A STUDY OF OPTIMIZATION OF EXCURSION TRAVELER BEHAVIOR USING CAR-SHARING IN REGIONAL AREAS

IDA, Naoto
Associate Professor & Dr. of Engineering
Department of Civil and Environmental Engineering
Hokkaido Institute of Technology
Address: 7-15-4-1, Maeda, Teine-ku, Sapporo 006-8585, JAPAN
TEL: +81-11-688-2280
E-mail: idanaoto@hit.ac.jp

SUZUKI, Yuji
Division of Civil Engineering and Architecture
Muroran Institute of Technology
Address: 27-1, Mizumoto, Muroran, Hokkaido 050-8585, JAPAN
TELEFAX: +81-143-46-5289
E-mail: 10051019@mmm.muroran-it.ac.jp

TAMURA, Tohru
Professor & Dr. of Engineering
Department of Civil Engineering and Architecture
Muroran Institute of Technology
Address: 27-1, Mizumoto, Muroran, Hokkaido 050-8585, JAPAN
TEL: +81-143-46-5287
FAX: +81-143-46-5288
E-mail: tamura@mmm.muroran-it.ac.jp

ABSTRACT

In Japan, regional areas are faced with problems in transportation policy making, a declining birth rate and an aging population. These problems have serious consequences on the sustainability of public transportation operation. The purpose of this study was to investigate the conditions for the introduction of car-share systems in these regions. A tourist area was used in this study where there are expected more car-share users. This study was able to clarify two points: first, a multi-station car-share system could be introduced to sightseeing activities in local tourist areas; second, effective vehicle operation was required to maximize tourist utility. Moreover, tourists' cooperativeness brought higher utility to themselves.

Keywords: traveler behavior, car-share system, multi-agent simulation

1. INTRODUCTION

In Japan, the society is aging and the birth rate is declining, and has entered a period of long-term population decline. One of the problems that will result from the effects of these issues will be the difficulty in maintaining public transportation operations. More specifically, it will be much harder for operators to ensure stable revenues as the number of people regularly using public transportation for their commute to and from work or school decreases. The loss of stable revenue could, in turn, lead to cases in which public transportation operators decrease their level of service, cut back on the number of routes, or decide to withdraw from certain businesses altogether. Generally speaking, one solution to this problem is the use of demand responsive transport systems. Reviews of transportation systems beyond the framework of public and private transportation will also be necessary.

From this perspective, our focus here is on a car-share system, a practice, that in recent years, has been introduced into many areas of Japan. In a car-share system, a single vehicle is shared by a number of people, and we have actually seen an increase in the number of car-share users in many urban areas. The expensive and unavoidable cost such as taxes and insurance leads to increasing car-share users. On the other hand, one reason why it has not made much headway into regional areas may be the difficulty in finding a sufficient number of users.

The purpose of this study was to investigate conditions for the introduction of a car-share system into regions where public transportation services were declining or non-existent. A tourist area was focused on this study to where there expected more car-share users. The study included as following three points: 1) modelling of sightseeing excursions using a car-share system with a multi-agent simulation; 2) clarification of issues the occur in sightseeing excursions using a car-share system; and 3) investigation of conditions such as levels of service that are needed to introduce a car-share system.

2. TRANSPORTATION PROBLEMS IN REGIONAL AREAS IN JAPAN AND THE FRAMEWORK OF THIS STUDY

2.1 Problems

The problems faced by Japan's public transportation services are described below. First, the population of the country is aging at a rate that is unparalleled worldwide (see Table 1). This means that in the long-term, demand for regular transportation, such as that for commuting to work and school, will fall. Second, a long-term decline of the population has already started; meaning that the transportation market itself is shrinking. Due to such changes in the social fabric, it is becoming increasingly difficult for public transportation operators to carry on depending on passenger fares alone. Even populous urban areas have recently seen a contraction of services for or termination of unprofitable routes. Needless to say, maintaining transportation services in regional areas that suffer from depopulation is extremely difficult because of declining transportation demand caused by the shrinking population in addition to the continuing decline in demand for public transportation due to the proliferation of private car ownership. As a result, there are many areas with no public transportation services or with services that are not fully satisfied the needs of users. However, in the super-aging society Japan seems destined to become, vibrant communities will not be created with a mobility system that assumes car ownership. Additionally in such a society, people may not be able to access life-related services such as shopping and medical care. Figure 1 shows the state of transportation demand and framework in regional areas.

Table 1 – Top aging rate countries in the world

Rank	1950		2010		2050	
	Country / Area	Rate (%)	Country / Area	Rate (%)	Country / Area	Rate (%)
1	France	11.39	**Japan**	**22.57**	**Japan**	**37.84**
2	Latvia	11.18	Germany	20.47	Republic of Korea	34.20
3	Belgium	11.01	Italy	20.44	Italy	33.25
4	United Kingdom	10.73	Sweden	18.32	Singapore	32.59
5	Ireland	10.68	Greece	18.32	Hong Kong SAR	32.58
⁞	⁞	⁞				
57	**Japan**	**4.93**				

(Source: National Institute of Population and Social Security Research. (2010))

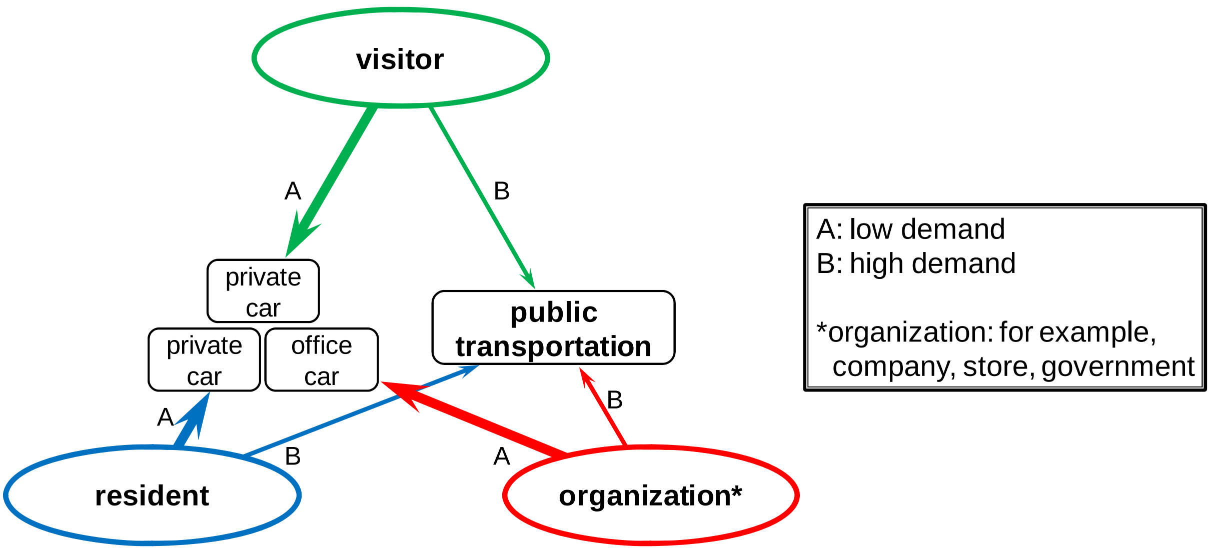

Figure 1 – State of transportation demand and framework in regional areas

In Japan, many researchers have studied new methods for providing public transportation services, such as shared taxis and community buses. Some research findings have already been put into practical use in areas with transportation problems. However, in the long-term, it will not be possible to solve all related problems with the currently proposed measures alone. Accordingly, we need to examine the possibility of providing new transportation services. Specifically, assuming that the current trend of population decline continues, it is easy to imagine that existing public transportation services based on mass or medium-capacity transportation will not be sustainable; with this in mind, we need to come up with a new transportation-service framework that provides mobility to the masses, including people without cars.

2.2 New Transportation-service Framework

2.2.1 Requirements of a New Transportation Service

There are three main requirements of a new transportation service: 1) it should flexibly deal with demand over wide areas and timeframes, and should be reasonably priced; 2) it should be profitable in areas with low transportation demand; and 3) it should effectively utilize existing local resources.

As for 1), existing public transportation systems assume high transportation demand. With current demand having fallen below the profitability line in many areas, transportation services are increasingly difficult to sustain. On the other hand, from the viewpoint of providing a means of transportation for daily use, it is desirable that service fees do not exceed their current levels.

As for 2), there is little prospect of seeing significant recovery in transportation demand in local areas; the current downward trend is likely to continue. Systems therefore need to be flexible enough to accommodate further demand decline in the future.

As for 3), current financial conditions will not allow the introduction of new transportation systems in regional areas, and any solution will need to leverage existing resources as much as possible. Also, initial investment can be reduced by using existing resources, which in turn will help to keep service fees low.

2.2.2 Investigation of a New Transportation System

A car-share system is a transportation system that satisfies the three requirements discussed in section 2.2.1 (Japan Institute of Design.(2004)). First started by students in Switzerland in 1987, it is an arrangement in which multiple users share single vehicles. In 2009, car sharing was widespread in Western countries, and the number of current users is thought to be around 650,000 (Ichimaru, S.(2009)).

In Japan, the Ministry of International Trade and Industry (now the Ministry of Economy, Trade and Industry) conducted a demonstration experiment on a car-share system in 1999. In July 2006, the Ministry of Land, Infrastructure, Transport and Tourism revised the Road Trucking Vehicle Law and other legislation to legally permit unattended lending of vehicles. With this as a turning point, the car-share market grew rapidly. However, car-share services tend to be concentrated in urban areas where a certain degree of demand can be expected, and few have been established in regional areas thus far.

The term “car sharing” has not been legally defined in Japan. Currently, regulations similar to a car rental business are applied to car sharing, which has hindered the car-share businesses from developing strategies to capitalize on the system’s unique advantages. The number of car-share users in Japan in 2009 was slightly less than 6,500 (Ichimaru, S.(2009)).

