Original Article

Research on the use of low-cost carriers and regional airports:

Changing long layovers to new value of tourism

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Abstract

Since Low-Cost Carriers (LCC) entered the Japanese aviation market, they increased their number of flights year by year and began to attract attention as an alternative to stimulate inbound tourism. Although these companies joined the Japanese market in full scale in 2012, they still face the problem of long layovers. It is also known that, when foreign tourists in Japan visit the countryside, they help revitalize the local economy. Therefore, in this study, we assumed that, if an LCC aviation network that considers regional airports was built, it could attract foreign tourists in Japan to visit the countryside during their layover time. Hence, we derived an optimal hub airport base for this purpose. The derivation techniques used were the Analytic Hierarchy Process (AHP) and multi-agent simulation. In one example, we evaluated the airports themselves and the use of layovers to visit world heritage sites. As a result, regional airports were rated highly, and the Nanki-Shirahama Airport had the highest number of arrivals in a simulation. This study showed that regional airports can function as optimal hub airport bases by utilizing long layovers as a new value of tourism and that LCC and regional airports can be effectively used to revitalize inbound tourism.

Keywords

low-cost carriers, regional airport, layovers, regional revitalization, analytic hierarchy process

1. Introduction

Low-cost carriers (LCC), which offer aviation services at reduced prices, entered the Japanese market in full scale in 2012. Since then, both the number of passengers of international and domestic flights and the market share of LCCs have increased, as shown in Figure 1 [Ministry of Land, Infrastructure, Transport and Tourism, 2019]. According to the survey on LCC users' attitude and behavior, about 25.5 % people were domestic LCC users and their purposes were mainly sightseeing (78.9 %) [JTB Tourism Research & Consulting, 2017].

Moreover, Figure 2 indicates that the utilization rate of LCCs among foreign tourists visiting Japan was about 25 % in 2016 and in neighboring countries in Asia, such as South Korea and the Philippines, the majority of travelers used LCCs [Japan Tourism Agency, 2016]. Based on the situation mentioned above, main customer segment of LCC is young people in their 20s and 30s for both foreign tourists visiting Japan and Japanese travelers [Japan Tourism Agency, 2016; JTB Tourism Research & Consulting, 2017]. Research shows that LCCs must consider the demand for inbound tourism in Japan from Asian countries if they want to grow. As a result, the number of routes is also expected to expand, creating a new challenge to maintain regional airports and routes in Japan [MLIT, 2013] [Hanaoka, 2015]. As part of the activities carried out domestically to support this growing demand, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has reduced

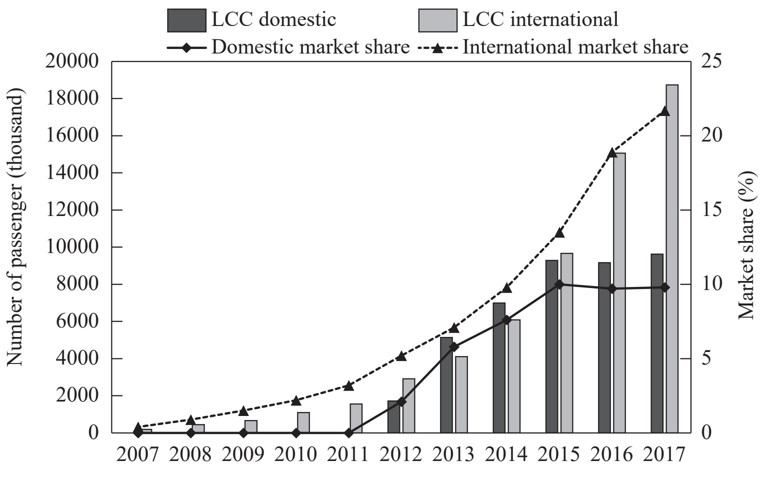

Figure 1: Variation of the number of LCC passengers (as of August 2018)

Source: Created by the authors based on MLIT, 2019.

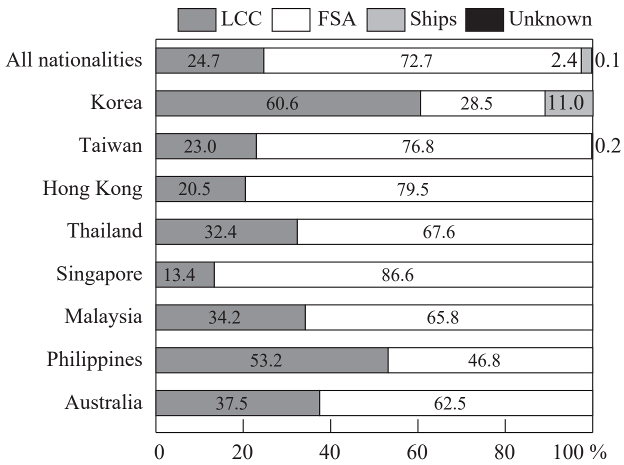

Figure 2: Utilization rate of LCCs in Asian countries and Australia
Note: LCC: Low-cost Carrier, FSA: Full-Service Airline.
Source: Created by the authors based on Japan Tourism Agency, 2016.

the landing fee of regional airports to promote the operation of LCCs [MLIT, 2017a]. In addition, Peach Aviation, a Japanese LCC based in Kansai International Airport, has applied the concept of local economy stimulation and regional revitalization and began publishing informative magazines about provincial cities and onboard sales of specialty goods from these regions [Peach Aviation, n.d.; 2016].

As airline routes expand, the networks become larger and more complex. One of the network structures designed to make airline operations more efficient is the so-called hub-and-spoke network, which was created in the 1980s in the USA. It is based on the concept of setting a hub airport that works as a base for many other airports around it, minimizing the number of routes and maximizing the number of connecting airports. This network structure makes it possible to transport passengers scattered across a wide area more efficiently. Another advantage of hub-and-spoke networks is that, since the users of each route have different final destinations, each route has higher load factor than that in the case when all routes consist of direct flights.

However, networks with hub airports also have some disadvantages. For example, when a hub airport is set, many users are forced to make a connection at that airport, which extends the time of wait between flights (layover). Cheaper air tickets tend to have itineraries that require connections. In some LCC flights, which are expanding all over the world, the layover time can surpass six hours.

The purpose of this study is not to reduce long layovers at the hub airport, but to create new value of "tourism" by incorporating long layover as a sightseeing time at existing airports, especially regional airports. Using this strategy could show the possibility of regional airports to become a hub airport. For this purpose, the visit to world heritage sites can be a case considering the demand of inbound tourism in Asia.

