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Awareness and Potential Choices of Carsharing: Comparative Analysis of Data from Four Japanese Cities

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Abstract. This study reports the results of a local survey of carsharing in four Japanese cities which includes the two cities having carsharing. The survey focused on respondents' awareness and expected actions regarding car ownership, and stated choice of carsharing membership. The survey was implemented in February to April, 2010. Sample sizes are 208 in Meidaimae, 275 in Hikarigaoka, 158 in Fujisawa, and 365 in Utsunomiya, respectively. No carsharing users are included in the respondents. After the data was gathered, the modal and carsharing membership choices were empirically analyzed. The survey results indicate the following: car owners are more aware of carsharing than non-owners, non-owners consider using carsharing more often than car owners, 30-40 percent of the surveyed individuals would choose to forego car ownership if they were a member of a carsharing service, individuals seem to make rational decisions regarding membership under different hypothetical cases, and the availability of carsharing services and public transportation, trip distance, and household income influence whether one participates in carsharing. Most of the findings support the results that have been reported in the carsharing studies in North America and Europe.

Keywords. Carsharing, awareness, potential demand, modal choice, carsharing membership choice, comparative analysis

INTRODUCTION

The carsharing market has been growing in many countries (*1*, *2*), including Japan (*3*). Many carsharing services operate in urban areas, where the number of carsharing members has been increasing rapidly. The number of members in Japan was 2,512 in 2007, 3,245 in 2008, 6,396 in 2009, 16,177 in 2010, and 79,993 in 2011(*4*). However, it is still an unpopular transportation service in Japan. Although it may contribute to the reduction of private car use and overall automobile emissions (*5*), the market potential and public awareness of carsharing have not been well understood by carsharing operators in Japan. Furthermore, the transportation planners have not explicitly considered carsharing in transportation planning in Japan. However, current carsharing market data is not sufficient to examine the potential impacts of carsharing on transportation demand.

The carsharing demand is, in general, dependent on (i) the level of carsharing service such as the accessibility to the carsharing stations and the charging system; (ii) the level of alternative transportation service such as the frequency of bus service, accessibility to rail stations, and private car ownership; and (iii) the personal attributes such as gender and age. Some research including Schuster et al. (*6*) and Celsor and Millard-Ball (*7*) assess the market potential of carsharing while Shaheen and Rodier (*8*) analyze the impacts of carsharing service on the individual's travels. Cervero (*9*) and Cervero and Tsai (*10*) have estimated the modal choice including carsharing for evaluating the short-term demand of carsharing service in San Francisco while Cervero et al. (*11*) have estimated the same model for evaluating the longer-term travel demand of carsharing. These analyses are made on the basis of revealed preference (RP) data of carsharing members. This study analyzes the individual's modal choice including hypothetical carsharing option. As Ciari et al. (*12*) points out, the estimation of carsharing demand is a challenging task because of the difficulties in collecting data with the classical travel demand analysis approach using the RP data. The alternative way is the stated preference (SP) survey, but it is costly and not necessary easily available. This may be one of the reasons for few SP surveys in Japan.

Our study team conducted paper-based questionnaire surveys to understand the awareness and preference of carsharing services in four Japanese cities. These cities include two cities in Tokyo prefecture, Meidaimae and Hikarigaoka, a suburban city in Kanagawa prefecture, Fujisawa, and the prefectural capital of Tochigi prefecture, Utsunomiya. They are selected because the potential carsharing market is expected to be growing although the carsharing demand is currently very small. The target areas are located near the residential area or the university campus. Additionally, the target areas are chosen so that the population density and the availability of public transit service vary among them. The surveys were implemented for 5 to 12 days in February to April, 2010. This study reports the findings from a comparative analysis with the SP data and discusses the implications of those findings for transportation policy and the carsharing industry in Japan. To the best of our knowledge, no study has reported the comparisons of individual awareness and/or preference of carsharing for multiple Japanese cities.

This paper is organized as follows: Initially, the background and goals of the study are presented. Subsequently, the survey method and descriptive statistics of the respondents are presented. The survey results are shown and the findings are discussed. Following this, the modal choices—including carsharing—and carsharing membership choice are empirically estimated with the collected data. Finally, the paper is concluded with a discussion of the implications of the survey results and further research issues.

DATA COLLECTION

Survey Areas

The study team, including the authors, surveyed local people's daily travel behaviors and preferences concerning choice of hypothetical carsharing services. Paper-based questionnaire surveys were conducted in the following four Japanese cities: Meidaimae, Hikarigaoka, Fujisawa, and Utsunomiya. The scope of the survey areas was to cover a circle with a 400-meter radius, on an average, from a specific point in each city. Table 1 summarizes the characteristics of the survey areas.

