

1 **Investigating the Characteristics of Carsharing Usage Pattern for Public Rental Housing**  
2 **Complexes: A Case Study in South Korea**

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5  
6 **Do-Gyeong Kim**

7 Professor

8 Department of Transportation Engineering

9 University of Seoul

10 163 Seoulsiripdaero, Dongdaemun-gu, Seoul, 02504, Republic of Korea

11 Phone: +82-2-6490-2826 ; Fax: +82-2-6490-2819 ; Email: [dokkang@uos.ac.kr](mailto:dokkang@uos.ac.kr)

12  
13  
14 **Jaeyoung Park**

15 Ph.D. Candidate

16 Department of Transportation Engineering

17 University of Seoul

18 163 Seoulsiripdaero, Dongdaemun-gu, Seoul, 02504, Republic of Korea

19 Phone: +82-2-6490-5684 ; Fax: +82-2-6490-2819 ; Email: [wodud0318@uos.ac.kr](mailto:wodud0318@uos.ac.kr)

20  
21  
22 **Dong-Joon Woo**

23 Graduate Research Assistant

24 Department of Civil and Environmental Engineering

25 Seoul National University

26 1 Gwanak-ro, Gwanak-gu, Seoul, 08826, Republic of Korea

27 Phone: +82-2-880-7368; Fax: +82-2-873-2684; E-mail: [ericwoo2014@snu.ac.kr](mailto:ericwoo2014@snu.ac.kr)

28  
29  
30 **Chungwon Lee, Ph.D (Corresponding author)**

31 Associate Professor

32 Department of Civil and Environmental Engineering

33 Seoul National University

34 1 Gwanak-ro, Gwanak-gu, Seoul, 08826, Republic of Korea

35 Phone: +82-2-880-7368; Fax: +82-2-873-2684; E-mail: [chungwon@snu.ac.kr](mailto:chungwon@snu.ac.kr)

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**1 ABSTRACT**

2 The primary objectives of this study are to investigate which attributes of the HappyCar, which is a  
3 closed carsharing service implemented in rental housing complexes, South Korea, should be  
4 improved to become an alternative transportation mode for low income households and to identify  
5 what kinds of characteristics of rental housing complexes influence a vehicle usage rate. For the  
6 analysis, two types of data were collected: survey data from carsharing members and operation  
7 record log files provided from a service operator. From the viewpoint of a methodology, an  
8 Importance -Performance Analysis (IPA) technique was employed to analyze which attributes of  
9 the HappyCar requires improvement and a beta regression model was estimated to identify factors  
10 affecting vehicle usage rate. The IPA results showed that three attributes such as the  
11 appropriateness of rental rates, thorough vehicle maintenance, and increase in the number of  
12 vehicles operated should be improved with top priority in order to make the HappyCar service  
13 more convenient and comfort. A total of five variables were found to be positively associated with  
14 vehicle usage rate: rental housing types (Type 2 and Type 3), number of households per complex,  
15 component ratio of one or two person households, and component ratio of five or more person  
16 households. This study enables a better understanding of the characteristics of carsharing,  
17 including use by low-income residents in rental housing, and provides many recommendations for  
18 HappyCar service providers and traffic policy decision makers.

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*Keywords:* Carsharing, Usage rate, Importance-Performance Analysis, Beta regression model,  
Rental housing complex, HappyCar

## 1 INTRODUCTION

2 Carsharing provides a service where a person can obtain the advantages of a personal  
3 transportation mode without vehicle maintenance costs and the various responsibilities of vehicle  
4 ownership (1). Carsharing services have received attention as an alternative transportation service  
5 that can minimize the negative impacts of existing transportation systems for several decades and  
6 is already implemented all around the world.

7 Many previous studies have shown that a carsharing service has advantages in solving  
8 various problems of existing transportation systems. The most typical advantage among those  
9 advantages is that a carsharing service is very efficient and reduces the number of vehicles on the  
10 road due to a decrease in vehicle ownership by households (2, 3, 4, 5). Additionally, vehicle miles  
11 traveled is also reduced (6, 7). A carsharing service plays a large role in reducing the number of  
12 vehicles per household, thereby providing an additional effect to reduce transportation costs such  
13 as the vehicle maintenance costs (1, 8, 9, 10). Traffic volumes decrease as vehicle ownership is  
14 reduced, and this reduces greenhouse gases (GHS) as well as particulate emission (8, 11, 12, 13).  
15 An additional very positive influence includes mitigating parking problems and traffic congestion  
16 (8, 10, 11).