As of March 2017, there were as many as 20 world heritage sites registered in Japan, representing its culture and nature, and most were located in the countryside [National Federation of UNESCO Associations in Japan, 2017]. Also, these world heritage sites are symbols of Japan's unique beauty. Therefore, this study focuses on deriving an optimal hub airport base considering world heritage sites that can be accessed from the airports by train, bus, and on foot.

This proposal is expected to make passengers see longer layovers as an advantage because they can use this time for sightseeing. Moreover, if the problem of long layovers is solved, many airline companies can expand their aviation networks using regional airports as a base. It is also believed that, if an aviation network based on regional airports is built, it may help revitalize not only the regional airports that work as hubs but also the region around them.

2. Previous research on hub airport networks

The following are examples of research on techniques to build hub-and-spoke aviation network models conducted both in Japan and overseas. Tamura et al. [Tamura et al., 1993] analyzed the fact that the structure of domestic aviation networks became complex due to the internationalization of airports and optimized the airport network using a genetic algorithm and verified its effectiveness. Janic and Reggiani [Janic and Reggiani, 2002] compared three multi-criteria decision-making methods for choosing a new hub airport for an imaginary EU airline company, which would start operating in the air transport market liberalized in Europe. The three decision-making methods that they used were the Simple Additive Weighting (SAW), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Analytic Hierarchy Process (AHP). In addition, Martín and Román [Martín and Román, 2004] proposed a game theory model designed to analyze the location of hub airports and competition in the aviation industry. Therefore, various techniques have been considered for decisions concerning hub airports and their networks.

This study involves various evaluation criteria, such as airports items (aviation demand and productivity, operating cost, and average arrival flight) and tourism items due to layover. Furthermore, this study involves evaluation by young people in their 20s and 30s using their qualitative judgement. Thus, this study develops analysis by carrying AHP and multi-agent simulations using Monte Carlo method in order to consider uncertainty of qualitative judgement.

3. Research method and technique

As shown in Figure 3, the first step of the research is to select hub airport candidates from existing airports in Japan. Then, it is necessary to determine the items to evaluate whether the selected airports can be turned into hub airports. With the global objective of determining a new hub airport, a hierarchical chart of AHP for this study must be created with the selected candidate airports and their evaluation items. Then, the total weight of each candidate airport is determined. Lastly, based on the total weight determined, a multi-agent simulation is conducted in order to assess the validity of the AHP result. In the simulation,

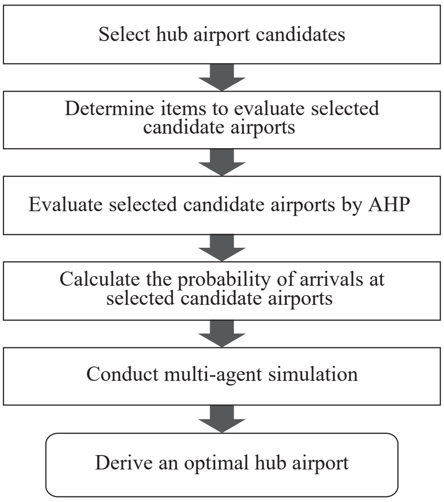

Figure 3: Procedure of this study

the airplanes are defined as the multiple agents and the candidate airports as the nodes. As the airplanes (agents) move between candidate airports (nodes) based on the respective weight, the number of arrivals of the airplanes (agents) is registered, and the airport (node) with the highest number of arrivals registered is derived as the optimal hub airport base of this study.

3.1 Selection of candidate airports

The hub airport candidates were chosen from the existing airports in Japan [National Federation of UNESCO Associations in Japan, 2017; MLIT, n.d.d]. The criterion used was being close to world heritage sites that can be accessed only by train, bus, and on foot. This is because if the proposal is to promote sightseeing using the limited amount of time during layovers, we thought that, ideally, the tourists should have easy access from the airport to the world heritage sites. As a result, candidates were the thirteen airports shown in Table 1, which include regional airports.

4. Evaluation and analysis of candidate airports by Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a technique proposed by Professor T. L. Saaty of the University of Pittsburgh in the 1970s. It is a decision-making method that mixes subjective judgment and system approach. Through paired comparison with hierarchical charts and definitions of each paired comparison value, as well as the calculation of weight by geometric mean, it makes it possible to perform comprehensive evaluation including items that cannot be easily quantified [Inoue et al., 2013]. Therefore, in this study, we applied the AHP to evaluate the hub airport candidates.

The procedure of AHP is shown in Figure 4. In the next section, we detail the process and results of AHP applied to this study following this procedure.

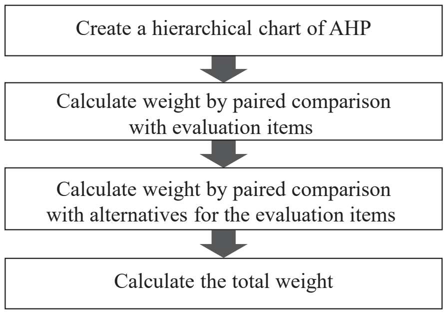

Figure 4: Procedure of AHP

4.1 Evaluation items and hierarchical chart

In this study, the candidate airports were evaluated to determine the optimal hub airport base. The evaluation items were designed to evaluate both the candidate airports themselves and the efficient use of layover proposed.

Table 2 shows the evaluation items and the data used for them. First, let us have a look at the evaluation items to assess

Table 1: Thirteen candidate airports selected and the respective world heritage sites nearby

Airport	World Heritage
Memanbetsu Airport	Shiretoko
Hanamaki Airport	Hiraizumi – Temples, Gardens and Archaeological Sites Representing the Buddhist Pure Land
Haneda Airport	The Architectural Work of Le Corbusier, an Outstanding Contribution to the Modern Movement (National Museum of Western Art)
Shizuoka Airport	Fujisan, sacred place and source of artistic inspiration
Toyama Airport	Historic Villages of Shirakawa-go and Gokayama
Osaka International Airport	Historic Monuments of Ancient Kyoto (Kyoto, Uji and Otsu Cities)
	Historic Monuments of Ancient Nara
Kobe Airport	Himeji-jo
Kansai International Airport	Buddhist Monuments in the Horyu-ji Area
Nanki-Shirahama Airport	Sacred Sites and Pilgrimage Routes in the Kii Mountain Range
Izumo Airport	Iwami Ginzan Silver Mine and its Cultural Landscape
Hiroshima Airport	Hiroshima Peace Memorial (Genbaku Dome)
Fukuoka Airport	Sacred Island of Okinoshima and Associated Sites in the Munakata Region
Naha Airport	Gusuku Sites and Related Properties of the Kingdom of Ryukyu

