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Finding Factors that Influence Carsharing Usage: Case Study in Seoul

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Abstract: The goal of this research is to investigate the factors that affect carsharing demand. As a proxy for carsharing demand, the number of (booking) transactions made by carsharing users is counted based on the data from one of the two major carsharing operators in Seoul, Korea. In order to identify the factors influencing station-based carsharing usage, multiple linear regression modeling was performed with the number of carsharing transactions as a dependent variable and with the three groups of independent variables: Built environment, demographic, and transportation variables. Instead of using the locations of the pods, this study uses the residential locations of carsharing users who made transactions, and the final result analyzing 420 districts shows that six variables significantly influence carsharing usage. Carsharing demand is high in an area where a higher proportion of building floor area is used for business, and which has a higher proportion of young residents in their 20s and 30s. It can also be predicted that the area with more registered cars and less subway entrances will show higher carsharing demand. The analysis result also suggests that providing additional carsharing pods, especially pods that utilize city owned public parking facilities, will help promote carsharing usage. This research establishes a basis for future research efforts to forecast carsharing demand and to identify areas with high potential, especially in major Asian cities.

Keywords: carsharing usage; carsharing demand analysis; transaction record; booking data; public-private partnership (PPP) carsharing in Seoul

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1. Introduction

The history of carsharing is much longer than most people realize. According to Shaheen et al., the earliest carsharing service was recorded in Europe in 1948 [1]. Since the late 1990s and early 2000s, carsharing has been mainstreamed in American cities and was recently introduced to major Asian cities including Seoul, Korea. Technological innovation in internet, mobile, and social media has opened up new opportunities for a more sharing economy, which has facilitated successful startups, such as Airbnb and Uber that emerged after the 2008 global economic crisis. The city of Seoul has started paying attention to the economic and environmental benefits that a sharing economy can bring to the future society. As an alternative to private mobility, carsharing has been promoted by the city since the late 2000s. In transportation, carsharing has long been viewed as a sustainable mode. Existing literature shows that carsharing can reduce car ownership, vehicle miles traveled (VMT), and even help improve air quality [2,3]. As carsharing can contribute to sustainable transportation and urban planning, and eventually help a city to consume less energy and resources, the success of carsharing in Seoul and other major Asian cities is important.

2. Literature Review

Since the inception of carsharing programs in American cities, carsharing has become one of the most popular research topics in transportation. Since the seminal studies published in the early 2000 [1,4], more than a hundred carsharing studies have been published. Existing carsharing research can be categorized into multiple subgroups including the followings: (1) user characteristics and behaviors; (2) environmental impact of carsharing; (3) demand analyses; and (4) service optimization. The first group focuses on the current carsharing users and their socio-economic profiles, especially on the reasons for choosing carsharing (e.g., environmental attitude). The second group of carsharing studies deals with the changes in the travel behaviors of carsharing users, such as car ownership, modal shift, and VMT or with the environmental impact of carsharing, such as greenhouse gas emissions. Demand analyses can be carried out with either current users or potential users. The current carsharing usage can be used as a proxy for demand under the assumption of supply-demand equilibrium, while potential demand can be estimated by various methods including stated preference surveys. With an emergence of one-way/free-floating services, with which a user can return the vehicle to another pod or any designated on-street parking spot within an operation area, optimization studies are recently gaining popularity [5,6]. The goal of these optimization studies is to find the optimal fleet size or to optimize the distribution of carsharing pods. Developing a vehicle relocation algorithm to solve supply and demand imbalance is the main focus in these studies.

However, a comprehensive demand analysis based on real carsharing usage data is identified here as a gap in the literature. An analysis revealing the spatially contextual urban and transportation factors that influence carsharing usage is particularly rare. Relatively little such research has been performed, mainly because of the lack of carsharing activity and user data available for researchers. For privacy protection, carsharing operators are reluctant to provide any personal information related to their users [7]. Because of this data deficiency, Celsor et al. used an alternative approach of utilizing the carsharing level of service (LOS) (the number of vehicles provided by carsharing operators) as a proxy for carsharing demand [8]. As a first meaningful study to test the impact of both built environment and socio-economic factors, Celsor et al. suggests the threshold values for minimum carsharing LOS in terms of demographics, commute mode share, vehicle ownership, and housing density. The method developed by Celsor et al. was further upgraded by Stillwater et al. [9]. With raw carsharing activity data acquired directly from an unidentified large operator in America, they analyzed the actual number of user hours at each carsharing pod as a proxy for carsharing demand and built the first meaningful regression model to test the effect of socio-economic characteristics, neighborhood built-environment, and transit accessibility [9].