17 Due to such advantages, carsharing services are increasingly popular (14). Carsharing  
18 services also have some social benefits including being an alternative transportation mode to meet  
19 the mobility needs of people who are unable to own a vehicle (11, 15). A recent study by Kim  
20 (2015) asserted that a marginalized neighborhood where the low-income household resided had  
21 very poor accessibility to public transportation. As such, the mobility of urban residents in such an  
22 area was limited. Therefore, a carsharing service could be a means to provide a new service to this  
23 demographic if problems related to rental rate can be solved. In another study, carsharing services  
24 using electric vehicles were investigated as another option for senior citizens residing in the  
25 Rossmoor Senior Adult Community located in the San Francisco Bay Area (17). In other words,  
26 carsharing services are increasingly being considered as a very effective transportation mode for  
27 solving problems with existing transportation systems. Additionally, a variety of efforts have been  
28 initiated to utilize it as alternative transportation to provide the same mobility for groups with  
29 mobility restrictions, such as low-income households and senior drivers.

30 As a part of such efforts, a carsharing service was implemented in South Korea from  
31 October 2013 on a trial basis targeting rental housing complexes with low-income households  
32 under the supervision of the Korea Land and Housing Corporation (The term "LH" is used to  
33 express this company throughout the remainder of this paper). This carsharing service offered by  
34 LH is called "HappyCar". LH plans to expand the HappyCar service to all rental housing  
35 complexes located throughout the country in the future if the results of the pilot project show that  
36 such a service can help improve and service the transportation needs of residents in rental housing  
37 complexes.

38 Generally, a lower-income group is known to have relatively poor accessibility to  
39 transportation modes in comparison to a higher-income group, with restriction in trips such as  
40 commuting, shopping and other social and economic activities (18). South Korea also faces a  
41 similar circumstance, and as such, piloted the HappyCar service. To date, this service is operated  
42 with only 1 or 2 vehicles per complex since it is in the test operation stage. As such, residents are  
43 often unable to reserve a vehicle at a preferred time when they wish to use the vehicle. This  
44 limitation has garnered complaints from residents. If the rate of reservation failure becomes high,  
45 it may become a factor that hinders full utilization of the service because existing users are not  
46 willing to use the service and it also may be difficult to attract new participants. If the usage rate  
47 increases while the number of vehicles used in the carsharing service is limited, the availability of

1 the carsharing service becomes increasingly poor, which would further reduce participant  
2 satisfaction. Therefore, it is necessary to manage the vehicle usage rate properly in terms of  
3 availability in order to optimize the HappyCar carsharing service.

4 The purposes of this study are to investigate various attributes to improve the HappyCar  
5 service, such that it becomes an alternative transportation mode for lower-income families residing  
6 in rental housing complexes and to identify factors among characteristics of a rental housing  
7 complex that influence vehicle usage rate. Factors affecting vehicle usage rate inform intensive  
8 management that influences vehicle usage rate and can make a large contribution toward  
9 increasing HappyCar availability. This study has a distinct difference from other carsharing-related  
10 studies in that a closed carsharing service, which is provided to only residents in rental housing  
11 complexes, is mainly dealt with in this study. Research focusing on a closed carsharing service has  
12 rarely been conducted.

### 14 **LH HappyCar: Overview**

15 The rental housing system in South Korea is aimed at providing rental housing that promotes  
16 residence stability for low-income households. This falls under the Housing Construction  
17 Promotion Act enacted in 1972 and the Rental Housing Construction Promotion Act enacted in  
18 1984 (19). Rental housing is classified into public rental housing and private rental housing. LH  
19 constructs and supplies public rental housing with the support of public funds such as government  
20 finance and the national housing fund (20).

21 Basically, those with a lower-income are eligible to move into public rental housing  
22 constructed and supplied by LH and public rental housing is classified into three types according to  
23 resident qualifications: Type 1 is rental housing classified as social welfare and was attempted for  
24 the first time in the country in 1989. The aim is to provide housing stability for persons requiring  
25 public assistance such as recipients of basic living security, patriots and veterans and single parent  
26 families, and those with the lowest income. Type 2 targets those who are homeless with a  
27 low-income defined as 70% or less of monthly average income per urban employee household.  
28 Lastly, Type 3 targets those with 100% or less of monthly average income per urban employee  
29 household and this type consists of households with the highest income and capital among the  
30 three types.

31 LH supplies 689 housing complexes as of 2013, and 270 complexes, which accounts for  
32 approximately 39%, are located in the Seoul Metropolitan area including Seoul, Gyeonggi-do  
33 Province and Incheon. LH has operated 53 vehicles targeting 45 out of 270 complexes since  
34 October 2013 as a pilot project (actually LH selected an operator and managed the service on a  
35 consignment basis) that includes 7 complexes for Type 1, 33 complexes for Type 2 and 5  
36 complexes for Type 3.