Table 2: Data of the evaluation items

	Gross production of prefecture (Million yen)	Population (People)	Average income (Thousand yen)	Annual airport user (People)	Revenue (Million yen)	Expenditure (Million yen)	Average arrival flight (Time)	One-way travel time (Minute)	No. of transfers (Time)	Fare (Yen)
Memanbetsu Airport	18,961,154	5,381,733	2,589	824,780	1,155	1,426	0.56	107	1	1,750
Hanamaki Airport	4,722,913	1,279,594	2,760	432,555	542	2,113	0.68	53	1	1,260
Haneda Airport	104,339,162	13,515,271	5,378	85,262,674	86,192	90,800	25.6	53	1	660
Shizuoka Airport	17,292,439	3,700,305	3,316	671,784	260	729	0.54	196	1	3,600
Toyama Airport	4,646,513	1,066,328	3,373	572,796	283	763	0.46	180	2	5,090
Osaka International Airport	39,106,932	8,839,469	3,127	15,597,777	17,551	11,154	7.94	50	0	1,310
Kobe Airport	20,494,996	5,534,800	2,752	3,109,042	2,692	2,692	1.42	90	1	1,300
Kansai International Airport	39,106,932	8,839,469	3,127	27,884,790	13,011	13,011	10.11	70	1	1,380
Nanki-Shirahama Airport	3,526,740	963,579	2,738	128,442	76	412	0.23	17	0	360
Izumo Airport	2,565,746	694,352	2,647	940,426	363	282	0.71	137	2	2,050
Hiroshima Airport	11,941,081	2,843,990	3,074	2,975,119	1,553	1,511	1.37	53	1	1,260
Fukuoka Airport	18,861,095	5,101,556	2,724	23,796,849	17,145	19,621	10.06	65	2	920
Naha Airport	4,141,564	1,433,566	2,166	20,973,082	31,615	51,739	9.46	36	0	330

Source: Created by the authors based on Cabinet Office n.d.a; Cabinet Office n.d.b; Hokkaido General Policy Department Airport Management Strategy Promotion Office, 2018; Kobe City, n.d.; MLIT, n.d.a; MLIT, n.d.b.; MLIT, n.d.c.; MLIT, 2017b.; MLIT, 2018.; Mt. Fuji Shizuoka Airport, n.d.; Prefectural Land Maintenance Department Planning Office, 2018; Osaka Prefecture, 2018; Shimane Prefecture, n.d.; and Toyama Prefecture, n.d..

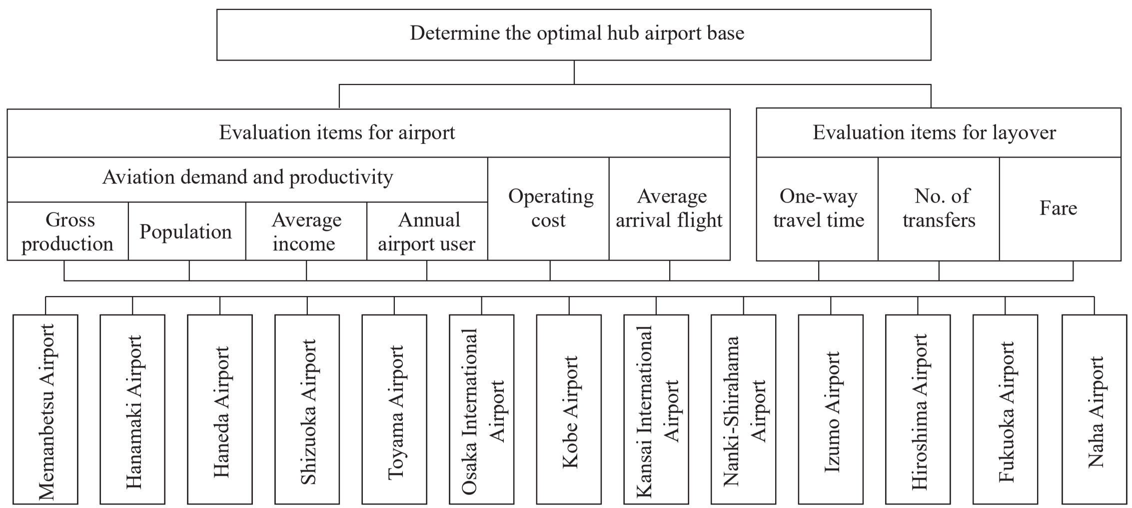

Figure 5: Hierarchical chart of AHP of this study

the airports themselves. Based on the study conducted by Janic and Reggiani on the selection of a new hub airport from seven existing airports in Europe, the airport evaluation items used in this study are Aviation Demand and Productivity, Operating Costs, and Airport Capacity [Janic and Reggiani, 2002]. In Table 2 the Aviation Demand and Productivity were evaluated in terms of the gross production, population, average income, and the annual number of airport users of the prefecture each airport is located [Cabinet Office n.d.a; Cabinet Office n.d.b; MLIT, 2018]. The operating cost is the difference between the revenue and expenditure of each airport, and the capacity is the average number of arrival flights per hour [Hokkaido General Policy Department Airport Management Strategy Promotion Office, 2018; Kobe City, n.d.; MLIT, n.d.a; b; c; 2017b; Mt. Fuji Shizuoka Airport, n.d.; Prefectural Land Maintenance Department Planning Office, 2018; Osaka Prefecture, 2018.; Shimane Prefecture, n.d.; Toyama Prefecture, n.d.].

Next, we add the possibility of visiting world heritage sites close to the airports during layovers as a new item in the decision of a hub airport. Since even long layovers have a predetermined boarding time, which limits the time available for tourism, the accessibility between the airports and the world heritage sites should be considered in the layover evaluation. Therefore, in this study, the items used are the one-way travel time from a world heritage site to the closest airport, the number of transfers, and the fare. The data generated by these evaluation items are indicated in Table 2.

The hierarchical chart of AHP to be performed was created with a structure that consists of the global objective, the evaluation items, and the alternatives. As shown in the hierarchical chart of Figure 5, there were nine evaluation items for the global objective of "Determining the optimal hub airport base" at the top: six items to evaluate the airport and three others to evaluate sightseeing during layovers. The "Operating Costs" in Figure 5 represent the "Revenue" and "Expenditure" indicated in Table 2. In addition, the alternatives located in the bottom layer are the thirteen candidate airports in Table 1.