In regional areas, where the ratio of car ownership is high, it is very important to keep door-to-door mobility—the biggest advantage of owning private cars—to win users. We selected a car-share system as this research subject because it is a new transportation system that does not significantly compromise this advantage.

2.2.3 Transportation Model for Car-share Introduction

The biggest problem in introducing car-share systems to regional areas is profitability. The smaller populations found there implies that economies of scale cannot be expected at a local level, and the reduction of car ownership costs—the biggest advantage of car sharing—would not be as great as in urban areas. As a result, demand for a car-share system will remain low, which further deprives the system of economies of scale, thereby making it difficult to promote the switch from private cars to a car-share system. It is therefore necessary to make up the demand shortage with people coming from other areas in order to ensure the benefits of scale that are enjoyed in urban areas. This study attempted to model such a system.

Figure 2 shows the model framework which we suggest. We assumed a study area in which public transportation services do not provide intra-transportation but do provide intercity transportation. We also assumed that the area has local industries, such as tourism, that can attract a certain number of visitors from outside.

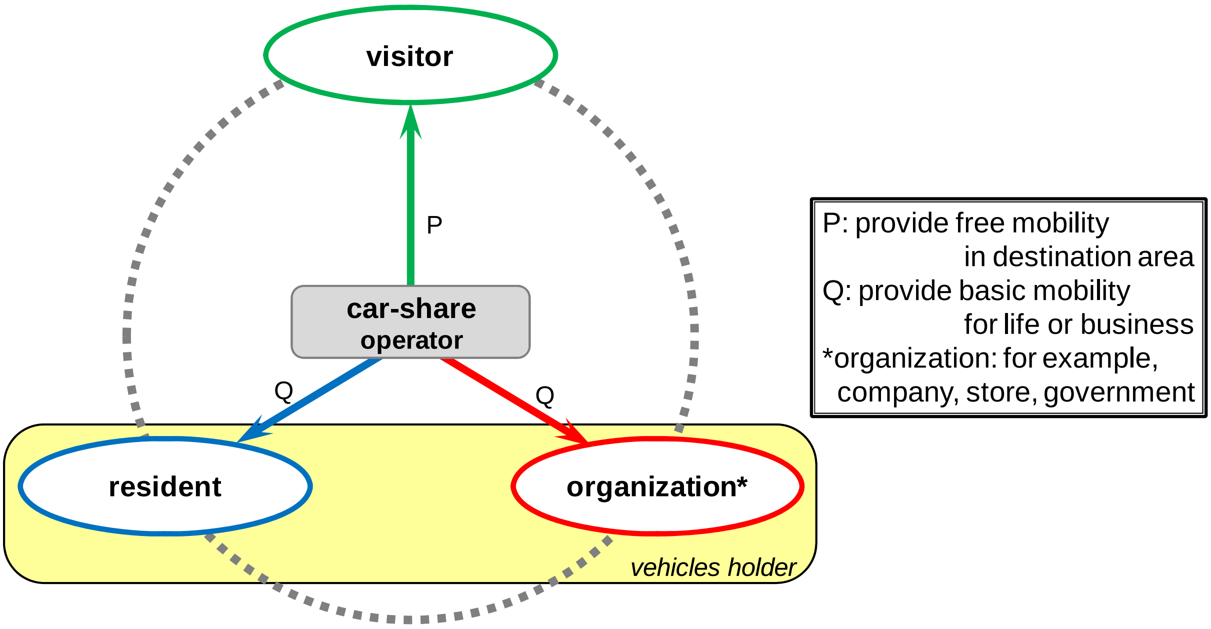

Figure 2 – Transportation model framework after introduced car-share system

Recently, a market has been established in which car owners can lend out their vehicles when they are not using them. In this study, we explored ways to share existing cars owned by local residents and organizations, such as companies, stores and government, with visitors while ensuring and improving the mobility of local residents. In Japan, reliance on cars is particularly high in regional areas (see Figure 3(a) and Figure 3(b)), where many people and companies own private vehicles. Utilizing these cars does not require much initial investment and allows the establishment of a new low-cost transportation system. We also discuss the question of what types of car-share system are appropriate for the new transportation model described above.

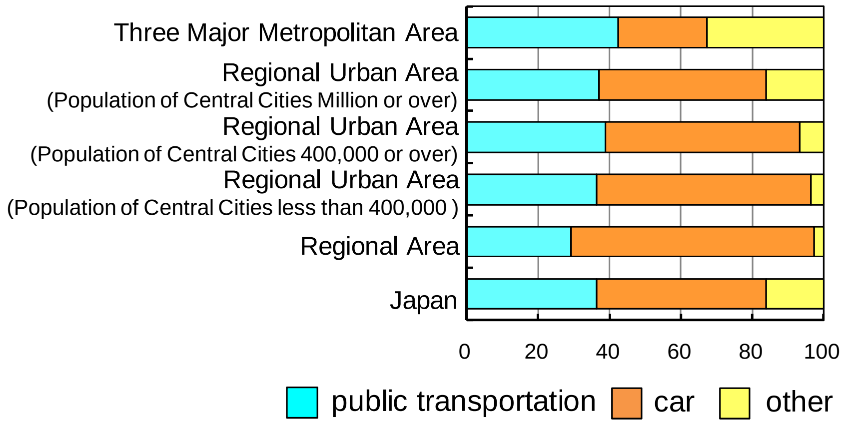

Figure 3(a) – Comparison of modal split of urban and local areas in Japan (weekdays)
(Source: Urban Transportation Planning Office, City Planning Division, City and Regional Development Bureau, Ministry of Land, Infrastructure and Transport of Japan. (2007))

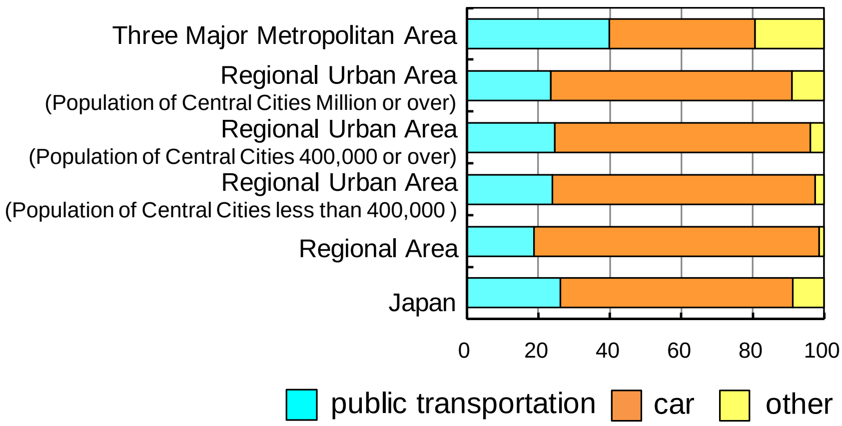

Figure 3(b) – Comparison of modal split of urban and local areas in Japan (weekends and holidays)
(Source: Urban Transportation Planning Office, City Planning Division, City and Regional Development Bureau, Ministry of Land, Infrastructure and Transport of Japan. (2007))

For this purpose, we constructed a transportation model using multi-agent simulation (Ueda, I.(2007)). There are two reasons for using multi-agent simulation:

- In order to share cars provided by local residents and organizations with other residents and visitors, coordination with owners' schedules is necessary. To make this car-share system function well, it is necessary to determine the types of transportation behavior that are desirable in agents participating in this framework. Accordingly, we chose a model that can describe and analyze the interactions of multiple agents.
- It is necessary to describe environments influenced by the behavior of the agents involved in car sharing (e.g., information on congestion in tourist areas and waiting time for available cars) and changes in the behavior of agents in response to environmental changes, thereby establishing a reinforcement learning model in which the system itself determines effective vehicle operation.

3. STUDY FIELD

3.1 Outline of Hokkaido

Hokkaido is the northernmost of Japan's four main islands (Figure 4). Situated approximately 800 km north of *Tokyo*, the country's capital, it has an area of 83,456 km^2 (22.1% of the nation's total area) and a population of 5,628,000 (4.4% of the nation's total population in 2005). A large proportion of people there are employed in primary industries such as agriculture and tertiary industries such as tourism. The prefecture is situated in the subarctic region, and the whole of its area is snowy and cold. It has a rich a natural environment, including "*Shiretoko*" (a World Natural Heritage site), "*Kushiro Wetland*" (a Ramsar Convention site) and the "*Toya Caldera and Usu Volcano Geopark*" (a UNESCO Global Geoparks Network site). Tourist spots are dotted around the prefecture, where a wide range of events based on the region's snow and low temperatures are actively held. Recently, the number of tourists coming from East Asia and Australia as well as from other prefectures has increased.

Next, transportation in *Hokkaido* is described. By land, the only connection between *Hokkaido* and *Honshu* (Japan's mainland region) is underwater by rail through the "*Seikan Tunnel*." Because of this, most travelers use airplanes or ferries for inter-prefecture transportation. Figure 4 shows expressways and railways networks, airports with regular flights and ports with regular ferries. Figure 5 shows transportation mode shares in inter- and intra-prefectural transportation. It can be seen that transportation within *Hokkaido* depends heavily on car usage.