37 The HappyCar can be referred to as a closed carsharing service in that only residents in  
38 rental housing complexes are eligible to register as a member. As of May 2015, the total number of  
39 the HappyCar members was 3,672 members with 1,949 men (53.1%) and 1,723 women (46.9%),  
40 indicating approximately 6.2% more men than women. According to the operation results for the  
41 20 months from October 2013 to May 2015, the accumulated number of uses for the HappyCar  
42 service was 27,036 cases, which is approximately 44.5 cases per day as shown in Table 1. The  
43 cumulative number of hours vehicles rented was 142,299 hours, indicating a vehicle was rented for  
44 approximately 4.4 hours per day, and the cumulative vehicle kilometers traveled was 1,267,287  
45 km with approximately 2,084 km per day and 39.3 km per day for each vehicle.

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1 **TABLE 1 Descriptive Statistics of HappyCar Operation Results for the 20 Months**

Classification	Number of vehicle usage	Number of hours vehicles rented	Vehicle kilometers traveled
Total	27,036	142,299	1,267,287
<i>Number of vehicles used for HappyCar</i>		53	
<i>Number of days operated</i>		608	
<i>Number of vehicle usage per day</i>		27,036/608=44.46	
<i>Number of hours a vehicle rented per day</i>		142,299/(608 x 53)= 4.42	
<i>Vehicle kilometers traveled per day</i>		1,267,287/608=2,084.3	

2

3 **DATA COLLECTION AND DESCRIPTION**

4 The purpose of this study is to analyze which attributes of the HappyCar service require  
 5 improvement in order to enhance the transportation convenience of residents and to identify which  
 6 characteristics of a rental housing complex influence vehicle usage rate. Two types of data were  
 7 employed for the analysis: survey results from members of the HappyCar service and operation  
 8 record log files provided from the service operator.

9

10 **Survey**

11 The survey was carried out targeting members who had an experience of using the HappyCar  
 12 service with a web-based survey questionnaire for two days from September 1, 2015 to September  
 13 2. The survey was conducted based on individual respondents. Since the Importance-Performance  
 14 Analysis (IPA) was used to investigate which attributes of the HappyCar service should be  
 15 improved for enhancing user convenience and comfort, the questionnaire mainly included the  
 16 following survey questions: diversification of vehicle type, appropriateness of rental rates,  
 17 increase in the number of vehicles for the HappyCar service, convenience in the reservation  
 18 system, thorough vehicle maintenance, convenience in time extension and return process, and  
 19 application of luxurious vehicle interior materials and options. In addition, personal information,  
 20 trip purpose, willingness to sell a vehicle, and avoiding an auto purchase were included in the  
 21 questionnaire for reference.

22 The number of members that participated in the survey was 354, with 173 men (49%) and  
 23 181 women (51%). With the distribution of age, the number of members in their 30s was 169  
 24 (47.7%) which was the largest, followed by 102 members in their 40s (28.8%), 48 members in  
 25 their 50s or higher (13.6%) and 35 members in their 20s (9.9%). Out of 354 respondents, only 226  
 26 members (63.8%) answered that they registered their personal vehicle with the maintenance office,  
 27 while the remaining survey respondents did not register a vehicle under their name. The reason for  
 28 asking about vehicle registration, rather than vehicle possession of each person at the time of  
 29 survey is because in some cases, rental housing residents register and use a vehicle even though  
 30 they do not have their own vehicles.

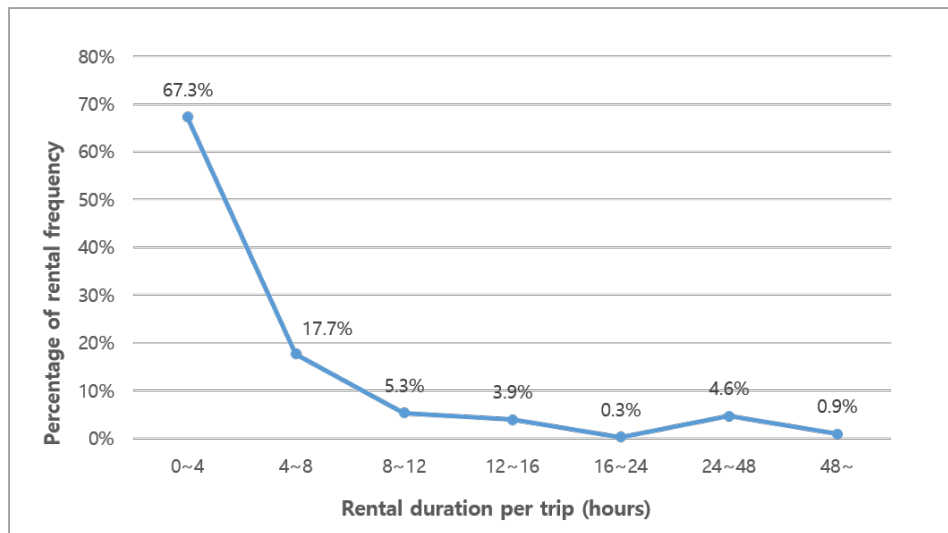
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32 **Investigation of Operation Details**

