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VALUE OF TRAVEL TIME SAVINGS FOR CARSHARE USERS IN SYDNEY

This study seeks to determine the "value of travel time savings" using travel data for carshare users in Sydney on the M2 and M4 motorways in Sydney (and their associated untolled alternative routes) via a Revealed Preference (RP) Study.

GPS logs were provided by a prominent car share company operating in Sydney. These logs covered trips undertaken over a period of approximately 6 months. In order to determine the value of travel time savings for drivers, these GPS logs were divided into unique trips. Travel time distributions were then compiled for each route assessed, and a binary logistic regression model was then applied in order to isolate the average value of time for the choice between a tolled route and an untolled alternative route.

The analysis determined the Value of Travel Time Savings to be $12.15 / hour with a Value of Reliability of $8.70 / hour.

1. Introduction

1.1 Scope of the Study

This paper seeks to determine a value of travel time savings for drivers in Sydney on specific corridors through undertaking a Revealed Preference (RP) study of GPS data. The GPS data provided for this study covers the period January 2012 to June 2012 and has been provided by a major carshare program operating within Sydney. However for confidentiality reasons, this company cannot be named within this paper.
The corridors of interest in this study are:

- M2 Motorway (and adjacent untolled road corridor); and
- M4 Motorway (and adjacent untolled road corridor).

The value of travel time savings will be achieved by identifying the key variables that influence the value of travel time savings, and utilising statistical and econometric techniques to model the aforementioned key variables. From this, it will be possible to identify the value of travel time savings for drivers on the corridors of interest for this study.

2. Literature Review

While many previous RP studies have focussed on simply asking survey participants whether they used a particular road at a particular time (sometimes by filling out a diary), Parkany et al (2006) utilised GPS loggers installed in the vehicles of participants to analyse the variations in travel times across different routes compared to the minimum travel time route. The data was collected from 276 households in Lexington, Kentucky, USA over a 10 day period. This differs from the GPS data available for this thesis which considers 5,053 drivers across approximately a six month period.

This unique approach of using GPS loggers provided substantially more data, as it collected data about, not only positioning, but also speed and heading, and also permitted the mapping of trips on GIS systems. Furthermore, as the GPS loggers directly recorded the route choices of drivers, this approach also allowed for the potential to directly compare these choices against other alternate routes. After controlling for potential differences in attitudes and driving habits across demographic groups, this enabled a clearer understanding of the different preferences for different demographic groups.

Parkany et al (2006) also undertook Stated Preference (SP) study which collected data regarding driving habits, attitudes and preferences. This data supplemented the RP data from the GPS loggers. The main advantage of combining the RP data from the GPS loggers with the SP survey data is that it allowed Parkany et al to identify and measure different variables that may not have been evident from purely using the GPS data. This is particularly important as research by Golledge and Stimson (1997) and Papinsky et al (2009) demonstrates that drivers consider more than just the basic user equilibrium variables of cost, time and distance. Examples of questions from the SP survey questions utilised by Parkany et al regarding driving habits, include:

- Whether trips are planned in their entirety prior to commencement;
- If drivers “rat-run”, or use local streets during peak hour (instead of main roads); and
- Preferences for routes with “scenery”.

The use of these questions (and many others) is advantageous in that it allows the analysis to be controlled for various driving habits drivers employ. For instance, a driver may elect to remain on their planned route instead of deviating when the congestion level increases; or a driver with a low value of time may elect to use local streets due to a dislike of disrupted flow on a motorway.

With respect to this paper, the analysis will be completed using only GPS data as a pure RP study. This is due to a lack of SP data available to permit controlling for potential variations in driving habits and attitudes; especially since this data was primarily collected for the purpose of invoicing carshare users. However unlike Parkany et al, the study will be extended to develop an understanding of the value of time, as opposed to analysing the implications of driving habits and attitudes on travel time and route choice.

3. Model Development and Results

3.1 Data processing

The analysis of the GPS data was undertaken across multiple stages. In summary, this methodology consisted of:

- Delineation of trips from raw data;
- Identification of corridors suitable for analysis; and
- Development of binary regression models to isolate the value of travel time savings.

