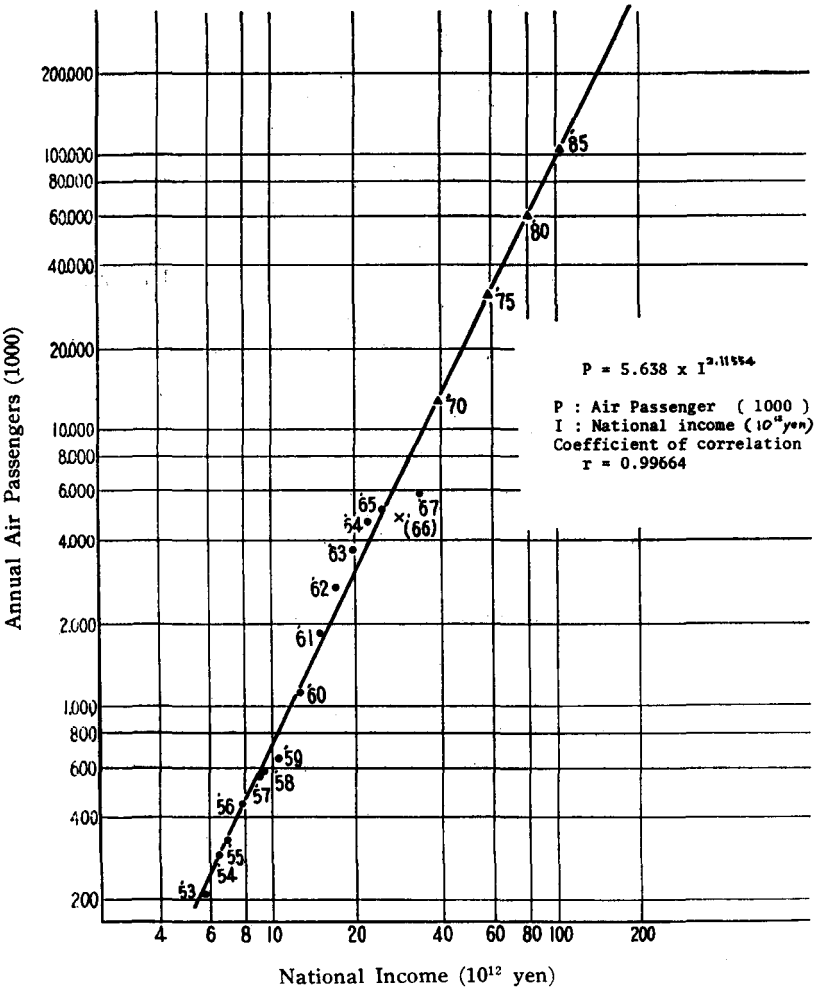

Fig. 3. Correlation between Domestic Air Passengers and National Income

passengers are given in the following way:

$$y=10^{8.0244}\ x^{-2.3211} \quad \text{for 1975},$$

$$y=10^{8.02502}\ x^{-2.3211} \quad \text{for 1980},$$

and

$$y=10^{8.4483}\ x^{-2.3211} \quad \text{for 1985}.$$

Therefore we assume that the slope of the straight line in Fig. 2 does not change in the future, however the line moves upward according to the increase of traveler's income. Thus we can obtain straight lines corresponding to the passenger's inclination on the time saving at the sacrifice of cost increase in the future. The lines showing the passenger's choice in 1975 and 1980 are included in Fig. 2.

In addition, we estimate the average rate of increase of the railway fare is about 5% per year, after analyzing the fare in 15 years since 1951 to 1966. For simplicity we presume that the fares of express train for economy class in 1975 and 1980 will become 1.5 and 2.0 times of those in 1966, while the fare of air transportation is assumed as unchanged in the future. The rate of speed up of national railway is estimated 5.14% per year and jet planes are assumed to be introduced in almost all air routes after 1975.

If two prefectures are selected arbitrarily, then the fare and the travel time of railway as well as those of air transportation will be estimated. Then corresponding to x, *i.e.*, the difference of fare divided by the reduction of travel time, the share of the air passengers to the total passenger y in 1975 and 1980 will be determined by means of Fig. 2.

On the other hand, an extremely detailed investigations have been worked out to predict the total quantities of passenger traffic between prefectures in Japan. For this estimation, the economy in the future in each prefectures has been taken into account. [4] Multipling the share of air passengers to the predicted total traffic, we can estimate the air passenger on each route in 1975 and 1980.

We shall call this method as the microscopic prediction of the air traffic passengers.