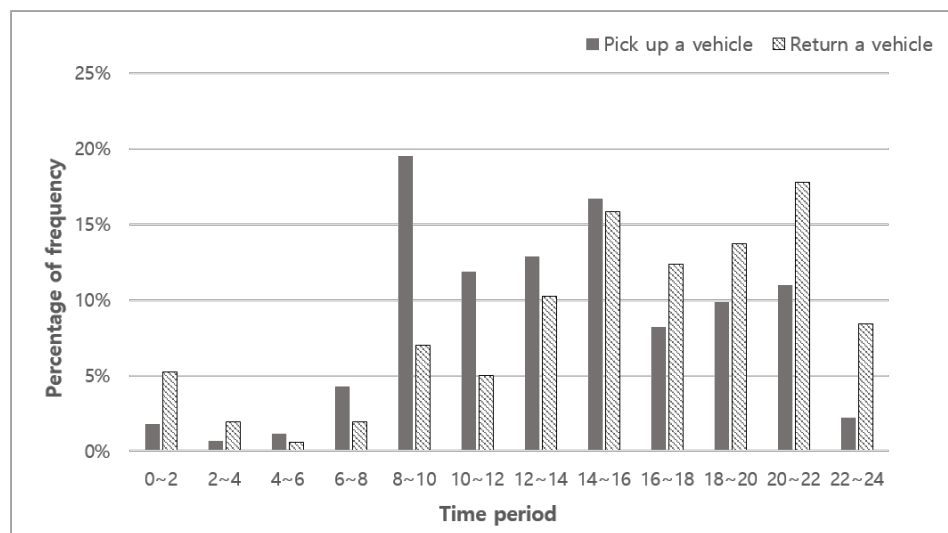
33 Data related to the HappyCar operation was separately stored as a log file into three categories:  
 34 inquiry, reservation and operation. Among three types of data, only reservation and operation data,  
 35 which were collected for 20 months from October 2013 to May 2015, were used for the analysis.  
 36 The total number of data used in the analysis was as follows: 33,782 reservation cases, 27,036

1 operation cases and 104,364 inquiry cases.

2 The operation-related data obtained by classifying the rental hours per 4 hours showed  
 3 that a short-term rental for 4 hours or less accounted for the largest portion among all usage types.  
 4 Figure 1a represents the negative relationship between the number of vehicles rented and the rental  
 5 duration per trip, indicating the number of vehicles rented tends to decrease as the rental duration  
 6 per trip increases. The frequency of vehicles rented for 24 hours or longer up to 48 hours accounts  
 7 for 4.6%, showing a relatively higher rate among long-term rentals. This might be due to a high  
 8 usage rate for a leisure activity with a short overnight itinerary. The percentage of those picking up  
 9 a vehicle between 8 A.M. and 10 A.M. is 19.5%, which was the highest, whereas the percentage  
 10 for returning a vehicle was highest between 8 P.M. and 10 P.M. as shown in Figure 1b. This is  
 11 consistent with the expectation that in general, a vehicle is rented in the morning and returned in  
 12 the evening.



14 (a) Relationship between the number of vehicles rented and the rental duration per trip



17 (b) Distribution of vehicle pickup and return time

18 **FIGURE 1 Example of the Analysis Results of the HappyCar Operation Records**

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From the analysis of rental duration and vehicle kilometers traveled by the types of rental housing complex, Type 2 had 96,461 hours and 862,390 km for the total number of hours for vehicles rented and vehicle kilometers traveled, respectively. This was significantly higher compared to other types (refer to Table 2). This might be from the fact that number of Type 2 was 33, which is the largest among all 45 housing complexes. Therefore, the total number of hours for vehicles rented and vehicle kilometers traveled was divided by the total number of vehicle usage to compare the data more accurately. As a result, Type 1 was found to have the longest number of hours vehicles rented per case (6.7 hours), as well as the longest vehicle kilometers traveled per case (57.3 km).

**TABLE 2 Cumulative Operation Related Data by Rental Housing Type**

Classification	Number of hours for vehicles rented (A)	Vehicle kilometers traveled (B)	Number of vehicle usage (C)	Average number of hours for vehicles rented per vehicle usage (=A/C)	Average vehicle kilometers traveled per vehicle usage (=B/C)
Type 1	27,460	234,836	4,095	6.7	57.3
Type 2	96,461	862,390	19,353	5.0	44.6
Type 3	18,378	170,061	3,588	5.1	47.4
Total	142,299	1,267,287	27,036	5.3	46.9