4.2 Evaluation by paired comparison

The weight was calculated by paired comparison between the evaluation items and the alternatives followed by the calculation of the geometric mean of each line of the paired comparison matrix.

The paired comparison was carried out; once with the evaluation items for the global objective and another with the alternatives for the evaluation items. These comparisons evaluated which element of that pair was more important in terms of the global objective or the evaluation items. This evaluation was a relative evaluation based on definitions of each paired comparison value shown in Table 3. Intermediate values such as 2, 4, and 6 could also be adopted if necessary.

If the number of items is expressed by n and the values of the paired comparison matrix A (i, j) as a_{ij}, the paired comparison matrix A can be expressed as Eq. (1). The diagonal of the paired comparison matrix is the reciprocal of the paired comparison values:

Table 3: Definitions of each paired comparison value

Paired comparison value	Value description
1	Both factors are equally important
3	Factor i is more important than Factor j
5	Factor i is far more important than Factor j
7	Factor i is very important compared to Factor j
9	Factor i is extremely important compared to Factor j

$$A = \begin{bmatrix} 1 & a_{11} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

Then, the weight of each item was calculated as the geometric mean of each line of the paired comparison matrix. With the geometric mean of the i_{th} line of A, $\sqrt[n]{a_{i1}\, a_{i2} \cdots a_{in}}$, the weight w_i can be calculated according to Eq. (2):

$$w_i = \frac{\sqrt[n]{a_{i1}\, a_{i2} \cdots a_{in}}}{\sum_{k=1}^{n} \sqrt[n]{a_{k1}\, a_{k2} \cdots a_{kn}}} \quad (2)$$

With this procedure, the weight of the evaluation items and their alternatives were calculated. When AHP is performed with S units of evaluation items, the weight of the evaluation items determined with Eq. (1) and (2), W_{eval}, is expressed as Eq. (3):

$$W_{eval} = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_S \end{bmatrix} \quad (3)$$

Moreover, w_t^s, which is the weight of the alternative t for the evaluation item s determined by the same method with T units of alternatives, is expressed as the matrix W_{alt}^s of Eq. (4):

$$W_{alt}^s = [w_1^s \;\, w_2^s \; \cdots \; w_T^s]^T \quad (4)$$

In order to assess the consistency of the paired comparison, the consistency index (C.I.) was determined. If the paired comparison is heavily biased or inconsistent, it reduces the reliability of the evaluation values. For this reason, before the evaluation values are determined, it is necessary to determine the consistency index of the paired comparisons to analyze whether they are consistent.

If the number of items of the paired comparison table is expressed as n and the largest eigenvalue of the paired comparison matrix as λ, in this case, $\lambda \geq n$, and if the paired comparison is completely consistent, λ and n coincide. Moreover, as the inconsistency increases, the eigenvalue also tends to increase.

If the value of the C.I. determined by Eq. (5) is between 0 and 0.1, that paired comparison is considered sufficiently consistent.

$$\text{C.I.} = \frac{(\lambda - n)}{(n-1)} \quad (0 \le \text{C.I.} \le 0.1) \tag{5}$$

The total weight of the alternatives, W_{total}, can be calculated as the sum of products of the weight of evaluation items, W_{eval}, and the weight of the alternatives for each evaluation criterion, W^{S}_{alt}, using Eq. (6):

$$W_{total} = [W^{1}_{alt} \ W^{2}_{alt} \cdots W^{S}_{alt}]W_{eval} \tag{6}$$

4.2.1 Paired comparison and weight of evaluation items

The paired comparison matrix of the evaluation items of the airports were based on previous research by Janic and Reggiani [Janic and Reggiani, 2002]. The weight calculated based on the previous research are listed in Table 4.

The paired comparison matrix of the layover evaluation was determined based on the results of a questionnaire applied to 22 people who were in their 20s and 30s because young people are the main clientele of LCCs. The questionnaire was applied to foreign and Japanese young people: 7 from Europe, 3 from South Asia, and 12 from Japan (14 males and 8 females). The questionees were first asked to imagine they were going sightseeing during the limited amount of time available between flights. Then, supposing they were going to the destination by public transportation, they were asked to rank "one-way travel time," "fare," and "number of transfers" in order of importance. Based on the result obtained from 22 questionees, we prioritized the one-way travel time, the fare, and the number of transfers. The results suggest that, because layovers have a limited amount of time, the passengers tend to prioritize the capacity of moving as fast as possible. The paired comparison values were determined based on the results of this questionnaire and Table 3. The weights, calculated with the paired comparison table and the geometric mean of each line of that table, are indicated in Table 5.

The next step was to evaluate the airports and layovers together. To this end, in this study, we decided to make a paired comparison of the airport evaluation items and the layover evaluation items. The same paired comparison values of Tables 4 and 5 were used. Calculating weights comparing layover evaluation items with airport evaluation items could lead the creation of new value of sightseeing during layovers at regional airports. In order to apply the uncertainty of the possibility of sightseeing during layovers at regional airports, combinations of weights for all the items were obtained by setting four levels of importance of layover evaluation items compared to the airport evaluation items: 3. More important, 5. Far more important, 7. Very important, and 9. Extremely important. The calculated weights are shown in Table 6.

Table 5: Paired comparison table and weight of layover evaluation

	One-way travel time OTT	Table no. of transfers TRN	Fare FR	Weight
OTT	1	5	3	0.637
TRN	1/5	1	1/3	0.105
FR	1/3	3	1	0.258
			Consistency index	0.019

Table 6: Weight of evaluation items of each paired comparison value

	3	5	7	9
GP	0.060	0.042	0.033	0.027
POP	0.060	0.042	0.033	0.027
AI	0.060	0.042	0.033	0.027
AU	0.060	0.042	0.033	0.027
OC	0.098	0.070	0.054	0.044
AF	0.041	0.029	0.022	0.018
OTT	0.283	0.333	0.361	0.378
TRN	0.146	0.172	0.186	0.195
FR	0.193	0.227	0.246	0.258
Consistency index	0.080	0.080	0.080	0.080

4.2.2 Paired comparison of the candidate airports and weight relative to the evaluation items

The paired comparison matrix of candidate airports on each AHP evaluation item was calculated by the following steps. First, we calculated the deviation value of the candidate airports for each evaluation item with quantitative data shown in Table 2. Table 7 shows the deviation values calculated from the data of the evaluation items in Table 2. Then, the paired comparison values were determined from Table 8 based on the