For the comprehensive analyses including all three types of variables, location information associated with carsharing usage data is critical. For example, Morency et al. analyzed carsharing transaction data without a location identifier and thus could not test neighborhood socio-economic and built environment variables [10]. With the data from the carsharing operator of Montreal, De Lorimier and El-Geneidy estimated a model that predicts the number of monthly hours-reserved per vehicle [11]. Along with vehicle- and operation-related variables, a relatively small number of socio-economic and built-environment factors are tested for their research. Three of the four such variables, average income, density of big box stores, and jobs measured within the station's spatial buffers, were actually significant. Instead of using the total hours of usage in each station, they denominated the variables by the number of carsharing vehicles. While this will improve the applicability of the modeling result for the operator's profit maximization, it might limit the ability to test the effect of neighborhood factors [11]. In a similar vein, Kim uses a usage rate, which is "calculated as the number of vehicles rented divided by the total number of vehicles in service" [7]. Instead of acquiring a raw usage log directly from the carsharing operators in New York City, Kim manually collected the vehicle information available for its members through the reservation platform. This study shows that it can be an effective alternative method for collecting carsharing usage data that is difficult to obtain.

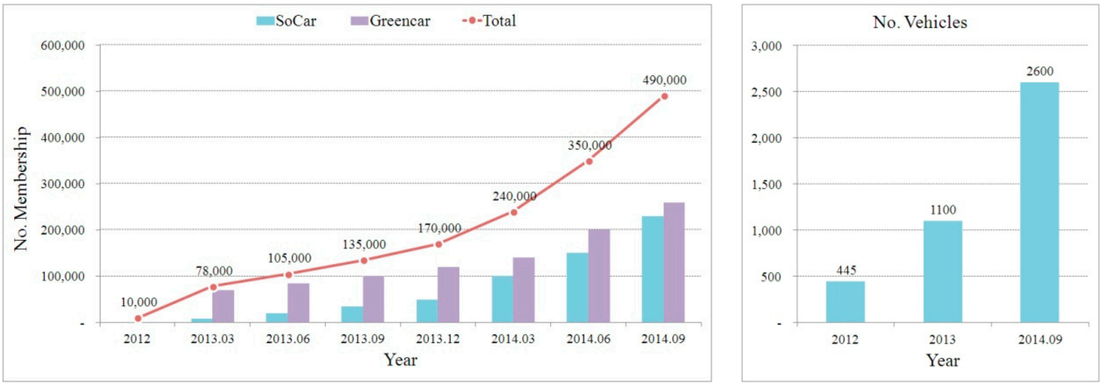
For the GIS analyses of all the aforementioned studies, the location identifier is a pod location. However, Schmoller et al. shows that spatial analyses that test socio-economic, built-environment, and transit accessibility would become more difficult with the booking data from new free-floating services [12]. Their research was performed based on carsharing booking data from Munich and Berlin, which have the GPS coordinates of trip start and end points instead of the traditional pod locations. This poses a dilemma for researchers who then need to choose either a trip starting or ending point, or to utilize an alternative point as a spatial identifier for extracting socio-economic, built-environment, and transit accessibility variables. In this case, information related to carsharing users' residential location can be a more effective spatial identifier, if available for researchers. According to a recent German study on free-floating services, more than 60% of transactions have either trip origin or end point within a half kilometer from the users' home addresses [13].

3. Carsharing in Seoul

Motivated by the increasing global sharing economy, as well as the increasing usage of smartphones, the first grass-roots carsharing program was started in 2009 in Gunpo, a small edge city of the Seoul metropolitan area [7]. In 2011, a profit-based carsharing service was initiated in Seoul by a private carsharing operator named GreenCar. Soon after, SoCar and other several startups launched carsharing services in Seoul. As smartphones are widely used in Korea, the penetration rate reached 83.9% overall and 99% for those in their twenties as of August 2015 [14]. While its well-connected mobile network is good for carsharing, Seoul may not be a favorable place for carsharing, mainly for the following two reasons. First, it has a good public transportation system well-known for the web of BRT lines and the nine subway lines with more than 300 stations [15]. In 2013, the bus and subway systems together comprise 65.9% of the mode share in Seoul, while the mode share of privately owned vehicles is only 22.9%. New carsharing startups need to compete with strong public transit systems, as well as the city's easily accessed affordable taxi service, which comprises 7% of the total mode share [16]. Ironically, to the supporters of sustainable transportation, the existing sustainable modes work against the inception of the new sustainable mode, as this well-developed transit system becomes a major threat to incubating carsharing startups.

