Stated-Preference Analysis to Estimate the Impact of Future Entry of LCCs into Domestic Aviation Services in Japan

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Abstract

Using a stated-preference survey, we examine changes in air transport demand resulting from the entry of low cost carriers (LCCs) into domestic aviation services between Tokyo International Airport and Kansai International Airport, and from the start of operation of the Linear Chuo Shinkansen (high-speed railway). The results showed that total aviation demand between the capital region and the Kinki area will increase even when the Linear Chuo Shinkansen begins operating. The impact of entry of LCCs is also significant on the route between the metropolitan area and Fukuoka prefecture and between Kinki area and Fukuoka prefecture: LCCs will take over a significant share of full service carriers and the Shinkansen.

Keywords:

Aviation Demand Forecast, Stated-preference, Low Cost Carriers (LCC)

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1. Introduction

One of the critical measures defined in the Japan Revitalization Strategy decided by Cabinet Council on June 14, 2013 is to increase the capacity of airports in the Tokyo metropolitan area. To provide the basis of a technical review for this purpose, the Japan Civil Aviation Bureau (2013) announced demand predictions at a meeting of the Transportation Policy Council on September 26, 2013 (Figure 1). The predictive model was developed and refined by the Airport Planning Division of the National Institute for Land and Infrastructure Management. We also gave technical advice to the Ministry regarding the application of the model.

The key points of the demand predictions are as follows:

(1) Based on past records, total aviation demand (Domestic + International) will continue to rise for the next 20 years.

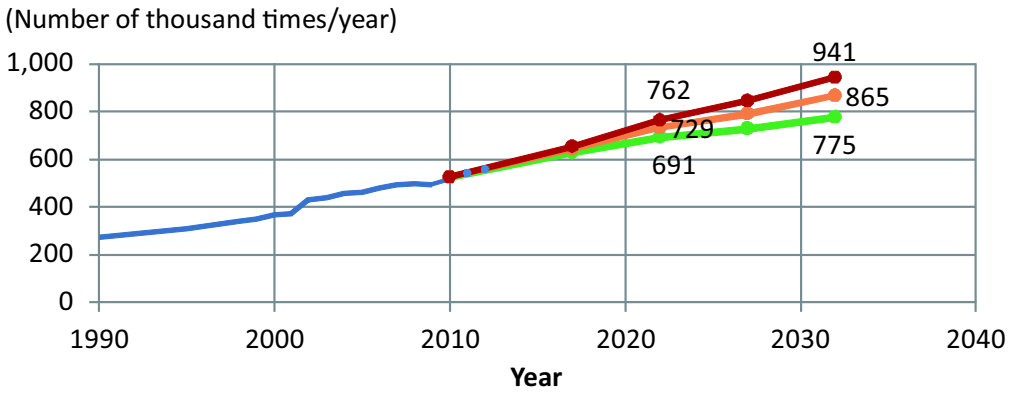

Figure 1: Predicted number of landing/departures (domestic + international) in the Tokyo metropolitan area

(2) The number of international passengers will increase significantly by 60-80% from 2012 to 2022.

(3) The number of domestic passengers will depend on economic growth in Japan: the prediction shows a slight increase of 0-10% from 2012 to 2022, but a slight decrease due to population decline in Japan if the growth rate scenario is set to remain at the present status (+0.7% in annual number).

(4) Total demand (Domestic + International) will exceed the capacity of airports in the Tokyo metropolitan area (747,000 landing/departure slots), regardless of Japan's economic growth.

The predictions assume that Low Cost Carriers (LCCs) continue not to operate from/to Tokyo International Airport (HND). If LCCs begin to operate from/to HND, demand will significantly increase as has already happened in many Southeast Asian countries. It is therefore important to predict the extent to which civil aviation demand in the Tokyo metropolitan area will be affected by the operation of LCCs. It is also important to consider the Linear Chuo Shinkansen (a magnetic levitation railway with speeds of up to 500 km/h), which is scheduled to begin operation between Tokyo and Nagoya in 2027.

Civil aviation demand predictions officially conducted by the government have been based on revealed-preference surveys. Of such surveys, the Inter-Regional Travel Survey, which is used to compile a database on the inter-regional movement of passengers in Japan, is particularly important for predicting demand not only for civil aviation but also for railways and road transportation.

However, a revealed-preference survey is not suitable where presently-nonexistent modes of transportation such as LCCs from/to HND or Linear Chuo Shinkansen should be taken into consideration for predicting transportation demand. In such cases, a stated-preference survey is used instead, since it can assess the inter-regional movement of passengers even where several presently-nonexistent modes of transportation are included as alternative means of transportation, whereas a revealed-preference survey can assess the movement of passengers only by existing alternatives. There have been many such studies in both air transportation and ground transportation, such as Fukuda et al. (2004) and Chang and Sun (2012).

In this paper, using a stated-preference survey, we examined changes in air transport demand by the entry of low cost carriers (LCCs) into domestic aviation services between Tokyo International Airport and Kansai International Airport and other trunk routes, and by the start of operation of the Linear Chuo Shinkansen (high-speed railway). The results showed that total aviation demand between the capital region and the Kinki area will increase even when the Linear Chuo Shinkansen begins operating.

This paper is based on a study first reported in the Technical Note No. 784 of the National Institute for Land and Infrastructure Management (Inoue et al. (2014), in Japanese) and its abbreviated and translated version. However, this secondary paper also includes additional trunk services in the analysis other than those between Tokyo International Airport and Kansai International Airport. The choice model for transportation modes was re-examined and re-developed.

2. Survey Design

2.1. Survey Date and Methodology

A stated-preference survey was conducted during five days between December 13 and December 17, 2013. The questionnaire was designed by the authors, and was distributed and collected via an Internet-based research system provided by Cross Marketing Inc.

2.2. Surveyed Persons

Persons who met the following three criteria were surveyed. Sample screening was performed by asking about their residence area, travel purpose (business trip, sightseeing, visiting friends or relatives, other), mode of transportation (including why they use such mode, and alternative modes they have considered), city of origin/destination, use of airport or station, age, and annual income.

2.2.1. Residence Area

Persons who resided in the metropolitan area, Kinki area, Douou area or Fukuoka prefecture were surveyed. The metropolitan area includes Tokyo metropolis, Chiba prefecture, Kanagawa prefecture and Saitama Prefecture. The Kinki area includes Osaka urban prefecture, Kyoto urban prefecture, Hyogo prefecture and Nara prefecture. The Douou area is defined by the Inter-Regional Travel Survey (published by the Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan) and includes Sapporo city, Otaru city, Muroran city, Takikawa city, Iwamizawa city and Tomakomai city. A map of such residence areas is provided in Figure 2.