Survey Method

The questionnaire sheets in the survey requested answers to the four types of questions. The first type of questions asked the respondents regarding their daily travel experiences on a typical weekdays and weekends, including the origin, destination, departure time from home, arrival time at destination, travel purpose, travel mode used, and travel time for all trips made. The experience of carsharing is also included in this type of questions. The second type of questions elicited responses to questions regarding three hypothetical cases, wherein different possibilities concerning carsharing membership fees, carsharing-use time-based charges, carsharing-use distance-based charges, and accessibility from the respondent's home to the nearest carsharing station are presented. There were two or three levels for each attribute. Seven types of hypothetical choice cases were prepared in advance on the basis of fractional factorial designs. Three cases are presented to the

TABLE 1 Characteristics of Survey Areas

Survey area	Prefecture	Population density	Public transit availability	Land-use characteristics
Meidaimae	Tokyo	Very high (over 14,000 persons/km^2)	● Two urban rail services (average distance to the nearest rail station is about 200 m) ● Bus service ● Some carsharing services	● High population density commercial/residential district ● Private university campus is located in the area ● 10 km away from the central business district (CBD) in Tokyo
Hikarigaoka	Tokyo	Very high (nearly 15,600 persons/km^2)	● Metro service (average distance to the nearest rail station is about 250 m) ● Bus service ● Some carsharing services	● High-story (over 10 floors) apartment district developed by public corporation ● 15 km away from the CBD in Tokyo
Fujisawa	Kanagawa	Middle (nearly 6,100 persons/km^2)	● About 1.0 km away from the nearest rail station ● Poor bus service ● No carsharing service	● Typical suburban residential district in the Tokyo Metropolitan Area ● 45 km away from the CBD in Tokyo
Utsunomiya	Tochigi	Lower-Middle (nearly 4,800 persons/km^2)	● About 2.5 km away from the nearest rail station ● Poor bus service ● No carsharing service	● Typical car-oriented local city in Japan ● Residential area ● National university campus is located next to the area

Note: Carsharing services in the four cities are identified from the list of carsharing operators prepared by the Foundation for Promoting Personal Mobility and Ecological Transportation.

respondents in the survey sheet: one of them is a base case, which is the same for all respondents, and the other two cases are randomly selected from the remaining six cases. The respondents are requested to indicate their choices concerning participation in carsharing membership and the travel mode for each trip that they would make while participating in carsharing for each hypothetical case. The third type of questions asked regarding the attributes of the respondent's household, including personal information such as age, gender, job, marital status, driver's license certification status of all household members, household income, types of cars owned by the household and the history of car ownership, the number of parking spaces used by the household, home address, structural details of the house, and distance from the home to the nearest bus stop. The final type of questions inquired regarding the respondent's preferences and opinions on the use of carsharing, type of automobiles, and electric vehicle use. The awareness of carsharing is asked in this type of questions.

The potential respondents were selected randomly from detailed maps of the survey areas. The interviewers visited potential respondents and requested them to participate in the survey. When a potential respondent was away from home, the surveyors left the survey sheets with a request letter in their postal mailbox. In the case of an apartment, a survey notice was posted in the apartment before the survey with the help of apartment managers; subsequently, the surveyors visited the residents that were willing to participate. The average time taken to answer the survey was approximately thirty minutes. One thousand Japanese yen (approximately equal to 12 US dollars) was given to all respondents for their contributions. The surveyors visited the respondents twice to collect the surveys. The respondents could choose the manner in which they wanted to submit their answers from among the following options: (1) answer the questionnaire sheets immediately during the first visit, (2) fill the sheets after the first visit and return them during the second visit, or (3) send in their completed surveys by postal mail.

The surveys were conducted between February 11 and February 22, 2010 in Meidaimae; between February 27 and March 3, 2010 in Hikarigaoka; between March 5 and March 14, 2010 in Fujisawa; and between April 16 and April 27, 2010 in Utsunomiya. In Meidaimae, 3,880 potential respondents were selected and the data of 208 individuals were collected. In Hikarigaoka, 7,150 potential respondents were selected and the data of 275 individuals were collected. In Fujisawa, 2,650 potential respondents were selected and the data of 158 individuals were collected, and in Utsunomiya, 1,760 potential respondents were selected and the data of 365 individuals were collected.