The second disadvantage for carsharing in Seoul is the lack of parking space. In Seoul, one of the oldest and densest major cities, finding spaces desirable for carsharing pods is very difficult for small carsharing startups. Unlike in American cities where carsharing is often provided jointly with transit-oriented developments (TOD), most subway stations in Seoul do not have parking lots, as the majority (about 80%) of subway users walk for their access trips to the station [17]. At the beginning, multiple carsharing startups exploited the opportunity and then later struggled, and the Seoul Metropolitan Government intervened to help. In February 2013, the government launched a new carsharing service called "Nanum Car" [18]. Nanum refers to the concept of "dividing equally and sharing" in Korean. As a first public-private partnership (PPP) carsharing program in Korea, the major role of the government is to provide parking spaces for the carsharing startups by using the public parking facilities operated by the city. It is one of the most frequently used public intervention tools to incubate a new carsharing program. In Sydney, for example, the city allocated on-street parking spaces exclusively for carsharing vehicles [19]. Through a public tendering process, the city of Seoul invited carsharing companies to commission the new program, in which two private carsharing operators, GreenCar and SoCar, were selected as the operators and four smaller startups were selected as electric vehicle-based carsharing operators. The commissioned private operators are allowed to use the city's public parking facilities and in return, they are obligated to station their vehicles to fill the designated lots assigned for the program by the city.

The basic fare initially set for the carsharing program is 3300 KRW (approximately 3 US dollars) for 30 min (the price of a Big Mac in Korea was 3700 KRW in 2012). Initially, it was a station-based two-way service with designated pods (with extra fees, one-way and free-floating options became available beginning November 2015). After the new program was launched, the number of pods, vehicles, and memberships grew rapidly. When the program was launched in February 2013, the total number of pods and vehicles was 292 and 492, respectively. By November 2014, the total membership of the Nanum carsharing service had grown rapidly to 350,000 and the total number of pods and vehicles had increased to 850 and 1816, respectively [20]. A national trend shows a similar rapid growth as shown in Figure 1. According to a Korean report, however, if a 300-m circular buffer from each pod is applied as a threshold for easy access, only 45% of the urbanized area of Seoul has good accessibility to the carsharing service, and the majority of the pods have only one or two carsharing vehicles [17].



(**a**) (**b**)

Figure 1. Nationwide Growth Trend of Carsharing Membership and Vehicles in Korea [21]. (**a**) Growth Trend of Carsharing Membership; (**b**) Growth Trend of Carsharing Vehicles.

4. Methodology

4.1. Data

The goal of this research is to investigate the factors that affect carsharing demand. Under the assumption that the carsharing supply-demand equilibrium in Seoul is maintained, carsharing usage is analyzed as a dependent variable representing carsharing demand. As a proxy for carsharing usage, we counted the number of (booking) transactions made by carsharing users. The transaction data used for this study are sourced from GreenCar, one of the two major carsharing operators in Korea (Figure 2). Often considered to be "proprietary", the transaction data are very difficult to access [9], which is one of the reasons for the lack of research on carsharing usage and demand. This research is possible by the generous contribution from GreenCar. The data include all the transactions occurred in the second week of December 2014 (before GreenCar added the one-way/free-floating service options). The primary reason the earlier data was not able to be used is that there is no information available related to the residential locations of carsharing users. The total number of GreenCar transactions during the week in Korea and in Seoul was approximately 9400 and 4800, respectively. Excluding transactions without the location information of users, the total number used for the present study is 2854. The seven day transaction data include the date of use, pickup and returning times, vehicle miles traveled, and the administrative district associated with the users' residences. As seen in the graph of the vehicle pickup times in Figure 3, there are two peak periods for carsharing demand in a day—10:00 a.m. to 3:00 p.m. and 7:00 p.m. to 1:00 a.m. The trend shows a tendency of carsharing users to avoid morning and evening commuting rush hours. More than 80 percent of usages are travels of less than 100 kilometers (Figure 3). An administrative district is called a "dong" in Korea, of which Seoul has more than 400. The average size of the districts in Seoul is approximately 1.4 km^2 and the average population is approximately 25,000. Due to a privacy protection regulation levied on public programs, the disclosure of members' detailed personal information, such as trip purpose, income, and home address was prohibited.