The detailed methodology undertaken for this part of the study is not detailed within this paper, but is presented in the original thesis.

3.2 Corridor Selection

In order to limit the data set to a manageable level given the time constraints for the preparation of the original thesis, GIS analysis was undertaken to isolate suitable corridors for analysis. Due to the limited number of trips identified in tolled corridors, it was decided to consider the analysis of the M2 tolled motorway and the surrounding road corridor. Further to this, the M4 motorway was also selected for analysis.

While the M4 Motorway is untolled, and also has alternative untolled routes in parallel, it is still possible to utilise the corridor to supplement the data set. This is because it is anticipated that route choice decisions in this corridor will be primarily dependent upon travel time (and travel time savings). Consequently, the corridor will still be able to assist in identifying the parameter values for the covariates.

As the primary difference in route choice is based upon the tolled or untolled state of a road, it was essential to identify parallel routes within the corridor adjacent to the respective motorways. In order to determine these alternative untolled routes, mapping software was consulted to identify the potential alternatives.

This process identified approximately parallel routes to the M2 and M4, thereby identifying a corridor of potential routes. Further to this, informal discussions were undertaken with drivers who regularly utilised these roads to confirm routes which would be viable alternatives. Based upon this, the corridors analysed are presented in **Figure 1** and **Figure 2** as:

- M2 Corridor
  - M2 Motorway
  - Epping Road
- M4 Corridor
  - M4 Motorway
  - Parramatta Road

Figure 1 M2 Motorway / Epping Road Corridor
Background: Nearmaps

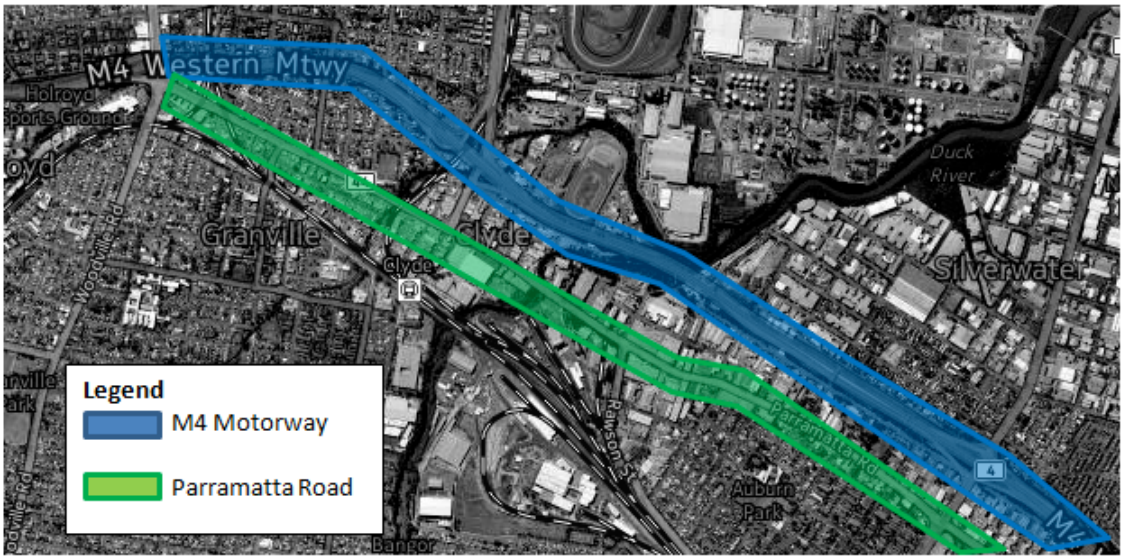

Figure 2 M4 Motorway / Parramatta Road Corridor
Background: Nearmaps

It is noted that analysis of the M5 and M7 Motorway corridors were considered, however there were insufficient trips in the data set to enable these corridors to be analysed.

3.3 Data Summary

Appendix A summarises the number of trips identified within the M2 and M4 Motorway corridors. In total, there were 1,320 trips analysed in this study.

Based upon **Appendix A**, it is evident that there are a low number of trips recorded within the M2 Motorway corridor. As a result of this, the M4 Motorway was considered for inclusion in the study. This would enable the inclusion of a supplementary data set to permit a more accurate estimation of model parameters by increasing the number of Degrees of Freedom in the analysis.