SURVEY RESULTS

Descriptive Statistics

First, the average age of the respondents was the lowest in Utsunomiya, followed by Hikarigaoka, Fujisawa, and Meidaimae, in that order. The high rate of young respondents in Utsunomiya reflects that the survey area includes a university area. Although Meidaimae also includes a university area, the average age there was the oldest among the cities because the survey area includes apartments for high-income workers. Second, the average gender varies from 0.5 to 0.7. Note that the gender is defined as 1 if a respondent is male and 0 otherwise. Male respondents are dominant in Hikarigaoka because many single senior male households exist in the apartment area. Third, the annual household income in Hikarigaoka is the highest, followed by Meidaimae, Fujisawa, and Utsunomiya, in that order. The reason for the higher household incomes in Hikarigaoka and Meidaimae is that they are located in Tokyo, the highest income region in Japan. It must be noted that the standard deviation of household income is higher in Meidaimae than in Hikarigaoka. This is mainly because the survey area in Meidaimae includes both low-income students and high-income workers. The annual household income is the lowest in Utsunomiya because many respondents from the region were university students. Fourth, car ownership is the highest in Utsunomiya, followed by Fujisawa, Hikarigaoka, and Meidaimae, in that order. Note that the car ownership is defined as the number of cars owned by the household that the respondent belongs to. This may reflect that the public transportation network is poor in Utsunomiya and Fujisawa, whereas the urban rail network is well organized in the other two cities in Tokyo prefecture. Fifth, the average travel distance is 8.6 km in Meidaimae, 12.0 km in Hikarigaoka, 11.2 km in Fujisawa, and 7.3 km in Utsunomiya. The travel distance in Hikarigaoka is the longest probably because many workers commute to the central business district, which is located far from their homes. Sixth, the average travel time is 24.3 minutes in Meidaimae; 29.9 minutes in Hikarigaoka; 26.3 minutes in Fujisawa; and 17.5 minutes in Utsunomiya. This implies that the average travel speeds are 21.2 kph in Meidaimae, 24.1 kph in Hikarigaoka, 25.6 kph in Fujisawa, and 25.0 kph in Utsunomiya. The average travel speeds in Fujisawa and Utsunomiya are higher than those in the two cities in Tokyo prefecture because individuals in Fujisawa and Utsunomiya mainly use automobiles for travel, whereas those in Meidaimae and Hikarigaoka mainly travel by rail. The rail-use travel time tends to be long because it includes the access/egress travel time, waiting time at stations, and rail-ride travel time. Seventh, the travel cost is the cheapest in Utsunomiya, followed by Fujisawa, Meidaimae, and Hikarigaoka, respectively. The travel cost is more expensive in the two cities in Tokyo prefecture because the individuals in Tokyo have to pay a transit fare, whereas individuals in local cities pay gas costs, which are much cheaper than transit fares. Eighth, the transfer in Fujisawa and Utsunomiya is nearly equal to zero, whereas that in Meidaimae and Hikarigaoka is 0.3. Note that transfer is defined as the number of changes in transportation mode during a trip. This is simply because the individuals in Fujisawa and Utsunomiya use only automobiles, whereas those in Meidaimae and Hikarigaoka use railways. Since the rail network is wider and more complicated in Tokyo, the rail users are often required to change trains at stations. This is also reflected in the transfer time. Finally, the average access/egress travel time is 3.3 minutes in Meidaimae, 3.5 minutes in Hikarigaoka, 2.4 minutes in Fujisawa, and 0.2 minutes in Utsunomiya. Note that the access/egress time is defined as the sum of the travel time from an origin to one public transit station/stop and the travel time from another public transit station/stop to a destination during a trip. This reflects that although the nearest stop for public transit in Utsunomiya is a bus stop, it is a rail station in the other cities. Note that it is difficult to compare the above descriptive statistics with the socio-demographic statistics given by authorities because the target areas are limited just near the specific points in each city. We assume, however, that those data represent the population in the target areas because they are selected in a random manner.

Awareness of Carsharing

Table 2 shows the comparison of respondents' awareness of carsharing by car ownership subgroup among the four cities. First, no respondent is currently a member of a carsharing organization, although carsharing services are available in Meidaimae and Hikarigaoka. This shows that the carsharing service is very limited in those areas. Second, 12.0 percent and 13.6 percent of the total respondents in Meidaimae and Fujisawa, respectively, have never heard of carsharing; moreover, 24.9 percent and 20.9 percent have never heard of carsharing in Hikarigaoka and Utsunomiya, respectively. Carsharing awareness is lowest in Hikarigaoka even though carsharing services are available there. This is probably because the distances that respondents in Hikarigaoka travel are longer there than in other areas; typically, in the context of Tokyo, long-distance travelers are expected to choose rail over carsharing services. The awareness of carsharing in Utsunomiya is low simply because no carsharing service is available there. Third, in all the cities, more car owners have heard of carsharing than non-owners. This may mean that the car owners are concerned with the availability of other car-based transportation modes and non-owners are not interested in carsharing or have no car license. Fourth, less than 10 percent of the respondents knew the names of carsharing operators, and very few respondents have

TABLE 2 Awareness of Carsharing (CS) in the Four Cities (Multiple answers)

	I have never heard of CS		I have heard of CS		I know the names of CS operators		I have considered using CS		I am now a member of CS		Total respondents
Meidaimae											
Non-owner	14	(18.9%)	46	(62.2%)	5	(6.8%)	9	(12.2%)	0	(0.0%)	74
Car owner	11	(8.2%)	101	(75.4%)	20	(14.9%)	7	(5.2%)	0	(0.0%)	134
Total	25	(12.0%)	147	(70.7%)	25	(12.0%)	16	(7.7%)	0	(0.0%)	208
Hikarigaoka											
Non-owner	26	(28.9%)	58	(64.4%)	11	(12.2%)	15	(16.7%)	0	(0.0%)	90
Car owner	42	(23.0%)	135	(73.8%)	22	(12.0%)	6	(3.3%)	0	(0.0%)	183
Total	68	(24.9%)	193	(70.7%)	33	(12.1%)	21	(7.7%)	0	(0.0%)	273
Fujisawa											
Non-owner	1	(14.3%)	5	(71.4%)	0	(0.0%)	1	(14.3%)	0	(0.0%)	8
Car owner	20	(13.6%)	114	(77.6%)	14	(9.5%)	3	(2.0%)	0	(0.0%)	147
Total	21	(13.6%)	119	(77.3%)	14	(9.1%)	4	(2.6%)	0	(0.0%)	155
Utsunomiya											
Non-owner	15	(36.6%)	26	(63.4%)	0	(0.0%)	0	(0.0%)	0	(0.0%)	41
Car owner	60	(18.9%)	248	(78.0%)	7	(2.2%)	1	(0.3%)	0	(0.0%)	318
Total	75	(20.9%)	274	(76.3%)	7	(1.9%)	1	(0.3%)	0	(0.0%)	359

Note 1: The percentages in parentheses represent the proportion of responses to the total number of respondents.
Note 2: The respondents that provided no answer were removed from the dataset.
Note 3: The total number of respondents may not be equal to the sum of the answered cases because multiple answers are included in each case.