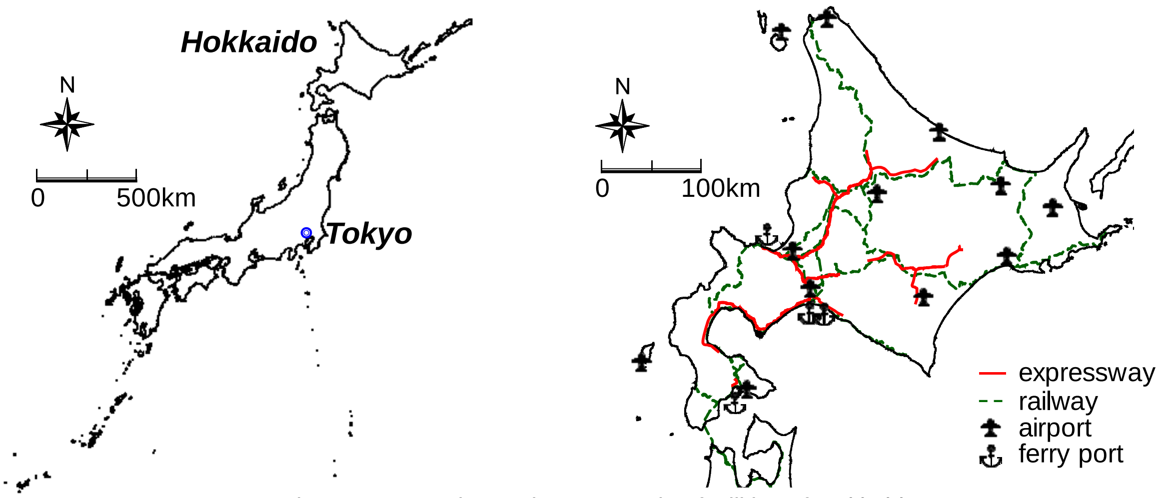

Figure 4 – Location and transportation facilities of *Hokkaido*

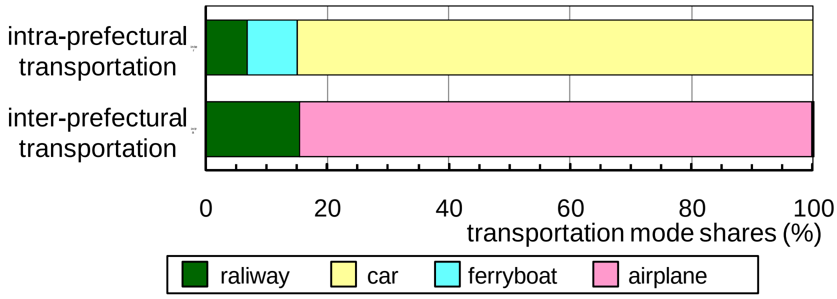

Figure 5 – Transportation mode shares in inter- and intra-prefectural transportation

(Source: Hokkaido District Transport Bureau, 2010)

3.2 Outline of Tourism in Hokkaido

The number of tourists visiting places in *Hokkaido* in 2007 was 49.58 million, which breaks down as 43.09 million from inside the prefecture (86.6% of the total) and 6.49 million from outside it (13.4%). Figure 6 shows the extent of tourism by municipality. It can be seen that sightseeing bases are spread across the prefecture.

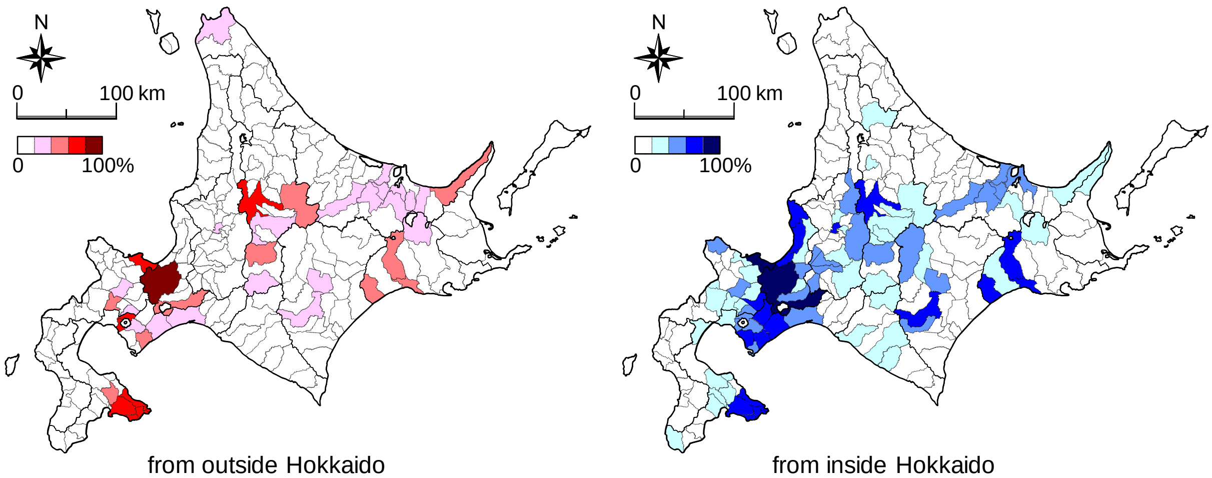

Figure 6 – Percentile of tourists by municipality in *Hokkaido*

(Source: Bureau of Tourism, Department of Economic Affairs, Hokkaido Government (2009))

Travel styles have become diversified, and tourists now increasingly prefer family and individual tours to group outings. Tourists' interests are also shifting from famous scenic spots to experience- or participation-based travel.

3.3 Transportation Problems Arising during Travel in Hokkaido

Even if intercity public transportation to access a particular tourist area is available, mobility within the area is often limited due to the continued decline of public transportation in local regions. For this reason, many tourists use their own cars or rented vehicles.

Urban areas of *Hokkaido* are widely dispersed, and the region is characterized by its long intercity distances. This means that, regardless of travel purposes, travel distances are longer than those in other prefectures. Although relatively smooth road traffic conditions are maintained during the snowy season, driving carries risks. Needless to say, long-distance driving by tourists who are often not used to local traffic is not safe. From an environmental viewpoint too, it is desirable to keep driving to a minimum.

Introduction of the transportation system we propose in this study to regional tourist areas will help solve these problems. First, by using existing public transportation networks, tourists are freed from the need to drive themselves. Additionally, by providing tourists with a means of transportation within sightseeing areas through a car-share system, a modal shift to intercity public transportation can be promoted while maintaining the advantages of cars as a flexible mode of transport.

4. CONSTRUCTION OF A SIGHTSEEING-PATTERN SIMULATION MODEL FOR LOCAL TOURIST AREAS

4.1 Outline of the Simulation Model

In this study, within the framework of the transportation model discussed in Chapter 2, we modelled the application of a car-share system to transportation in a regional tourist area. Using this mode, the relationship between sightseeing behavior chosen by tourists and vehicle operation was analyzed. The model was constructed with focus on the following points:

- Tourists can freely create their own sightseeing schedules.
- Tourists change their sightseeing schedules in response to problems that may arise during sightseeing activities (in this study, the term “problems” refers to tourists not being able to use car-share vehicles as planned).
- Car-share operators can make decisions in vehicle operation as appropriate in response to tourist-related transportation demand.

In this study, the purposes of introducing a car-share system to regional areas are the following three points: 1) to increase demand for transportation systems in the areas, 2) to increase demand for intercity public transportation, and 3) to reduce the physical and mental burdens of travelers. To this end, we constructed a simulation model for a hypothetical tourist area in which public transportation from other areas is available. The details of the model are discussed below.

4.2 Spatial Setting

Figure 7 shows the simulation model space. In this space, an intercity public transportation terminal is positioned at the center. Six sightseeing points are located in a concentric pattern around the terminal, and the terminal and all sightseeing points have a check-in/check-out station for car sharing. Tourists can use the car-share service for any section of their choice, and can reach sightseeing points only by using the straight roads that connected from the terminal to the points. Congestion during transportation is ignored, and the time taken is constant (10 steps). The sightseeing points are identical in quality, and there is no difference in the sightseeing utility that tourists obtain from each one. In this simulation, the sightseeing time that tourists can spend in a day is 500 steps.

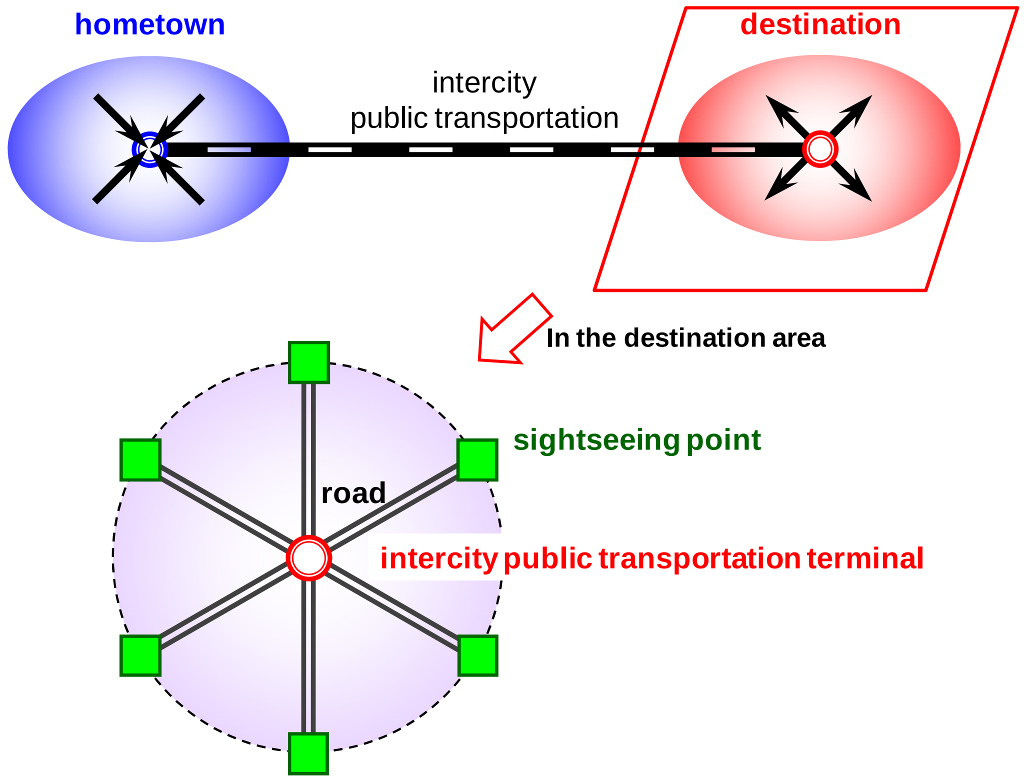

Figure 7 – Hypothetical space of the simulation model

4.3 Tourist Setting

The number of tourist groups visiting this area is 75 per day. All tourists arrive at the terminal by intercity public transportation and tour the sightseeing points using car-share vehicles. The tourists return car-share vehicles to a car-share station at a destination sightseeing point. After touring the points, they come back to the terminal and return to home using intercity public transportation. All of their trips are one day in duration, and travelers visit all sightseeing points where possible. Car sharing is the only means of transportation within the area.