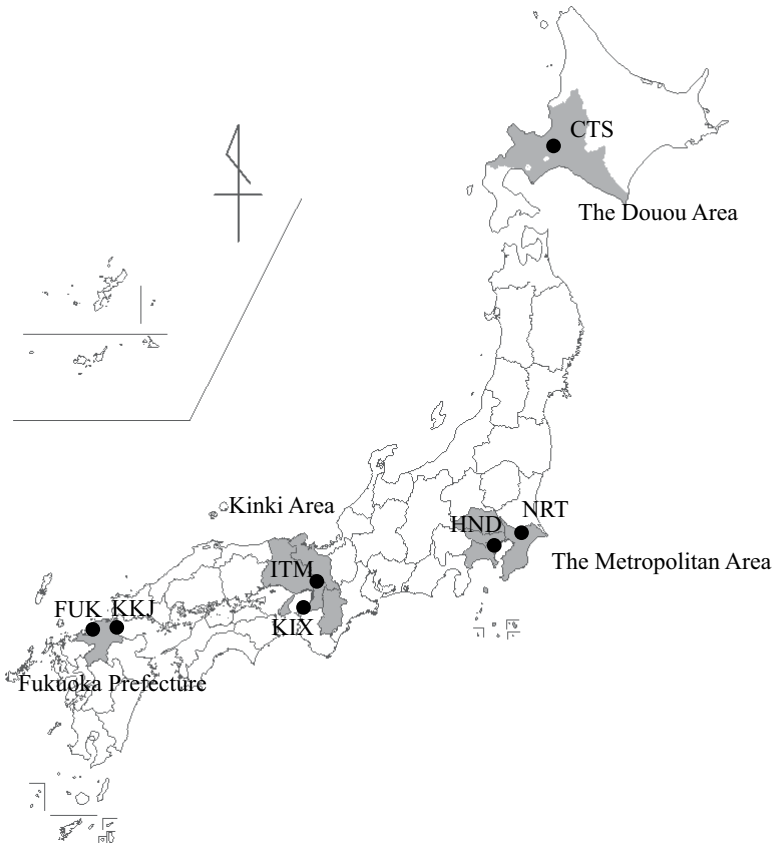

Figure 2: Residence area

2.2.2. Travel Experience

Persons who had traveled between the metropolitan area and Kinki area; the metropolitan area and Fukuoka prefecture; the metropolitan area and Douou area; the Kinki area and Fukuoka prefecture; or Kinki area and Douou area by air (both LCCs and Full Service Carriers (FSC)), railway or express-way bus in the last twelve months from the survey date.

2.2.3. Use of Airports

Persons who met the following criteria were surveyed:

- Among travelers who departed from/arrived at the metropolitan area, only passengers who used HND or Narita International Airport (NRT) were surveyed;
- Among travelers who departed from/arrived at the Kinki area, only passengers who used Osaka International Airport (ITM) or Kansai International Airport (KIX) were surveyed;
- Among travelers who departed from/arrived at the Douou area, only passengers who used Shin-Chitose Airport (CTS) were surveyed; and
- Among travelers who departed from/arrived at Fukuoka prefecture, only passengers who used Fukuoka Airport (FUK) were surveyed.

2.3. Sample Composition

The number of samples surveyed was 1,500, as shown in Table 1 which lists individual travel experience and means of transportation.

A stated-preference survey for a specific route (i.e. between the metropolitan area and Kinki area) was intended to be answered by a traveler who had traveled the same route in the last twelve months from the survey date. Each respondent was asked to answer a two stated-preference questionnaire on average.

Table 1: Sample Composition of the stated-preference survey

	LCC	FSC	the Shinkansen	express bus	Sums
The metropolitan area-Kinki Area	100	100	100	100	400
The metropolitan area-The Douou Area	100	100			200
The metropolitan area-Fukuoka Prefecture	100	100	100		300
Kinki area-The Douou Area	100	100			200
Kinki area-Fukuoka Prefecture	100	100	100	100	400
Sums	500	500	300	200	1,500

2.4. Stated-Preference Questionnaire

2.4.1. Selectable Means of Transportation on the Questionnaire

LCCs, FSCs, the Shinkansen (a high-speed railway), combination of the Shinkansen and the Chuo Linear Shinkansen (Linear/Shinkansen) and express bus were options on the questionnaire. The Linear/Shinkansen is a means of transportation whereby a traveler uses the Chuo Linear Shinkansen between Tokyo metropolis and Nagoya city and the Shinkansen for the rest of the route. Daytime buses were excluded from express buses because they are hardly used on the routes surveyed.

Some of the selectable means of transportation were excluded in some cases. For example, the Shinkansen, Linear/Shinkansen and express bus were excluded for the route between the metropolitan area and Douou area because it is impractical on the route. Table 2 lists the selectable means of transportation on the questionnaire by route.

2.4.2. Attributes of the Questionnaire

Attributes of the questionnaire were set by the following four categories: “Total Fares”, “Total Travel Time”, “Frequency” and “Other”.

We defined “Total Fares” as the sum of the following three sub-categories: “Access Fares”, “Line-Whole Fares” and “Egress Fares”.

Table 2: Selectable means of transportation on the questionnaire by route

	LCC	FSC	the Shinkansen	Linear/Shinkansen	express bus
The metropolitan area-Kinki Area	○	○	○	○	○
The metropolitan area-The Douou Area	○	○			
The metropolitan area-Fukuoka Prefecture	○	○	○	○	○
Kinki area-The Douou Area	○	○			
Kinki area-Fukuoka Prefecture	○	○	○		○

Access Fares/Egress Fares were defined as the fares that a traveler paid for transportation between the origin/destination of travel and airports, stations of the Shinkansen or the Chuo Linear Shinkansen or stops of express buses. Line-Whole Fares were defined as the fares of LCCs, FSCs, the Shinkansen, the Linear/Shinkansen or express buses.

In this paper, the above three sub-categories were unified into one attribute. While they should be considered separately when examining changes in demand by a choice model, we decided to unify them because we wished to quickly examine changes in demand caused by the entry of LCCs, rather than develop a detailed choice model.