The Domestic Air Traffic Affairs (Macroscopic Prediction)

The predicted air passengers on each route is accumulated to complete

the total air passengers in the future. The passenger's behavior model [5] of ALSS is applied to obtain the actual passengers from the potential air passengers. Corresponding to the upper and the lower prediction of the total traffic, we have the two limits of the predicted air passengers. The predictions of the actual passengers in 1975 and 1980 are connected by thick lines while the potential passengers are connected by dotted lines.

The forecast based on the gross national product are passing between two limits in 1975 and 1980. As is indicated in Fig. 4, there exists a remarkable correlation between the number of the domestic air passengers and the gross national product per capita in many countries. We conclude the predictions based on the national gross product are reliable as fas as the forecast G.N.P. is reasonable. The figure is indicating that the present method of microscopic prediction can provide a probable estimation for the passenger volume on each air route.

As is indicated in Fig. 2, a comparatively large discordance is observed for the trunk lines. Therefore a correction taking into account of average prefectural income level has been conducted to achieve a satisfactory coincidence. The predicted passengers on the trunk lines are indicated in Fig. 5. The subtraction of trunk line passengers from the total passengers corresponds to the total number of passengers on the local air routes. The difference of the total local air-route passenger from the extension of the present local air-route passengers based on the development of the gross national product is indicated as the hatched area in the figure. This part can be considered as the increase of the domestic air passenger due to the increased number of the local air routes. It is noticed that the number of routes which will be opened in the future are comparatively small in comparison with the increased amount of the air passengers.

In Fig. 5, also the forecast announced by the Ministry of Transportation (denoted by a diamond at 1971) and the predicted value (designated by a cross) interpolated from the time series between 1956 and 1965 by

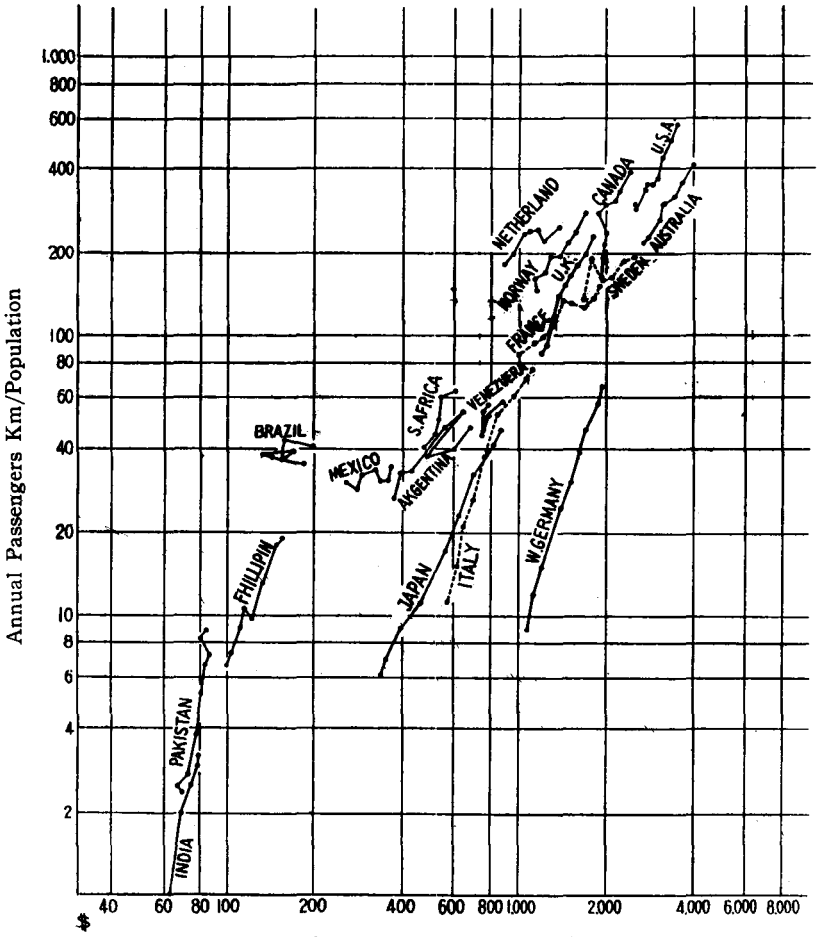

Fig. 4. Air Passenger v.s. G.N.P.

means of the Census method [6] are included. It might not be worthwhile to deploy a further discussion on the appropriateness of these predictions at present. The fitness will be proved when the actual number of passengers become available in the future. So far, we like to conclude that the microscopic prediction can provide a reasonable