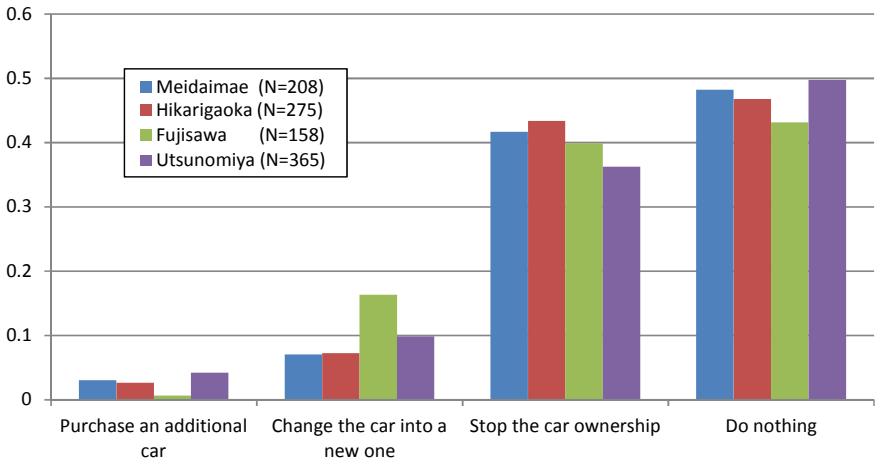

FIGURE 1 Expected Actions in a Case of being a Member of Carsharing Service (Single Answer)
Note 1: The respondents who gave no answer were removed from the dataset.
Note 2: The data is defined as 1 if the respondent answers "yes" to the given category and 0 otherwise.

considered carsharing in Fujisawa and Utsunomiya. This is probably because no carsharing service is available in those two cities.

Figure 1 shows the expected actions if an individual were a member of a carsharing service. First, 43–50 percent of the respondents would do nothing, even if they were members; however, 36–43 percent of the respondents said that they would get rid of their cars. The share of those willing to "stop car ownership" was the lowest in Utsunomiya, followed by Fujisawa. This is probably because the local people there have difficulties using other transportation modes since the public transportation is poor. Next, 3–4 percent of the respondents in Meidaimae, Hikarigaoka, and Utsunomiya would "purchase an additional car," whereas 0.7 percent would do so in Fujisawa. Furthermore, 7–10 percent of the respondents in Meidaimae, Hikarigaoka, and Utsunomiya would "replace their old car with a new one," whereas 16.3 percent would do so in Fujisawa. These results indicate the fact that respondents from Fujisawa were more interested in replacing their old cars than purchasing additional ones. This is probably because the household size is larger in Fujisawa than in other areas. Note that Fujisawa is a typical suburban area, where a couple and their child or children typically reside in a household. Families in

these areas typically have a family car with a large capacity; however, participation in a carsharing service would allow them to downsize the capacity of their cars.

Table 3 shows the results of the stated choices concerning carsharing membership under different hypothetical cases among the four cities. Case 0 is the base case wherein the monthly membership fee is 3 000 yen (33.33 dollar), time-based charge is 200 yen (2.22 dollar) per 15 minutes, distance-based charge is 15 yen (0.17 dollar) per kilometer, and travel time from home to the nearest carsharing station is 5 minutes. The levels of service in Case 0 refer to the typical carsharing services in urban areas in the Tokyo Metropolitan Area. They may be also more or less similar to those in the carsharing service in North America. For example, one of the basic service plans in Zipcar (extra value plans/EVP$50) is provided with 50 dollar for monthly commitment and 6.98–7.75 dollar for hourly driving cost as of November, 2011. The other cases have different combinations of fees/charges and accessibility. As stated earlier, three cases were presented to the respondents in the survey sheet. The respondents were asked to answer whether they would join the carsharing service in each case. First, in Case 0, the shares of respondents who would join the carsharing service was 18.3 percent in Meidaimae, 18.5 percent in Hikarigaoka, 20.3 percent in Fujisawa, and 9.3 percent in Utsunomiya. The shares of respondents agreeing to join in Fujisawa and Utsunomiya may reflect the shares of respondents that considered carsharing "economical." This implies that recognition of carsharing-related costs significantly affects carsharing membership. Second, Case 1 was the most preferred in Meidaimae and Utsunomiya, whereas Case 4 was the

TABLE 3 Membership Choice of Carsharing (CS) under Different Hypothetical Cases in the Four Cities