Table 4: Paired comparison table and weight of airport evaluation

	Gross production of prefecture GP	Population POP	Average income AI	Annual airport user AU	Operating cost OC	Average arrival flight AF	Weight
GP	1	1	1	1	1/2	2	0.154
POP	1	1	1	1	1/2	2	0.154
AI	1	1	1	1	1/2	2	0.154
AU	1	1	1	1	1/2	2	0.154
OC	2	2	2	2	1	4	0.308
AF	1/2	1/2	1/2	1/2	1/4	1	0.077

Table 8: Paired comparison values relative to the difference of deviation values between two candidate airports

Paired comparison value	Difference of deviation values
1	0-5
3	5-10
5	10-15
7	15-20
9	Over 20

difference of these deviation values between two candidate airports. The weights are listed in Table 9.

4.3 Total weight of the candidate airports

With the weight of the evaluation items obtained so far and the weight of the candidate airports relative to each evaluation item, it is possible to calculate the total weight of the candidate airports. It was obtained as the sum of products of the weight of the evaluation items and the weight of the candidate airports relative to each evaluation item, using Eq. (6).

Figure 6 indicates only the total weight of airport evaluation and Figure 7 only indicates the total weight of layover evaluation. Figure 8 is the total weight of the two evaluations combined. Since the paired comparison of layover with candidate airport was performed with four levels (3, 5, 7, and 9), four patterns of results were obtained for the total weight as well.

From Figure 6 it is possible to note that Haneda Airport obtained the highest score in airport evaluation. On the other hand, from Figure 7 Nanki-Shirahama Airport obtained the highest score in layover evaluation.

Next, let us explain the results of total weight in Figure 8. This figure shows the results after changing the weights of layover evaluation and airport evaluation in four patterns. When the layo-

Table 7: The deviation value of each airport with each evaluation item

	GP	POP	AI	AU	OC	AF	OTT	TRN	FR
Memanbetsu Airport	48.747	52.208	43.659	44.173	52.705	43.271	45.877	49.111	50.000
Hanamaki Airport	43.379	41.275	45.966	44.001	50.452	43.434	56.068	52.936	50.000
Haneda Airport	80.935	73.883	81.290	81.265	45.188	78.697	56.068	57.619	50.000
Shizuoka Airport	48.118	47.727	53.462	44.106	52.362	43.233	29.082	34.672	50.000
Toyama Airport	43.350	40.707	54.230	44.062	52.343	43.128	32.102	23.042	35.280
Osaka International Airport	56.342	61.422	50.913	50.662	53.175	53.716	56.634	52.546	64.720
Kobe Airport	49.325	52.615	45.859	45.176	64.262	44.484	49.085	52.624	50.000
Kansai International Airport	56.342	61.422	50.913	56.060	53.175	56.778	52.860	51.999	50.000
Nanki-Shirahama Airport	42.928	40.433	45.661	43.867	52.594	42.803	62.861	59.961	64.720
Izumo Airport	42.566	39.716	44.436	44.224	53.316	43.479	40.216	46.770	35.280
Hiroshima Airport	46.100	45.445	50.199	45.117	53.248	44.410	56.068	52.936	50.000
Fukuoka Airport	48.709	51.461	45.472	54.264	48.884	56.703	53.803	55.590	35.280
Naha Airport	43.160	41.686	37.939	53.024	18.296	55.864	59.276	60.195	64.720

Table 9: Weight of the candidate airports relative to each evaluation item

	GP	POP	AI	AU	OC	AF	OTT	TRN	FR
Memanbetsu Airport	0.053	0.065	0.028	0.023	0.067	0.023	0.036	0.050	0.053
Hanamaki Airport	0.025	0.019	0.040	0.024	0.067	0.023	0.097	0.050	0.074
Haneda Airport	0.415	0.360	0.415	0.417	0.034	0.420	0.097	0.050	0.114
Shizuoka Airport	0.038	0.045	0.081	0.023	0.067	0.022	0.010	0.050	0.014
Toyama Airport	0.025	0.018	0.087	0.023	0.067	0.023	0.010	0.013	0.009
Osaka International Airport	0.116	0.147	0.069	0.088	0.067	0.088	0.090	0.204	0.074
Kobe Airport	0.053	0.065	0.040	0.024	0.291	0.024	0.049	0.050	0.074
Kansai International Airport	0.116	0.147	0.069	0.102	0.067	0.102	0.079	0.050	0.068
Nanki-Shirahama Airport	0.025	0.017	0.033	0.023	0.067	0.023	0.207	0.204	0.164
Izumo Airport	0.023	0.016	0.031	0.024	0.067	0.024	0.019	0.013	0.035
Hiroshima Airport	0.035	0.024	0.059	0.024	0.067	0.024	0.090	0.050	0.074
Fukuoka Airport	0.053	0.059	0.033	0.102	0.062	0.102	0.080	0.013	0.099
Naha Airport	0.025	0.019	0.015	0.102	0.009	0.102	0.136	0.204	0.150
Consistency index	0.058	0.062	0.056	0.047	0.042	0.038	0.040	0.053	0.053

