Synopsis of Users' Behaviour of a Carsharing Program: A Case Study in Toronto

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Abstract

The paper presents a comprehensive investigation of the behaviour of carsharing members through the analysis of administrative datasets of a dominant carsharing program in Toronto. The key objective of the investigation is to enhance our understanding on carsharing behaviour in the City of Toronto. Unlike other studies on carsharing, this paper intends to build a comprehensive understanding of the multiple dimensions of users' behaviour including attitude towards environment, attitude towards safety, frequency of usage, membership duration, vehicle type choice and monthly demand, in terms of total vehicle-kilometre and vehicle-hour travel. The paper uses both descriptive and econometric approaches for in-depth investigations. One of the key contributions of the paper is linking carsharing with carbon off-setting. Investigations reveal that carsharing members are in general environmentally conscious people and are willing to pay for carbon offsetting if given an option. However, having the carbon offsetting option also encouraged a higher amount of driving per month. Results show that carsharing is most often used for off-peak period travel or on weekends, when transit service is poor and traffic congestion is low. The majority of trips made by carsharing members are short-distance trips. It is clear that carsharing is providing a segment of the population with enhanced accessibility and mobility and thus playing an important role in providing a seamless, integrated transportation service in the City of Toronto.

1. Introduction

Urban carsharing services allow individuals to gain the benefits of private vehicle use without the costs and responsibilities of vehicle ownership. Carsharing is becoming increasingly popular as an alternative urban mode of transportation in many cities around the world. Although relatively new compared to in Europe, carsharing is gaining considerable momentum in North American cities (Cervero and Tsai, 2004; Zhou and Kockelman, 2008). Shaheen et al (2009) provide a comprehensive overview of the history and evolution of carsharing in North America. Since the beginning of organised carsharing activities, it has been the impression that carsharing can encourage sustainable travel behaviour by reducing the necessity of owning personal vehicles as well as promoting dense urban forms. In an earlier study, Fellow and Pitfield (2000) argue that carsharing can create a very high net benefit to society, comparable to investing in building new roads. Literature routinely explains carsharing in the context of sustainable mobility and reduction of environmental impact of urban transportation (Steininger et al 1996, Cervero et al 2007, Firnkorn and Muller 2011 etc. are few recent examples). However, the relationship between carsharing, sustainable transportation behaviour (such as public transit usage) and urban form are not properly understood as of yet.

Huwer (2004) suggested that carsharing is suitable as a supplement to public transport, however, Stillwater et al (2009) found that the relationship between access to public transit and carsharing activities is often ambiguous. The majority of the investigations that reveal the positive and expected effects of carsharing on mobility and urban form are often based on small sample surveys (Cervero 2002, Huwer 2004, Rose 2008, Martin et al 2010). Detailed investigations of the land use and mobility impacts of carsharing in large urban areas are difficult because of data unavailability. Carsharing is a relatively new urban mode and therefore, has a very low market share compared to the other established urban modes. Consequently, it is very unlikely that large scale household travel survey data would contain detailed information on carsharing. Celsor and Millard-Ball (2007), describe whether or not and how carsharing works in relation to household size, what mode people take to work, neighbourhood density, and vehicle ownership. Therefore, the best way to investigate the impact of carsharing in detail is through targeted sample data collection. As targeted data collection can be very costly, an efficient alternative can be examining administrative datasets of carsharing services. Such datasets are collected by the carsharing service providers for administrative and service planning purposes. Morency et al (2007) successfully show that such administrative datasets can be very useful in understanding users' behaviour of a carsharing program in Montreal (Communauto). Morency et al (2010) used this dataset to investigate the factors influencing activity persistency of carsharing users. Habib et al (2009) presents an econometric model for predicting membership duration jointly with monthly activity persistency of carsharing members by using the same dataset. However, the Montreal dataset is the only one that is used for investigating carsharing behaviour as available in published literature. Therefore, the use of similar datasets from other cities for investigating users' behaviour of carsharing programs would contribute to the increasing understanding and growing body of literature on carsharing.

This paper presents the results of an investigation of carsharing users' behaviour through the examination of administration datasets of a dominant carsharing service in the City of Toronto. The administrative datasets are supplemented by aggregate zonal census and land use data to overcome the information shortage in the administrative datasets. Although the choice of information used in this study is limited by the data availability, sufficient information is available to investigate key issues of interest. Unlike all other studies on carsharing, this paper intends to build a comprehensive understanding on multiple dimensions of users' behaviour of a carsharing program. In fact, very few studies focus solely on user's behaviour of carsharing program. Among those, Morency et al (2007, 2008 and 2010) and Habib et al (2009 and 2011) are the notable ones. However, all of these previous studies focus mainly on activity persistency and membership duration of carsharing. In this paper, we extend our focus beyond just activity persistency (frequency of usage) and membership duration. We also focus on attitude towards environment, attitude towards safety, preference to vehicle type and aggregate monthly demand of carsharing. The key issues of interests that are investigated in this paper are defined in order to add to the growing literature on the relationship between carsharing, travel demand, and urban form. These include travel patterns of carsharing users, as well as the attitude of carsharing users towards the environment and sustainability. The prime objective is to define key characteristics of people using carsharing in a mixed land use city, such as Toronto. We are interested in improving the understanding of the factors that influence members to become environmentally conscious and safe drivers together with member's trips making and vehicle type choice behaviour. Results of this investigation will help urban transportation planners to better understand the characteristics and impacts of this emerging mode, as well as to devise efficient carsharing programs for large urban areas.

The paper uses both descriptive and econometric approaches for the investigation. In the case of the descriptive analysis, key variables are plotted and investigated compared to other variables. The prime objective of the descriptive analysis is to improve the understanding of overall patterns of carsharing behaviour. Following the descriptive analysis a number of decisions of the carsharing members are explicitly modelled as a function of carsharing service attributes, member's attributes and aggregate population and land use attributes. Econometric modelling techniques are used to investigate influences of these attributes on key carsharing decisions. Four types of econometric models are employed: binary logit model for binary decision modelling, parametric hazard (accelerated failure time) model for duration modelling, negative binomial model frequency modelling, multivariate regression model continuous decision modelling and multinomial logit model for discrete choice modelling. To supplement the administrative datasets, we also imputed aggregate zonal characteristics of the home zones of the member by using census and land use data of the City of Toronto. The next section of the paper presents the descriptive analysis of the case study and is followed by the econometric analyses. The paper concludes with key findings and direction for further investigations.