Access Fares and Egress Fares were set as follows. For LCCs, they were set based on the use of NRT, KIX and FUK, the first two of which are secondary airports for domestic services. For FSCs, they were set based on the use of HND, ITM and FUK, the first two of which are primary airports for domestic services. Other selectable means of transportation were set as zero. As there are several access/egress means of transportation for NRT or KIX, Access Fares and Egress Fares were set between 3,000 and 5,000 yen for using LCCs between the metropolitan area and Kinki area. On the other hand, Access Fares and Egress Fares were set at 1,000 yen uniformly for using FSCs between the metropolitan area and Kinki area. The origin/destination

of the metropolitan area and Kinki area were set as Tokyo Metropolitan City Hall and Osaka Prefectural Head Office.

Line-Whole Fares were set as follows. For LCCs or FSCs, they were set based on maximum and minimum fares searched on websites. For the Shinkansen or express buses, they were set based on the current fares. For the Linear/Shinkansen, they were set to the Line-Whole Fares of Shinkansen plus 1,000 yen, based on a newspaper article (Nihon Keizai Shinbun (2013, September 13)). Specifically, the Line-Whole Fares for LCCs between the metropolitan area and Kinki area were set between 4,000 and 8,000 yen, while the Line-Whole Fares for FSCs, the Shinkansen, the Linear/Shinkansen and express buses were set between 9,000 and 25,000 yen, and were set as 14,000 yen, 15,000 yen and 8,000 yen, respectively.

We introduced three kinds of attributes as Total Fares for LCCs or FSCs: the first one was the maximum sum of Access Fares, Line-Whole Fares and Egress Fares set as mentioned above; the second one was the minimum sum of those fares; and the last one was the simple average of the former two amounts. One of these fares was randomly shown on-screen to each respondent when a stated-preference survey was performed. As for other means of transportation, we introduced the simple sum of Access Fares, Line-Whole Fares and Egress Fares mentioned above. Tables 3, 4 and 5 comprehensively list the attributes used for the stated-preference survey. Table 3 is for the route between the metropolitan area and Kinki area; Table 4 is for the route between the metropolitan area and Fukuoka Prefecture; and Table 5 is for the route between Kinki area and Fukuoka Prefecture.

Another category of attributes for the questionnaire is Total Travel Time.

Table 3: Attributes used for the stated-preference survey (for the metropolitan area-Kinki area)

	LCC	FSC	the Shinkansen	Linear/Shinkansen	Express bus
Total Fare	a. 13,000 yen b. 10,000 yen c. 7,000 yen	a. 26,000 yen b. 18,000 yen c. 10,000 yen	14,000 yen	15,000 yen	8,000 yen
Total Travel Time *1 Line-Whole Travel Time *2 Access and Egress Travel Time	a. 310 minutes *1 (130 minutes) *2(180 minutes) b. 260 minutes *1 (130 minutes) *2(130 minutes) c. 210 minutes *1 (130 minutes) *2(80 minutes)	a. 220 minutes *1(100 minutes) *2(120 minutes) b. 200 minutes *1(100 minutes) *2(100 minutes) c. 180 minutes *1(100 minutes) *2(80 minutes)	220 minutes *1(160 minutes) *2(60 minutes)	170 minutes *1(110 minutes) *2(60 minutes) including 10 minutes as the connecting time at Nagoya station	540 minutes *1(480 minutes) *2(60 minutes)
Frequency	a. 12 services a day (one service every 1.5 hours) b. 6 services a day (one service every 2.5 hours) c. 3 services a day (one service every 5 hours)	a. 32 services a day (2 services every hour) b. 16 services a day (one service every hour) c. 8 services a day (one service every 2 hours)	150 services a day (10 services every hour)	75 services a day (5 services every hour)	departing between 21:00 and 24:00
Other	No reservation change Baggage fees required No frequent flyer program Narrow seat pitch	Reservations can be changed No baggage fees Frequent flyer program Ordinary seat pitch	Reservations not required No frequent flyer program Ordinary seat pitch	Reservations not required No frequent flyer program Ordinary seat pitch	No reservation change No baggage fees No frequent flyer program Ordinary seat pitch

Table 4: Attributes used for the stated-preference survey (for the metropolitan area-Fukuoka prefecture)

	LCC	FSC	the Shinkansen	Linear/Shinkansen
Total Fare	a. 18,000yen b. 13,000 yen c. 7,000 yen	a. 40,000yen b. 27,000 yen c. 14,000 yen	22,000 yen	23,000 yen
Total Travel Time *1 Line-Whole Travel Time *2 Access and Egress Travel Time	a. 290minutes *1(170 minutes) *2(120 minutes) b. 260 minutes *1(170 minutes) *2(90 minutes) c. 230 minutes *1(170 minutes) *2(60 minutes)	a. 270 minutes *1(150 minutes) *2(120 minutes) b. 240 minutes *1(150 minutes) *2(90 minutes) c. 210 minutes *1(150 minutes) *2(60 minutes)	400 minutes *1(330 minutes) *2(70 minutes)	330 minutes *1(280 minutes) *2(50 minutes)
Frequency	a. 12 services a day (one service every 1.5 hours) b. 6 services a day (one service every 2.5 hours) c. 3 services a day (one service every 5 hours)	a. 36 services a day (2 services every hour) b. 18 services a day (one service every hour) c. 9 services a day (one service every 2 hours)	52 services a day (3.5 services every hour)	75 services a day (5 services every hour)
Other	No reservation change Baggage fees required No frequent flyer program Narrow seat pitch	Reservations can be changed No baggage fees Frequent flyer program is available Ordinary seat pitch	Reservations not required No frequent flyer program Ordinary seat pitch	Reservations not required No frequent flyer program Ordinary seat pitch

Table 5: Attributes used for the stated-preference survey (for Kinki area-Fukuoka prefecture)