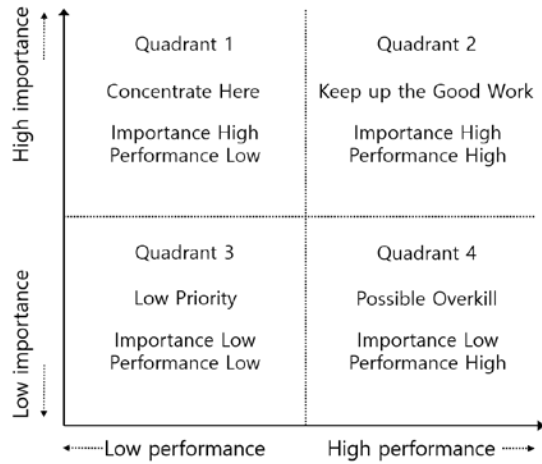
## METHODOLOGY

The Importance-Performance Analysis (IPA) technique was used in order to determine which attributes of the HappyCar service requires improvement to enhance this transportation service for residents. In addition, a beta regression model was estimated to identify factors affecting vehicle usage rate. A beta regression model was employed because the usage rate takes a value of between 0 and 1 and this model is capable of modeling the dependent variable that assumes values in such an interval (0, 1).

### Importance-Performance Analysis (IPA)

The IPA technique suggested by Martilla and James (1997) is used to analyze the importance level and satisfaction level on important properties of a product or a service for the purpose of identifying the prioritization of attributes to be improved. This technique has been utilized in various fields of study including medical examination, competitiveness analysis of hospitals and the banking industry, assessment of adult education, and quality measurement of online services. IPA is an evaluation tool to compare and analyze the relative importance and achievement level of each attribute at the same time by allowing a user to evaluate the importance of each attribute before using the service and the satisfaction level after using the service in order to evaluate the actual level of satisfaction perceived by the user (22).

As shown in Figure 2, the IPA evaluation tool aims to enable effective usage of manpower and budget by comparing the characteristics of service and presenting matters to be solved preferentially. Quadrant 1 is labeled as “Concentrate Here”, indicating that attributes falling into this area are considered important by a user, but the satisfaction level on such items is low and as such active improvements are necessary as a top priority (23). For more detailed information on Quadrants 2 and 4, refer to prior research conducted by Wong et al. (2011).



1  
2 **FIGURE 2 A Two Dimensional IPA Grid (23)**

3  
4 **Beta Regression Model**

5 In general, it is not appropriate to use conventional linear regression models when a dependent  
6 variable is restricted to the interval between 0 and 1, because fitted values by the model may  
7 exceed the lower and upper bounds (24). Thus, a beta regression model is applied when a  
8 dependent variable, such as the rate of change and fractional number, takes a value of between 0  
9 and 1. It is widely used since the range of predicted values is the same as the range of observed  
10 values.

11 The beta regression model can be expressed as a conditional mean for the dependent  
12 variable  $y$  when the independent variable  $x$  is given,  $E(y|x) = \mu$ . However, the dependent variable  
13  $y$  has a value between 0 and 1, so it is expressed as follows by using a link function to the  
14 conditional mean  $\mu$  so as to have the mean value  $\mu$  between 0 and 1.

15  
16 
$$g(\mu) = x\beta \quad \text{or} \quad \mu = g^{-1}(x\beta) \quad (1)$$

17  
18 Typically, a logit function is used as the link function, and Equation (1) can be expressed  
19 as follows when the logit function is applied.

20  
21 
$$\ln\left(\frac{\mu}{1-\mu}\right) = x\beta \quad \text{or} \quad \mu = \frac{\exp(x\beta)}{1+\exp(x\beta)} \quad (2)$$

22  
23 The conditional variance of beta distribution is as follows, and  $\phi$  is the scale factor<sup>1</sup> and  
24 should always be greater than 0. Assuming that the mean is the same, when  $\phi$  becomes larger, the  
25 variance of  $y$  becomes smaller.

26  
27 
$$\text{Var}(y|x) = \frac{\mu(1-\mu)}{(1+\phi)} \quad (3)$$

28  
29 The density function of the beta distribution and the mean and variance of  $y$  are

30  
31 
$$\pi(y; p, q) = \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} y^{p-1}(1-y)^{q-1}, \quad 0 < y < 1 \quad (4)$$

<sup>1</sup> The shape of beta distribution is determined by the value of two parameters  $p$  and  $q$  (Both of two parameters should be higher than 0) and  $\phi$  means the sum of two parameters ( $p+q$ ),



$$E(y) = \frac{p}{p + q}, \quad Var(y) = \frac{pq}{(p + q)^2(p + q + 1)}$$

By substituting  $p + q$  by  $\phi$ , it is expressed as  $p = \mu\phi$  and  $q = (1 - \mu)\phi$ . Therefore, the density function of probability variable  $y$  is converted as follows.

