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An analysis of the effect of bundled airport privatization on an airline network

Ryuichi Tani[a]*, Ibuki Takashima[a], Teppei Kato[b], Toru Tamura[c], Kenetsu Uchida[d]

[a]*Graduate School of Engineering, Hokkaido University, North 13 West 8 Kita-ku, Sapporo 060-8628, Japan*
[b]*School of Engineering, Saitama University, 255 Shimo-okubo, Sakura-ku, Saitama 338-8570, Japan*
[c]*Hokkai School of Commerce, 6-6-10 Toyohira-ku, Sapporo, 062-8607, Japan*
[d]*School of Engineering, Hokkaido University, North 13 West 8 Kita-ku, Sapporo 060-8628, Japan*

Abstract

Depopulated regions face decline of traffic demand for airline service. Airline network in Hokkaido, Japan also plays an important role in economy, medication and sightseeing. For maintaining the airline network in Hokkaido, “bundled privatization” of airports has been discussed. In this system, several airports as a package are privatized and managed by a single company. This study proposes a model for analyzing behaviors of airports, airline companies and passengers when bundled privatization is introduced to an airline network. Under the bundled privatization condition, an airports management company can determine the landing fees of all airports so as to maximize the profits of all airports. An airline company determines both its service frequencies and aircraft sizes so as to maximize its profit. By solving two problems, an equilibrium state would be obtained as the results of both profit maximization behaviors. At the last, the proposed model is applied to the airline network in Hokkaido and results of numerical calculation are discussed.

Keywords: *air lines; landing fee; airport privatization; traffic demand; passenger behavior*

1. Introduction

Depopulated region would face decline of travel demand for airline service. This trend is expected to continue in future decades. Hokkaido, which is an island in northern part of Japan is one of the such regions. Its population density

* Corresponding author. Tel.: +81-11-706-6211; fax: +81-11-706-6211.
E-mail address: ryuichitani@eis.hokudai.ac.jp

is relatively smaller than the other regions of Japan. Main cities are dispersedly located in the island and most of them are distributed discontinuously. In Hokkaido, air transport plays important roles in economy, medication and sightseeing. However, due to the recent demand decline, low-profitable local airlines have shrunk. They miniaturized aircraft sizes or concentrated management resources on highly-profitable lines. As for financial situation of airports, all airports in Hokkaido except for New Chitose airport are in the red. For improving financial situation of these airports in the red, privatization of such airports has been discussed all over Japan. The main scheme of airport privatization discussed in Japan is concession contract. In concession contract, private companies with goodwill make their business in the airport facilities and set the landing fees at their own discretion, while national or local government continues to possess ownership of land and facilities for the airport. In Hokkaido, "bundled privatization" of several airports has been discussed. By the bundled privatization, it is expected that the efficient management of airports is possible thanks to the network effect, e.g., agglomeration economy.

Ministry of Land, Infrastructure, Transport and Tourism (MLIT) announced that seven airports in Hokkaido are planned to be privatized, and they are managed by a single private company from 2020 for 30 years (MLIT, 2018). The bundled privatization is explicitly different from other existing cases of airport privatization in Japan (e.g. Sendai, Takamatsu, Fukuoka). In other existing cases, each airport is privatized independently. As positive effects of bundled privatization, it is expected that the travel demands from New Chitose airport to the other local airports increase. It may be difficult to increase airline capacities at New Chitose airport by corresponding to the travel demands these days.

Route choice behavior of airline passengers have been analyzed in the literature (e.g. Kanafani and Ghobrial, 1985; Adler, 2001). Takebayashi and Kuroda (2007) dealt with efficient airports usage in Japan methodologically, and clarified differences in both features and demands among three airports located in Kansai region, Japan. They focused on both airline competition and route choice behavior of airline passengers. Takebayashi (2018) analyzed behavior of airline companies and airline passengers by changing both landing fees and terminal charges in airports. However, as far as we know, there is no study that analyzes changes in airline market by the introduction of the bundled airport privatization. The objectives of this study are to propose a model which analyzes behaviors of passengers, airports and airline companies, and to analyze the airline market in Hokkaido after the introduction of the bundled privatization.

We propose a model for analyzing behaviors of airports and airline companies by taking the difference between bundled and normal airport privatization into account at the same time. In this proposed model, the relationships between travel demand, selection of the size of aircraft and service frequency are explicitly addressed. The important features of this proposed model are summarized as:

- The model analyzes bundled privatization of airports where several airports are managed by a single private administrator.
- Airports behave as maximizing their profits by changing their landing fees.
- Airline companies behave as maximizing their profits by changing both service frequencies and aircraft sizes.
- The passengers choose both transport mode and transport company so as to maximize their utilities.

This paper is organized as follows. In section 2, we propose a model which represents behaviors of passengers, airports and airline companies. In section 3, the proposed model is applied to the airline network in Hokkaido, in Japan where the introduction of the bundled privatization is considered, and the results obtained are discussed. Finally, we provide concluding remarks of this study and mention future tasks.