	LCC	FSC	the Shinkansen	Express bus
Total Fare	a. 13,000yen	a. 25,000yen	15,000 yen	7,000 yen
	b. 9,000 yen	b. 18,000 yen		
	c. 5,000 yen	c. 11,000 yen		
Total Travel Time	a. 220minutes	a. 200 minutes	240 minutes	680 minutes
	*1(120 minutes)	*1(100 minutes)	*1(170 minutes)	*1(620 minutes)
*1 Line-Whole	*2(100 minutes)	*2(100 minutes)	*2(70 minutes)	*2(60 minutes)
Travel Time	b. 200 minutes	b. 180 minutes		
*2 Access and Egress	*1(120 minutes)	*1(100 minutes)		
Travel Time	*2(80 minutes)	*2(80 minutes)		
	c. 180 minutes	c. 160 minutes		
	*1(120 minutes)	*1(100 minutes)		
	*2(60 minutes)	*2(60 minutes)		
Frequency	a. 8 services a day	a. 24 services a day	54 services a day	departing between 21:00 and 24:00
	(one service every 2 hours)	(3 services every 2 hours)	(3.5 services every hour)	
	b. 4 services a day	b. 12 services a day		
	(one service every 4 hours)	(one service every 1.5 hours)		
	c. 2 services a day	c. 6 services a day		
	(one service every 8 hours)	(one service every 2.5 hours)		
Other	No reservation change	Reservations can be changed	Reservations not required	No reservation change
	Baggage fees required	No baggage fees		No baggege fees
	No frequent flyer program	Frequent flyer program is available	No frequent flyer program	No frequent flyer program
	Narrow seat pitch	Ordinary seat pitch	Ordinary seat pitch	Ordinary seat pitch

We defined this as the sum of the following three sub-categories: "Access Travel Time", "Line-Whole Travel Time" and "Egress Travel Time" in the same way as Access Fares, Line-Whole Fares and Egress Fares, respectively.

Access Travel Time/Egress Travel Time were defined as the time that a traveler spent for transportation between the origin/destination of travel and airports, stations of the Shinkansen or the Chuo Linear Shinkansen or stops of express buses. Line-Whole Travel Time was defined as the time spent on-board of LCCs, FSCs, the Shinkansen, the Linear/Shinkansen or express buses. These three sub-categories were unified into one attribute for the same reason mentioned above.

Access Travel Time and Egress Travel Time were set as follows: for LCCs, they were set based on the use of NRT, KIX and FUK in the same way as Access Fares and Egress Fares. Two kinds of travel time, one being the

shortest by express service and the other being the longest by local service, were introduced; for FSCs, three kinds of travel times were set in the range between ±20 minutes relative to the current travel time; and for other transportation means, such travel times were set as the current ones. Specifically, as there are several access/egress means of transportation for NRT or KIX, Access Travel Time and Egress Travel Time were set between 80 and 180 minutes for the use of LCCs between the metropolitan area and Kinki area. On the other hand, Access Travel Time and Egress Travel Time were set between 80 and 120 minutes for the use of FSCs between the metropolitan area and Kinki area. As for other transportation means, respective Access Travel Time and Egress Travel Time were set as 60 minutes based on the current travel time.

Line-Whole Travel Time was set based on the current travel time for all selectable means of transportation. Specifically, the Line-Whole Fares for LCCs between the metropolitan area and Kinki area were set as 130 minutes, while the Line-Whole Travel Time for FSCs, the Shinkansen and express buses were set as 100 minutes, 160 minutes and 480 minutes, respectively. Line-Whole Travel Time for the Linear/Shinkansen was set as 110 minutes based on the newspaper article (Nihon Keizai Shinbun (2013, September 13)) and 10 minutes as the connecting time at Nagoya station.

We introduced three kinds of attributes as Total Travel Time for LCCs or FSCs: the first was the maximum sum of Access Travel Time, Line-Whole Travel Time and Egress Travel Time set by the procedure mentioned above; the second was the minimum sum of those travel times; and the third was the simple average of the first two values. One of these times was randomly

shown on-screen to each respondent accompanying the Access Travel Time and Egress Travel Time when a stated-preference survey was performed. As for other means of transportation, we introduced a simple sum of Access Travel Time, Line-Whole Travel Time and Egress Travel Time as mentioned above. Tables 3, 4 and 5 list comprehensive sets of attributes used for the stated-preference survey for each route.

Another category of attributes, Frequency, was set as follows: for LCCs or FSCs, three kinds of attributes were set including the current frequency (the largest frequency of all the airlines serving the route), double frequency and half frequency; for the Shinkansen, a single kind of attribute was set based on the current frequency of the fastest service, "Nozomi"; and for the Linear/Shinkansen, a single kind of attribute was set based on the newspaper article (Nihon Keizai Shinbun (2013, September 13)). As for the express buses, no quantitative attribute was set; instead, a single qualitative attribute, say "departing between 21:00 and 24:00" was shown on-screen to each respondent. Tables 3, 4 and 5 list comprehensive sets of attributes used for the stated-preference survey for each route.

The last category of attributes, Other, was set based on the current service level regardless of the transportation modes. Tables 3, 4 and 5 list comprehensive sets of attributes used for the stated-preference survey for each route.

2.5. Characteristics of Respondents

2.5.1. Resident Area

Figure 3 provides a classification of 1,500 respondents on the basis of their resident area.

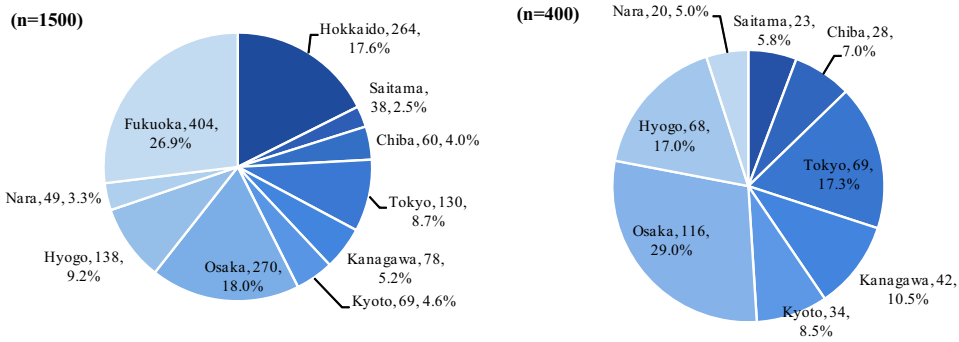

Figure 3: Classification of 1,500 respondents on the basis of their resident area (Left: All samples, Right: Respondents traveling between the metropolitan area and Kinki area)

2.5.2. Annual Incomes

Figure 4 classifies the 1,500 respondents by their annual income. About 30% of respondents had annual incomes below 2 million yen, implying that more people in the lower income group responded to the stated-preference survey, compared with the classification of the Private Salary Actual Statistical Survey conducted by the National Tax Agency of Japan (National Tax Agency (2013)).