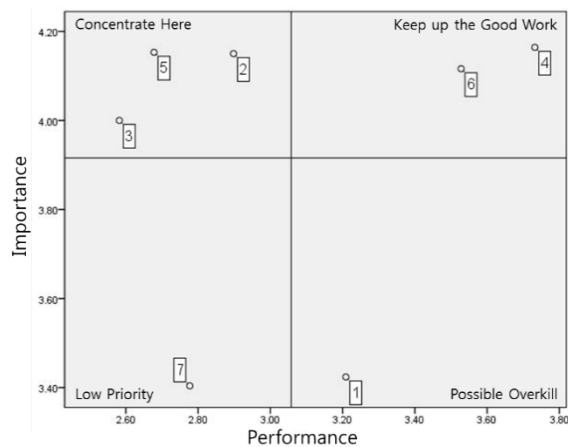
$$f(y; p, q) = \frac{\Gamma(\phi)}{\Gamma(\mu\phi)\Gamma((1-\mu)\phi)} y^{\mu\phi-1}(1 - y)^{(1-\mu)\phi-1}, \quad 0 < y < 1 \quad (5)$$

## ANALYSIS RESULTS

### Survey Results

Out of 226 respondents who owned a personal vehicle, 138 respondents answered that the frequency of using their own vehicle decreased after using the HappyCar service, indicating the possibility of a modal shift from personal vehicles to carsharing services. In addition, 63 respondents (27.9%) answered that they had an inclination to see their own vehicles. This result is very similar to previous study results. Shaheen et al. (2009) reported that carsharing service had an effect of vehicle disposal by approximately 15~32%. Moreover, 102 respondents (45.1%) among the members who owned their own vehicles answered that they gave up on buying a second car after using HappyCar. This is somewhat consistent with prior research because this result falls into a range of between 17% and 77% (25). Therefore, the carsharing service implemented in rental housing complexes has an almost identical effect as conventional carsharing, and it might become an alternative transportation mode that could help service the transportation needs of low-income households.

The IPA results showed that three attributes such as the appropriateness of rental rates, thorough vehicle maintenance and increase in the number of vehicles for the HappyCar service fall into the Quadrant 1(Figure 3), indicating these attributes should be addressed and improved upon as soon as possible. The respondents think that the appropriateness of rental rates can be helpful in increasing the usage rate of the carsharing, and this is consistent with the results of the study conducted by Kim (2015). He investigated the relationship between the rental rates and the usage rate of the carsharing service by looking at low-income household use of a carsharing service during time periods that has a discounted rate. Therefore, it is necessary to adjust the rental rates at an appropriate level in order to increase the carsharing usage rate.



Attributes	Importance	Performance
1. Diversification of vehicle types	3.424	3.209
2. Reasonable rental rates	4.15	2.898
3. Increasing the number of vehicles	4	2.582
4. Convenient reservation system	4.164	3.732
5. Thorough vehicle maintenance	4.153	2.678
6. Convenient return process	4.116	3.528
7. Luxurious vehicle interior	3.404	2.777
Average	3.916	3.058

FIGURE 3 The IPA Results

1 The second attribute is thorough vehicle maintenance. For carsharing, unlike a rental car,  
 2 vehicle maintenance may be neglected once a trip is completed since there is not enough time to  
 3 wash the car and provide a checkup before the next service. This becomes a factor affecting  
 4 comfort and safety, resulting in avoidance in use of the carsharing service. Therefore, thorough  
 5 vehicle maintenance such as periodic vehicle checkups and car washes will be helpful in  
 6 increasing the carsharing usage rate. Lastly, an increase in the number of vehicles for the  
 7 HappyCar service was identified as an attribute for improvement. Currently, only one or two  
 8 vehicle (s) are used for the HappyCar in each rental housing complex, and thus members are often  
 9 unable to reserve a vehicle at a desired time. As also mentioned in the previous studies (2, 16), the  
 10 number of vehicles used for the carsharing service has a positive relationship with the usage rate,  
 11 so it is expected that an increase in the number of vehicles will help increase the vehicle usage rate.

12 Contrary to our expectation, the diversification of vehicle type was not included in the  
 13 attributes to be improved. It was expected that there would be a demand for luxury vehicles and  
 14 SUVs since economy-type vehicles might not meet the various needs of members. However, the  
 15 analytical results did not bear out this hypothesis. Probably, the likelihood of an increase in the  
 16 rental rates for more luxurious vehicles was a factor in participant feedback.

### 17 **Model Estimation Results**

18 The beta regression model was developed to analyze how the characteristics of rental housing  
 19 complex influence vehicle usage rate. The beta regression model can be estimated by using  
 20 programs such as SAS, SPSS, R/SPlus, Mathematica and WinBUGs. The model in this study was  
 21 developed using STATA 14, which is a commercial software program.