3.4 Model Variables

In developing the binary model for this study, a series of different variables were available for inclusion. **Appendix B** details the variables that were included in the final model. The statistical significance of the variables will be discussed in **Section 3.5** and is formally tabulated in **Appendix C**.

3.5 Model Specification

Appendix C details the results of the preferred model specification. In summary, the preferred model specification involved a series of fourteen (14) variables under a Logistic Regression. The joint significance of these 14 variables was found to have a p-value of 0.0000 and a pseudo-R^2 of 0.3358. As a result, the results indicate the model is a strong fit for the data.
It is noted that the pseudo-R^2 is lower than would normally be expected for statistical models. However, in the context of an econometric model using data with many latent variables (some of which could not be included due to limitations in the data collected), the pseudo-R^2 value of 0.3358 represents a strong fit.

An interesting finding from **Appendix C** is that the difference in sector travel time (*tt_diff_avg*) is not statistically significant, with a p-value of 0.214. However, the standard deviation in the first difference of sector travel time (*tt_diff_sd*) is statistically significant, with a p-value of 0.006. This would suggest that route choices are more strongly related to the reliability of the travel time saving, as opposed to the travel time saving itself. However, this conclusion conflicts with the lower coefficient on "*tt_diff_sd*", which would imply a lower value of reliability compared to value of travel time savings.

Finally, while the coefficient for "*avgspeed*" would suggest that the average speed of the trip is not particularly relevant to the model (although the p-value is 0.000, indicating strong statistical significance). It is noted that the coefficient is low due to the units of the variable which is due to the units of metres / day. As a result, the coefficient is scaled to reflect the large values for each observation in the data set. Despite this, "*avgspeed*" shows a very strong statistical significance with a p-value of 0.000. As a result, this indicates that the choice of a toll road is strongly related to the total trip travel time, such that drivers are more likely to take a tolled route (over an untolled alternative route) when trips a longer, or when the average speed of the trip is relatively low.

3.6 Results

3.6.1 Value of Travel Time Savings

The Values of Travel Time Savings (VTTS) is based upon the following general decomposition:

$$\frac{\partial C}{\partial T} = \frac{\partial P}{\partial T} \times \frac{1}{\partial P/\partial C}$$

In the context of this binary mode:

- 'P' refers to the variable "Choice"
- 'C' refers to the variable "Toll_Route"
- 'T' refers to the variable "tt_diff_avg"

Based upon this decomposition and the coefficients for the respective variables presented at **Appendix C** (based upon the regression analysis described in **Section 3.5)**, the Value of Travel Time Savings is **$12.15 / hour**.
Note that "tt_diff_avg" has units of minutes. A comparison of results to previous studies is presented in **Section 3.7**.

3.6.2 Value of Reliability

The Values of Reliability (VOR) is based upon the following general decomposition:

$$\frac{\partial C}{\partial R} = \frac{\partial P}{\partial T} \times \frac{1}{\partial P/\partial R}$$

In the context of this binary mode:

- 'P' refers to the variable "Choice"
- 'C' refers to the variable "Toll_Route"
- 'R' refers to the variable "tt_diff_sd"

Based upon this decomposition and the coefficients for the respective variables presented at **Appendix C** (based upon the regression analysis described in **Section 3.5)**, the Value of Reliability is **$8.70 / hour**.
Note that "tt_diff_avg" has units of minutes. A comparison of results to previous studies is presented in **Section 3.7**.

3.7 Comparisons to Similar Studies

3.7.1 Value of Travel Time Savings

Table 1 summarises the comparison of the VTTS result for this study ($12.15 / hour) against those in previous studies. This comparison reveals that the VTTS for the data set in this study is significantly lower than the VTTS identified for other cities. It is proposed that this result is a consequence of the data set in this study being specific to the carshare user group. As a result, it would be more reasonable to conclude that the VTTS of $12.15 / hour is the VTTS for carshare users, and is not representative of all drivers in Sydney.