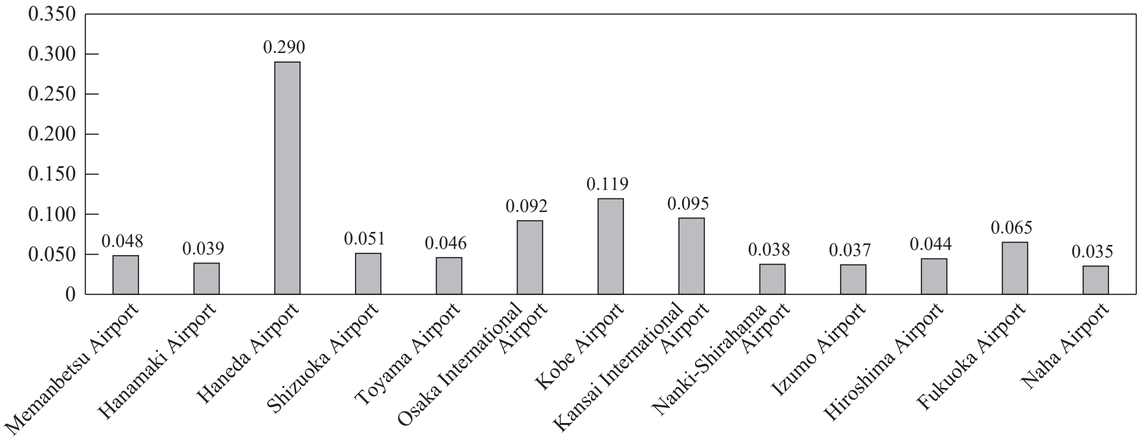

Figure 6: Total weight of airport evaluation

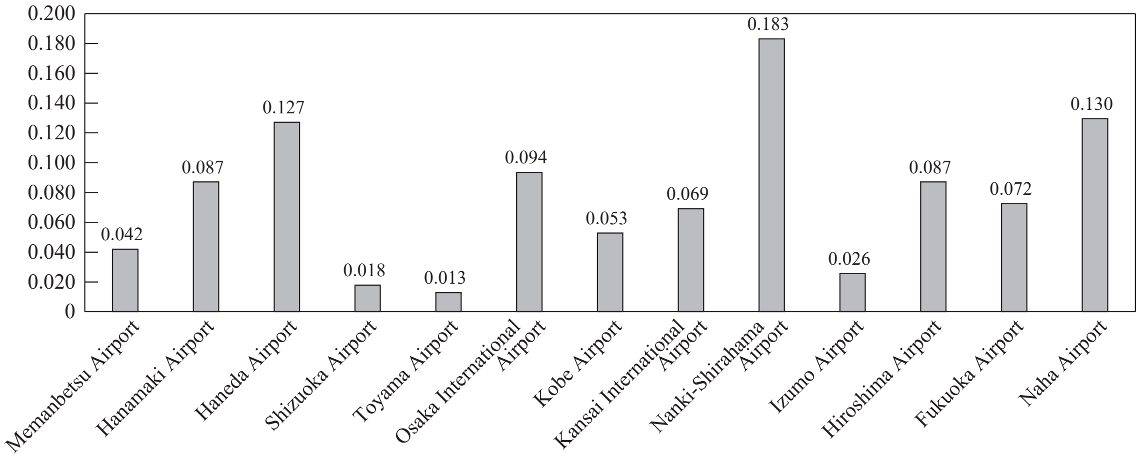

Figure 7: Total weight of layover evaluation

ver evaluation was "More important": 3, Haneda Airport ranks higher than Nanki-Shirahama Airport and Naha Airport. However, when it changed to "Far more important": 5, total weights of Haneda Airport and Nanki-Shirahama Airport became similar. Furthermore, as the importance of layover evaluation increased, Nanki-Shirahama Airport surpassed Haneda Airport and Naha Airport. Then, the layover evaluation was "Extremely important": 9, Nanki-Shirahama Airport was ranked the highest followed by Naha Airport, then Haneda Airport. It can be said that Nanki-Shirahama Airport as a regional airport is attractive in terms of sightseeing during layovers. In other words, Haneda Airport, which is large and located in Tokyo, the capital of Japan, ranks higher in airport evaluation, but when layover is considered, the regional airport of Nanki-Shirahama outranks it. Moreover, in the "Sacred Sites and Pilgrimage Routes in the Kii Mountain Range," the closest world heritage site to Nanki-Shirahama Airport (the highest-ranked regional airport), the Kumano Kodo pilgrimage trail was considered as a layover sightseeing spot and was evaluated with layover evaluation. Because of this, the fact that the one-way trip between the airport and the Kumano Kodo pilgrimage trail is the quickest of all may have been highly valued.

5. Multi-agent simulation for validation

Multi-agent systems consist of multiple interdependent agents. Since each agent is allowed to have different characteristics, it seeks to reproduce the actual conditions of phenomena, even those that are difficult to predict. For this reason, it has been commonly employed in fields that focus on the structure, characteristics, and intelligence of society, such as social science and economics. Nowadays, even evacuation guidance, logistics, and sports are modeled with multi-agent systems.

In this study, a multi-agent simulation was conducted with agents as airplanes and nodes as airports.

5.1 Simulation procedure

Considering the possibility of sightseeing during layovers, the results of total weights shown in Figure 8 are obtained by performing the four patterns of weights between airport evaluation and layover evaluation. In order to check the validity of this results of the total weights, the multi-agent simulation by Monte Carlo method is conducted with the number of arrivals of the multiple agents (airplanes) at the nodes (candidate airports).

The simulation procedure is shown in Figure 9. First, a cu-

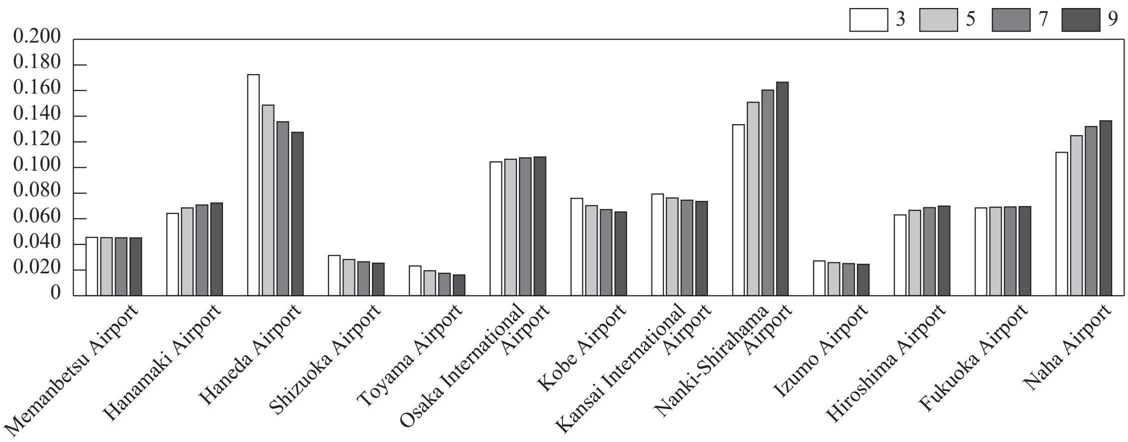

Figure 8: Total weight (overall evaluation)