Case	Member-ship fee	Time charge	Distance charge	Walk time to the nearest CS station	Will join the CS service		Will not join the CS service		Not available		Total
	Yen (US$)/ month	Yen (US$)/ 15 min.	Yen (US$)/ km	Minutes	(%)		(%)		(%)		
Meidaimae											
0	3000 (33.33)	200 (2.22)	15 (0.17)	5	38	18.3	162	77.9	8	3.8	208
1	3000 (33.33)	100 (1.11)	25 (0.28)	1	17	24.6	49	71.0	3	4.3	69
2	3000 (33.33)	300 (3.33)	5 (0.06)	10	5	7.5	58	86.6	4	6.0	67
3	1000 (11.11)	200 (2.22)	25 (0.28)	10	13	19.1	52	76.5	3	4.4	68
4	1000 (11.11)	300 (3.33)	15 (0.17)	1	15	21.7	51	73.9	3	4.3	69
5	5000 (55.55)	100 (1.11)	15 (0.17)	10	4	5.4	69	93.2	1	1.4	74
6	5000 (55.55)	200 (2.22)	5 (0.06)	1	4	5.8	61	88.4	4	5.8	69
Hikarigaoka											
0	3000 (33.33)	200 (2.22)	15 (0.17)	5	51	18.5	208	75.6	16	5.8	275
1	3000 (33.33)	100 (1.11)	25 (0.28)	1	20	23.0	61	70.1	6	6.9	87
2	3000 (33.33)	300 (3.33)	5 (0.06)	10	6	5.7	89	84.0	11	10.4	106
3	1000 (11.11)	200 (2.22)	25 (0.28)	10	26	25.5	74	72.5	2	2.0	102
4	1000 (11.11)	300 (3.33)	15 (0.17)	1	23	29.5	46	59.0	9	11.5	78
5	5000 (55.55)	100 (1.11)	15 (0.17)	10	9	10.2	70	79.5	9	10.2	88
6	5000 (55.55)	200 (2.22)	5 (0.06)	1	7	7.9	72	80.9	10	11.2	89
Fujisawa											
0	3000 (33.33)	200 (2.22)	15 (0.17)	5	32	20.3	117	74.1	9	5.7	158
1	3000 (33.33)	100 (1.11)	25 (0.28)	1	15	26.3	34	59.6	8	14.0	57
2	3000 (33.33)	300 (3.33)	5 (0.06)	10	1	2.2	39	84.8	6	13.0	46
3	1000 (11.11)	200 (2.22)	25 (0.28)	10	7	14.0	41	82.0	3	6.0	50
4	1000 (11.11)	300 (3.33)	15 (0.17)	1	17	31.5	36	66.7	1	1.9	54
5	5000 (55.55)	100 (1.11)	15 (0.17)	10	3	5.0	54	90.0	3	5.0	60
6	5000 (55.55)	200 (2.22)	5 (0.06)	1	7	14.3	38	77.6	4	8.2	49
Utsunomiya											
0	3000 (33.33)	200 (2.22)	15 (0.17)	5	34	9.3	312	85.5	19	5.2	365
1	3000 (33.33)	100 (1.11)	25 (0.28)	1	19	16.5	86	74.8	10	8.7	115
2	3000 (33.33)	300 (3.33)	5 (0.06)	10	1	1.1	84	89.4	9	9.6	94
3	1000 (11.11)	200 (2.22)	25 (0.28)	10	11	9.3	101	85.6	6	5.1	118
4	1000 (11.11)	300 (3.33)	15 (0.17)	1	15	11.9	101	80.2	10	7.9	126
5	5000 (55.55)	100 (1.11)	15 (0.17)	10	7	5.6	108	86.4	10	8.0	125
6	5000 (55.55)	200 (2.22)	5 (0.06)	1	6	3.9	130	85.5	14	9.2	152

Note: 1 US dollar was equal to 90 yen as of March 1, 2010.

most preferred in Hikarigaoka and Fujisawa. There are two possible reasons for Case 1 to be preferred over Case 4 in Meidaimae and Utsunomiya, even though the monthly membership fee in Case 1 is three-times greater than that in Case 4. Note that the accessibility in Case 1 is the same as that in Case 4. A possible explanation is that the trip distance is shorter in Meidaimae and Utsunomiya than in Hikarigaoka and Fujisawa. Note that the distance charge in Case 1 is higher than that in Case 4. The results show that the average trip distance is 8.6 km in Meidaimae and 7.3 km in Utsunomiya, whereas it is 12.0 km in Hikarigaoka and 11.2 km in Fujisawa. Another possible reason is the expected monthly carsharing-use time, including travel time while carsharing and activity time at the destination, is longer for Meidaimae and Utsunomiya than for Hikarigaoka and Fujisawa. Note that the time-charge in Case 1 is lower than that in Case 4. The results show that the average travel time in Meidaimae and Utsunomiya is shorter than that in Hikarigaoka and Fujisawa. Additionally, it is difficult to assume that the activity duration in one city is significantly longer than that in another city. Thus, the monthly frequency of carsharing-use may be higher in Meidaimae and Utsunomiya than in other cities. Since the actual reason is unclear from the above analysis, further analysis is required in order to determine the actual reason. Third, overall, Case 2 was the least preferred. Particularly in Hikarigaoka, Fujisawa, and Utsunomiya, the share of the respondents that would join the carsharing service was the lowest for Case 2. A ten-minute walk to the nearest station and the expensive time charge may have discouraged individuals from becoming members. Fourth, interestingly, over ten percent of respondents preferred Case 5 in Hikarigaoka, whereas approximately five percent preferred it in the other cities. This may mean that the individuals in Hikarigaoka expected to use the carsharing service for a much longer period than those in the other cities. Note that the time charge of Case 5 was the cheapest among all the cases, whereas its monthly membership fee and the accessibility to the nearest station were the worst among the cases.