22 A total of five independent variables were used as presented in Table 3. The vehicle usage  
 23 rate, which is a dependent variable, was calculated as the number of hours vehicles rented divided  
 24 by the total number of hours vehicles are in service during a 20-month period. The average vehicle  
 25 usage rate was approximately 18.9% and it ranged from a minimum of 6.5% to a maximum of  
 26 41.6%. For the type of rental housing, Type 2 accounted for approximately 73.3% among 45  
 27 housing complexes and Type 3 and Type 1 accounted for 11.1% and 15.6%, respectively. The  
 28 average number of households in each complex was approximately 1,385 and the number of  
 29 vehicles registered per household was approximately 0.7 vehicles per household. About 53.8% of  
 30 households were one or two person households, and three or four person households accounted for  
 31 approximately 37.2%. Also, the average of bus routes stopping by a bus stop located within a 500  
 32 m radius around each complex was approximately 16.1 routes.

33 **TABLE 3 Descriptive Statistics of Variables Used in the Analysis**

Variables	Mean	St. Dev	Min	Max
<i>Dependent Variable</i>				
Vehicle Usage Rate	0.189	0.084	0.065	0.416
<i>Independent Variable</i>				
Rental Housing Type				
Type 1	0.156	0.367	0	1
Type 2	0.733	0.447	0	1
Type 3	0.111	0.318	0	1
Number of households (×1,000 household)	1.385	0.525	0.531	2.634
Number of vehicles registered per household (veh/household)	0.697	0.301	0.197	1.769

Proportion of households by number of household members (%)				
One or two person household	53.8	11.6	28.4	79.8
Three or four person household	37.2	10.1	17.1	62.2
Five or more person household	5.2	2.3	1.9	10.8
Number of bus routes*	16.11	8.153	4	41

\*: It represents the level of public transportation supply per each complex and means the number of bus routes that stop by a bus stop located within a 500m radius around each complex.

Table 4 presents the estimation results of the beta regression model. Five variables, except for the number of bus routes and the number of vehicles registered per household, were found to be statistically significant at a 95% confidence level. As a result of analyzing the type of rental housing with Type 1 set as the reference variable, Type 2 and Type 3 showed a higher usage rate than Type 1. This result might be because the income of households residing in Type 2 and Type 3 is higher than that of households residing in Type 1, and as the income is higher, financial conditions to use transportation modes besides public transportation is more favorable and the demand to use the HappyCar service for shopping and leisure activities is relatively high.

**TABLE 4 Estimation Results of a Beta Regression Model**

Variables	Beta Regression		Marginal Effects	
	Estimates	<i>p</i> -value	Estimates	<i>p</i> -value
Constant	-4.712 (1.096)	0.000		
<i>Rental Housing Type</i>				
Type 2	0.925*** (0.255)	0.000	0.140 (0.038)	0.000
Type 3	0.938** (0.441)	0.034	0.142 (0.067)	0.033
Type 1 (reference variable)				
Number of households (×1,000 household)	0.555*** (0.142)	0.000	0.084 (0.021)	0.000
Number of vehicles registered per household	-0.027 (0.346)	0.938	-0.004 (0.052)	0.938
<i>Proportion of households by number of household members (%)</i>				
One or two person household	0.025** (0.012)	0.042	0.004 (0.002)	0.042
Five or more person household	0.114** (0.057)	0.044	0.017 (0.009)	0.044
Three or four person household (reference)				
Number of bus routes	-0.014* (0.009)	0.099	-0.002 (0.001)	0.099

Note: For parameter estimates, standard errors appear in parentheses.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The results showed that the number of households has a positive relationship with usage

1 rate, indicating that the usage rate tends to increase as a housing complex has a higher number of  
2 households. This result corresponds to a common expectation that a housing complex with a  
3 higher number of households has a relatively larger potential demand to use carsharing service.

4 In order to analyze a change in the vehicle usage rate according to the rate of number of  
5 households per household member, a reference variable should be determined. In this study, a three  
6 or four person household was considered to be a normal form of household structure and was set as  
7 a reference variable. The results showed that the usage rate increased when the component ratio of  
8 one or two person households in the complex was higher than the component ratio of three or four  
9 person households, and the usage rate also increased when the component ratio of five or more  
10 person households was high. Considering the fact that one or two person households have a  
11 relatively insufficient economic capacity to own a personal vehicle and a high rate of dependence  
12 on public transportation (26), there is a high possibility for them to use the HappyCar for shopping  
13 or traveling. For five or more person households, the vehicle is used frequently by another member  
14 when needed, so the mode change to the HappyCar service occurs naturally.

15 Although the number of bus routes was not significant at a 95% significance level, the  
16 number of bus routes has a negative relationship with usage rate, indicating that as the number of  
17 bus routes passing around the rental housing complex is higher, the vehicle usage rate decreases.  
18 Generally, a large number of bus routes passing around the housing complex means that the  
19 environment for using public transportation is favorable, and as such, there are many alternative  
20 bus routes that can be selected to achieve a trip purpose without using the HappyCar, and therefore  
21 the vehicle usage rate eventually decreases.