2.5.3. Travel Purposes

Figure 5 classifies the 1,500 respondents by their travel purpose. About 20% of respondents were on business trips, implying that fewer people responded compared with the classification of the Inter-Regional Travel Survey (Ministry of Land, Infrastructure, Transport and Tourism (2013)).

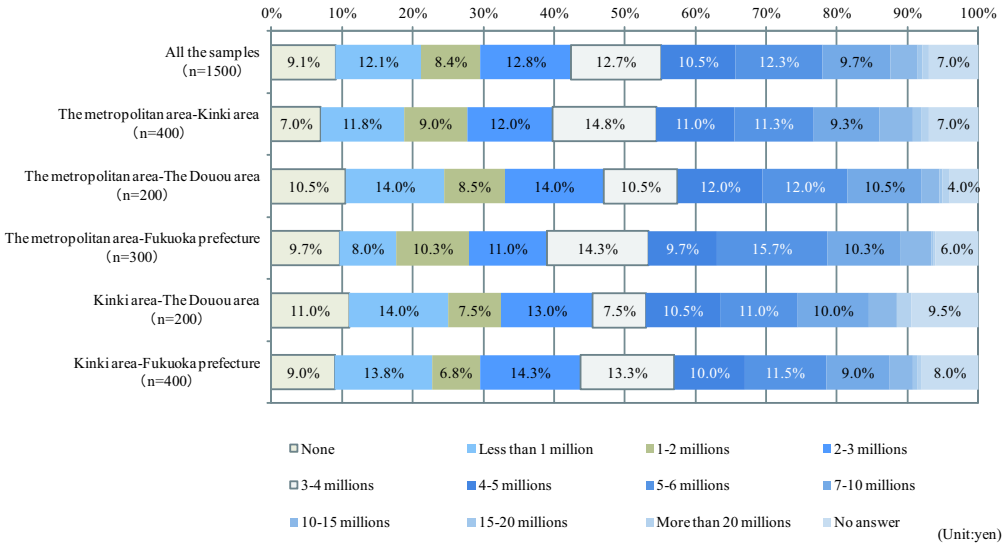

Figure 4: Classification of 1,500 respondents on the basis of their annual incomes

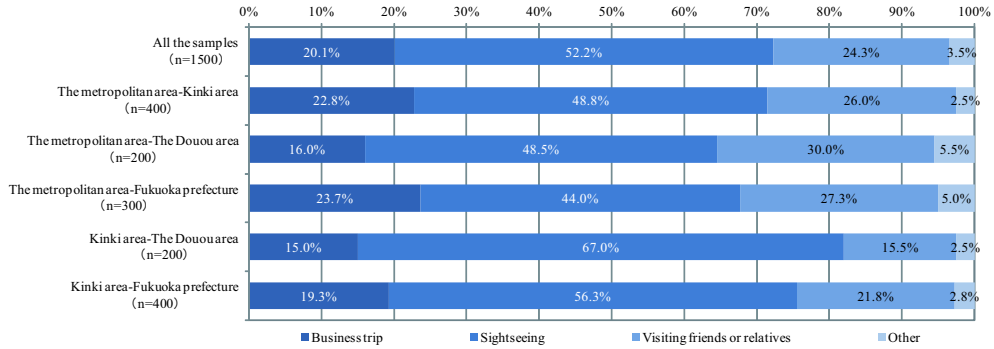

Figure 5: Classification of 1,500 respondents on the basis of their travel purpose

2.5.4. Reason for Selection of Transportation Mode

Figure 6 classifies the 1,500 respondents by the reasons why they selected the means of transportation (multiple answers allowed).