Nomenclature

I	Set of air routes
H	Set of airports
M	Set of transport modes ($M = \{a:\text{air}, o:\text{others}\}$)
C_m	Set of transportation companies which provide service of transportation mode $m \in M$
K	Set of aircraft sizes
$r(i)$	Origin node (or airport) of air route $i \in I$
$s(i)$	Destination node (or airport) of air route $i \in I$

f_{i_n} Fare of air route i operated by company $n \in C_a$

$u_{i_n}^k$ Route frequency on air route $i \in I$ using an aircraft with the size of $k \in K$ that is set by airline company $n \in C_a$

g_{i_n} Generalized cost of air route $i \in I$ operated by airline company $n \in C_a$

s_i Inclusive cost of air route $i \in I$

$\hat{g}_i$ Generalized cost required for traveling from $r(i)$ to $s(i)$ by using transport mode o

π_h Profit of airport $h \in H$

r_h Non-Aeronautical Revenues of airport $h \in H$

c_h Costs of airport $h \in H$

v_k Seating capacity of an aircraft with the size of $k \in K$

l_i^k Fees of an aircraft with the size of $k \in K$ required for landing at airport $s(i)$

θ_n Additional costs of airline company $n \in C_a$ that are generated by the congestion at destination airports

χ_i Air route capacity on route $i \in I$

p_i Probability of a passenger choosing transport mode a when traveling from $r(i)$ to $s(i)$

p_{i_n} Probability of an airline passenger choosing airline company $n \in C_a$ when traveling from $r(i)$ to $s(i)$

ω_i Demand for traveling from $r(i)$ to $s(i)$

q_i Demand for traveling from $r(i)$ to $s(i)$ by using transport mode a

$\hat{q}_i$ Demand for traveling from $r(i)$ to $s(i)$ by using transport mode o

π_n Profit of airline company $n \in C_a$

c_n Cost of airline company $n \in C_a$

δ_i^n Variable that equals 1 if airline company $n \in C_a$ operates air route $i \in I$, and 0 otherwise

$\tilde{\delta}_{s(i)}^h$ Variable that equals 1 if destination airport of air route $i \in I$, $s(i)$, is airport $h \in H$, and 0 otherwise.

2. Formulation

For each air route $i \in I$, it is assumed that there is a composite transport mode o that represents all possible transport modes available in traveling from $s(i)$ to $r(i)$, and that there exists at least one airline company. The passenger traveling from $s(i)$ to $r(i)$ will choose either transport mode a or o. The passenger who choose air transport mode when traveling from $s(i)$ to $r(i)$ will choose an airline company from all available airline companies.

We assume the incorporative competition among airports and airline companies. The sketch of our proposed model is shown in Fig. 1. Section 2.1 describes a passenger assignment model represented by Nested-logit model. Section 2.2 shows an aircraft assignment problem which is formulated as profit maximization problem for an airline company. Section 2.3 shows a landing fee setting problem which is formulated as airport's profit maximization problem of one or several airports privatized.

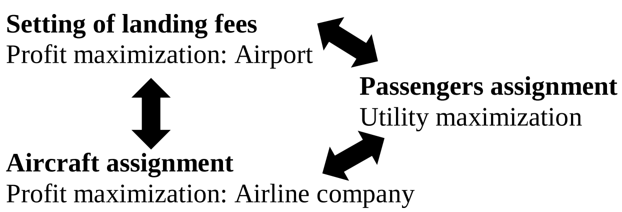

Fig. 1. Concept of proposed model

2.1. Passenger's behavior

In this study, passengers are assumed to maximize their utilities when they choose their transport modes and routes for their trips. We assume that passenger's transport mode choice behavior is represented by Nested-logit-model. As mentioned above, non-aviation modes such as railways and buses are assumed to exist for each air route. Fares of non-aviation modes of route *i* are represented as a constant value which refers to Takebayashi and Kuroda (2007). Without loss of generality, we assume that such fares of non-aviation modes are represented by a single value. Such non-aviation transport modes are denoted by the composite transport mode *o* in this study. For detailed discussion, the reader is referred to the literature (e.g. Adler et al., 2010, Takebayashi, 2011 and Takebayashi, 2014) which deal with competition or cooperation between high speed railway and airline is considered. Passenger's transport mode choice and airline company choice behaviors correspond to the passenger's utility maximization behavior. At first, we define two generalized costs for using airline company *n* on air route *i* and for using the transport mode *o* that are respectively given as:

$$g_{i_n} = \begin{cases} f_{i_n} + \dfrac{\alpha}{\sum_{k\in K} u_{i_n}^k} & \text{if } \delta_i^n = 1 \\ \infty & \text{otherwise} \end{cases} \quad \forall n \in N,\, i \in I \tag{1}$$

$$\hat{g}_i = const \quad \forall i \in I \tag{2}$$

where the calibration parameter of α in (1) is a positive scalar. As shown in (1), the generalized cost of air route *i* operated by the airline company *n* is comprised of its fare and service frequencies for aircrafts the company has. By adding perception errors which follow multivariate error distribution, $\boldsymbol{\varepsilon} = (\varepsilon_1, \cdots\ \varepsilon_{|M|\cdot|C_m|})$, to the generalized costs, transport mode choice probabilities and airline company choice probabilities can be given based on random utility theorem. Probability density function of error distribution is shown as:

$$f(\boldsymbol{\varepsilon}) = \exp\left(-\sum_{m\in M} \left(\sum_{n\in C_m} \exp\left(-\frac{\varepsilon_n}{\lambda} \right)^{\lambda} \right) \right) \tag{3}$$

where λ in (3) is a calibration parameter that holds $0 < \lambda \le 1$. By introducing the above-mentioned error distribution, probability for a passenger choosing air route *i*, and that of the passenger who chooses air route *i* and the airline company *n* are respectively represented as:

$$p_i = \frac{\exp(-s_i)}{\exp(-s_i) + \exp(-\hat{g}_i)} \quad \forall i \in I \tag{4}$$

$$p_{i_n} = p_i \cdot p_i^n \quad \forall n \in N,\, i \in I \tag{5}$$

where

$$p_n^i = \frac{\exp(-g_{i_n}/\lambda)}{\sum_{n'\in C_a} \exp(-g_{i_{n'}}/\lambda)} \quad \forall n \in N,\, i \in I \tag{6}$$

$$s_i = -\lambda \cdot \ln \sum_{n\in C_a} \exp\left(-\frac{g_{i_n}}{\lambda} \right) \forall i \in I \tag{7}$$

Note that utility functions of passengers are linear with respect to their generalized costs. Travel demand for the air route *i* is summation of travel demands for all airline companies that operate air route *i*.

$$q_i = \sum_{n\in C_a} q_{i_n}, \quad \left(\hat{q}_i = \omega_i - q_i \right) \quad \forall i \in I \tag{8}$$

$$q_{i_n} = \min\left(p_{i_n} \cdot \omega_i,\ \sum_{k\in K} v_k \cdot u_{i_n}^k \right) \quad \forall i \in I,\, n \in N \tag{9}$$

$$q_i \geq 0,\ \ \hat{q}_i \geq 0,\ \ q_{i_n} \geq 0 \quad \forall i \in I, n \in N, \tag{10}$$

As shown in (9), travel demand of airline company *n* that operates air route *i* is restricted by the total seating capacities of aircrafts that airline company *n* has. In other words, travel demand of passengers using each air route is constrained to capacity provided by all airline companies that operate the air route.

2.2. Airline company's behavior

We assume that airline companies determine service frequencies for maximizing their profits. We assume that the aircrafts are categorized only by their sizes. We assume that seating capacity and landing fees at airports are specific to aircraft size. This effects of the capacity and fees on the behaviors of the passenger and airport are described later. Accordingly, it is reasonable to consider the following profit maximization problem of the airline company *n* with respect to its service frequencies.

$$\max \pi_n\left(\mathbf{u}_{i_n}\right) = \sum_{i\in I} f_{i_n} \cdot q_{i_n} - c_n\left(\mathbf{u}\right) \quad \forall n \in N \tag{11}$$

where

$$\mathbf{u}_{i_n} = \left(u_{i_n}^1, \cdots, u_{i_n}^{|K|}\right) \quad \forall n \in N, \forall i \in I \tag{12}$$

$$\mathbf{u} = \left(\mathbf{u}_{1_1}, \cdots, \mathbf{u}_{1_{|C_a|}}, \cdots, \mathbf{u}_{|I|_1}, \cdots, \mathbf{u}_{|I|_{|C_a|}}\right) \tag{13}$$

$$c_n\left(\mathbf{u}\right) = \sum_{i\in I}\sum_{k\in K} u_{i_n}^k \cdot l_i^k + \theta_n\left(\mathbf{u}\right) \quad \forall n \in N \tag{14}$$

$$\theta_n\left(\mathbf{u}\right) = \sum_{i\in I} \eta_1 \cdot \delta_i^n \cdot \exp\left(\eta_2 \cdot \frac{\sum_{j\in I}\sum_{n\in C_a}\sum_{k\in K} u_{j_n}^k}{\chi_i}\right) \qquad \forall n \in N \tag{15}$$

As shown in (14), cost of airline company *n* is given as the summation of landing fees weighted by service frequencies and additional costs which are generated by the congestion at the destination airports. η_1 and η_2 in (15) are calibration parameters. Note that air route capacities are assumed to be exogenously given as constants.

2.3. Airport's behavior

In this study, airports concerned are assumed to be privatized and managed by one company. Landing fees are assumed to be determined by an airport administrator so as to maximize its profit. Thus, a landing fee decision problem can be formulated as a profit maximization problem for the airport administrator. We consider two cases of privatization scheme; individual privatization and bundled privatization. In the case of individual privatization, each airport administrator runs its airport and determines the landing fees for maximizing its profit. In this case, some of low profitable airports may be in the red and such airports may withdraw from the airport market. The profit maximization problem of an individually privatized airport is represented as:

$$\max \pi_h\left(\mathbf{l}_h\right) = r_h + \sum_{i\in I}\sum_{n\in C_a}\sum_{k\in K} \tilde{\delta}_{s(i)}^h\, u_{i_n}^k \cdot l_i^k - c_h \quad \forall h \in H \tag{16}$$

where

$$\mathbf{l}_h = \left(\ldots, l_{\hat{i}}^1, \cdots, l_{\hat{i}}^{|K|}, \ldots\right) \quad \forall h \in H \tag{17}$$

In (17), the air routes $\forall \hat{i} \in I$ are the routes such that $\tilde{\delta}_{s(\hat{i})}^h = 1$. Note that non-aeronautical revenue of airport is assumed to be exogenously given as a constant term, because we concentrate on discussion of behavior of passenger airline market.