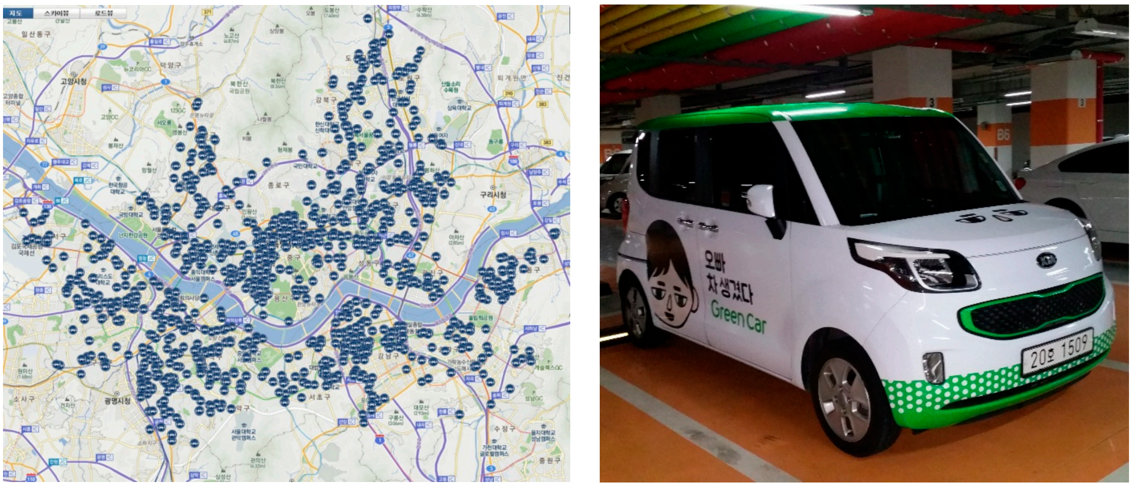


Figure 2. Carsharing Pod Locations in Seoul [22] and a carsharing vehicle.

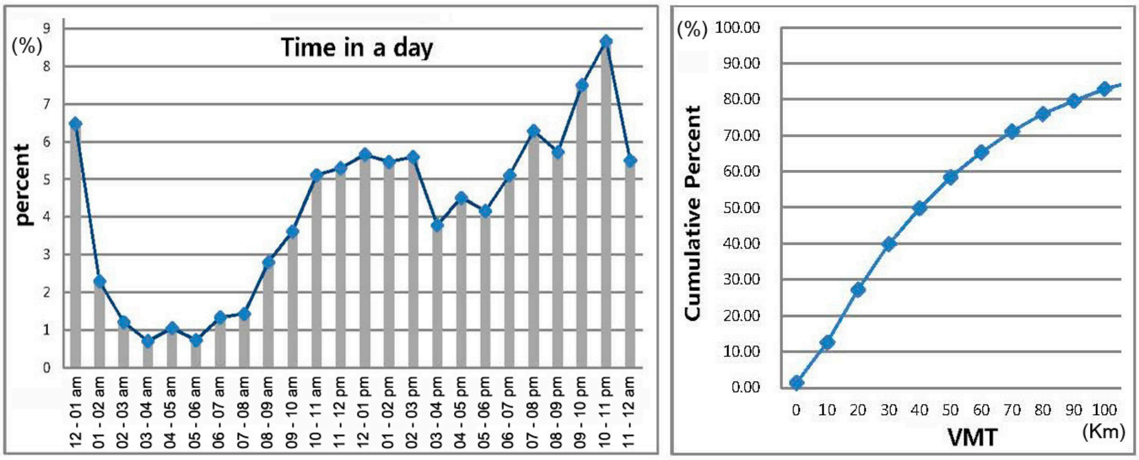


Figure 3. Vehicle pickup times and vehicle miles traveled (VMT) (km) district.