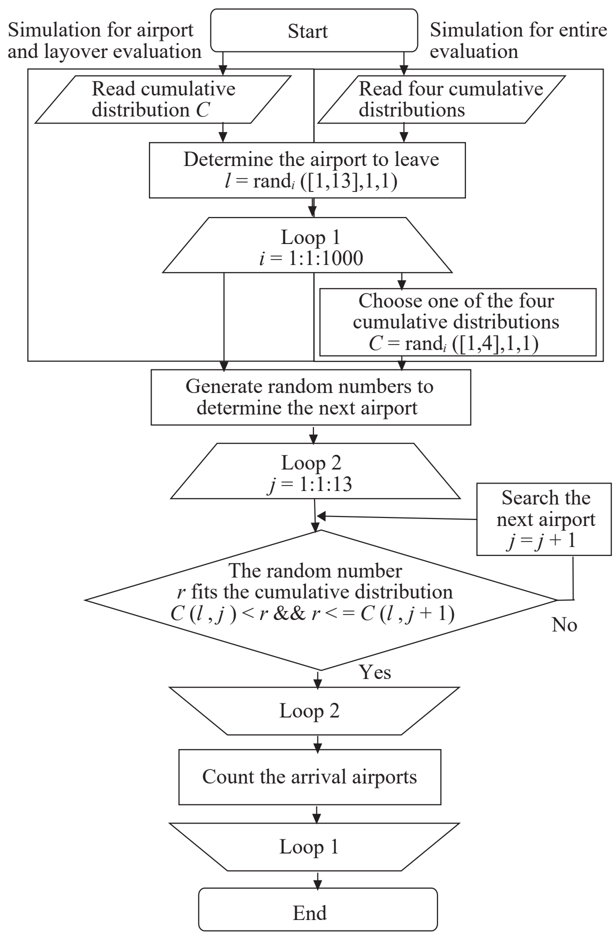

Figure 9: Multi-agent simulation flowchart

mulative distribution of probability of going to each airport was set up by calculating the probability of going to each airport with four patterns of the total weights for candidate airports. This would be an accumulation of probability of going to candidate airports from each of thirteen airports.

To run the simulation, we calculated the probability of going from airport *j* to airport *i*, P_{ij}, from the total weight of airport *k*, w_k, and Eq. (7):

$$P_{ij} = \frac{w_i}{\sum_{k=1}^{13} w_k - w_j} \tag{7}$$

Then, the pattern that we used for this simulation was selected randomly by a uniform random number with the airport of departure from each one of the thirteen airports and one of the four patterns of cumulative distribution. Choosing the pattern randomly can make the multi-agent simulation involve the uncertainty of layover evaluation against airport evaluation, which means that the simulation can involve to what extent the items related to tourism should be considered.

Then, the destination airport was determined based on the probability of arrival. The agents then move from the departure airport. This motion was repeated 1,000 times for each of the five airplanes (agents), and the number of arrivals at each airport was registered. This 1,000-time simulation was repeated 100 times, and 95 % and 99 % confidence intervals for the number of arrivals at each airport were determined. Therefore, the airport with the highest average number of arrivals of the five airplanes registered is determined as the optimal hub airport base considering the uncertainty of the possibility of sightseeing during layovers in this study.

5.2 Simulation result

Table 10 shows the number of arrivals at each airport determined with 95 % and 99 % confidence intervals repeated 100 times. In addition, the average number of arrivals of those five airplanes registered is shown in Figure 10. The average of the four cumulative distribution chosen with a uniform random number was 246 times with a paired comparison value of 3 (More important), 252 times with a value of 5 (Far more important), 236 times with 7 (Very important), and 266 times with 9 (Extremely important).

From Table 10 and Figure 10, the confidence intervals of the number of arrivals at Haneda Airport and Nanki-Shirahama Airport are obtained. The average number of arrivals at Haneda Airport was 139.254, a standard deviation of 9.896, 138.384-140.124 arrivals with a 95 % confidence coefficient and 138.110-140.398 arrivals with a 99 % confidence coefficient. Meanwhile,

Table 10: 95 % and 99 % confidence intervals of the 1,000-time simulation (overall evaluation)

	Average arrivals	Standard deviation	95 % confidence interval		99 % confidence interval	
			Lower value	Upper value	Lower value	Upper value
Memanbetsu Airport	47.496	6.617	46.915	48.077	46.731	48.261
Hanamaki Airport	71.256	7.332	70.612	71.900	70.408	72.104
Haneda Airport	139.254	9.896	138.384	140.124	138.110	140.398
Shizuoka Airport	30.188	5.390	29.714	30.662	29.565	30.811
Toyama Airport	20.702	4.325	20.322	21.082	20.202	21.202
Osaka International Airport	106.142	8.912	105.359	106.925	105.111	107.173
Kobe Airport	71.664	8.209	70.943	72.385	70.715	72.613
Kansai International Airport	77.602	8.195	76.882	78.322	76.654	78.550
Nanki-Shirahama Airport	143.634	8.925	142.850	144.418	142.602	144.666
Izumo Airport	27.892	5.150	27.439	28.345	27.296	28.488
Hiroshima Airport	69.678	7.318	69.035	70.321	68.832	70.524
Fukuoka Airport	71.830	7.675	71.156	72.504	70.943	72.717
Naha Airport	122.662	8.524	121.913	123.411	121.676	123.648

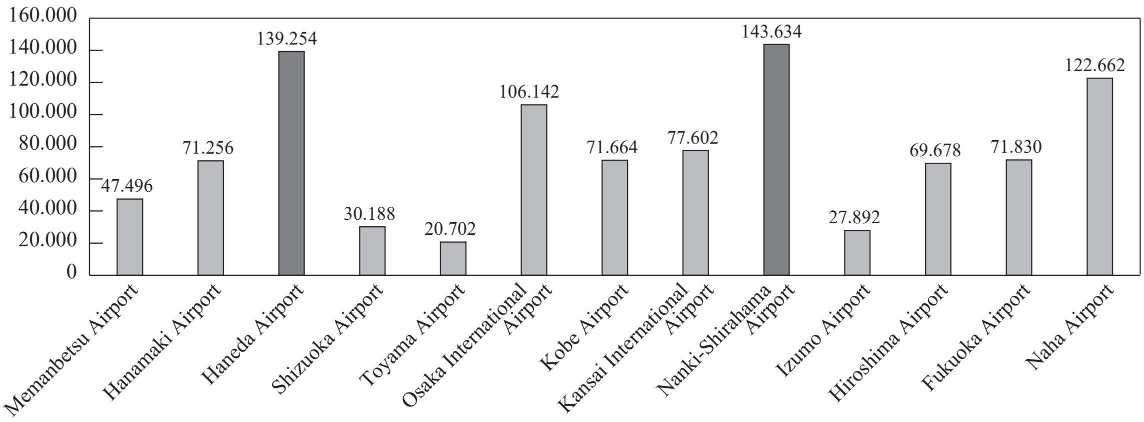

Figure 10: Result of the 1,000-time simulation of the average number of arrivals

the confidence interval of the number of arrivals at Nanki-Shirahama Airport has an average number of arrivals of 143.634, a standard deviation of 8.925, 142.850-144.418 arrivals with a 95 % confidence coefficient, and 142.602-144.666 arrivals with a 99 % confidence coefficient. As a result, the highest number of arrivals was Nanki-Shirahama Airport.