EMPIRICAL ANALYSIS

Modal Choice including Carsharing

The data collected in our survey include RP data and SP data. It is widely known that SP data has more biases than RP data. In order to analyze the individual choice behavior with RP data and SP data, a combined RP/SP model was applied in addition to the RP and SP models (*13*). The RP model estimates the choice model with only the RP dataset, whereas the SP model does so with only the SP dataset. The RP/SP model is especially used to correct any reported SP biases by introducing RP information.

The empirical analysis assumes a binary mode choice for analytical simplicity. The choice set is assumed as follows. First, if an individual chose a car in an RP question, the choice set of the RP model for the trips made by this individual is assumed to comprise car transport and available public transport. The choice set of the SP model for the trips made by this individual is assumed to be composed of car transport and carsharing. Second, if the individual chose public transit in an RP question, the choice set of the RP model for the trips made by this individual is assumed to be composed of public transit and car transport (for car owners) or other available means of public transport. When no means of public transport is available, it is assumed that the alternative mode of travel is walking. The choice set of the SP model for the trips made by this individual is assumed to comprise public transit and carsharing. Third, if the individual chose to walk in an RP question, the choice set of the RP model for the trips made by this individual is assumed comprise walking and car transport (for car owners) or available public transit. The choice set of the SP model for the trips made by this individual is assumed to comprise walking and carsharing.

The utility function is assumed to be a linear function of explanatory variables. After a number of trials and errors considering the various combinations of explanatory variables in the utility function, the utility functions are specified with a set of the same variables among the four cities. This is because the estimated results will be compared according to city. The estimated result with the binary logit are summarized in Table 4. In-vehicle travel time is defined as the travel time including riding public transit, driving a car/carsharing, and traveling as a passenger in a car. Out-of-vehicle travel time is defined as walking time to carsharing stations and/or public transit stops/stations and waiting time at public transit stops/stations. Travel cost is defined as the travel expenses including public transit fares, fuel costs, and carsharing charges. Male dummy (car) is defined as a car-specific variable that is equal to 1 if the individual is male and 0 otherwise. High income dummy (car) is defined as a car-specific variable that is equal to 1 if the annual income of the household that the individual belongs to is over seven million yen and 0 otherwise. Constant (rail, bus, car, carsharing) is defined as a mode-specific dummy variable. The scale parameter is defined as the ratio of the standard deviation in the error component of the SP-based utility function to that of the RP-based utility function.

First, in Meidaimae, the three models have high model fitness. The signs of the coefficients are all reasonable. The t-statistic of the carsharing-specific constant shows that it is significantly negative, which implies that carsharing has a negative attraction in comparison to other travel modes. The scale parameter estimated in the RP/SP model is significant, but almost equal to zero, which implies that the variance of error components in the SP model is much larger than that in the RP model. The values of in-vehicle time and out-of-

TABLE 4 Estimation Results of Modal Choice with RP, SP, and RP/SP Binary Logit Models in the Four Cities

	Meidaimae						Hikarigaoka					
	RP		SP		RP/SP		RP		SP		RP/SP	
Variable	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.
In-vehicle travel time	-0.054	-5.1**	-0.088	-3.1**	-0.059	-5.4**	-0.076	-6.4**	-0.039	-3.1**	-0.078	-6.7**
Out-of-vehicle travel time	-0.122	-7.5**	-0.027	-0.8	-0.127	-7.7**	-0.113	-7.8**	-0.016	-0.8	-0.106	-7.7**
Travel cost	-0.002	-6.2**	-0.001	-2.4**	-0.002	-6.1**	-0.003	-9.0**	-0.001	-3.7**	-0.002	-7.4**
Male dummy (Car)	0.311	1.1	-0.059	-0.1	0.293	1.0	0.650	2.6**	0.374	0.6	0.607	2.4**
High income dummy (Car)	0.001	0.0	-0.585	-1.3	0.005	0.0	0.161	0.8	-0.609	-1.6	0.137	0.7
Constant (Rail)	-0.720	-1.9*	-1.074	-1.5	-0.799	-2.1**	-0.621	-1.5	-1.292	-2.4**	-0.758	-1.9*
Constant (Bus)	7.498	0.5	-8.942	-0.3	4.739	1.1	1.850	2.4**	-1.565	-2.6**	1.480	2.0*
Constant (Car)	-1.368	-3.1**	-2.529	-4.0**	-1.506	-3.3**	-0.873	-2.4**	-3.390	-4.9**	-1.161	-3.0**
Constant (Carsharing)			-2.071	-4.5**	-18.305	-1.8*			-2.211	-6.5**	-7.563	-2.2**
Scale parameter					0.062	1.7*					0.114	2.3**
Number of observation	451		354		805		607		457		1064	
Initial log-likelihood	-312.6		-225.3		-558.0		-420.7		-311.9		-737.5	
Final log-likelihood	-213.9		-150.4		-412.1		-297.8		-206.5		-568.2	
Adjusted rho-squared	0.29		0.29		0.24		0.27		0.31		0.22	