4.2. Variables Tested for the Analysis

The district served as a basic unit of the analysis and the total number tested for this study is 420, excluding three districts without some key data available (Figure 4). The descriptive statistics of the tested variables are listed in Table 1. The number of carsharing transactions is used as a proxy for carsharing usage, which is the outcome variable for the regression model. Instead of using the locations of the pods, this study uses the residential locations of carsharing users who made transactions. The reason for using residential locations is twofold. First, analyzing the residential locations of carsharing users is a rare opportunity for researchers. As residential locations are difficult to acquire, most carsharing demand research uses the location of pods under the assumption that pods are close to the carsharing users' place of residence. If the general trend of the carsharing business shifting from two-way to one-way/free-floating continues, however, residential locations may be more important than the pod locations. We believe that free-floating will be a norm in the near future when autonomous vehicles will be mainstreamed and used for carsharing. The total number of transactions occurred during the second week of December 2014 are compiled and counted by each district, the basic unit of analysis. As the distributions of carsharing transactions were positively skewed, natural log-transformations are performed for the carsharing usage variable.

Table 1. Variables tested (N = 420 districts).

Variable Description	Min.	Max.	Mean	Std. Dev.
Outcome Variable				
Total Number of carsharing transactions in a week	0	44	6.8	6.85
Built Environment Attributes				
Population density (pop/ha) of the district	8.43	599.40	248.46	123.33
Ratio of total floor area for residential use in the district (%)	2.97	97.95	70.42	18.07
Ratio of total floor area for commercial use in the district (%)	0.67	93.42	25.29	16.35
Ratio of total floor area for business use in the district (%)	0.00	5.81	0.72	0.78
Ratio of total floor area for educational use in the district (%)	0.00	69.98	0.23	3.43
Demographic Attributes				
Average number of residents in a household (#/household)	1.45	3.41	2.42	0.33
Percentage of male population (%)	43.98	61.15	49.44	1.78
Percentage of population between 20 and 39 year old (%)	18.94	56.84	31.49	5.11
Percentage of population over 65 years old (%)	6.61	23.00	12.35	2.47
Transportation-related Attributes				
Total number of registered cars	0.00	24490	6932.97	3251.27
Average number of cars owned by a household	0.00	4.9	0.73	0.41
Total number of bus lines serving the district	0.00	424	58.56	55.36
Total number of shuttle bus lines serving the district	0.00	44	8.06	9.00
Total number of subway entrances in the district	0.00	28	3.51	4.03
Total number of carsharing pods in the district	0.00	15	2.4	2.40
Frequency of using pods assigned by the PPP program *	0.00	14	1.69	2.24
Existence of the PPP pods (dummy: yes = 1; no = 0)	0.00	1	0.59	0.49

* PPP means "public-private partnership".

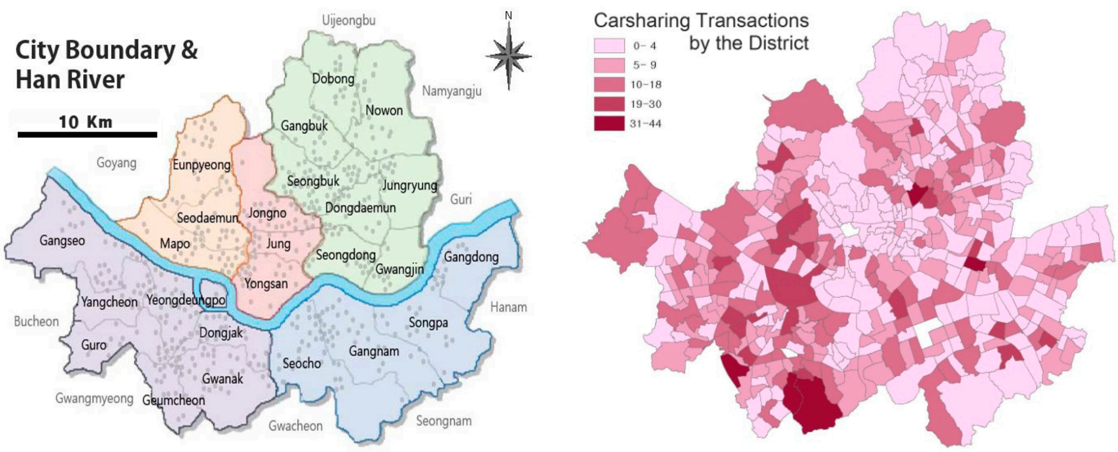


Figure 4. Map of Seoul [18] and carsharing transaction counts according to the district.

We tested three groups of independent variables: built environment, demographic, and transportation-related. The list of variables and their descriptive statistics are presented in Table 1. The database of building floor area usage is created based on KRIHS land use database and demographic data are extracted from Seoul Statistics [23,24]. The transportation-related database is built based on the Korea Transport DataBase (KTDB) [25]. The data are spatially integrated using a Geographic Information System (GIS) and variables are extracted from the database.