In the case of bundled privatization, an administrator determines the landing fees of all airports by maximizing total profit of all airports. In this assumption, the administrator could set high landing fees on high profitable or congested airports and low landing fees on low profitable airports for maintaining local airlines, ideally. The profit maximization problem of the bundled privatized administrator is represented as:

$$\max \pi(\mathbf{l}) = \sum_{h\in H} \pi_h = \sum_{h\in H}\left(r_h + \sum_{i\in I}\sum_{n\in C_a}\sum_{k\in K} \tilde{\delta}^h_{s(i)} \cdot u^k_{i_n} \cdot l^k_i - c_h \right) \quad (18)$$

where

$$\mathbf{l} = \left(\mathbf{l}_1, \cdots, \mathbf{l}_{|H|}\right) \quad (19)$$

Same as the case of individual privatization, a landing fee of each airport can be different from those of others. In the case of bundled privatization, it is thought that high landing fees can be set at profitable airports or highly-congested air routes and low landing fees can be set at low-profitable minor air routes. Flexible landing fees setting scheme enables the administration company to maximize total profits of all airports, and the local airline network to become sustainable. However, we could not answer whether this kind of scenario works properly or not. Thus, in the next section, we apply our proposed method to the airline network in Hokkaido, Japan where bundled privatization is considered. Note that this scheme is different from the social welfare maximization scheme in the airline network. We assume that a set of airports are privatized altogether and are perfectly managed based on profit maximization principle.

3. Case study

3.1. Assumptions for numerical calculation

In this section, we will show the results obtained by applying the proposed model to the airline network in Hokkaido, Japan. The airline network is composed of eight airports and four airline companies. Eights airports are composed of seven airports in Hokkaido, i.e., New Chitose, Wakkanai, Kushiro, Hakodate, Asahikawa, Obihiro and Memanbetsu, and the Haneda in Tokyo, Japan. New Chitose airport is the largest in Hokkaido and is working as the hub of airline network in Hokkaido. All seven airports in Hokkaido are directly connected with Haneda airport and only Asahikawa and Obihiro do not directly connected with New Chitose. The airline network and eleven air routes are shown in Fig. 2. Inputs data used in the proposed model are shown in Tables 1 and 2. Fares and service frequencies at present are shown in Tables 1 and 2, respectively. These two tables show the present situations of four airline companies as of January 2018. Specifically, the four airline companies are Japan Airlines, All Nippon Airways, Air Do and Skymark Airlines, and they are respectively denoted as n=1, n=2, n=3 and n=4 in the following all Tables and Figures. Note that the elements that are denoted by “-“ in Tables 1 and 2 show that the values for such elements are infinities and zero, respectively.

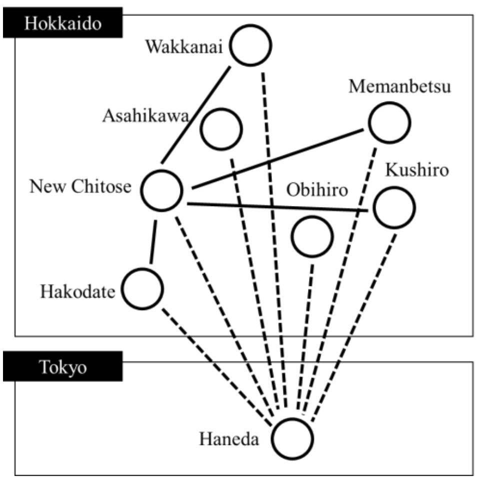

Fig. 2. Airline network

Table 1. Fares (10,000JPY)

Route	Airline companies			
	n=1	*n*=2	*n*=3	*n*=4
New Chitose – Wakkanai	2.53	-	-	-
New Chitose – Kushiro	2.46	-	-	-
New Chitose – Hakodate	2.01	2.01	-	-
New Chitose – Memanbetsu	2.63	2.63	-	-
New Chitose – Haneda	4.02	4.02	3.38	2.22
Wakkanai – Haneda	5.09	-	-	-
Kushiro – Haneda	4.64	4.64	3.96	-
Hakodate – Haneda	3.79	3.79	3.16	-
Asahikawa – Haneda	-	4.69	4.00	-
Obihiro – Haneda	-	4.57	3.90	-
Memanbetsu – Haneda	-	4.88	4.19	-

Table 2. Service frequencies (flights/day)