2. Carsharing in Toronto: A Case Study

AutoShare, a Toronto based carsharing company offers an alternative option to owning a vehicle and dealing with the responsibilities that come with vehicle ownership. It is located in downtown Toronto and has more than 200 parking locations across the city. The company was created in 1998, and since then, its membership has increased to more than 10,000 to date. The company is in a partnership with the organization "ZeroFootprint" to offer the members the option of offsetting their carbon emissions for as low as 0.5¢ per kilometre. The service offered by AutoShare is based on membership of several categories. Eligible members must have a full

Ontario drivers licence and be over the age of 23 with a clean driving record. After the payment of a one-time membership and application fee, a member gets access to a wide range of vehicles. Members can be an individual member or jointly share an account with household members. Members may also belong to different organizations (corporate, government or non-profit organizations). Members can make reservations for a vehicle as short as half an hour before the trip to as long as several days in advance. Members pick up a car from any carsharing parking lot convenient to them, and return it to the same location. A variety of savings plans for long distance and off-peak trips are available for each of the member categories. Reduced rates are also offered for trips made before 7 am. The weekday daily rate is higher than the weekend daily rate. The usage cost includes insurance, maintenance, and gas. Another option offered to members is a collision deductible. Members do not need to deal with insurance, but the vehicles are required to be insured. In the case of an accident, AutoShare insurance covers the costs after the respective deductible has been covered. This paper uses the complete monthly transaction and membership directory data of AutoShare from January 2008 to November 2010.

The company has been continually growing since its beginning. In 2010, a total of 84,773 trips were made by 6,085 active members. A member is considered active if at least one transaction has been made during the year. In terms of fleet size, in 2010, the AutoShare fleet size reached 224 cars. By 2010, more than 5 million km were travelled by these cars; averaging a distance travelled per car of 23,910 km in three years. By November 2010, the company has 213 parking lots across Toronto. Members reside at locations across the city, generally around these parking lots. Figure 1 presents the related distribution of home location of the members and the locations of parking lots and shows the dispersion of the members across the city. Members are distributed across the city with a concentration of members towards west end of the downtown area. The parking lot locations are strategically distributed to cover the service area, even where the concentration of members is lower. By comparing this figure to the population density of the City of Toronto, it is evident that members are concentrated in dense neighbourhoods. The highest concentration area (the south west part of the City) is the liveliest and most active area, where mixed land use is served by well designed transit services.

3. Descriptive Analysis of Travel Behaviour of Carsharing Users

To improve our understanding of the travel behaviour of carsharing members, we considered AutoShare in Toronto as a case study. We started by focusing on vehicle type chosen by the carsharing members for making trips. The vehicles available in AutoShare's fleet were classified into nine generic categories: sedan, wagon, Nissan Cube, cargo minivan, passenger minivan, Mini Cooper, hatchback, smart car (electric car) and Mini Cooper convertible. Data from the last three years of transactions indicate that sedans and wagons are the most demanded vehicle types in Toronto carshare users.

Members are given the option of offsetting their carbon emissions while using the vehicles. Data shows that majority of the members are considering this option of carbon offsetting. However, the carbon offsetting charge is very low (0.5¢ per kilometre); and therefore, the strength of the commitment towards the environment of the members opting for the carbon offsetting option is difficult to estimate from this information. However, it is fair to state that given the opportunity to contribute to environmental protection, people are willing to do so. In this case, a charge of

0.5¢ per kilometre does not represent a major expense for most of the people, but it does create a social consciousness.

Trips made by the members can be divided into two categories: local trips and out-of-city trips. Local trips are of durations shorter than a 24-hour day, and out-of-city trips are of durations longer than a day. Average yearly usage in terms of kilometres travelled for local trips by members is around 50 km, whereas the yearly usage in terms of kilometres travelled for out-of-city trips by members is around 340 km. However, a wide range of distributions of trip length are visible. Figure 2 presents the number of trips made per year in the last three years and the trip length distribution. The majority of members made less than 30 trips per year. It can be seen from the figure that the percentage of members making a smaller number of trips per year is increasing over the years. In terms of trip length distributions, more than 60 percent of trips are for less than 40 km of travel. This indicates that carsharing is contributing to the increase in short-distance urban auto trips in Toronto. This is also true in other cities around the world (Firnkorn and Muller 2011; Morency et al 2007; Nobis 2006; Zheng et al 2009; Zhou et al 2008). However, for situations where members do not own a private automobile, a less frequent use of carsharing services indicates lower auto-based travel demand. This implies that carsharing can be an effective alternative in reducing automobile travel demand. Such expectation was also discussed by others such as Zhou et al (2008), who used stated preference survey data to investigate the impacts of carsharing on travel demand.

To enhance the understanding of the trip making behaviour of carsharing members, Figure 3 presents the distribution of the average monthly frequency as well as time of the day and day of the week distribution of the trips. From Figure 3a**,** it can be seen that less than 10 percent of members make more than three trips per month. Similar trends are found in other cities around the world, where it is seen that majority of carsharing members are making a smaller number of trips and shorter distance trips per month or per year (Nobis 2006; Morency, et al, 2008; Morency et al 2010). The database available for this study gives detailed information about the trip making behaviour of carsharing members (such as trip timing and weekly variations) that are rarely reported in other published literature. It is interesting to note that trips are made by the carsharing members throughout the whole day. However, the majority of the trips are made between 9:00 to 11:00 am, which is right after the morning peak period. In terms of the day of the week, the percentage of trips is lowest at the beginning of the week and increases as the week continues. The major peak occurs on the weekends, particularly on Saturday. In terms of trip start time across the week, all weekdays have similar patterns of peaking time. However, in weekends peak usage time is around 10 am in the morning.

The analysis of active members over the last three years indicates that only 40% of the members remain active after one year of becoming a member and around 25% of the members remain active after three years of becoming a member. There is a considerable drop in the activity of members over the duration of their membership. Therefore, simply increasing the membership pool is not effective in increasing carsharing activity. Morency et al (2010) and Habib et al (2011) also report similar finding for a carsharing program in Montreal. In the case of Toronto, it is found that activity persistency and usage of the service are very much influenced by the accessibility to the parking lots (in terms of the distance between home and the nearest parking lot is a critical factor).