4.2.1. Built Environment-Related Variables

Built environment is measured according to the population density and the ratios of building floor uses. In previous studies on public transit usage or auto-dependency, population (or housing) density has been tested as a major determinant. High-density is necessary for sustainable transportation modes, including walking, bicycling, and carpooling [4]. Especially in American cities, carsharing is also expected to show an association with a high-density urban built environment, for the following two reasons. First, carsharing must compete with privately owned vehicles, which consistently show a negative relationship with density. Secondly, a carsharing service is often provided jointly with rail transit stations, where high-density is expected and necessary. According to a 2005 report, 95% of carsharing members are concentrated in the "metropolitan cores," where high density and parking pressure support carsharing businesses [26].

Another attribute that is most frequently used for measuring built environment is land use or a mix of land uses [27]. Along with high density, land use mix is expected to facilitate the success of a carsharing business [26]. We utilized the ratio of the total building floor area used for a specific purpose within a district, and four different floor area uses are measured: residential, commercial, business, and educational. In a highly developed city in which vertical mixed-use is allowed, building floor area uses can represent the neighborhood built environment more effectively than land uses. For example, unlike many American cities that traditionally allow only a single use exclusively for a property, many commercially vibrant neighborhoods in Seoul are actually designated as residential or business areas, as the city's complex land use rules allows a vertical mix for most commercial activities while effectively excluding undesirable uses. In this case, building floor area use works better than land use.

4.2.2. Demographic-Related Variables

Four demographic-related attributes are measured for each district: the average number of residents in a household, percentage of male population, percentage of population between 20 and 39 years old, and percentage of population over 65 years old (Table 1). The one or two person household was mentioned as one of the characteristics of carsharing users [20] and later Celsor and Millard-Ball tested the percentage of "1-person households" [8]. The gender of carsharing users has been tested in several studies, revealing that males use carsharing services more frequently than females [10,28,29]. For this study, the average household size and percentage of male population are measured for each district and tested as an independent variable.

Age difference is one of the demographic attributes expected to be influential, as mentioned by numerous studies. The median age of the City CarShare users in San Francisco was 36 years in 2003, about 43% of which were between the ages of 25 and 34 [30]. A 2012 study, based on a Montreal carsharing service, found that the average age was 39.5 years, while 40.4% of the members were aged between 30 and 39 [28]. In a study on a free-floating service in Munich, the percentage of persons between 30 and 39 years had the highest (positive) correlation with booking frequency [12]. Stillwater et al. tested three age-related variables: Population between the ages of 22 and 24, between 25 and 29, and between 30 and 34. The present study included two variables: The percentage of population between 20 and 39 year old and the percentage of population over 65 years old. A positive relationship is expected for the former and a negative relationship is expected for the latter.

4.2.3. Transportation-Related Variables

Three groups of transportation-related variables are tested: variables related to (1) privately owned cars; (2) public transits; and (3) parking for carsharing. The most frequently tested variable for carsharing research is the number of cars owned by a household. Based on previous research, it is expected that carsharing demand will be higher in an area with lower than average car ownership [26]. The variable of households with no car was tested for Cervero and Tsai [30], while an average vehicle per household within the 0.5-mile radius of carsharing pods was measured for Celsor and Millard-Ball [8]. For this study, the average number of cars owned by a household is measured and tested. As an alternative, the total number of registered cars within each district is also included, in consideration of the different situation in Seoul, where car ownership and car dependency is relatively low, compared to American cities. In regard to public transit accessibility, three variables are measured.

Through GIS mapping, we measured the total number of bus lines serving each district, as well as the total number of town bus lines. In Korea, a town bus is a unique but indispensable transit system connecting travelers' homes and nearby subway stations or major bus stops. Town bus vehicles are smaller than normal bus transit vehicles and run on shorter routes covering only several districts.

Access to public transits, to subway stations in particular has been considered as a major determinant of carsharing demand, especially in American cities where carsharing pods are often located within station parking facilities. Testing the influence of transit accessibility was the main focus for Stillwater et al., which tested five variables related to the availability of rail transit services, including the number of subway or elevated rail lines [9]. In Seoul, most subway stations are built underground and for some transferring subway stations with multiple lines, the distance between their entrances is over a half kilometer. As the locations of subway entrances and their numbers are more important than the locations of stations, the total number of subway entrances in each district is measured for this research. The third group of transportation variables is related to parking. The total number of carsharing pods in each district is measured and tested. A similar variable was tested by Stillwater et al. and Kim [7,9]. To evaluate the effect of the public-private partnership (PPP) intervention in Seoul, two parking-related variables are also included: the frequency of using pods assigned by the PPP program and the existence of PPP pods within the district (Table 1).