Air route	Airline companies											
	n=1			*n*=2			*n*=3			*n*=4		
	Aircraft sizes											
	k=1	*k*=2	*k*=3	*k*=1	*k*=2	*k*=3	*k*=1	*k*=2	*k*=3	*k*=1	*k*=2	*k*=3
New Chitose – Wakkanai	-	-	2	-	-	-	-	-	-	-	-	-
New Chitose – Kushiro	-	-	3	-	-	-	-	-	-	-	-	-
New Chitose – Hakodate	-	-	2	-	-	-	-	-	-	-	-	-
New Chitose – Memanbetsu	-	-	3	-	-	3	-	-	-	-	-	-
New Chitose – Haneda	13	2	2	14	-	1	-	8	3	-	-	8
Wakkanai – Haneda	-	-	1	-	-	-	-	-	-	-	-	-
Kushiro – Haneda	-	-	1	-	-	3	-	-	1	-	-	-
Hakodate – Haneda	-	1	2	-	1	2	-	2	-	-	-	-
Asahikawa – Haneda	-	-	-	-	2	2	-	2	1	-	-	-
Obihiro – Haneda	-	-	-	-	2	2	-	-	3	-	-	-
Memanbetsu – Haneda	-	-	-	-	-	3	-	-	2	-	-	-

We assume that each airline company has three types of aircrafts with different sizes. The three types of aircrafts are B-777, B-767 and B-737. Seating capacities of the three types of aircrafts are set as 375, 252 and 165, respectively. Table 3 shows travel demand of each air route. “Demand for airline” and “Modal share of airline” in Table 3 are set by referring to MLIT (2015b) and MLIT (2009), respectively. “Total travel demand” in Table 3 is then estimated by using both “Demand for airline” and “Modal share of airline”. Table 4 shows air route capacities. In general, runway capacity is determined by the number or the type of runways. Runway capacities of single runway, open parallel runway and intersection parallel runway are respectively set as 140,000, 300,000 and 160,000 times per year (Takebayashi et al., 2001). In this study, we define route capacities as the product of runway capacity and “air route ratio” since our concern focuses on analyzing specific air routes that are relating only to Hokkaido. For example, runway capacity of Haneda airport in Tokyo is assigned to many routes connecting to other regions in Japan. Therefore, the air route ratio in this study is defined as the number of flights of air route *i* divided by the number of whole flights arriving at the airport $s(i)$. Table 4 shows air route capacities that we defined.

Table 3. Travel demands (passengers/day)

Air route	Total travel demand	Demand for airline	Modal share of airline
New Chitose – Wakkanai	620.0	126.7	0.204
New Chitose – Kushiro	1,134.0	252.9	0.223
New Chitose – Hakodate	3,286.0	169.2	0.051
New Chitose – Memanbetsu	1,360.0	498.8	0.366
New Chitose – Haneda	25,020.6	24,620.3	0.984
Wakkanai – Haneda	312.9	308.5	0.986
Kushiro – Haneda	1,323.9	1,321.2	0.998
Hakodate – Haneda	3,609.2	3,010.0	0.834
Asahikawa – Haneda	2,328.3	2,291.0	0.984
Obihiro – Haneda	1,511.7	1,508.6	0.998
Memanbetsu – Haneda	1,241.3	1,238.8	0.998

Table 4. Air route capacities (flights/day)

Air route	Capacity	Route	Capacity
New Chitose – Wakkanai	5.3	Kushiro – Hanedacau	8.1
New Chitose – Kushiro	8.0	Hakodate – Haneda	13.0
New Chitose – Hakodate	5.3	Asahikawa – Haneda	11.4
New Chitose – Memanbetsu	16.0	Obihiro – Haneda	11.4
New Chitose – Haneda	83.1	Memanbetsu – Haneda	8.1
Wakkanai – Haneda	1.6		

For each air route *i*, there is the air route $\hat{i}$ such that $s(\hat{i}) = r(i)$ and $r(\hat{i}) = s(i)$. The landing fee for each aircraft size shown in section 2 is set to each airport. However, by considering a round trip by using air route *i*, such variables for two air routes *i* and $\hat{i}$ need to take the same values at the two airports $s(i)$ and $s(\hat{i})$. Based on this idea, landing fees can be defined by using an air route. Table 5 shows landing fee of each air route. In general, the amount of landing fees increases as aircraft size increases. The standard amount of landing fees of air routes, “New Chitose - Haneda” and “New Chitose - Memanbetsu” are shown in Table 5. Each landing fee could decrease by multiplying “Reduced rate” which is set to each air route. “Reduced rate” is set by airport administrators for promoting increments of service frequencies or aircraft sizes. We set both standard landing fee and reduced rates of all air routes as shown in Table 5. Table 6 shows that the daily revenue and costs of eleven airports. In this case, the daily revenue does not include the revenue from airline companies such as landing fees. Note that the values in Table 6 are set by referring to MLIT (2015). Table 7 shows congestion cost for each air route paid by each airline company. It is preferable to estimate congestion costs based on types of air traffic controls or direction of runways, but this study sets the congestion cost as the remains of overall sales subtracted by both profit and cost for aircraft operation for simplicity. Note that the elements that are denoted by “-“ in Tables 6 and 7 show that the values for such elements are zero. By using the data that presents current situation of the airline network, the calibration parameters of α, λ, η_1 and η_2 in (1), (6), (7) and (14) were estimated by minimizing the sum of mean squared errors on modal shares and shares of airline companies. The calibration parameters were finally estimated as 0.80, 1.50, 210 and 1.30, respectively.