The location of carsharing parking lots near members' household is critical in order to have a door-to-door mobility option similar to private automobiles. Analysis indicates that an increase in the number of active members is more correlated to the increase in spatial coverage of the service rather than simply increasing the fleet size. This is also evident in other cities in Canada, such as Montreal (Habib et al 2009). The analysis of carsharing in Toronto found that 65% of the total trips are accessed from a distance less than 1 km, while more than 80% of trips originated within 3 km of any parking lot. In an effort to better understand the relationship between home to parking lot distance and trip characteristics, the distribution of trip duration and distance travelled with respect to the distance between home and parking lot was investigated. It was found that increasing home to parking lot distance reduces trip duration. The majority of trips are made are by the members with access to vehicles in parking lots within 1 km of their residence. Interestingly, the longest trips (in terms of kilometres travelled) are made if the access distance is less than 100 metres. It can be inferred that accessibility, in terms of shorter walking distances to the parking lots, is a crucial factor influencing the travel behaviour of people who partake in carsharing.

The majority of the members live in dense neighbourhoods near downtown Toronto. Stillwater et al (2008); Cervero (2003); Shaheen and Rodier (2005) and Burkhardt and Millard-Ball (2006) also support similar findings elsewhere. Therefore, it may be stated that choosing the location of a parking lot based on population density reaps the benefit of increasing membership as well as usage. It is apparent that a higher population density is conducive to an increase in carsharing activities. Higher numbers of members come from denser neighbourhoods; though this does not necessarily mean that members from dense neighbourhood would stay longer. Population density is not the only factor that influences membership however; income also plays a role. It is seen that carsharing is popular among individuals with lower incomes. Access to income and job information of the members was not available for the analysis; however, by comparing the median income of the area where members live, it was found that the members living in lower income neighbourhoods are high frequency users. Similarly, the members from lower income areas are more likely to remain members for longer durations. Douma and Guag (2009) also reported that carsharing is popular among middle-income population groups. Cervero et al (2007) also found that income is inversely proportional to the carsharing activities, meaning that carsharing is popular among middle and lower income groups. Burkhart and Millard-Ball (2006) argue that different income levels may define different motivations towards carsharing than defining success and failure of a carsharing program. For example, lower income people may be motivated by the affordability and mobility freedom of carsharing and higher income people may be motivated by the convenience of using a car from carsharing service. However, since we do not have individual member's income information, we cannot investigate such hypotheses.

With the aim of further enhancing the understanding of the behaviour of carsharing members, econometric investigations of key decisions of carsharing members was conducted. The key decisions of interest are defined by the information available in the dataset used in this investigation. The decisions investigated are:

- Decision to buy carbon offsetting
- Decision to buy collision deductible
- Membership duration

- Monthly frequency model
- Vehicle type choice
- Monthly VKT and VHT travel

The decision to opt for the carbon offsetting option indicates environmental consciousness of the carsharing member while the decision to buy a collision deductible reflects a commitment to safe driving. Membership duration reflects the consistency in using carsharing as an urban transportation modal option over time. Monthly frequency was investigated to reveal auto driving trip generation behaviour. Total VKT and VHT travel per month indicate the total demand for using carsharing and vehicle type choice indicates attitude and likings toward automobile technology. Of interest to this study are the factors that influence these decisions. The factors used include service characteristics, membership type and aggregate zonal characteristics of the home zone of the members. The next section presents the econometric investigations on these decisions.

4. Econometric Investigation

The decisions under investigation are of binary discrete choice, continuous duration choice, count variable, multivariate regression and multinomial discrete choice types. Each decision under investigation was modelled using appropriate econometric modelling techniques as follows.

4.1: The decision to buy carbon offsetting is a binary decision and is modelled as a binary logit model;

4.2: The decision to buy collision deductible is a binary decision and is modelled as a binary logit model;

4.3: Membership duration is a continuous decision and to capture the dynamic of duration it was modelled as continuous hazard (accelerated failure time) model;

4.4: Considering a wide variety of monthly frequency values, frequency was modelled as a count variable model. However, to recognize the dispersion in frequency behaviour it was modelled as a negative binomial regression model rather than a poison regression model.

4.5: Vehicle type choice is a discrete choice decision, and hence, it was modelled using Random Utility Maximizing (RUM) multinomial logit model.

4.6: Aggregate monthly demand of the individual members in terms of total Vehicle Kilometre Travel (VKT) and total Vehicle Hour Travel (VHT) are modelled as regression models of various member-specific and service attributes. To recognize the fact that VKT and VHT are directly correlated variables, we use multivariate regression model for analysis.

In the case of the binary logit models, there is the underlying assumption that an individual member gains a certain level of utility in making a decision. The utility is composed of two components: systematic utility and random utility. The systematic utility (V) is considered linear in parameter function of variables (x) and corresponding parameters (β). Considering that the random utility component follows a logistic distribution, then the probability of choosing the binary decision can be written as:

$$\Pr(Binary\ decision) = \frac{\exp(V)}{1+\exp(V)} = \frac{\exp(\beta x)}{1+\exp(\beta x)} \qquad (1)$$

The parameters (β) of the model can be estimated using the maximum likelihood estimation process. Train (2009) explains various estimation techniques, statistical tests and goodness-of-fit measures of such model. The estimated coefficients are considered statistically significant if the corresponding two-tailed '*t*' statistics satisfies the 95% confidence interval, (t = 1.96). Some variables with statistically insignificant parameters are also retained in the models because they provide considerable insight into the behavioural process. Retention of some of the insignificant variables is also due to the expectation that, if a larger data set were available, these parameters might show statistical significance.

4.1: Decision to buy carbon offsetting model:

Table 1 summarizes the estimated parameters of the binary logit model for the decision to buy carbon offsetting. The pseudo R-squared value of the model is 0.22, which explains a reasonable goodness-of-fit of the binary logit model. A number of variables are used in the model. In terms of membership type, it is clear that individual or joint household members posses a very high and positive utility of paying for carbon offsetting compared to the member from different organizations. Since the majority of the members belong to these two groups, it can be stated that the majority of carsharing members are environmentally conscious and are willing to pay to offset their carbon emissions. This is further supported by the fact that monthly frequency of usage has a positive effect; that is, members who use the service more frequently are more likely to enrol for carbon offsetting.

Monthly savings gained from having the membership plan (compared to the total cost calculated by using average hourly rate) seems to have a negative, but very low impact on choosing carbon offsetting option. A possible explanation is that members who are concerned about saving money from the membership plans are less likely to spend money for carbon offsetting. The investigation also shows that members living in dense and higher income neighbourhoods are more willing to pay for carbon offsetting. A counter argument could be that environmentally conscious people prefer to live in dense neighbourhoods, following smart growth principles. In either case, it is clear that carsharing is preferred by environmentally conscious people. Hence promoting this model through better integration with transit, biking, and walking facilities would be conducive to sustainability.