One of the main reasons for choosing LCCs was their "Low cost" (87.0%

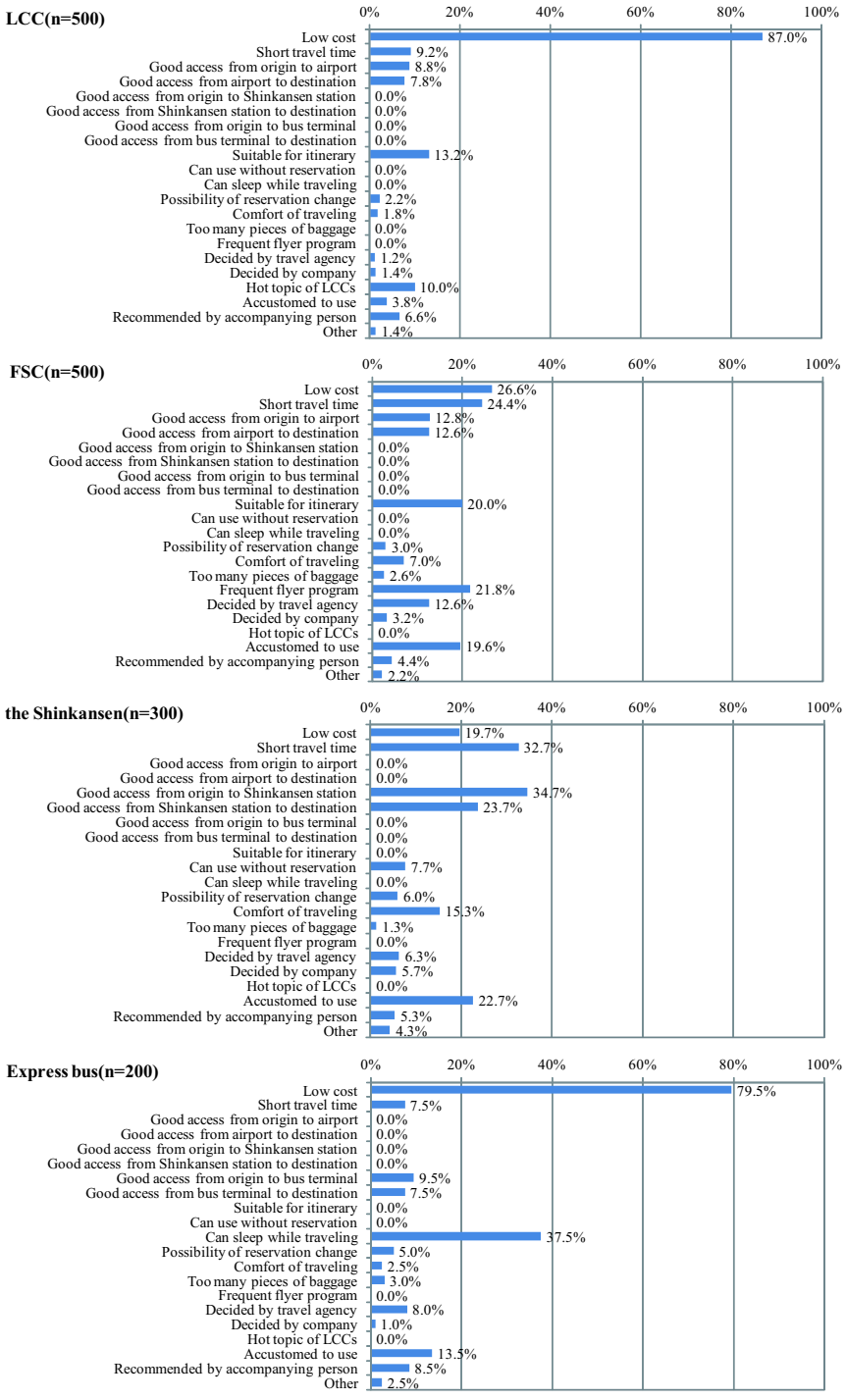

Figure 6: Classification of 1,500 respondents on the basis of their means of transportation

of the respondents). On the other hand, "Short travel time" was rarely chosen (9.2%), suggesting that speed is not the determining factor for choosing LCCs.

"Low cost" was also the main reason for choosing FSCs, reflecting airline deregulation in the year 2000, which enabled airlines to set fares without the consent of the administrative body. "Short Travel Time" was the second major reason for choosing FSCs, in contrast with choosing LCCs. "Frequent flyer program" (21.8%) and "Accustomed to use" (19.6%) were the next major reasons.

Major reasons for choosing the Shinkansen were "Good access from origin to Shinkansen station" (34.7%), "Short Travel Time" (32.7%) and "Good access from Shinkansen station to destination" (23.7%), suggesting that its access convenience was highly evaluated by users.

"Low Cost" was chosen by the majority of respondents who used express buses (79.5%). The second major reason was "Can sleep while traveling" (37.5%), which was not chosen by respondents who used other transportation modes.

3. Choice Modeling and Simulation

3.1. Development of the Choice Model

3.1.1. Fundamental Concepts for Developing the Choice Model

A choice model for transportation modes was developed by using the data of the stated-preference survey whose respondents had experienced traveling between the metropolitan area and Kinki area; the metropolitan area and Fukuoka prefecture; and Kinki area and Fukuoka prefecture. While the cur-

Table 6: List of weightings for adjusting stated-preference data

	FSCs	Shinkansen
Traveling between the metropolitan area and Kinki area	12	64
Traveling between the metropolitan area and Fukuoka prefecture	13	3
Traveling between Kinki area and Fukuoka prefecture	1	8

rent civil aviation forecasting model (National Institute for Land and Infrastructure Management (2007)) officially used by the Government of Japan is a three-tiered transition choice model comprising mode choice, route choice and access/egress choice, we decided to adopt a two-tiered transition choice model in order to quickly examine changes in demand by the entry of LCCs. We also decided to estimate model parameters by a single travel purpose in order to simplify the model, whereas the current forecast model used three kinds of travel purpose (business trip, sightseeing and others).

The data of the stated-preference survey was weighted in order to reflect the current inter-regional movement of passengers demonstrated by the Inter-Regional Travel Survey. Such weightings are listed in Table 6. Data provided by respondents who used LCCs or express buses were excluded because these transportation modes were hardly used, as shown by the Inter-Regional Travel Survey.

3.1.2. Development of the Choice Model

The choice model was developed based upon a Nested Logit (NL) model, in the same way as the current civil aviation demand forecasting model. We adopted a model structure and a combination of explanatory variables so as to ensure high reproducibility of the current situation, taking into consideration some statistics indicators including the hit ratio, likelihood

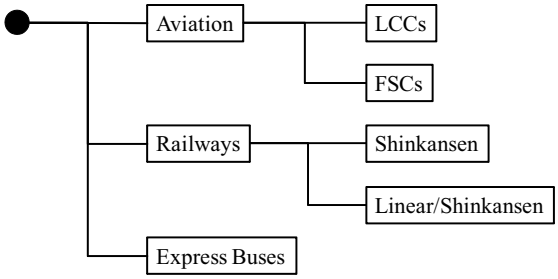

Figure 7: Model structure

ratio, sign condition, and so on.

Hence, we adopted a model structure with a two-tiered transition, as shown in Figure 7. The first tier consisted of "Aviation", "Railways" and "Express Buses". Under "Aviation" and "Railways", "LCCs" and "FSCs"; and "Shinkansen" and "Linear/Shinkansen" were deployed in parallel, respectively.

The representative components of the utility function where a passenger uses the transportation mode ij are defined by:

$$V_{ij} = \sum_k \beta_k x_{kij} + \delta_{ij} + \zeta_{il}, \tag{1}$$

where V_{11} denotes the representative components of the utility if a passenger used LCCs; V_{12} denotes those if a passenger used FSCs; V_{21} denotes those if a passenger used the Shinkansen; V_{22} denotes those if a passenger used the Linear/Shinkansen; and V_{31} denotes those if a passenger used express buses.

We adopted eight explanatory variables which constitute the components of the utility function where x_{1ij} denotes the Total Fare (in 10,000 yen); x_{2ij} denotes the Total Travel Time (in hours); x_{3ij} denotes the inverse of

the Frequency (per day); δ_{11}, δ_{21}, δ_{22} and δ_{31} are dummy variables for the use of LCCs, the Shinkansen, the Linear/Shinkansen and express buses, respectively; and ζ_{21} and ζ_{22} are dummy variables for traveling between the metropolitan area and Fukuoka prefecture, and between Kinki area and Fukuoka prefecture, respectively. x_{331} is set as zero reflecting that no quantitative attribute was set for express buses in the stated-preference survey. $\beta_1 \sim \beta_3$ are parameters estimated by the data.

The inclusive variable V_i is defined by:

$$V_i = \frac{1}{\gamma_i} \ln \left(\sum_j \exp \gamma_i V_{ij} \right) \tag{2}$$

where V_1 denotes the inclusive variable for the use of "Aviation"; V_2 denotes that for "Railways"; V_3 denotes that for express buses, which is equal to V_{31}; and γ_1 and γ_2 are parameters estimated by the data. The inclusive variable V_i represents the expected value of the maximum of V_{ij}, according to the random utility theory.