All tourists are homogeneous, and visit the points in random order. The time they spend at each point is constant (40 steps), and if no cars are available when they have finished at a point, they wait until one becomes available. If there are several people waiting for cars at the same point, vehicles are assigned to those who have been waiting longer.

4.4 Car-relocation Setting

When unused cars become available at a sightseeing point and other points need them, the vehicles are relocated to these points for efficient operation.

Relocation of unused cars between the terminal and a tourist point takes 10 steps – the same number required for the transportation of tourists. Relocation is performed by employees of the car-share operator. Since this study does not consider the number of employees, it is assumed that relocation is performed immediately as appropriate.

4.5 Decision-making Rules for Agents

4.5.1 Tourists

Tourists leave the terminal for home if they have met at least one of the conditions below:
- They have fished the trip as planned.
- They will not able to go home within the day if they visit the next sightseeing point.
- They have been waiting at a sightseeing point so long that the utility of sightseeing will not exceed the disutility of waiting.

Tourists obtain the sightseeing utility from visiting the sightseeing points U_s (equation (1)). The disutility of waiting at a station until cars become available is $\sum_i U_{w,i}$ (equation (2)). The disutility of remainders U_r is determined at the end of day if tourists are made to remain this area and finally cannot leave the terminal for home (equation (8)). The overall utility of sightseeing is U (equation (9)).

$$U_s = 25m \quad \cdots \quad (1)$$

Where m : number of points visited

$$\sum_i U_{w,i} = \sum_i \left[U_{w,i}' \times \prod_i \frac{U_{w,\min,i}}{U_{w,\min,1}} \right] \quad \cdots \quad (2)$$

$$U_{w,i}' = -\exp(\alpha \beta_i t_{w,i}) + 1 \quad \cdots \quad (3)$$

Where $U_{w,i}'$: disutility of waiting at the i th wait

α is defined as the level of tourists' tolerance to waiting. It is constant for all tourists in this study. β is the coefficient determined by equations (4)–(7). It is shown that the maximum permissible limit for waiting is reduced whenever tourists wait at any station.

$$\beta_i = \ln(1 - U_{w,\min,i}) \times (\alpha \cdot t_{w,\max,i})^{-1} \quad \cdots \quad (4)$$

$$\beta_1 = 1 \quad \cdots \quad (5)$$

Where β_i : maximum permissible coefficient at the i th wait

$U_{w,\min,i}$: lower limit of waiting disutility at the i th wait (equation (6))

$t_{w,\max,i}$: upper limit of waiting time at the i th wait (equation (7))

$$U_{w,\min,i} = U_{w,\min,1} - U_{w,i}' \quad \cdots \quad (6)$$

Where $U_{w,\min,1}$: early-stage lower limit of waiting disutility and a constant determined by the timing and distribution of generation

$$t_{w,\max,i} = \ln(1 - U_{w,\min,i}) \times (\alpha \cdot \beta_{i-1})^{-1} \quad \cdots \quad (7)$$

$$U_r = -\max(U_s) \quad \cdots \quad (8)$$

$$U = U_s + \sum_i U_{w,i} + U_r \quad \cdots \quad (9)$$

4.5.2 Car relocation

Relocated cars are created based on the uneven distribution of tourist demand for them. More specifically, cars are sent from Station j, which has low demand for cars, and the greatest number of surplus vehicles is sent to Station i, with its high demand for cars and its longest total waiting time $T_{w,i}$. This total waiting time is defined by equation (10), and the number of surplus cars $N_{e,j}$ is defined by equation (11):

$$T_{w,i} = \sum_{k=1}^{n} t_{w,k} \quad \cdots \quad (10)$$

$$N_{e,j} = (N_{v,i} + N_{c,i} + N_{o,i}) - N_{p,i} \quad \cdots \quad (11)$$

Where $t_{w,k}$: waiting time of the tourist k at Station i

k : index number of tourist waiting at Station i

n : number of tourists waiting at Station i

$N_{v,i}$: number of tourists staying or waiting at Station i

$N_{c,i}$: number of tourists driving to Station i

$N_{o,i}$: number of cars being relocated to Station i

$N_{p,i}$: number of cars parked at Station i

5. ANALYSIS USING THE SIGHTSEEING SIMULATION MODEL

5.1 Analysis-case Setting

In this study, to investigate ways of efficiently operating car-share vehicles, hypothetical cases were analyzed in terms of 1) vehicle operation methods, 2) demand fluctuation at peak times, and 3) tourists' cooperativeness with vehicle operation.

5.1.1 Vehicle operation method

As ways of efficiently relocating cars as required in the multi-station car-share system, two cases were examined. In the first case, the number of cars that need to be added and the total tourist waiting time were calculated for all stations. As the result, the origin and destination stations of relocated cars and the number of such cars were determined. In the second case, cars were not relocated between stations in principle. However those returned to the terminal at the end of sightseeing were relocated. The effectiveness of car allocation could be examined by comparing these two cases.

5.1.2 Demand fluctuation at peak times

Transportation demand in tourism is generally irregular and tends to fluctuate greatly. In order to examine the extent to which the car-share system can accommodate demand fluctuation at peak times, two cases were therefore examined. In the first case, the number of tourists arriving at the terminal in the early steps of the day was high, and thereafter gradually decreased (triangular distribution) (Figure 8). In the second case, a constant number of tourists arrived at the terminal throughout the day (rectangular distribution) (Figure 9). By comparing these cases, the level of tourism demand suitable for a car-share system could be determined, and the ability of the system to deal with demand fluctuations could be examined.

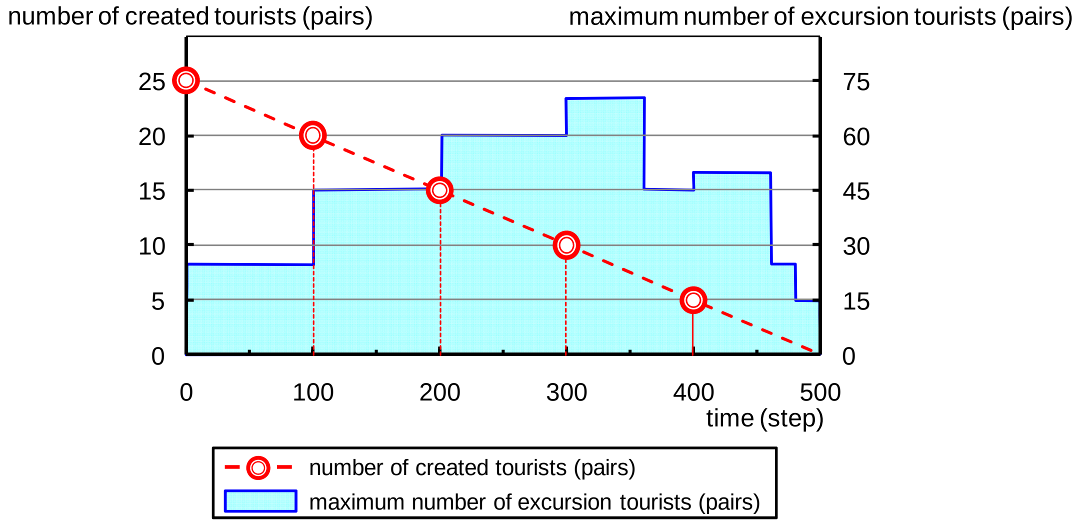

Figure 8 – Creation distribution and the maximum number of excursion tourists (triangular distribution)

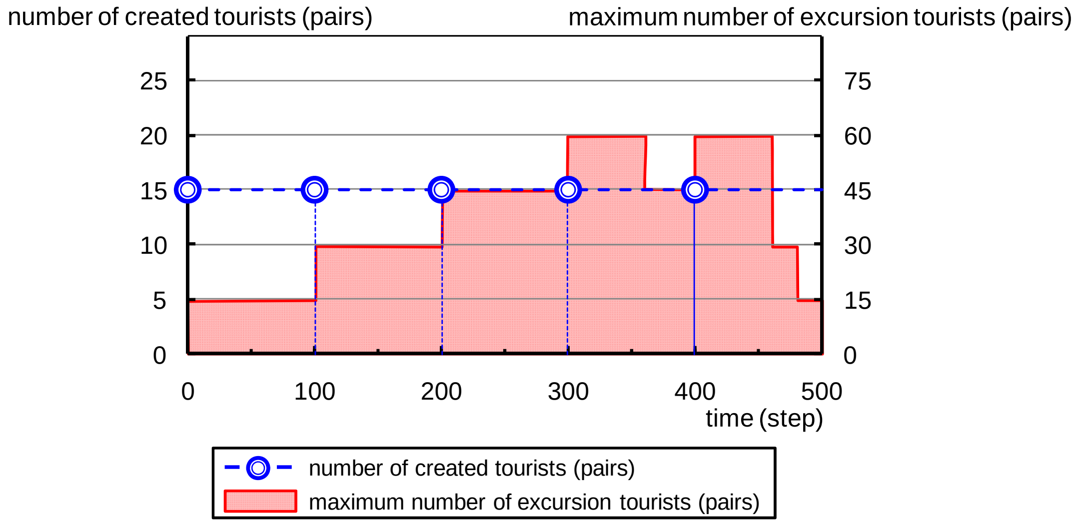

Figure 9 – Creation distribution and the maximum number of excursion tourists (rectangular distribution)

5.1.3 Tourists' cooperativeness with vehicle operation

We examined whether the cooperation of tourists using car sharing with vehicle operation would lead to efficient operation. In this study, by assuming that the maximum permissible limit of tourists in terms of vehicle waiting time is equivalent to their willingness to cooperate, the following three cases were examined: 1) the group exhibited the lowest maximum permissible limit and rarely cooperate with vehicle operation; 2) the group exhibited the highest maximum permissible limit and most cooperated with vehicle operation; and 3) the group exhibited intermediate levels of the maximum permissible limit and cooperativeness between the above two cases. By comparing these cases, the effects of tourists' behavioral changes on vehicle operation in car sharing could be analyzed.