Table 5. Landing fees (10,000JPY)

	Aircraft sizes			Reduced rate
Air route	*k*=1	*k*=2	*k*=3	
New Chitose - Wakkanai	42.8	13.2	5.0	0.60
New Chitose - Kushiro	42.8	13.2	5.0	0.60
New Chitose - Hakodate	42.8	13.2	5.0	0.60
New Chitose - Memanbetsu	71.3	22.1	8.3	1.00
New Chitose - Haneda	71.3	22.1	8.3	1.00
Wakkanai – Haneda	23.8	7.4	2.8	0.33
Kushiro – Haneda	42.8	13.2	5.0	0.60
Hakodate – Haneda	42.8	13.2	5.0	0.60
Asahikawa – Haneda	35.6	11.0	4.1	0.50
Obihiro – Haneda	35.6	11.0	4.1	0.50
Memanbetsu - Haneda	35.6	11.0	4.1	0.50

Table 6. Daily Revenues and costs of seven airports (10,000JPY)

Airport	Revenue of non-aviation business	Cost
New Chitose	750.7	2,046.8
Wakkanai	49.6	232.6
Kushiro	71.5	329.0
Hakodate	173.4	513.4
Asahikawa	74.8	246.8
Obihiro	137.0	286.8
Memanbetsu	10.4	141.4
Haneda	44,360.3	17,988.0

Table 7. Congestion costs of airlines (10,000JPY/day)

Route	Airline companies			
	n=1	*n*=2	*n*=3	*n*=4
New Chitose - Wakkanai	305.2	-	-	-
New Chitose - Kushiro	592.2	-	-	-
New Chitose - Hakodate	323.7	-	-	-
New Chitose - Memanbetsu	624.4	624.4	-	-
New Chitose - Haneda	35,960.1	34,108.3	13,297.7	4,590.7
Wakkanai - Haneda	1,494.5	-	-	-
Kushiro – Haneda	1,167.0	3,501.0	995.9	-
Hakodate - Haneda	3,788.4	3,788.4	2,735.2	-
Asahikawa - Haneda	-	5,674.9	3,882.3	-
Obihiro – Haneda	-	4,118.0	2,085.7	-
Memanbetsu - Haneda	-	3,452.4	1,976.1	-
Summation	44,255.6	55,267.3	24,973.0	4,590.7

3.2. Results of numerical calculation

Based on the input data shown in previous section, we performed numerical calculations for the airline network in Hokkaido, Japan. Table 8 shows changes of the number of passengers and landing fees before and after the bundled privatization of seven airports in Hokkaido. Fig. 3 shows that changes of landing fees of all air routes. All landing fees decrease by about 7 % almost equally. Table 9 shows the service frequencies for each airline company after bundled privatization of the seven airports. Note that the elements that are denoted by "-" in Tables 9 show that the values for such elements are set at zero from the beginning. Service frequencies of routes between an airport in Hokkaido and Haneda such as denoted by air routes 5, 8 and 9 in Table 9 increase, but those of routes within Hokkaido such as denoted by air routes 1-4 decrease. Fig. 4 shows the changes of the number of aviation passengers of all air routes. These results show that the numbers of passengers of local air routes within Hokkaido decrease, while service frequencies of such air routes decrease in the same way. However, the numbers of passengers of air routes between each airport in Hokkaido and Haneda tend to increase after bundled privatization of the seven airports.

Table 8. Passengers of airlines and landing fees of routes

	Number of passengers (people/day)		Landing fees	(10,000JPY)
Route	Before	After	Before	After
New Chitose - Wakkanai	104	0	42.8	40.1
New Chitose - Kushiro	233	0	42.8	40.1
New Chitose - Hakodate	155	0	42.8	40.1
New Chitose - Memanbetsu	536	0	71.3	66.8
New Chitose - Haneda	21,912	24,995	71.3	66.8
Wakkanai - Haneda	147	313	23.8	22.3
Kushiro - Haneda	1,289	1,323	42.8	40.1
Hakodate - Haneda	2,676	3,390	42.8	40.1
Asahikawa - Haneda	2,095	2,110	35.6	33.4
Obihiro - Haneda	1,659	1,507	35.6	33.4
Memanbetsu - Haneda	1,160	1,238	35.6	33.4
Summation	31,966	34,876		

Table 9. Service frequencies

	Airline companies											
	n=1			*n*=2			*n*=3			*n*=4		
	Aircraft sizes			Aircraft sizes			Aircraft sizes			Aircraft sizes		
Route	*k*=1	*k*=2	*k*=3	*k*=1	*k*=2	*k*=3	*k*=1	*k*=2	*k*=3	*k*=1	*k*=2	*k*=3
New Chitose – Wakkanai	-	-	-	-	-	-	-	-	-	-	-	-
New Chitose – Kushiro	-	-	-	-	0.0	-	0.0	0.0	-	-	-	-
New Chitose – Hakodate	-	-	-	-	-	-	-	-	-	-	-	-
New Chitose – Memanbetsu	-	-	-	-	-	-	-	-	-	-	-	-
New Chitose – Haneda	14.7	0.7	-	15.7	0.0	-	-	19.6	0.0	-	-	41.0
Wakkanai - Haneda	-	-	0.8	-	0.0	-	-	-	-	-	-	-
Kushiro - Haneda	0.1	1.1	0.1	0.4	1.3	-	-	-	1.8	-	-	-
Hakodate - Haneda	-	0.8	1.8	-	1.4	1.5	-	-	4.6	-	-	-