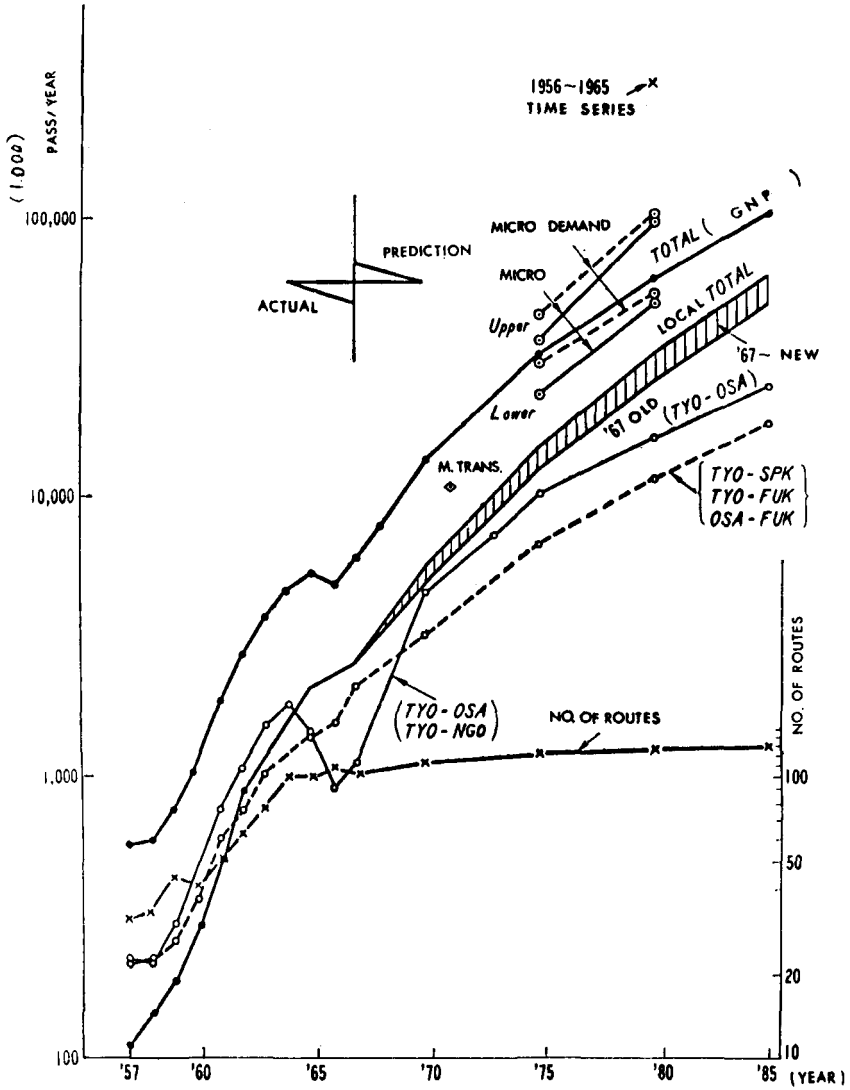

Fig. 5· The Trend of the Domestic Air Passenger in Japan

value for the total air traffic in the future.

Conclusion

A new model of passengers' selection of travel means is established to obtain the share of the air traffic in the gross transportation. This method will provide a method for understanding the competition between several means of transportations. The value of the reduction of the travel time against the sacrifice of the transport fare is evaluated for the first time.

Thus, it has been shown that the air passengers on each route can be estimated. The microscopic predictions of the air passengers are assembled to estimate the gross national air passenger and the relatively good coincidence is obtained with the forecast based on the correlation with the gross national product.

The present study is conducted as a part of the operations research of the new jet transport plane which is sponsored by the Society of Japanese Aircraft Constructors under the contract with The Ministry of International Trade and Industry. The work is carried out at the Operations Research Center of the Society of Japanese Aircraft Constructors.

References and Notes

[1] Metra, J., Perspectives de traffic aerien, 5 (1966), 2 (June), 249–258.

[2] Survey reports, published by Rolls-Roys, Boeing, Lockheed and Douglas, etc. also ICAO reports.

[3] Stratford, A., *Air Transport Economics in the Supersonic Era*, MacMillan (1967).

[4] Mr. M. Ohta, Inst. of Research and Productivity, Waseda University carried out the prediction of total survey of local passenger transportation in 1964 for the Ministry of Transportation. The present author would like to express his sincere appreciation to Mr. Ohta.

[5] Kondo J., "Air Line System Simulation-A Computer System," *J. Op. Res. Soc. Japan*, **10** (1968), 145–159.

[6] Census Method has been developed by the Census Bureau of U.S.A.. A computer programming of this method is completed.