4.2: Binary logit model for the decision to buy collision deductible:

Table 1 also summarizes the estimated parameters of the binary logit model for the decision to purchase a collision deductible. The goodness-of-fit value of this model is very low, meaning that the variables chosen are not enough to explain this choice. However, a number of variables show very high statistical significance. From these values it is evident that members belonging to different organizations prefer to have collision deductible options more than the individual or joint household members. Data show that members who prefer to opt for carbon offsetting also prefer to opt for the collision deductible. This behaviour may be seen as members opting for the collision deductible in order to save money and compensate for the fact that they opted to pay for carbon offsetting, even though it may involve some extent of risk taking. It is also revealed that members with higher monthly frequency of usage are more likely to experience an accident and hence do not prefer to have collision deductibles. However, this is not true for higher total money spent and higher total distance travel per month. It seems that members who spend more money per month for longer distance travelled tend to prefer a collision deductible. It also underlines that fact that frequent users may not always be long distance travellers, but rather tend to be shorter distance auto trip makers in urban areas.

4.3: Accelerate failure hazard model for membership duration:

In order to understand the influences of carbon offsetting and collision deductible options together with a number of other covariates, membership duration was modelled using an accelerated life continuous time hazard model. Membership duration data is generated by left censoring at January 2008 and right censoring at December 2010. The accelerated failure time hazard model treats the temporal duration as a continuous variable. Distribution of this continuous variable produces the corresponding hazard model (Habib and Miller 2006). In the case of accelerated failure time hazard model, the duration, T is considered a non-negative random variable. The hazard is the limiting probability of the remaining member in a given interval. Unlike proportional hazards models, the regression parameter estimates from accelerated failure time hazard models is more robust to omitted covariates and is less affected by the choice of probability distribution (Lambert et al 2004, Keiding et al 1997). Hazard models are usually estimated using maximum likelihood techniques. Basic formulation and classification of hazard models are now well-established in literature. Keifer (1988), Lancaster (1990) and STATA (2009) present detailed formulation of various types of hazard models as well as estimation techniques. The accelerated failure time hazard model has two components: a baseline hazard rate distribution and a covariate function. In this case, the log-logistic distribution is found to be the best for the baseline hazard rate distribution and the covariate function is a linear in parameter function.

Table 2 summarizes the estimated model parameters of the accelerated failure time hazard model of membership duration. The p-value clearly proves the statistical justification of incorporating the covariates in the model. The estimated parameters clarifies that members who are not enrolled through any specific organizations tend to have longer membership duration. In addition, individual members are more likely to keep the membership than joint household members. Interestingly, members willing to pay for carbon offsetting tend to have a shorter duration of membership. Similarly members willing to opt for the collision deductible also tend to have a shorter duration of membership. We have not found any studies investigating the connection between carbon offsetting and collision deductible decisions with membership duration. In addition, we also have the unique opportunity of correlating membership duration with monthly expenditure. Previously Katzev (2003) and Habib et al (2011) specifically investigated membership duration of carsharing programs, but their dataset did not include detail expenditure information. In our case, it is evident that higher monthly expenditure reduces membership duration; members who experience a high monthly cost of using carsharing may decide to purchase a car and terminates their membership. However, intuitively, the perceived savings per month of having membership plan compared to average hourly rate does influence members to stay. Interestingly, it seems that members from higher density neighbourhoods tend stay shorter in duration as members. This may be due to an increased competition of getting the vehicle type the members want in a dense neighbourhood. This is also a unique finding that was possible to investigate because of our unique dataset.

4.4: Negative binomial regression model for monthly frequency of usage:
To enhance the understanding of the factors influencing monthly frequency of usage of the members, the monthly frequency was modelled as a count variables model. A negative binomial regression model was considered for this count variable modelling. Unlike a Poisson regression model for a count variable, a negative binomial model explicitly addresses the dispersion parameter to capture wide variances in frequency of usage across the members. Greene (2008) explains various estimation techniques, statistical tests and goodness-of-fit measures of such model.

Table 2 summarizes the estimated model parameters of the negative binomial model. The high statistical significance of the dispersion parameter justifies the negative binomial regression model for frequency of usage modelling. In terms of membership category, it is clear that the monthly usage of joint household members is the least. Individual members use the service more often than joint member and members from non-profit organization use the service more often than individual members. The reference membership category used is the members from different professional organizations which had the highest monthly usage rate. This is quite the opposite of what was found for membership duration. There it was found that individual and joint members stay with the carsharing service longer. Therefore, it can be stated that members who stay longer have a lower monthly usage and members who have higher frequency of monthly usage tend to have shorter duration. However, a similar pattern of behaviour is not true in the case of home zone population density. It seems that members from higher population density zones tend to have lower monthly frequency as well as shorter duration. Intuitively monthly perceived saving encourages the use of carsharing services and increases the monthly frequency of usage. Very few studies focused on activity persistency (monthly frequency of usage) of carsharing members. Among those, Morency et al (2010) and Habib et al (2011) investigated frequency for a carsharing program in Montreal. Our finding related to carsharing frequency and zonal population density is consistent with the findings of Habib et al (2011), where it was found that higher population density influenced lower frequency of usage by the individual members in Montreal.

4.5: Multinomial logit model for vehicle type choice:
Vehicle type choice is modelled using a discrete choice model. In this case, members have the option of choosing one of nine possible vehicle types. Although vehicle type choice may also be influenced by availability of a specific type of vehicle, there are many other factors that may influence vehicle type choice. A Multinomial Logit (MNL) model was used to model vehicle type choice. Similar to the binary logit model, the MNL model assumed that individual members gain utility in choosing a specific vehicle type. The total utility of any vehicle type choice is composed of two components: systematic component (V) and random component (ε). The systematic utility (V) is considered linear in parameter function of variables (Z) and corresponding parameters (γ). The random component is assumed to follow Type I extreme value distribution with the Independent and Irrelevant Alternative (IIA) assumption. As per this definition, the probability of choosing one specific vehicle type (j) becomes:

$$\Pr(\textit{Vehicle Type } j) = \frac{\exp(V_j)}{\sum_{J=1}^{N}\exp(V_J)} = \frac{\exp(\gamma Z)_j}{\sum_{J=1}^{N}\exp(\gamma Z)_J}; \text{ Here N is the total vehicle type} \qquad (2)$$

The parameters (γ) of the model can be estimated using a maximum likelihood estimation process. Train (2009) explains various estimation techniques, statistical tests and goodness-of-fit measures of such models. The estimated coefficients are considered statistically significant if the corresponding two-tailed '*t*' statistics satisfy the 95% confidence interval, (t = 1.96). Some variables with statistically insignificant parameters are also retained in some systematic utility functions for comparison with the other systematic utility functions. Moreover, the retention of some of the insignificant variables is also due to the expectation that, if a larger data set were available, these parameters might show statistical significance. Table 3 summarizes the estimated model parameters. The reference alternative is the sedan. There were too few observations of the smart cars to have significant parameters and are therefore not included in Table 3. Comparing the Alternative Specific Constants (ASC), it can be seen that all are negative compared to the zero value for sedan. This indicates that the baseline preference is for a sedan among the members. After a sedan, the second most popular vehicle type is a wagon. This is followed by the Cube, cargo minivan, hatchback, Mini Cooper, passenger minivan and the Mini Cooper convertible. The baseline preference following the respective proportion of the vehicle types in the total fleet.