	Fujisawa						Utsunomiya					
	RP		SP		RP/SP		RP		SP		RP/SP	
Variable	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.
In-vehicle travel time	-0.088	-6.8**	-0.067	-2.1**	-0.089	-6.9**	-0.053	-4.7**	-0.083	-2.3**	-0.054	-4.8**
Out-of-vehicle travel time	-0.065	-5.9**	-0.046	-2.4**	-0.067	-6.2**	-0.160	-2.1**	-0.018	-0.4	-0.162	-2.1**
Travel cost	-0.004	-3.2**	-0.001	-2.3**	-0.004	-3.4**	-0.015	-4.3**	-0.002	-2.7**	-0.015	-4.4**
Male dummy (Car)	0.207	0.8	0.349	1.1	0.256	1.0	0.014	0.1	0.306	1.0	0.019	0.1
High income dummy (Car)	-0.310	-1.1	1.308	3.1**	-0.187	-0.7	-0.158	-0.6	0.215	0.5	-0.153	-0.6
Constant (Rail)	0.166	0.3	-1.657	-1.6	0.203	0.4	1.047	1.0	2.541	0.2	1.067	1.0
Constant (Bus)	0.268	0.5	-0.718	-0.9	0.342	0.7	2.264	2.1**	-3.047	-2.8**	2.307	2.2**
Constant (Car)	-0.777	-2.1**	-2.555	-3.6**	-0.896	-2.5**	0.410	1.6	-4.739	-5.5**	0.390	1.5
Constant (Carsharing)			-1.526	-2.2**	-0.120	-0.1			-3.875	-4.7**	-34.498	-0.7
Scale parameter					0.162	2.3**					0.015	0.8
Number of observation	450		297		747		735		313		1048	
Initial log-likelihood	-311.9		-201.7		-517.8		-509.5		-212.1		-726.4	
Final log-likelihood	-197.0		-182.9		-396.9		-255.3		-150.2		-459.9	
Adjusted rho-squared	0.34		0.05		0.21		0.48		0.25		0.35	

Note: ** indicates that the coefficient is significant at the 95 percent confidence level and * indicates that the coefficient is significant at the 90 percent confidence level.

vehicle time estimated using in the RP/SP model are 27.1 yen per minute and 58.3 yen per minute, respectively. The values of walking and waiting time are higher than that of in-vehicle time.

Second, in Hikarigaoka, the three models have high model fitness. The signs of coefficients are all reasonable. Once again, the t-statistic of the carsharing-specific constant shows that it is significantly negative. In both the RP model and the RP/SP model, the car-specific male dummy is significantly positive. This implies that males tend to choose cars more than females. As expected, the scale parameter estimated in the RP/SP model is also strongly significant and smaller than 1. The values of in-vehicle time and out-of-vehicle time estimated using the RP/SP model are 33.4 yen per minute and 45.5 yen per minute, respectively.

Third, in Fujisawa, the RP and RP/SP models have high model fitness, whereas the SP model has low model fitness. One possible reason for this result is that the respondents may have had difficulty imagining that carsharing stations could be located near their homes. Since the survey area is located in the typical sub-urban districts where the population density is rather low, the hypothetical case of a carsharing service may not be realistic for the respondents. The values of in-vehicle time and out-of-vehicle time estimated using the RP/SP model are 20.9 yen per minute and 15.7 yen per minute, respectively. The values of walking and waiting are lower than that of in-vehicle time. This is also different from other results.

Fourth, in Utsunomiya, the three models have high model fitness. However, although the scale parameter is smaller than 1, it is not statistically significant. The values of in-vehicle time and out-of-vehicle time estimated using the RP model are 3.5 yen per minute and 10.6 yen per minute, respectively, whereas those estimated using the SP model are 47.4 yen per minute and 10.0 yen per minute, respectively. The value of out-of-vehicle travel time in the SP model is much lower than that of in-vehicle travel time. One of the possible reasons for this is that the respondents cannot appropriately imagine situations wherein they walk to the carsharing station. Another reason is that, compared with other areas, it is highly expected that the residents of Utsunomiya have less knowledge or experience of carsharing services. It should be noted that most of the carsharing services in Japan operate in urban areas.

Finally, the results in the four cities show that the estimation results of SP models are more instable than those of RP models. The results suggest that the RP/SP models can mitigate the instability of SP models with the stability of RP data.

Carsharing Membership Choice

Membership choice was analyzed with the nested logit models using logsum (LS) variables estimated with the modal choice models shown in Table 4. The results are shown in Table 5. Carsharing membership fee is defined as the daily cost of being a carsharing member. The RP modal choice model was used for estimating the LS variable for non-members, whereas the RP/SP modal choice model was used for estimating the LS variable for CS members. The results show that the model fitness is sufficiently high in all the four cities. Most of the coefficients of the explanatory variables are also statistically significant and consistent with their hypothesized effects on utility in the four cities.