5. Analysis Result and Discussion

In order to identify the factors that affect carsharing usage, linear regression modeling was performed with the number of carsharing transactions occurred in the district as a dependent variable and with the three groups of independent variables: built environment, demographic, and transportation variables. We analyze 420 districts and the final result shows that six variables enter the best-fitting model at the 0.05 alpha level (Table 2). The R-squared value is 0.4839, meaning that the six independent variables collectively account for 48.39% of the variance observed in the carsharing usage data.

Table 2. Regression model estimating carsharing usages.

Variables	Estimate	Robust Standard Error	t-Ratio	Prob > |t|
Ratio of total floor area for business use in the district (%) *	0.0765	0.04	2.01	0.045
Percentage of population between 20 and 39 year old (%) **	3.5007	0.58	6.02	0.000
Total number of registered cars **	0.0001	0.00	7.04	0.000
Total number of subway entrances in the district **	−0.0393	0.01	−4.72	0.000
Total number of carsharing pods in the district **	0.0571	0.01	4.31	0.000
Existence of the PPP pods (dummy: yes = 1; no = 0) **	0.7606	0.06	12.61	0.000
Constant	−0.2207	0.19	−1.15	0.251
Summary Statistics:				
Number of observation	420			
R-squared	0.483			
F-Statistics (Probability)	70.70 (0.00)			

* Significant at the 0.05 alpha level; ** Significant at the 0.01 alpha level.

Among the built environment variables, the ratio of total floor area for business use exerts a statistically significant influence on carsharing usage. With a positive sign of its coefficient, this can be inferred that building floors used for businesses help promote the carsharing usage within the district. Unlike the initial expectation, we cannot find such effect from the floor area used for commercial uses. The usage (per vehicle) model estimated based on the carsharing program in Montreal includes variables that represent both business and commercial uses: the number of jobs and big box stores within 30 min by car [9]. However, our result is consistent with the finding by Schmoller et al. on free-floating services in Munich and Berlin, for which the number of companies (per square km) has a positive impact [12].

For the present research, the population density is not included, which is different from American carsharing literature which emphasizes that population density high enough to support both public transit and carsharing is essential for the success of carsharing startups. Density may not be as critical in a high-density city, such as Seoul, as it is in low-density American cities. Seoul's population density is approximately 17,200 inhabitants per square kilometer, which is almost 4.5 times higher than the minimum density threshold of 10,000 people per square mile (equivalent to 3861 per km^2) used by Zipcar [8]. Celsor and Millard-Ball used housing density as one of the six criteria for carsharing level of service and suggested five housing units per acre as a threshold density; however, they also mentioned, "density may not be as dominant in explaining carsharing market settings as it is in the case of transit" [8]. The household density was tested by Stillwater et al., but not included in their final model [9].

Only one demographic variable, the percentage of population between 20 and 39 year old, enters our model at the statistically significant level. This result directly supports the notion that carsharing demand is higher in the internet- and mobile-savvy young generation. Stillwater et al. tested three age variables (population between the ages of 22 and 24, between 25 and 29, and between 30 and 34), but none was statistically significant [9]. The difference may be explained by the fact that privately owning a car is relatively more expensive for young Koreans than for young Americans. Contrary to the literature on American carsharing experience, the influences of household size and gender on carsharing usage are not significant in Seoul.

Fifty percent of the transportation-related variables tested were statistically significant, including the number of registered cars, the number of subway entrances, the number of carsharing pods in the district, and the existence of the PPP pods. The fact that the total number of cars measured for each district is included for the final model indirectly demonstrates that in Seoul, the carsharing demand is higher in a more auto-dependent area in contrast to the situation of American cities where carsharing demand seems higher in more transit-oriented areas. On the other hand, no significant influence from the average number of cars owned by a household is found, unlike some previous studies performed based on American cities. The average vehicle per household within a 0.5-mile radius is included for Celsor and Millard-Ball and the household with one vehicle is significant for the model estimated by Stillwater et al. [8,9]. This result might be the most distinctive difference between the present and previous research and might result from the fact that the present research uses residential locations for spatial referencing, while the previous research uses pod locations; alternatively it can be explained by the difference between Asian and North American cities. Further research needs to be performed to verify the reasons for the difference observed.