The baseline preferences to vehicle type choices indicate that trips made by carsharing members are mostly for personal and/or household related trips. Although we do not have any information on trip purposes, the relative attraction of wagon type vehicles most likely indicates that many of the trips made by this vehicle types were for grocery or other household shopping trips. Such understandings are consistent with the findings of Huwer (2004), Fukuda et al (2005), Burkhart and Millard-Ball (2006), Cervero et al (2007), Catherine et al (2008), Zhou et al (2008) and Clavel et al (2009), where they found that shopping activities were the most dominant purposes of carsharing. Similarly, relatively low preference to convertible vehicles also indicates that carsharing is less likely used for luxury purposes.

Cost was not considered as a variable in the vehicle choice model as it was found that cost is highly correlated with trip distance and trip duration. Trip distance and trip duration have opposite signs in the systematic utility functions. A possible explanation is that people tend to choose other vehicle types other than a sedan for longer hour travel, but for shorter distance travel. In the case study of downtown Toronto, trips distance and trip duration are not linearly correlated. This allows us having both of these two variables in the models. In the case of the Nissan Cube and passenger minivan, trips distance has statistically insignificant parameters; however, trip duration has a highly significant and positive effect. Nissan Cubes and passenger minivans are for a larger number of passengers than other vehicle types. Therefore, the selection of one of these two types of vehicles may be dependent on the number of travellers and may be the only options suitable to them. In such cases, the trip distance has no significant effects, but longer duration of travel influences the selection of these two types of vehicle over sedan. In the case of cargo minivans, longer distance trips reduce its utility, but longer duration trips increase utility over sedans. This is also true for wagons, Mini Coopers, hatchbacks and Mini Cooper convertibles.

Members who prefer Nissan Cubes, cargo minivans, passenger minivans, hatchbacks and Mini Cooper convertibles usually start trips earlier in the day compared to the members who choose other vehicle types. However, members choosing sedans tend to start earlier than the members that choose wagons and Mini Coopers. Having the option of carbon offsetting significantly influence some vehicle type choices. For example, members that opted for the carbon offsetting option prefer hatchbacks over sedans. However, they prefer sedans over all other types of vehicles available. Similarly, members with a collision deductible option prefer sedans over wagons and cubes, but they also prefer all other types over sedans. Home to parking lot distance characterizes the accessibility to the carsharing facility by walking and significantly influences vehicle type choice. The inclusion of this variable in the model addresses the willingness to walk to choose the specific vehicle type. It is interesting to note that members are willing to walk longer for sedans than all other vehicle types except Nissan Cubes. It seems that Nissan Cubes have a specific type of demand (possibly members travelling with a larger number of passengers, however prefer not to have a large van type vehicle) for which members are willing to walk longer distances to get the service. Membership duration (in days) seems to have a very strong and significant impact on vehicle type choice. Interestingly, the older members (in terms of longer duration of membership) prefer sedans over Nissan Cubes, Mini Coopers and hatchbacks. However, they prefer wagons, cargo minivans, passenger minivans and Mini Cooper convertibles over sedans.

It is interesting that no other studies using transaction and membership directory data of any carsharing program investigated the members' vehicle type choice preferences. Morency et al (2010) and Habib et al (2011) are the only ones that use similar large scale datasets for investigating users' behaviour of carsharing program in Montreal. However, their datasets do not include information of vehicle type choice. In our case, such unique information available in the database allows us to develop inferences about users' travel behaviour based on their vehicle type choices.

4.6: Multivariate regression model for monthly VKT and VHT travel demand:

Aggregate monthly usage of the service in terms of total Vehicle Kilometres Travel (VKT) and Vehicle Hour (VHT) travel were modelled jointly as a multivariate regression model. The estimated coefficients were considered statistically significant if the corresponding two-tailed '*t*' statistics satisfy the 95% confidence interval, (t = 1.96). Table 4 summarizes the estimated model parameters. In term of goodness-of-fit measure, the VHT model gives better fit to the observed data than the VKT mode. This is largely due to the fact that members are charged in terms total time of usage in each reservation. However, VKT and VHT are correlated, even though it may not be linear in nature (because of traffic congestion in Toronto). The constant of VKT model is very high compared to that of the VHT model meaning that there are many other variables in addition to those that were chosen that influence VKT per month. Results show that members from different organization are more likely to have higher VKT and VHT per month than member from non-profit organizations as well as individual and joint household members. The usage of joint household members is the lowest among all membership categories.

It was also found that having the carbon offsetting option encourages higher VKT, but lower VHT travel. This indicates travelling during off-peak period or weekends when traffic congestion is low. This is also evident from the start time and day of the week distribution of carsharing trips. Having the collision deductible option seems to influence higher VKT per month, but its effect on monthly VHT travel is insignificant. The most significant variable in influencing monthly usage was found to be the savings gained by having membership plans rather than simply the hourly rates. Evidence shows that higher amounts of savings influences higher VKT as well as VHT travel per month.

The aggregate zonal attributes of the home zones of members reflects neighbourhood and social network characteristics of the members and have a significant impact on monthly usage of the members. The analysis shows that people from higher income as well as dense neighbourhoods tend to have higher VKT, but lower VHT travel per month. This indicates that people from dense as well as higher income neighbourhoods tend to avoid congested periods of the day and week. It also reflects their consciousness regarding time loss due to traffic congestion. Similar picture is visible in the case of high male-female ratio. Higher male-female ratio tends to positively influence monthly VKT, but negatively influence monthly VHT travel.

5. Conclusions and Further Research

Though carsharing is a relatively new urban mode of transportation, it is also considered to be instrumental in reducing personal vehicle ownership in urban areas. Reducing vehicle ownership is critical to reducing automobile travel. Carsharing programs maintain a membership pool and provide its members with a range of vehicle options without the burdens of vehicle ownership, such as, insurance, investment cost, etc. Although carsharing is becoming popular in many North American cities, the impact of this mode on overall urban transportation system is not fully understood yet. Evidence suggests that carsharing is most often used for off-peak period travel, when transit service is seen to be poor. Considering the impact on overall urban travel demand, it appears that carsharing is not contributing to auto travel by any significant margin. If it is assumed that the members do not own private cars, carsharing members are non-auto oriented people in general. By using one of the biggest carsharing companies in Toronto, AutoShare, as a case study, this paper hopes to enhance the understanding of carsharing activity in the City of Toronto.