22 The number of vehicles registered per household was found to have a negative influence  
23 on the usage rate, but no statistically significant result was obtained. Although this variable was  
24 not statistically significant, the tendency of a lower vehicle usage rate at a housing complex with a  
25 larger number of vehicles registered per household is consistent with common sense assumptions.

26 In the beta regression model, a regression coefficient of independent variables does not  
27 mean the change amount of the dependent variable  $y$  when the independent variable  $x$  changes by  
28 one unit, just as with a conventional linear regression model. This is because a dependent variable  
29 and independent variables are linked with a logit function. Therefore, the change amount of the  
30 dependent variable  $y$  when the independent variable  $x$  changes by one unit in the beta regression  
31 model can be examined through the marginal effect.

32 As also shown in Table 4, Type 2 and Type 3 increased usage rate by 0.140 and 0.142,  
33 respectively, compared to Type 1, and Type 3 had a slightly higher influence on the usage rate than  
34 Type 2. The usage rate increased by approximately 8.4% (0.084) when the number of households  
35 increased by 1,000 households and the component ratio of one or two person households and the  
36 component ratio of five or more person households increased the usage rate by 0.4% and 1.7%,  
37 respectively. For number of bus routes, the usage rate decreased by approximately 0.2% when the  
38 number of bus routes increased by 1 bus route.

## 39 **CONCLUSIONS**

40 This study focused on a closed carsharing service which is operated in rental housing complexes.  
41 Even though various studies have been conducted on whether a carsharing could actually play a  
42 role as an alternative transportation in an area where residents are primarily low-income  
43 households or in community with elderly people, little research has been done on a closed  
44 carsharing service. This study provides insights to better understand which attributes should be  
45 improved so that the HappyCar service can become an alternative transportation mode for  
46 low-income households and identifies which factors among the characteristics of rental housing  
47

1 complex influence vehicle usage rate.

2 The survey results targeting current users of HappyCar showed that 27.9% of members  
3 who owned a vehicle had an inclination to sell their own vehicles and 45.1% gave up on buying a  
4 second car due to the carsharing service. These results are very similar to the results presented in  
5 prior research. The IPA technique identified three attributes that should be prioritized for  
6 improvement: reasonable rental rate, thorough vehicle maintenance, and increase in the number of  
7 vehicles. Diversifying vehicle types was not identified as an attribute for improvement because  
8 there might be a concern about increases in the rental rates with more luxurious vehicles.

9 The main findings from model estimation results are as follows. Firstly, the usage rate in  
10 Type 2 and Type 3 was higher than Type 1, where the lowest-income households reside, and this  
11 was because the transportation demands increased as income increased. Secondly, a housing  
12 complex with a higher number of households had a higher vehicle usage rate. Thirdly, the usage  
13 rate increased as the component ratio of 3 or 4 person households in a complex was higher than the  
14 component ratio of 1 or 2 person households, and this is because 1 or 2 person households have a  
15 higher tendency for dependence on public transportation. The number of bus routes stopping near  
16 a complex and the number of vehicles registered per household were not found to be statistically  
17 significant, but these variables had a negative association with the vehicle usage rate as expected.  
18 From the viewpoint of the marginal effects of variables, the type of rental housing was found to  
19 have the highest effect on vehicle usage rate. This is because income and the usage rate of  
20 carsharing are very closely related to each other, and thus the costs for use of a carsharing service  
21 become a burden if income is low.

22 The possibility for the carsharing service to become an alternative transportation mode  
23 that could secure the mobility of a marginalized neighborhood was confirmed through the results  
24 of this study. In addition, this study enables a better understanding of the characteristics of  
25 carsharing, including use by low-income residents in rental housing, and provides many  
26 recommendatio for HappyCar service providers and traffic policy decision makers. Especially,  
27 this study can help in determining the most appropriate supply sizes of the HappyCar service for  
28 each complex by considering the characteristics of rental housing complexes.

29 This study is significant in that analysis was done using actual log files provided by the  
30 service operator. This study, however, had the following limitations that require improvement in  
31 order to draw more useful implications. First, the trip purposes for use of the HappyCar per each  
32 usage were not collected in the log files, and as such it was not possible to do analysis on the usage  
33 rate according to purpose. Considering the possibility that the vehicle type may vary depending on  
34 the purpose of using the service, an analysis of usage rate for each purpose for use of the service  
35 could be very helpful to operators of the HappyCar service in terms of making various decisions  
36 related to vehicle supply. Another limitation was the phenomenon of exclusive usage included in  
37 the calculation of usage rate, which was the main area of interest in this study. When the  
38 phenomenon of exclusive usage prevails, it may increase the usage rate as well as the reservation  
39 failure rate of the HappyCar service, and thus may become a factor that hinders effective  
40 utilization of the HappyCar service. Therefore, it is expected that considering the reservation  
41 failure rate as it relates to the phenomenon of exclusive usage when analyzing factors influencing  
42 the usage rate could provide more reliable results.

43

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