The impact of the total number of subway entrances within the district is significant, but unexpectedly with a negative sign, meaning that the area with fewer entrances shows a higher level of carsharing usage. This finding is opposite to the previous studies done in the U.S. Stillwater et al. found that light-rail availability has a positive relationship with carsharing demand and the percent of public transportation commute is significant for a carsharing study performed in New York [7,9]. But the evidence drawn from American cities could be complicated by the fact that many rail transit stations have their own parking facilities available for carsharing pods and thus more carsharing happen to be provided near stations than in other areas. Unlike American cities, most subway stations in Seoul do not have parking facilities that could be utilized for carsharing. That may be one reason for this study yielding the opposite result in relation to transit accessibility. In general, the opposite result can be explained by the different relationship between carsharing business and public transit. In American cities, their relationship is a mutually beneficial partnership. In Seoul, however, its relationship to public transit is similar to its relationship to the rental car business in America. The immediate goal of carsharing in Seoul is to secure a bridgehead by surviving from an uphill battle up against existing public transit systems, which are already well-established and highly accessible. In this context, our finding that carsharing usage tends to be higher in an area where public transit accessibility is relatively low sounds reasonable.

Unlike the access to the subway entrances, the variables that represent bus service availability are not significant. It is consistent with Stillwater et al., in which two variables related to bus service frequency were tested, but no significant relationship with carsharing usage could be found [9].

Additionally included in our model are the total number of carsharing pods and the existence of the PPP pods within the district. The variable related to the number of carsharing pods was tested in previous studies, but no significant effect was found [7,9]. The present result can be interpreted in two ways: the existence of the carsharing pods within the city-operating parking facilities through the PPP intervention positively influences the carsharing usage, or the locations of those facilities and the public support through PPP encourage carsharing operators to increase the number of vehicles for their service.

6. Conclusions and Future Direction

The final model is quite different from what has been estimated based on American cities. This research establishes a basis for future research efforts to forecast carsharing demand and find areas with high potential, especially in major Asian cities with urban conditions similar to Seoul. The analysis result shows that carsharing demand is high in an area where a higher proportion of building floor area is used for business, and which has a higher proportion of young residents in their 20s and 30s. It can also be predicted that the area with more registered cars and less subway entrances will show higher carsharing demand. These findings can be utilized for carsharing startups to assess the market potential in Asian cities. While it might be almost impossible (or unjustifiable) to change the first four aforementioned attributes—the ratio of total floor area for business use, percentage of population in their 20s and 30s, and total number of registered cars and subway entrances—only for promoting carsharing, the analysis result also suggests that providing additional carsharing pods, especially pods that utilize city owned public parking facilities, will help promote carsharing usage. It can be inferred that in densely developed Asian cities, the success of carsharing could depend on securing convenient, easily accessible locations for pods, while the government support for desirable pod locations through a public-private partnership could also be important. The one important future policy implication that is opposite to the finding from previous American studies is that carsharing businesses in Seoul should strategically target the areas with relatively low level of transit accessibility. In the cities with existing dominant public transit systems, carsharing can play a different but still important role, which is to help those who cannot afford to own a car but have to live with limited transit accessibility. Public support can also be justified if carsharing can contribute to transportation equity, which is as important as environmentally beneficial transportation. Unlike previous analyses based on pod locations, we use the residential location of carsharing users for spatial referencing; some of the research outcomes can therefore also be utilized for a free-floating service, which is gaining popularity and will be a norm with automated vehicle technologies in the future.

This study has several limits. Although the authors are grateful for the opportunity to analyze real carsharing transaction data, due to the privacy regulation, no detailed location information of carsharing users can be obtained, and therefore the administrative district is the smallest spatial unit available for this analysis. The district is still too large for small-scale built environment measurement such as micro walkability [31,32]. With location and other socio-economic information measured at the finer resolution, a multi-level regression analysis can be performed at micro- and meso-levels [33]. If carried out successfully, such analysis will provide a clearer understanding on how carsharing is performed differently, according to its location and built environment characteristics. In addition, the transaction data used for this research is acquired from only one of the two major carsharing operators in Seoul. The present analysis is also based on the data from the period of just one week. A more complete result might be obtained if data representing the entire industry and covering the entire year are available.

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