The probability that "Aviation", "Railways" or express buses are respectively chosen is given by:

$$P_i = \frac{\exp \lambda V_i}{\sum_i \exp \lambda V_i} \tag{3}$$

where P_1, P_2 and P_3 are for "Aviation", "Railways" and express buses, respectively; and λ is a parameter estimated by the data. The probability that LCCs, FSCs, the Shinkansen, the Linear/Shinkansen or express buses are chosen is given by:

Table 7: Estimated parameters

Explanation variables	Parameter	t-value
Total Fares(in ten thousands yen): β_1	-2.519	-45.7
Total Travel Time(hour): β_2	-0.419	-17.1
Inverse of Frequencies(services/day): β_3	-0.604	-3.2
Dummy Variable for the use of LCCs: δ_{11}	-0.771	-17.2
Dummy Variable for the use of Railways: δ_{21}, δ_{22}	1.468	22.4
Dummy Variable for the use of Express Buses: δ_{31}	-2.209	-10.9
Dummy Variable for traveling between the metropolitan area and Fukuoka prefecture: ζ_{21}	-2.002	-14.1
Dummy Variable for traveling between Kinki area and Fukuoka prefecture: ζ_{22}	-0.479	-4.5
γ_2	3.421	4.9
λ	0.792	27.7
Number of samples	20,200	
Likelihood Ratio	0.275	
Value of travel time	1,663yen/hour	
Hit Ratio	0.481	

$$P_{ij} = P_i \times \frac{\exp \gamma_i V_{ij}}{\sum_j \exp \gamma_i V_{ij}} \tag{4}$$

where P_{11}, P_{12}, P_{21}, P_{22} and P_{31} are for LCCs, FSCs, the Shinkansen, the Linear/Shinkansen and express buses, respectively; and γ_i is a parameter estimated by the data..

The estimated parameters are listed in Table 7. These nine parameters were simultaneously estimated with the condition $\gamma_1 = 1$.

3.1.3. Reproduction of the Current Status by the Model

In order to evaluate the current reproducibility of the model specified, we compared the estimated shares of each transportation mode with the current shares in the year 2010. The current shares were obtained by the Inter-Regional Travel Survey as of December 2010. The estimated shares were calculated by each subdivided OD: the metropolitan area is divided

into Tokyo metropolis, Chiba prefecture, Kanagawa prefecture and Saitama prefecture; the Kinki area is divided into Osaka urban prefecture, Kyoto urban prefecture, Hyogo prefecture and Nara prefecture; and Fukuoka prefecture is divided into the Fukuoka sub-region and the Kitakyushu sub-region. We estimated the shares for 16 subdivided ODs for the route between the metropolitan area and Kinki area; 8 subdivided ODs for the route between the metropolitan area and Fukuoka prefecture; and 8 subdivided ODs for the route between the Kinki area and Fukuoka prefecture. Consequently, we calculated the estimated shares for each targeted route by taking the average of the shares for subdivided ODs weighting by the actual number of passengers listed in the Inter-Regional Travel Survey. For simplification, however, we assumed that the Fukuoka sub-region and Kitakyushu sub-region represented three-fifths and two-fifths of the whole of Fukuoka prefecture, respectively reflecting the shares of the populations of Fukuoka city and Kitakyushu city.

The level of service (LOS) for each transportation mode was set as follows. The representative points of the subdivided ODs are each of their prefectural capitals.

Transportation network, as one component of the LOS, was assumed as follows: the following five routes, HND-ITM, HND-KIX HND-FUK, HND-KKJ (Kitakyushu) and ITM-FUK, are considered for FSCs; no route is considered for LCCs nor the Linear/Shinkansen because no service was available as of the reference month. The real airfares specified by the method proposed by Tansei (2010) and Tansei et al. (2011) were input as the Whole-Line Fares of FSCs. If there is more than one route between the targeted ODs, averaged real airfares weighted by the actual number of passengers were input

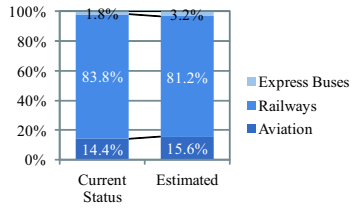

Figure 8: Results of reproduction of the current status by the model (traveling between the metropolitan area and Kinki area)

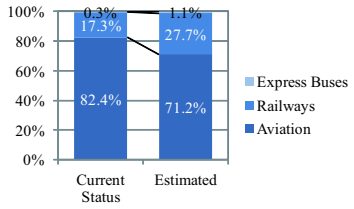

Figure 9: Results of reproduction of the current status by the model (traveling between the metropolitan area and Fukuoka prefecture)

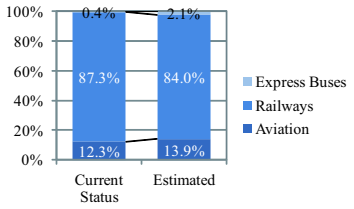

Figure 10: Results of reproduction of the current status by the model (traveling between Kinki area and Fukuoka prefecture)

into the specified model. Whole-Line Fares for other transportation modes, and Access Fares and Egress Fares for all the modes were input based on the current relevant fares. Both Total Travel Time and Frequency were input in exactly the same manner as the Total Fares. For simplification, we assumed that all the travelers using FSCs from/to the Fukuoka sub-region must use FUK and those from/to the Kitakyushu sub-region must use KKJ.

Figures 8, 9 and 10 show the results of reproduction of the current status by the model with the inputs described above. The estimated share of using Airlines between the metropolitan area and Kyushu area (71.2%) is slightly below the current status (82.4%). Other shares of use of transportation modes for other ODs are estimated very well. Hence, we decided to apply the model for the policy simulation.

3.2. Policy Simulation

We conducted a policy simulation for the entry of LCCs on some trunk domestic routes and the beginning of operation of the Linear Chuo Shinkansen

by applying the specified choice model.