5.2 Results And Discussion

Simulation was carried out for the 12 cases described in 5.1 (see Table 2). For each case, the number of cars used was increased from 0 to 75, and for each number, simulation was carried out 50 times to obtain an average. The results of analysed are explained in this paper by the numbered cases in Table 2.

Table 2 – Simulated and analyzed cases

Case No.	Creation Distribution of Tourists	Tourists' Cooperativeness	Car Relocation System
1	Triangular	MIDDLE cooperative	NON-implementation
2	Rectangular	MIDDLE cooperative	NON-implementation
3	Triangular	MIDDLE cooperative	implementation
4	Rectangular	MIDDLE cooperative	implementation
5	Triangular	MORE cooperative	NON-implementation
6	Rectangular	MORE cooperative	NON-implementation
7	Triangular	MORE cooperative	implementation
8	Rectangular	MORE cooperative	implementation
9	Triangular	LESS cooperative	NON-implementation
10	Rectangular	LESS cooperative	NON-implementation
11	Triangular	LESS cooperative	implementation
12	Rectangular	LESS cooperative	implementation

5.2.1 Relationship between the number of cars and tourist utility

The relationships between the number of cars and the utility tourists obtain from sightseeing, the disutility of waiting for available cars, the disutility of remainders and the sum of the three (the overall utility) are shown below. There are four patterns depending on the creation distribution of tourists and the implementation/non-implementation of car relocation (Figures 10–13). The number of cars necessary to obtain the maximum utility was lower in rectangular distribution regardless of the implementation of relocation. Also, both the utility of sightseeing and the disutility of waiting increased with the implementation of car relocation regardless of the creation distribution of tourists, thereby increasing their overall utility.

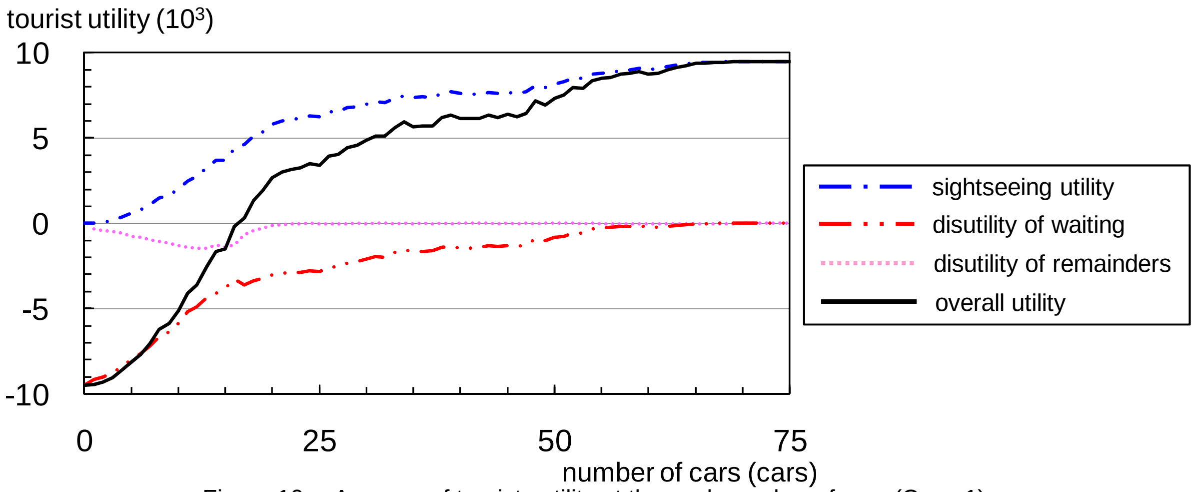

Figure 10 – Average of tourists utility at the each number of cars (Case 1)

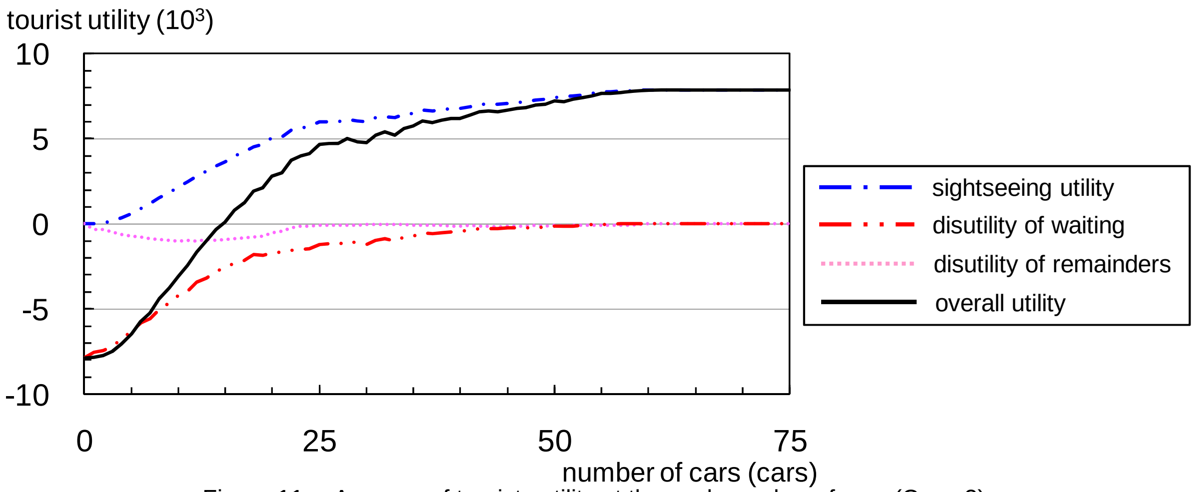

Figure 11 – Average of tourists utility at the each number of cars (Case 2)

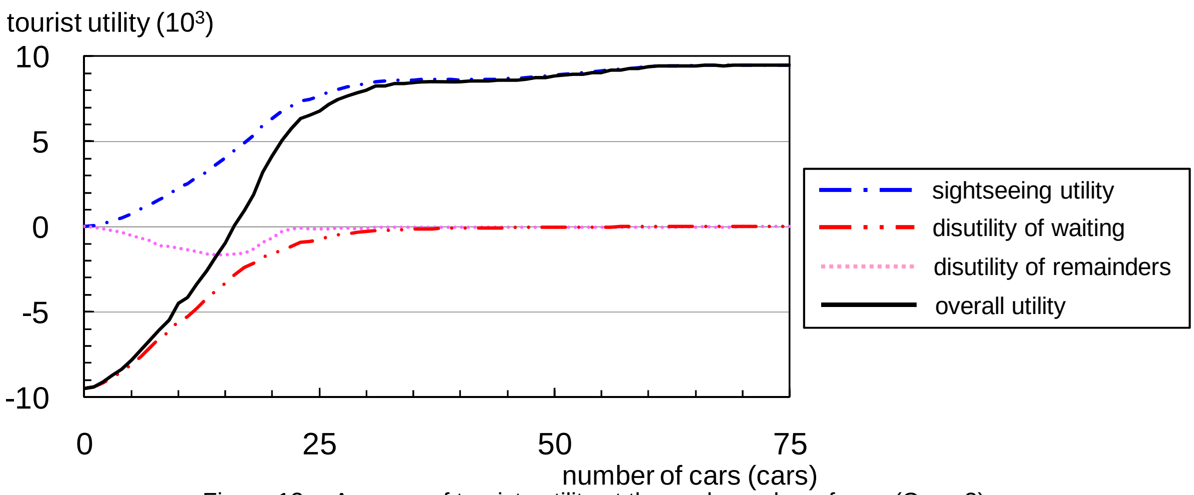

Figure 12 – Average of tourists utility at the each number of cars (Case 3)

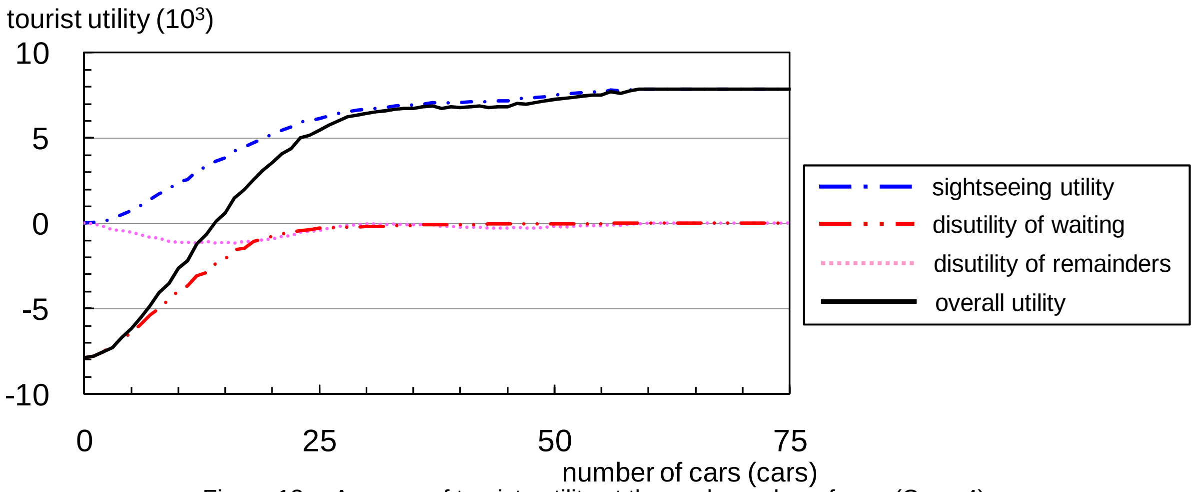

Figure 13 – Average of tourists utility at the each number of cars (Case 4)

5.2.2 Relationship between the number of cars and the composition of tourists by day-end satisfaction level

Levels of tourist satisfaction after sightseeing were determined by grouping them into one of the following four categories: 1) “Completed excursion tourist” (those who had visited all the sightseeing points planned); 2) “Not completed excursion tourist” (those who had visited some of the sightseeing points planned); 3) “Dissatisfied tourist” (those for whom the time spent waiting for available cars exceeded their tolerance limit); and 4) “Remainder” (those who could not return to the terminal at the end of the day).