From the above, the comprehensive evaluation, which combines all the airport and layover items, indicates that although by a small difference, confidence intervals of two airports were not overlapped. Therefore, it is possible to conclude that Nanki-Shirahama Airport was chosen as the optimal hub airport base outranking Haneda Airport. This result suggests that by incorporating the added value of "sightseeing during layovers" into route development – instead of evaluating only the current airport conditions –, and considering the uncertainty of its possibility, even regional airports can function as hub airports.

6. Discussion: optimal hub airport bases and world heritage sites

6.1 Nanki-Shirahama Airport

Nanki-Shirahama Airport was founded in 1968 as the aerial entrance of Wakayama prefecture. Because the Nanki region is a treasure house of tourism and resort resources, coupled with the fact that Nanki-Shirahama Airport is located in the central area of Shirahama, one of the most popular touristic sites in Wakayama prefecture, the percentage of tourists among its users is extremely high. Therefore, the airport plays an important role as an access point for industrial, economic and cultural promotion in the Nanki region.

In 1996, the airport was re-inaugurated with a runway with 1,800 meters, and the flights to Tokyo became more convenient when the airplanes switched to jet engines. Further, in 2000, it acquired a 2,000-meter runway with a capacity to receive medium jet aircraft, which enhanced and accelerated the interaction with both domestic and foreign entities. The current airport area is 74.1 ha, with a 2000-meter-long and 45-meter-wide runway and a 2,120-meter-long and 150-meter-wide runway strip, as well as a three-story passenger terminal. The only regular flight at the moment is bound to Haneda Airport operated by Japan Air Lines, but it used to operate regular flights to Osaka International Airport, Nagoya Airport, Yao

Airport, Hiroshima Airport, and Fukuoka Airport. Moreover, an international charter flight by TransAsia Airways between Nanki-Shirahama Airport and Taipei and Hualien in Taiwan was inaugurated in March 2015, and in September of the same year, a charter flight by Fuji Dream Airlines made a round trip to Wakkanai Airport [Wakayama Prefecture, n.d.a].

6.2 World heritage site "Sacred Sites and Pilgrimage Routes in the Kii Mountain Range"

The "Sacred Sites and Pilgrimage Routes in the Kii Mountain Range" were registered as a cultural heritage site in 2004. The fact that the cultural landscape of the Kii Mountain Range is a unique example of exchange and development of religious culture in East Asia, and that shrines and temples are now home to archeological and cultural assets related to lost buildings and religious rites, representing important places for the inheritance of religious culture, was rated highly. The buildings and remains, which are prominent examples of the characteristics of Japan's unique form of worship, and the monasteries and sacred natural objects that remain in the mountains, creating a singular cultural landscape, also contributed.

This is the second "route" registered as a world heritage site after the pilgrimage route to Santiago de Compostela, which extends over Spain and France. The registered region has an area of 506.4 ha of assets, 12,100 ha of a buffer zone that protects those assets, and a total of 347.7 km of registered pilgrimage trails. It consists of a group of heritage sites that span the prefectures of Wakayama, Nara, and Mie [Wakayama Prefecture, n.d.b]. Of these, the Kumano Kodo pilgrimage trail was considered in this study because it is the closest tourism spot from Nanki-Shirahama Airport.

7. Conclusion

The purpose of this study was to build an LCC network that can allow regional airports to function as hubs. To this end, we proposed using long layovers between flights for tourism and applied the AHP and multi-agent simulation to derive the optimal hub airport base. The utilization rate of LCCs is particularly high among foreign visitors to Japan in their 20s and 30s. Stimulating foreign visitors to Japan to go to the countryside and thereby revitalize the region is an important initiative to promote tourism into the country. In this study, we assumed that, if foreigners could use the layover time to visit world heritage sites, it would be the best way for them to discover the beauty of Japan's interior. Therefore, we proposed a method to determine the optimal hub airport base for that purpose.

The items in the AHP were designed to evaluate the airports themselves and the possibility of sightseeing during layovers we proposed. Therefore, we gradually increased the level of importance of the layover evaluation items and calculated four patterns of weight. As a result, the Haneda Airport and Nanki-Shirahama Airport were the highest-ranked airports in airport evaluation and layover evaluation, respectively. In the evaluation that combined these two elements, the regional airport of Nanki-Shirahama became even more predominant as the level of importance of the layover evaluation items was raised.

To make a comprehensive evaluation of the multiple results of AHP, we observed the number of arrivals of the agents (airplanes) at the nodes (airports) and thereby determined the optimal hub airport base. As a result, although the difference was small, the number of arrivals at the regional airport of Nanki-Shirahama surpassed that at the Haneda Airport, becoming the optimal hub airport base. Therefore, this result indicates that, if the added value of sightseeing during layovers is incorporated into the development of routes, even regional airports can function as hub airports. With this, passengers may begin to prefer longer layovers as a time that can be used for tourism. Furthermore, if regional airports become bases, it is possible that the entire area around those airports is revitalized.

In the simulation conducted in this study, if the impact of the hub airport is factored in by changing the operating costs, the number of passengers, and the airport size, it may be possible to build a more realistic aviation network, but the method to determine the paired comparison values between the evaluation items needs to be improved even further.

In the tourism department, the MLIT has promoted the policy of "Regional Airport In/Regional Airport Out," which aims at stimulating the inauguration of international lines in regional airports and revitalizing inbound tourism. It stresses the importance of attracting tourists to visit not only the so-called golden routes but also the countryside more than once [MLIT, n.d.e]. Regional revitalization through local development is possible with the presence of foreign visitors. We believe that the technique proposed in this study can help boost provincial economies. As a next step, we plan to study the potential of other regional airports to function as hub airports, considering tourism spots other than the world heritage sites picked in this study. The possibility that regional airports can work as hub airports is essential for promoting tourism.

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(Received March 26, 2020; accepted April 20, 2020)