3.2.1. Premises of the simulation

The following are premises of the policy simulation in this study:

- The two cases (with/without the Linear Chuo Shinkansen between the Tokyo metropolis and Nagoya city) were tested in order to understand the effect of the beginning of its operation. The Whole-Line Fares for the Linear/Shinkansen were set as the amount equivalent to the sum of the Line-Whole Fares of Shinkansen plus 1,000 yen, and the Total Travel Time was set as the current travel time of the Shinkansen minus 50 minutes;
- The number of landing/departure slots (specifically at HND and FUK) is assumed to be unlimited;
- LCCs would begin operating between HND-KIX, HND-FUK, HND-KKJ and ITM-FUK. We assumed the two cases that the Whole-Line Fares of LCCs would be both 30% and 50% off the current Whole-Line Fares of FSCs;
- The frequency of LCCs would be five and/or fifteen times a day depending on the targeted OD, and as fixed even where the capacity of LCCs is exceeded;
- All travelers using LCCs from/to the Fukuoka sub-region must use FUK and those from/to the Kitakyushu sub-region must use KKJ; and
- As for other LOS, we used the same inputs as the current status.

3.2.2. Result

Figures 11, 12 and 13 show the simulation results. The impact of entry of LCCs is estimated to be significant for all the targeted ODs. As for the route between the metropolitan area and Kinki area, the share of Airlines is boosted by about 10% by the entry of LCCs with 50% off the Whole-Line Fare, even when the Chuo Linear Shinkansen begins operation. In this case, the total share of FSCs decreases by about half.

The impact of entry of LCCs is more significant on the route between the metropolitan area and Fukuoka prefecture: LCCs would take over the share of FSCs and the Shinkansen even when the Chuo Linear Shinkansen begins operation. The shares of FSCs and Railways significantly decrease from 71.2% to 12.0% and from 27.7% to 8.7%, respectively. This is not only because LCCs with 50% off the Whole-Line Fare are highly competitive in terms both of fares and speed, but also because we assumed that LCCs began

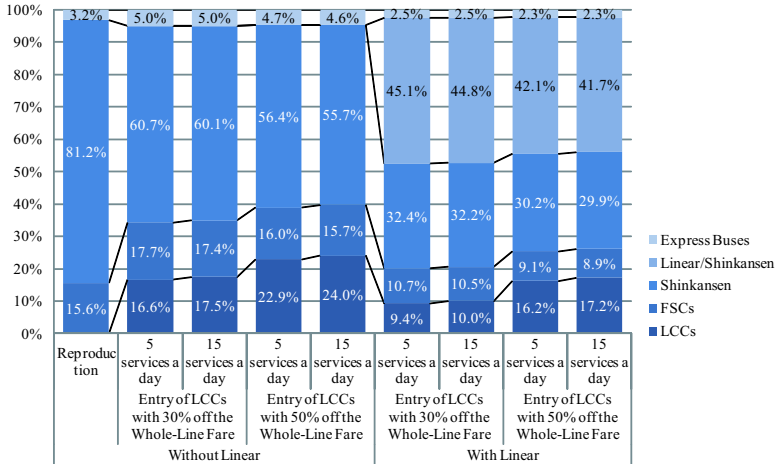

Figure 11: Simulation result (traveling between the metropolitan area and Kinki area)

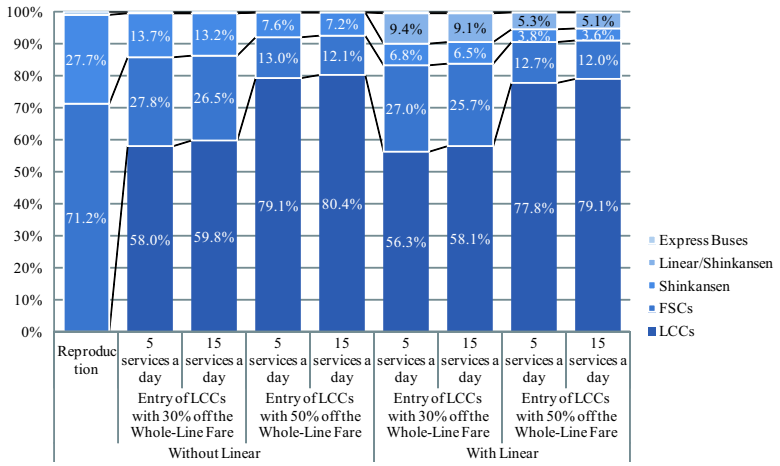

Figure 12: Simulation result (traveling between the metropolitan area and Fukuoka prefecture)

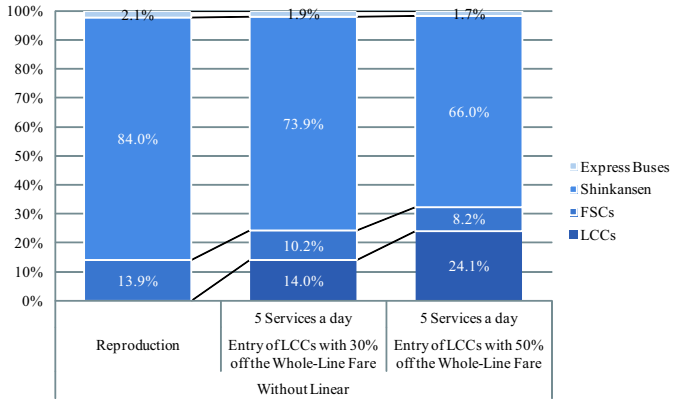

Figure 13: Simulation result (traveling between Kinki area and Fukuoka prefecture)

operation both at FUK and KKJ, and the former is the primary airport of Fukuoka prefecture.

As for the route between the Kinki area and Fukuoka prefecture, the impact of entry of LCCs seems to be very similar in that LCCs would take over a significant share of FSCs and the Shinkansen. The share of Airlines would account for 2.5 times the current status reproduction while that of FSCs would drastically decrease.

4. Conclusion

Using a stated-preference survey, we examined changes in air transport demand by the entry of low cost carriers (LCCs) into domestic aviation services between Tokyo International Airport and Kansai International Airport and other trunk routes, and by the beginning of operation of the Linear Chuo Shinkansen (high-speed railway). The results showed that the total aviation demand between the capital region and the Kinki area will increase even when the Linear Chuo Shinkansen begins operating. The impact of entry of LCCs is also significant on the route between the metropolitan area and Fukuoka prefecture and between Kinki area and Fukuoka prefecture: LCCs would take over a significant share of full service carriers and the Shinkansen.

In this paper, we adopted a two-tiered transition transportation choice model for simplification while the civil aviation demand forecast model officially adopted by the government is a three-tiered one. We plan to elaborate the stated-preference choice model encompassing a route choice model and an access/egress choice model, corresponding to the official civil aviation demand forecast model, in order to conduct more detailed analyses.

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