In the same way as with utility, there are four patterns depending on the creation distribution of tourists and the implementation/non-implementation of car relocation (Figures 14–17). When the number of cars was low, the day-end satisfaction level of tourists was higher in rectangular distribution. On the other hand, when the number of cars was high, the level was higher in triangular distribution, where “Dissatisfied tourist” and “Remainder” evaluations were absent. These differences were due to the concentration of demand. In triangular distribution, the maximum demand for the day occurred in the early steps, and subsequent accumulation of demand was slow. However, in rectangular distribution, demand occurred constantly, and the accumulated demand increased significantly with demand creation. Because this increase was not dealt with well, “Dissatisfied tourist” and “Remainder” evaluations were not eliminated with an increased number of cars.

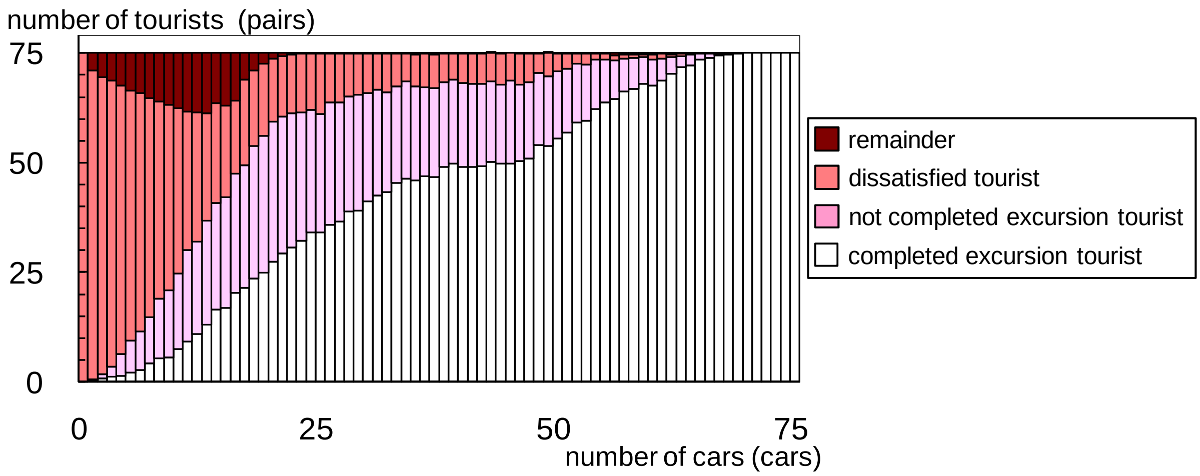

Figure 14 – Composition of tourists by day-end satisfaction level (Case 1)

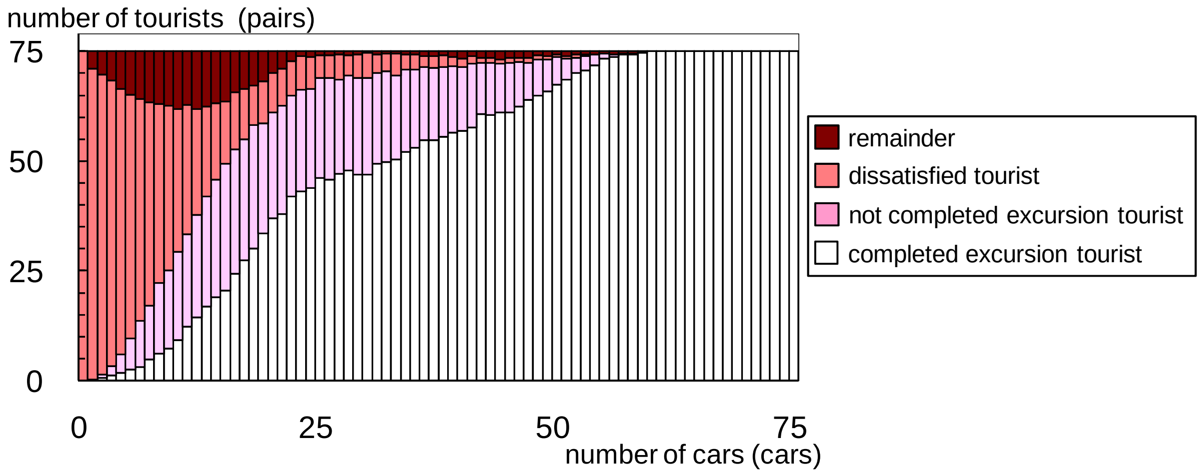

Figure 15 – Composition of tourists by day-end satisfaction level (Case 2)

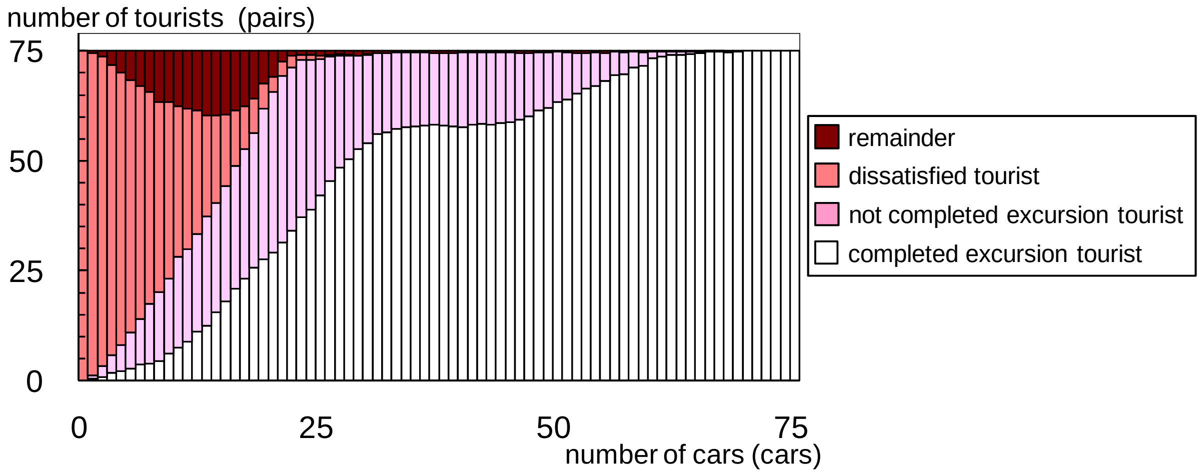

Figure 16 – Composition of tourists by day-end satisfaction level (Case 3)

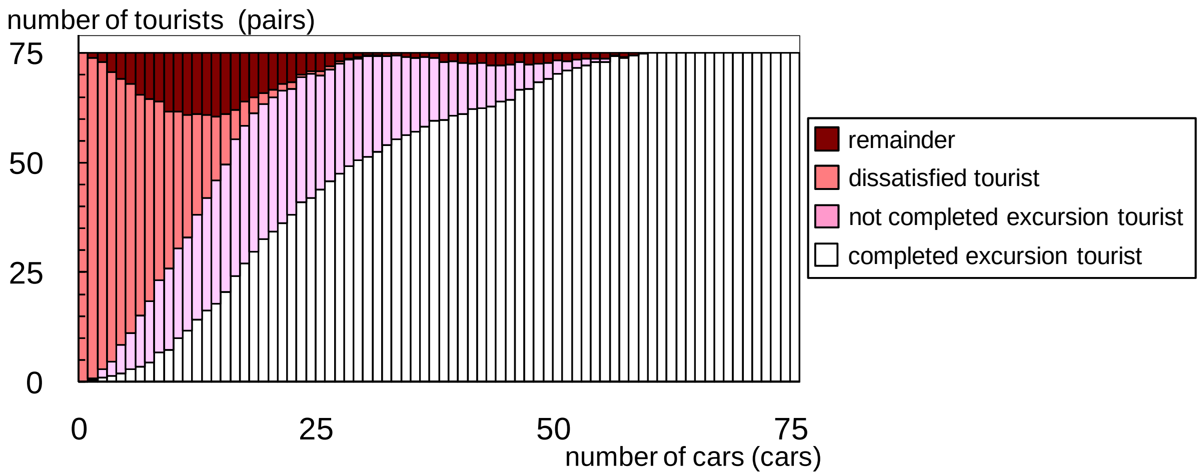

Figure 17 – Composition of tourists by day-end satisfaction level (Case 4)

5.2.3 Car operation method

The operation rate of cars is determined that the driving steps for tourists divided by the all driving steps for tourists and car-relocated. The satisfaction rate of tourist is determined that the actual number of points visited divided by the scheduled number of points visited.