Unlike other studies on carsharing, this paper provides a comprehensive understanding of the multiple dimensions of users' behaviour of a carsharing program. These includes attitude towards environment, attitude towards safety, frequency of usage, membership duration, vehicle type choice and total monthly demand in terms of monthly vehicle-kilometre and vehicle-hour travel. One of the key contributions of the paper is linking carsharing activities with carbon off-setting. The paper investigates factors influencing carsharing members to participate in carbon offsetting program as well as how the decision to participate in the carbon off-setting program affects other dimensions of carsharing activities.

This study reveals that carsharing activities are in continuous demand in Toronto and that access to the service is critical for the growth of membership as well as the frequency of usage of the service. The majority of members access the service from distances of less than 1 km. The analysis shows that the spatial distribution of carsharing services in terms of a greater number of parking lots would increase membership and activities to a greater degree than simply increasing the size of the vehicle fleet. On an average, the members make less than 30 trips per year. More than 60 percent of members travel distances less than 40 km per year, however, it was also found that members are travelling longer distances over time. Trip rates are higher on weekends than on weekdays and are short distance trips that occur most often during the off-peak period.

The vehicle type choice model reveals that sedans and wagon type vehicles are the most common vehicles used and sought after by members. Through the analysis it can be inferred that auto trips made by carsharing members are mostly non-work shopping, social or recreational trips. The model also reveals that vehicle choice may also be related to the start time of a trip. This too is related to trip purpose as shopping and social or recreational trips are often off-peak trips.

The econometric analysis revealed that higher monthly expenditures and less perceived savings lead to shorter membership durations. Therefore, it can be stated that in order for carsharing to be seen as competitive with personal vehicle ownership, rates must be low enough and perceived savings must be great enough to ensure that members do not cancel their membership and purchase their own vehicles. Perceived savings is also important when examining the frequency of usage as members may be more inclined to use the carsharing service more frequently if they see that they are saving money.

The investigation implies that carsharing members may, in general, be environmentally conscious people and are willing to pay for carbon offsetting if given an option. This information along with the idea that carsharing can lead to fewer vehicles on the road indicate that carsharing can play a significant role in sustainable transportation behaviour. Carsharing can be used to supplement the off-peak period drop in transit service and consequent drop in mobility and accessibility to non-auto owners. Therefore, the promotion of carsharing would lead towards a better integrated and balanced multi-modal urban transportation system.

The investigation of the aggregate demographic and land use information and carsharing members' activities found that population density is a critical factor for a successful carsharing program. Membership duration as well as activity persistency are high in dense neighbourhoods. Therefore, increasing carsharing activities across the city may reduce the requirements of residential parking spaces. Thus, it can be inferred that carsharing has the potential to influence smart growth initiatives in the City. Because carsharing attracts environmentally conscious people and coincides with smart growth initiatives in the City, any incentive that enhances carsharing activities in the City would be beneficial and help achieve a sustainable transportation system.

However, any further investigation on the travel behaviour of carsharing members requires individual and household specific information. It requires further data collection from carsharing members as well as non-members in the city. Information of non-members is a vital component needed to assess the public's overall view of carsharing. It can help reveal some of the barriers to carsharing as well as what can be done to make carsharing a more attractive mode of transportation. While there are a wide range of options for further data collection and investigation, the key issues as indentified in this paper for the next stage of investigation are as follows: the effects of carsharing on household private automobile ownership; the willingness to pay for improved carsharing service by the members; the impacts of carsharing on overall daily and weekly travel demand; and the contribution of carsharing on improved accessibility and mobility of the members. Owning a private car may also be considered a status symbol by some and therefore, carsharing may be seen as giving up this status symbol, whether by choice or economic necessity. Further investigations should examine this issue as well. For these investigations, further data collection from carsharing members is both unavoidable and needed and is being considered for future research.

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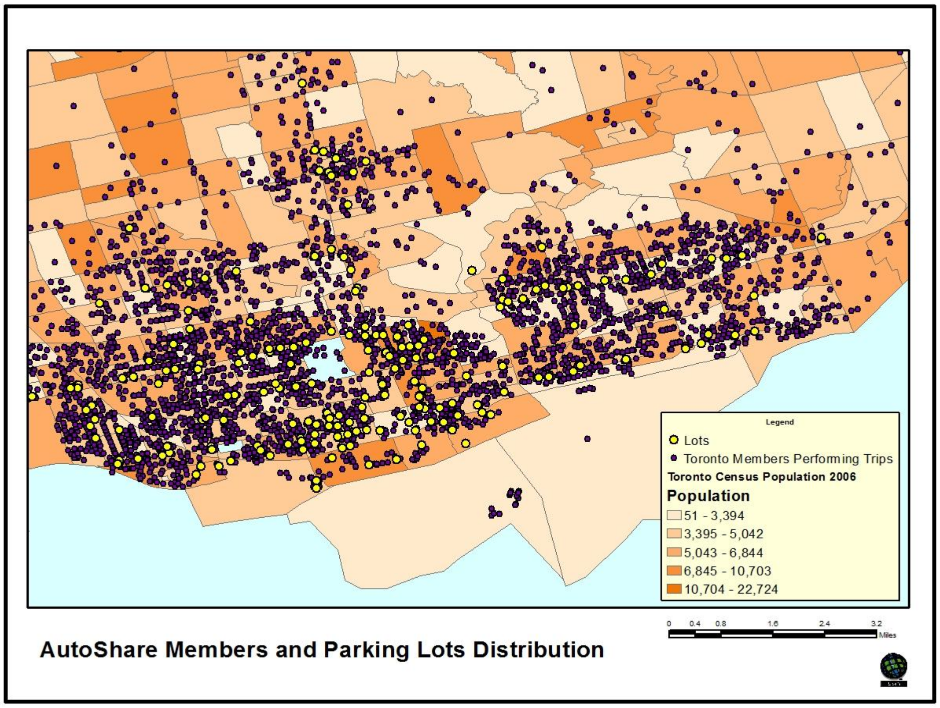
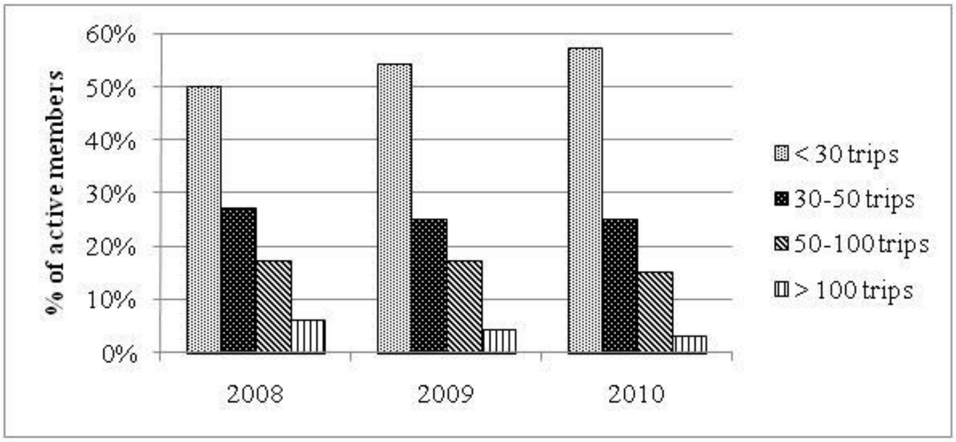