Asahikawa - Haneda	-	0.1	-	0.0	2.7	-	-	-	3.9	-	-	-
Obihiro – Haneda	-	-	-	1.2	1.1	-	-	-	2.7	-	-	-
Memanbetsu – Haneda	0.1	-	-	0.7	1.2	-	-	-	2.3	-	-	-

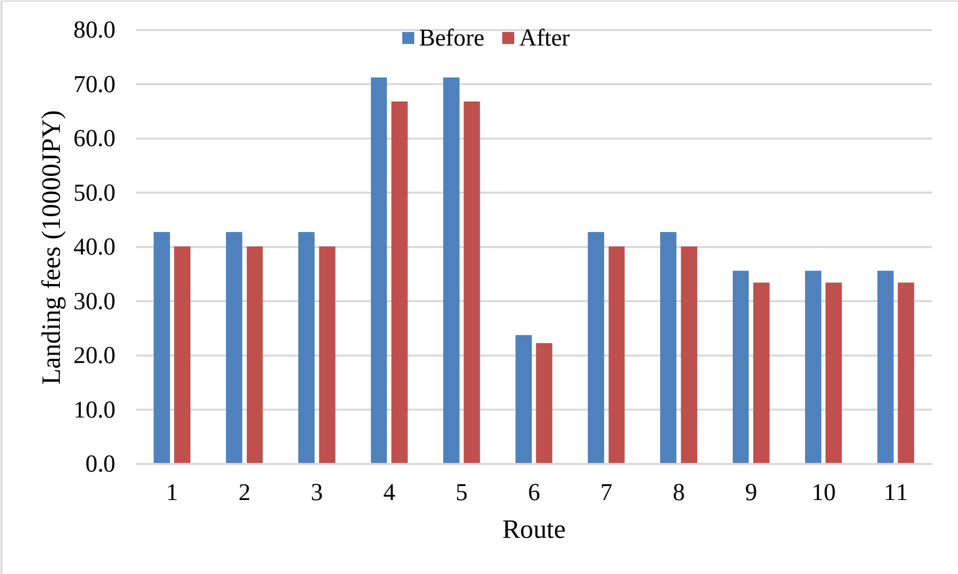

Fig. 3. Changes of landing fees

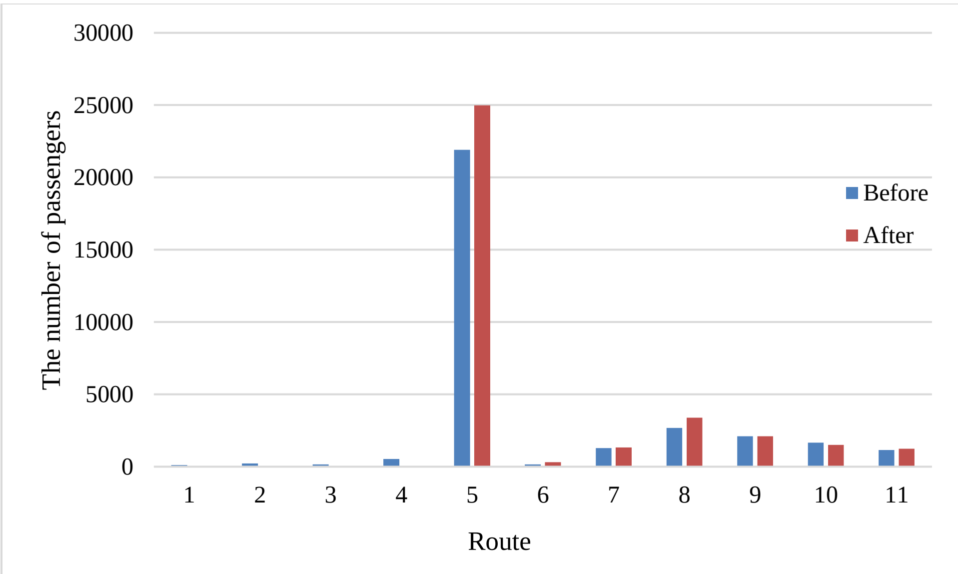

Fig. 4. Changes of aviation passengers

Fig. 5 shows profits of eight airports before and after bundled privatization. After bundled privatization, the profits of New Chitose and Haneda airports increase and the deficits of four airports in Hokkaido, i.e., Kushiro, Hakodate, Asahikawa and Memanbetsu, decrease, whereas the deficits of Wakkanai and Obihiro airports increase. Fig. 6 shows profits of four airline companies before and after bundled privatization. The results show that the profits of airlines 1 and 2 which have local air routes that connect airports within Hokkaido decreases. On the other hand, the profits of airlines 3 and 4 that do not have local air routes but only have air routes between airports in Hokkaido and Haneda in Tokyo increase.