The relationship between the number of cars, their operation rate and the satisfaction rate of tourist is shown in Figures 18-19 (without car relocation) and Figures 20-21 (with car relocation). Regardless of the implementation of car relocation, the satisfaction rate started to increase once the operation rate reached 0.7. Then, in the case without car relocation, both the operation rate of cars and the satisfaction rate gradually increased with the number of cars. In the case with car relocation, on the other hand, the satisfaction rate rapidly increased to 0.9 while the operation rate remained constant. Then, as in the case without relocation, both the operation rate and the satisfaction rate increased gradually with the number of cars used.

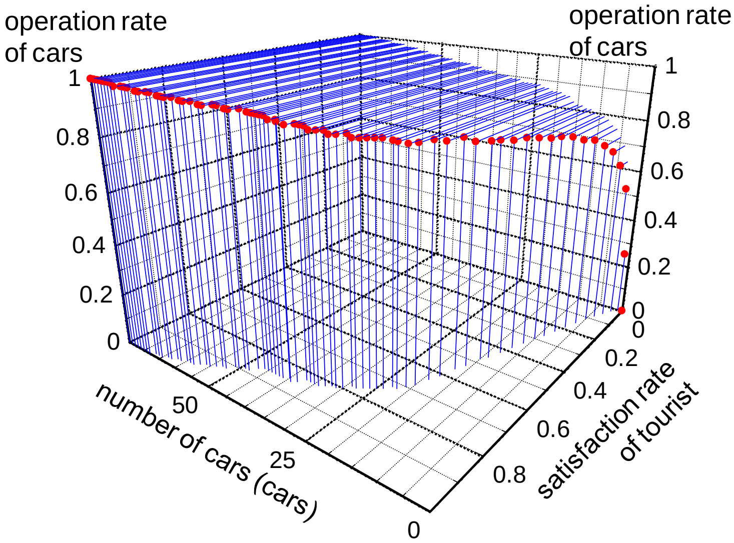

Figure 18 – Number of cars, operation rate of cars and satisfaction rate (Case 1)

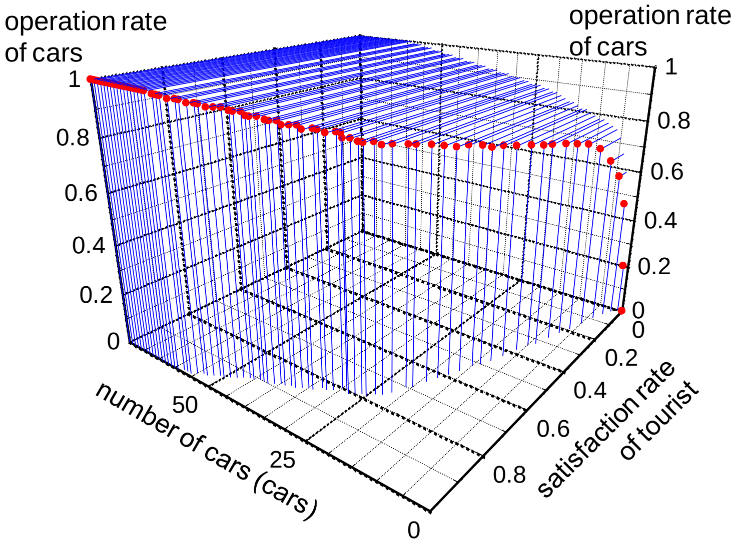

Figure 19 – Number of cars, operation rate of cars and satisfaction rate (Case 2)

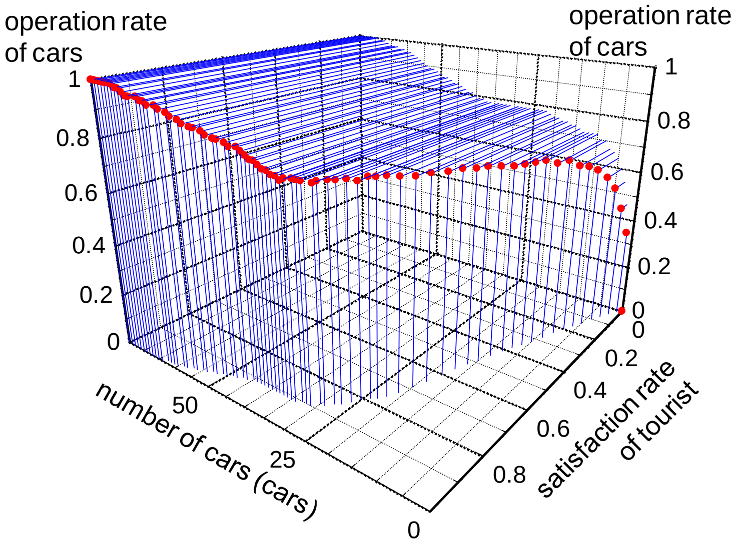

Figure 20 – Number of cars, operation rate of cars and satisfaction rate (Case 3)

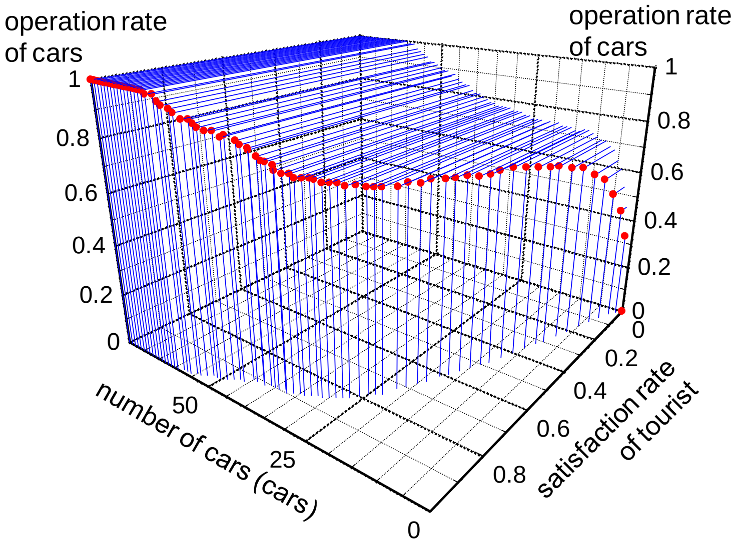

Figure 21 – Number of cars, operation rate of cars and satisfaction rate (Case 4)

It was therefore shown that the relocated-car creation effect was the highest in both distribution cases when the operation rate of cars was 0.7–0.8 or the number of cars was 10–40. Additionally, with car relocation, the satisfaction rate was higher with the same number of cars, making vehicle operation more efficient and indicating that tourist demand and vehicle operation were matched.

5.2.4 Cooperativeness of tourists with vehicle operation

Changes in the utility of sightseeing and the disutility of waiting and remained for different numbers of cars used in response to tourists' cooperativeness with vehicle operation are shown in Figures 22-23 (without car relocation) and in Figures 24-25 (with car relocation). Figures 24-25 show that with relocation, the utility of sightseeing differed little in response to changes in tourists' cooperativeness, whereas the absolute value of disutility of waiting decreased with their high level of cooperativeness. On the other hand, without car relocation, both the utility of sightseeing and the disutility of waiting and remained differed in response to changes in levels of tourist cooperativeness. Furthermore, without car relocation, cooperativeness greatly influenced the utility of sightseeing and the disutility of waiting and remained, and the influence was even greater when the number of cars used was small.

Accordingly, unless the number of cars exceeds a certain level, car-share operators can improve themselves few level of tourist utility. Active cooperation with vehicle operation on the part of tourists also allows efficient operation, which ultimately reduces the disutility of waiting for tourists themselves.

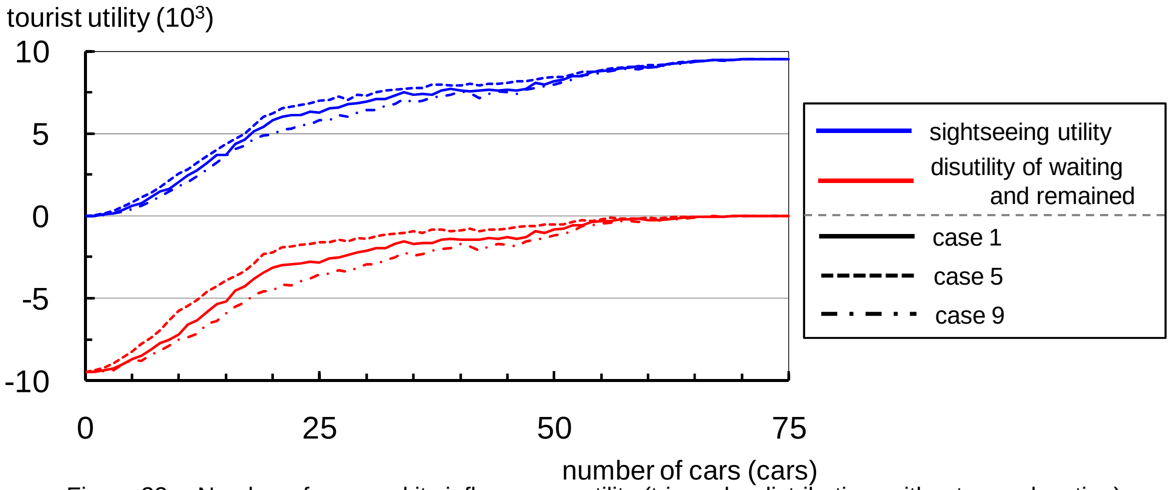

Figure 22 – Number of cars and its influence on utility (triangular distribution, without car relocation)