Figure 1: AutoShare Parking Lots in Toronto

a)



b)

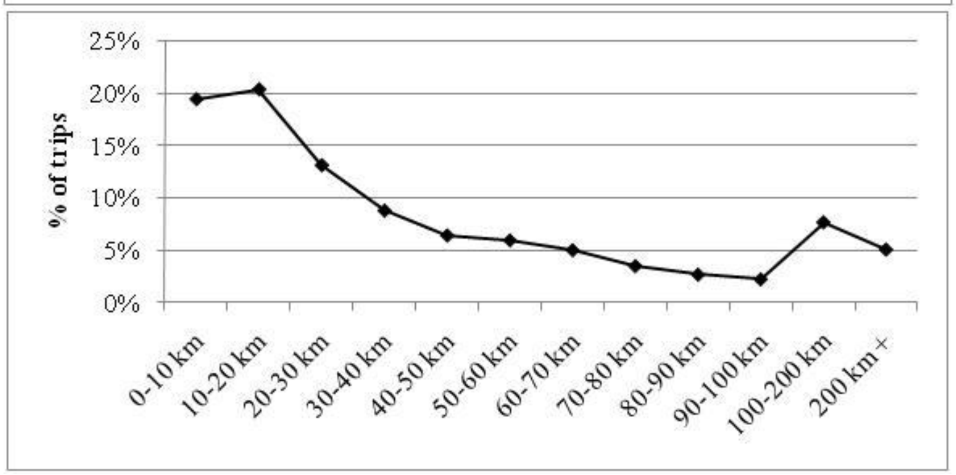


Figure 2: Trip Frequency and Trip Length Distribution

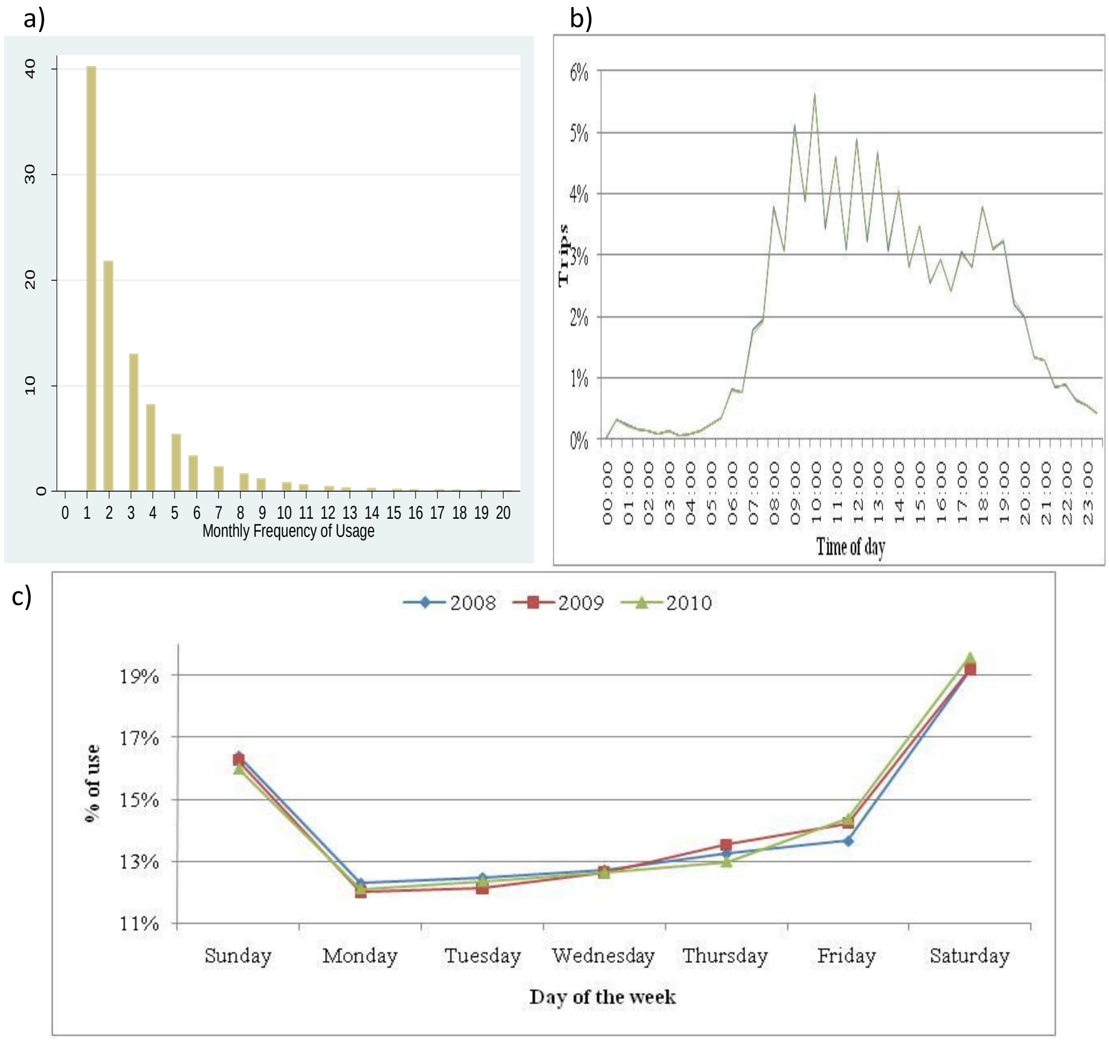


Figure 3: Monthly Frequency of Usage, Trip Start Time and Day of the Week Distribution