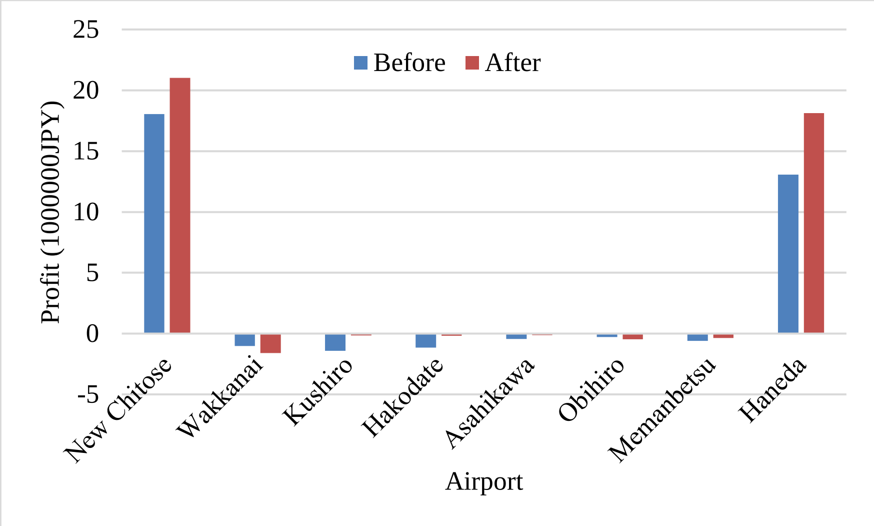

Fig. 5. Profits of airports

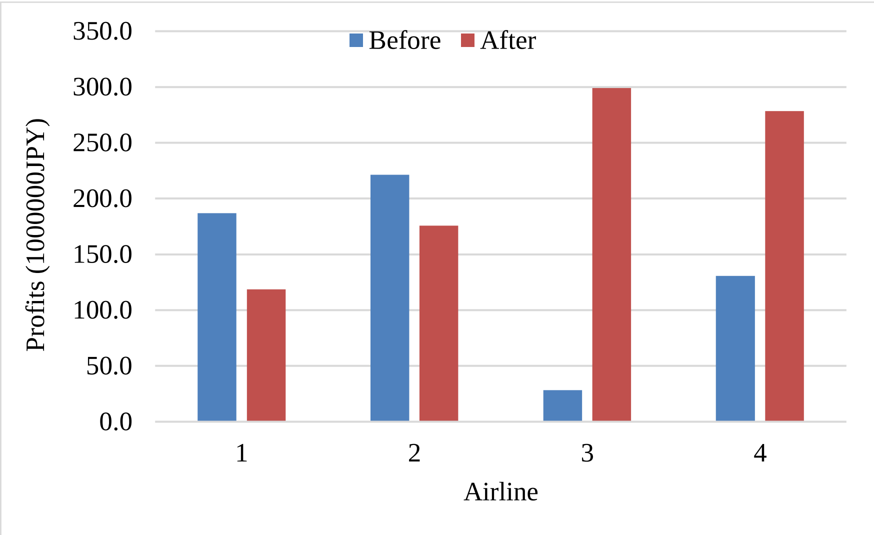

Fig. 6. Profits of airline companies

4. Concluding remarks

This study proposes behavior models of passengers, airline companies and airport administrators for analyzing the changes of passenger assignments, service frequencies and landing fees related to local airline network by the bundled privatization of seven airports in Hokkaido, Japan. The proposed model can determine travel demand, service frequency of airline companies and landing fees at an equilibrium state.

The numerical calculation for Hokkaido airline network was carried out. The indicative features of numerical calculation results are listed below. As far as the assumptions adopted in this study, (i) landing fees of all airports decreases almost equally due to the bundled privatization. (ii) The number of service frequencies of local airline network in Hokkaido decreases. (iii) The potential passengers who travel within Hokkaido shift to other transport modes from air transport mode, and all airlines which connects airports in Hokkaido withdraw. (iv) The profits of airline companies having local air routes connecting airports in Hokkaido decrease, but these of other airline companies having only routes connected with Haneda, Tokyo increase. (v) Financial situations of six airports are improved, while rest of two airports are worsened.

In summary, bundled privatization results in improvement of financial situations of most of the airports concerned, and in deterioration of transportation convenience for residence in Hokkaido. Aviation routes within Hokkaido are not competitive than other transport modes such as railways and buses from the aspects of fare and service frequency. They are not expected to be main transport in Hokkaido but are expected to play complementary role of transportation. It could be thought that simple representation of competition between airlines and other transport modes makes regional air routes within Hokkaido to withdraw.

As future tasks, the proposed model could be improved. First, transferring behavior of passengers should be considered. The proposed model does not consider the transferring behavior from a local airport to Haneda airport via New Chitose airport. This may lead to withdrawal of four local air routes within Hokkaido. Second, fares of airlines should fluctuate corresponding to changes of aviation markets. If fares are fixed and air routes are not competitive compared to other modes, potential passengers would not choose air routes, and airline companies would not assign management resources to non-competitive air routes actively. Third, the effects of expanding international markets could be included to our proposed model. In fact, the number of international tourists who visit to Japan increases. It is expected to compensate the decline of demand of airline service in a depopulated region such as Hokkaido.

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