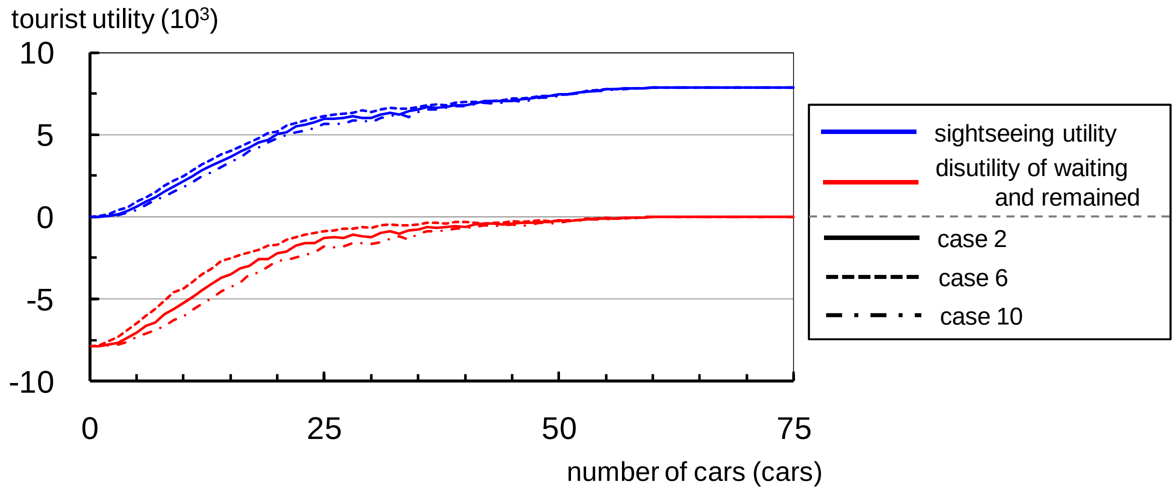

Figure 23 – Number of cars and its influence on utility (rectangular distribution, without car relocation)

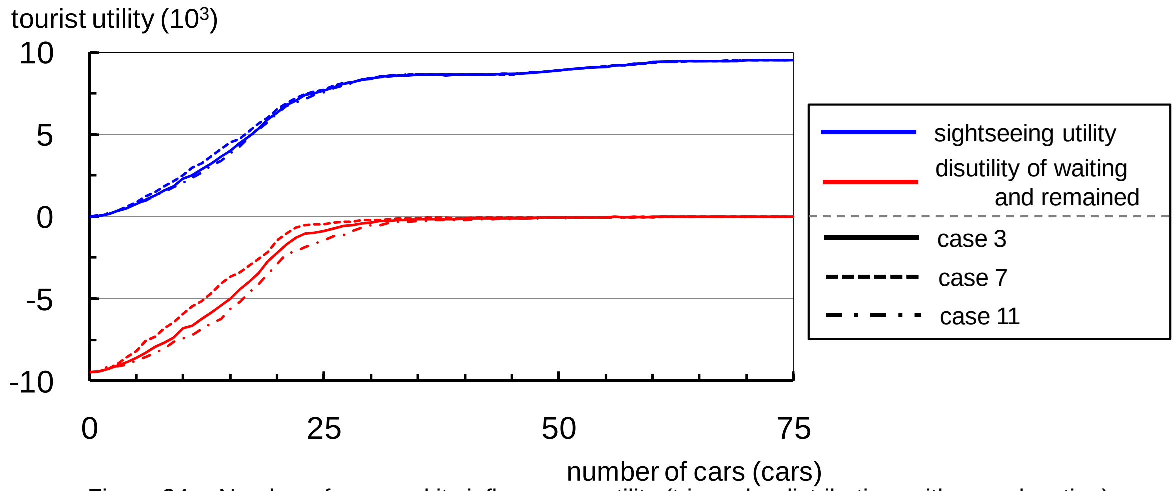

Figure 24 – Number of cars and its influence on utility (triangular distribution, with car relocation)

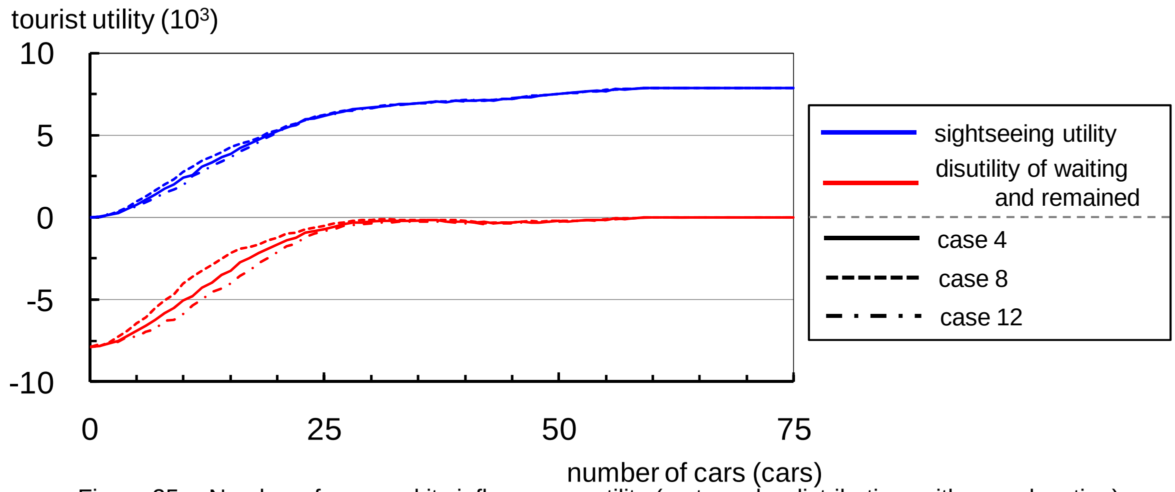

Figure 25 – Number of cars and its influence on utility (rectangular distribution, with car relocation)

5.3 Summary

The analysis outlined in this chapter revealed the following three points. First, tourist utility increased under triangular distribution and with car relocation. Next, vehicle operation was improved under rectangular distribution when the number of cars was small, but was improved under triangular distribution as the number of cars increased. Finally, it was shown that not only improvements in vehicle operation efficiency by car-share operators but also tourist cooperation with vehicle operation contributed to the improvement of utility for tourists themselves.

To consider these results comprehensively, a car-share system adaptability assessment indicator EI_k defined by equation (12) below, was calculated for each analysis case (Table 3). A greater EI_k value means that utility is high even with a small number of cars, and thus represents a high level of adaptability for a car-share system to regional areas.

$$EI_k = \frac{\int_{\min(C)}^{\max(C)} U_k dN_c}{\max(|U_k|) \times (\max(C) - \min(C))} \times 100 \qquad (12)$$

Where C : number of cars
U_k : utility function
k : value indicating the type of utility function

Table 3 shows that the difference between the maximum and minimum values of sightseeing utility was 16.17, and that of disutility of waiting and remained was 18.77. Accordingly, the disutility of waiting and remained changed more significantly and had a stronger influence on overall utility. As a result, rather than increasing the utility of sightseeing, we should consider reducing the disutility of waiting and remained to improve overall utility.

Table 3 – Car-share adaptability assessment indicator values for each analysis case

Case No.	Sightseeing Utility		Disutility of Waiting & Remained		Overall Utility	
	EI_{su}	Rank	EI_{du}	Rank	EI_{ou}	Rank
1	68.75	5	-27.78	11	40.97	10
2	60.75	11	-18.64	6	42.11	9
3	74.80	2	-20.47	7	54.33	2
4	62.59	8	-16.05	3	46.54	7
5	71.65	4	-22.08	9	49.57	4
6	62.33	9	-15.32	2	47.01	6
7	75.56	1	-17.63	4	57.93	1
8	63.32	7	-13.78	1	49.54	5
9	66.11	6	-32.55	12	33.56	12
10	59.39	12	-21.54	8	37.85	11
11	74.41	3	-22.67	10	51.74	3
12	62.16	10	-17.88	5	44.28	8

6. CONCLUSIONS

This study investigated the feasibility of introducing a car-share system to regional tourist areas. Specifically, by adopting a multi-agent simulation, the sightseeing behavior of tourists using car-share vehicles was modelled, and 12 cases were analyzed to determine the effects of tourist creation distribution, vehicle operation methods and levels of tourist cooperativeness. The results clarified the following two points:
- When the number of cars was low, demand at peak times could not be adequately dealt with. As a result, even with car relocation, many returned home dissatisfied. Accordingly, it is enough for tourists to be satisfied that the number of cars is the same as a peak number of arriving tourists at the terminal. However, a car-share system would be difficult to accommodate the significant fluctuation of tourist numbers in sightseeing areas.
- A car-share operators can improve themselves few level of tourist utility by vehicle operating. For this reason, there is a need for a system in which tourists using car sharing cooperate with car-share operators to make vehicle operation more efficient. It was also shown that was possible to increase tourist utility through harmonized efforts by car-share operators and tourists to improve vehicle operation while keeping the number of cars low.

Based on these results, this study was shown that a multi-station car-share system could be introduced to sightseeing in regional tourist areas. It was also clarified that effective vehicle operation is required to maximize tourist utility, and that to this end, tourists themselves also need to travel in a cooperative manner.

REFERENCES

National Institute of Population and Social Security Research. (2010). Population Statistics of Japan 2010, Tokyo.

Japan Institute of Design. (2004). Redesign of Car Society - Proposal for near future mobility, Kajima Publishing, Tokyo.

Ichimaru, S. (2009). Study on Issues and Measures for Promotion of Carsharing in Japan: Proceedings of Infrastructure Planning, Vol.39, CD-ROM. Japan Society of Civil Engineers, Tokyo.

Urban Transportation Planning Office, City Planning Division, City and Regional Development Bureau, Ministry of Land, Infrastructure and Transport of Japan. (2007). Results from the 4th Nationwide Person Trip Survey, Tokyo.

Ueda, I. (2007). Emergent and Multi-agent System, Baifukan, Tokyo.

Hokkaido District Transport Bureau (2010). The Annual Report of Hokkaido Transport, Sapporo.

Bureau of Tourism, Department of Economic Affairs, Hokkaido Government (2009). The Report of the Number of Tourists in Hokkaido (FY2008), Sapporo.