Table 1 Binary Choice Models for Carbon Offsetting and Collision Deductible

Binary Logit Model of Choosing Carbon Offsetting Option		
Log likelihood:	-23758.85	
Pseudo R-Squared:	0.22	
Utility of Choosing Carbon Offsetting Option		
Variable	**Coeff**	**t-Stat**
Non-Profit Organizational Members	-0.5798	-4.09
Joint Member	4.7657	60.75
Individual Members	4.7090	58.27
Monthly Frequency of Usage	0.0260	4.72
Monthly Saving in Cost Because of Having Membersip Plan	-0.0008	-6.07
Home Zone Population Density	0.000006	3.03
Median Income in Home Zone	0.00001	7.89
Constant	-2.6765	-27.20

Binary Logit Model of Choosing Collision Deductible Option		
Log likelihood:	-50271.21	
Pseudo R-Squared:	0.02	
Utility of Choosing Collision Decuctible Option		
Variable	**Coeff**	**t-Stat**
Joint Member	-3.6515	-16.49
Indiviodual Members	-3.9942	-18.02
Monthly Frequency of Usage	-0.0377	-7.75
Monthly Total Distance Travel	0.0005	5.77
Monthly total Cost of Usage	0.0010	4.52
Monthly Saving in Cost Because of Having Membersip Plan	0.0005	3.01
Having Carbon Offestting Option	0.0312	1.11
Home Zone Population Density	0.000008	7.42
Constant	4.3588	19.75

Table 2: Membership Duration and Monthly Frequency of Usage Models

Logligistic Hazard Model for Membership Duration		
Log likelihood:	-908.95	
Likelihood Ratio for Adding Covariates	22.24	
P-Value	0	
Covariate Function of Continuous Time Hazard Model		
Variable	**Coeff**	**t-Stat**
Joint Member	0.9470	2.38
Individual Members	1.0605	2.42
Having Collision Deductible	-0.0890	-1.68
Having Carbon Offestting Option	-1.1822	-2.41
Monthly total Cost of Usage	-0.0030	-2.31
Monthly Saving in Cost Because of Having Membersip Plan	0.0016	1.39
Home Zone Population Density	-9.47E-06	-1.24
Constant	7.5168	13.27

Negative Binomial Model for Monthly Frequency of Usage		
Log likelihood:	-176505	
Pseudo R-Squared:	0.03	
Covariate Function of Count Variable Model		
Variables	**Coeff**	**t-Stat**
Non-Profit Organizational Members	-0.3306	-13.48
Joint Member	-0.7905	-51.85
Individual Members	-0.6840	-43.09
Monthly Saving in Cost Because of Having Membersip Plan	0.0018	65.71
Male-Female Ration in the Home Zone	-0.1066	-5.44
Home Zone Population Density	-0.000001	-2.46
Median Income in Home Zone	-0.000002	-5.71
Constant	1.8698	68.06
Dispersion Parameter: ALFA	0.29	105.00

Table 3: Multinomial Logit Model of Vehicle Type Choice

	Wagon		Cube (Nissan)		Cargo Minivan		Passenger Minivan		Mini Cooper		Hatchback		Minicooper Convertible	
Variable	Coeff	t-Stat	Coeff	t-Stat	Coeff	t-Stat	Coeff	t-Stat	Coeff	t-Stat	Coeff	t-Stat	Coeff	t-Stat
Membership Duration in Months	0.00003	4.9	-0.00002	-1.4	0.0001	4.9	0.00003	1.3	-0.0001	-5.2	-0.0001	-3.7	0.0001	2.1
Home to Parking Lot Distance (Metre)	-1.7192	-15.2	0.0941	3.8	-0.4914	-9.0	-0.6099	-4.2	-0.6542	-4.9	-0.4988	-5.4	-0.8442	-3.2
Having Collision Deductible	-0.0215	-6.0	-0.0299	-4.4	0.0384	5.7	0.0350	2.3	0.0291	2.2	0.0730	6.4	0.0445	2.3
Having Carbon Offestting Option	-0.0706	-5.2	-0.0192	-0.8	-0.2616	-11.3	-0.2769	-5.5	-0.0344	-0.7	0.2460	5.4	-0.5001	-8.1
Trip Start Time	-0.0715	-2.7	0.0016	0.0	0.1554	3.2	0.2407	2.3	-0.1402	-1.5	0.2472	3.1	0.5611	4.1
Trip Duration in Hours	0.0043	6.3	0.0068	6.2	0.0090	7.2	0.0121	7.2	0.0022	1.1	0.0026	1.2	0.0069	3.1
Trip Distance in KM	-0.0003	-5.0	0.0000	0.2	-0.0021	-13.6	0.0000	-0.1	0.0008	5.2	-0.0007	-3.2	0.0008	4.0
Alternative Specific Constant	-0.5039	-21.4	-2.1755	-49.5	-2.1001	-49.1	-3.9259	-42.2	-3.4075	-41.4	-3.6290	-47.8	-4.5326	-38.2

Table 4: Monthly VKT and VHT Model

Joint Multivariate Regresion of Monthly VKT and VHR Travel		
R-Squared Value of VKT Regression Model	0.54	
R-Squared Value of VHR Regression Model	0.71	
VKT Travel Regression		
Variables	**Coeff**	**t-Stat**
Non-Profit Organizational Members	-183.9731	-27.87
Joint Member	-247.0850	-52.45
Individual Members	-231.4397	-47.79
Having Carbon Offestting Option	2.4032	1.00
Having Collision Deductible	3.3454	6.75
Monthly Saving in Cost Because of Having Membersip Plan	2.1466	300.97
Male-Female Ration in the Home Zone	2.2572	0.50
Home Zone Population Density	0.0002	2.47
Median Income in Home Zone	0.0003	3.96
Constant	314.7351	44.75
VHR Travel Regression		
Variables	**Coeff**	**t-Stat**
Non-Profit Organizational Members	-15.5999	-27.53
Joint Member	-22.4103	-55.41
Individual Members	-21.0964	-50.74
Having Carbon Offestting Option	-0.4044	-1.97
Having Collision Deductible	0.0048	0.11
Monthly Saving in Cost Because of Having Membersip Plan	0.2730	445.78
Male-Female Ration in the Home Zone	-2.8115	-7.20
Home Zone Population Density	-0.000015	-1.71
Median Income in Home Zone	-0.000032	-5.32
Constant	33.5735	55.60