TABLE 5 Estimation Results of Carsharing (CS) Membership Choice Model

	Meidaimae		Hikarigaoka		Fujisawa		Utsunomiya	
Variable	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.
CS membership fee (Yen)	-0.16	-5.7**	-0.07	-4.9**	-0.06	-3.1**	-0.07	-4.0**
LS parameter: Non-member	0.08	8.0**	0.13	14.7**	0.09	9.8**	0.11	7.5**
LS parameter: CS member	0.01	0.7	0.07	7.4**	0.06	6.5**	0.07	4.7**
CS member dummy	2.79	1.3	-3.57	-2.2**	-9.75	-4.3**	-11.19	-4.8**
Number of observation	2904		3520		1984		3556	
Initial log-likelihood	-1432.74		-1790.40		-1016.85		-1773.76	
Final log-likelihood	-699.58		-701.22		-642.28		-813.37	
Adjusted likelihood ratio	0.51		0.61		0.36		0.54	

Note: ** indicates that the coefficient is significant at the 95 percent confidence level.

DISCUSSION

The implications of the survey and analysis results are summarized as follows: First, car owners are more aware of carsharing than non-owners; however, as compared to non-owners, fewer car owners have considered using carsharing services. This may mean that the individuals have difficulty rearranging their lives to be car-free once they own a car. On the other hand, carsharing may be attractive to non-owners because it provides opportunities to use a car. It could be suggested that carsharing may increase the overall usage of cars because non-owners may start using cars through carsharing services, and car owners may not change their transportation mode.

Second, 30–40 percent of the surveyed individuals said that they did not need to continue owning cars if they became members of carsharing services. Cevero and Tsai (*10*) presents that the change in household motor vehicle ownership within the first two years of the San Francisco City CarShare Program, indicating that 29.1% of CS members reduce one or more cars while only 8.0 % of non-members reduce so. This may mean

that the individuals in the four cities may more sensitively change their car-ownership once they become carsharing members than those in San Francisco.

Third, the individuals seemed to make rational decisions regarding their membership choices. Lower membership fees, cheaper carsharing-use charges, and better accessibility to the nearest carsharing station were preferred. This supports the results shown by other studies in other countries such as the survey in San Francisco (Cevero, *9*) and the survey for university students in the United States (Zheng, et al., *14*). This suggests that a balanced combination of membership fees, time-charges, distance-charges, and accessibility is critical for enlisting more carsharing members even in the context of Japan.

Fourth, the comparative analysis of the four cities showed that the availability of carsharing services, public transportation service quality, trip distance, and household income all influence carsharing membership. Individuals have a better chance of becoming a member in an area where carsharing services are available. Individuals have less motivation to use carsharing in areas where cars are the dominant transportation mode owing to poor public transportation. The market potential of carsharing may be weaker in areas with high average trip distances. Individuals in low-income areas may not consider carsharing to be economically viable. These results suggest that the potential carsharing markets may be located in urban areas where middle- to high-income people reside and where high-quality public transportation is available. This may be regarded as the neighborhood residential model typically found at the early stage in North America (Shaheen, et al., *1*). This probably reflects the fact that the carsharing market in Japan is still at the primitive stage and its diversification has not yet started much.

Finally, although the modal choice models in Fujisawa and Utsunomiya did not have sufficient goodness of fit, the modal choice and carsharing-membership-choice models were successfully estimated. They could be useful for analyzing the potential demand of carsharing.

CONCLUSIONS

This paper reported the results of a questionnaire survey of carsharing in four Japanese cities. Initially, the awareness, expected actions regarding car ownership, stated choice of carsharing membership, and modal choice were analyzed using the collected data. Subsequently, the modal and carsharing membership choices were analyzed. These results give lessons to carsharing operators. For example, the results showed that the ten-minute walk to the nearest station discourage individuals from becoming members. This may suggest that the CS stations should be located at the places within ten-minute-walk distance from residential areas. The results also showed that the awareness of carsharing highly depends on the car ownership. This may suggest that the carshraing operators should have the different marketing strategies to car owners from those to non-owners. Next, the results also suggest important findings to the transportation planners. For example, the results indicated that carsharing may increase the overall usage of cars because non-owners may start using cars through carsharing services while car owners may not change their transportation mode. Furthermore, the estimated demand models also contribute to the estimation of the potential impacts of carsharing introduction on the local transportation market in the four cities. Particularly the results may suggest that the combination of SP and RP data leads to the stable estimation of the demand forecast models. This could be useful for local transportation planner to predict the future travel demands including carsharing.

It should be noted, however, the survey data have limitations. For example, like other stated preference surveys, this study is subject to an optimism bias, indicating over 20 % of respondents reported that they will join the CS member under the specific conditions in the three cities. It may be also affected by the selection bias because, in our survey, some data were collected through the face-to-face interviews while other data were collected through the self-completion report. More research is required to overcome these limitations including the in-depth interview surveys and focus group meeting.

Several issues that must be addressed in further research are as follows: First, the dataset do not contain any carsharing users in the four cities. This simply reflects the results of the random sampling in the target areas. As the data of carsharing users should be useful for understanding the potential carsharing use, the additional surveys covering carsharing users are required to strengthen the results of this survey. Second, the modal choice models in Fujisawa and Utsunomiya must be explored further. A model with a non-linear utility function may be tried for better estimation results. Third, the demand models for carsharing should be verified with the observed dataset of modal choice of existing carsharing users. One of the difficulties of this analysis was collecting data on existing carsharing users. In fact, no current carsharing user responded to our household surveys. The customer information of carsharing services is usually collected by private carsharing operators and is not available to the public. Thus, it may be necessary to conduct joint research with these private operators to verify the data.

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