It is believed that carshare users possess a lower VTTS due to the need for potential users to overcome various hurdles prior to (and sometimes during) the use of a carshare vehicle. This is because potential drivers are required to book the vehicle ahead of time, including a prospective booking duration. Furthermore, drivers are required to organise their own transport to the vehicle to commence the trip (usually by walking), refuel the vehicle if the fuel gauge falls below one-quarter full and must return the vehicle to the designated parking bay until completion of the booking. As a result of these hurdles which the driver must overcome in order to utilise the vehicle, carshare program participants are accustomed to "delays" in undertaking or completing their trip. Consequently, a lower VTTS for this user group would seem logical and reasonable.

Table 1 Comparison of VTTS to Other Studies

Study Authors	City, Country	Type of Study	Value of Travel Time Savings ($ / hour)	Difference ($ / hour)
Small, Winston and Yan (2005)	**Los Angeles, USA**	Combined Revealed and Stated Preference	21.46	-9.31
Hensher, Greene and Li (2011)	**Brisbane, Australia**	Stated Preference	17.71	-5.56
Li, Hensher and Rose (2010)	**Brisbane, Australia**	Stated Preference	22.52	-10.37
Devarasetty, Burris and Shaw (2012)	**Houston, USA**	Stated Preference	22.00	-9.85

Note: Comparative value for the study by Hensher, Greene and Li (2011) uses the mean value of VETTS derived from the different "Multinomial Logit with non-linear probability weighting function" specifications.

3.7.2 Value of Reliability

Table 2 summarises the comparison of the VOR result for this study ($8.70 / hour) against those in previous studies. This comparison reveals that the VTTS for the data set in this study is significantly lower than the VOR identified for other cities. It is proposed that this result is a consequence of the data set in this study being specific to the carshare user group. As a result, it would be more reasonable to conclude that the VOR of $8.70 / hour is the VOR for carshare users, and is not representative of all drivers in Sydney.

Similarly to the explanation for VTTS in **Section 3.7.1**, it is believed that carshare users possess a lower VOR due to the need for potential users to overcome various hurdles prior to (and sometimes during) the use of a carshare vehicle. This is because potential drivers are required to book the vehicle ahead of time, including a prospective booking duration. Furthermore, drivers are required to organise their own transport to the vehicle to commence the trip (usually by walking), refuel the vehicle if the fuel gauge falls below one-quarter full and must return the vehicle to the designated parking bay until completion of the booking. As a result of these hurdles which the driver must overcome in order to utilise the vehicle, carshare program participants are accustomed to "delays" in undertaking or completing their trip. Consequently, a lower VOR for this user group would seem logical and reasonable.

Table 2 Comparison of VOR to Other Studies

Study Authors	City, Country	Type of Study	Value of Travel Time Savings ($ / hour)	Difference ($ / hour)
Small, Winston and Yan (2005)	**Los Angeles, USA**	Combined Revealed and Stated Preference	19.56	-10.86
Li, Hensher and Rose (2010)	**Brisbane, Australia**	Stated Preference	35.87	-27.17
Devarasetty, Burris and Shaw (2012)	**Houston, Texas**	Stated Preference	28.00	-19.30

4. Study Limitations and Further Studies

There are many limitations to the study as completed for this study. As a result, there are many opportunities available to extend upon this study in order to achieve a more well-rounded and accurate result. These limitations and further studies opportunities will be detailed in this section.

4.1 Estimation of Risk Parameters

The process of estimating the risk parameter under the assumption of Constant Absolute Risk Aversion (CARA) was unsuccessful. However, tracking of the value of the risk parameter (α) showed that in all attempts at parameter estimation, the value of α converged to zero (0). This result would suggest that the drivers in this study were risk neutral, which would conflict with previous studies completed on the risk aversion of motorists. This complication is believed to be the result of insufficient data on tolled corridors, such as the M2 Motorway. As a result, the risk parameter estimation process is highly dependent upon the data from the M4 Motorway corridor which does not have a toll. As a result, there is little data available to allow the comparison between drivers paying the toll and those who do not pay the toll. It is believed that this causes a skew towards the risk neutrality conclusion in the CARA risk model.

In order to correct for this, more data would be required, particularly on tolled routes. As the data collection process by the carshare program is ongoing, there are substantial opportunities in future to undertake more detailed studies which utilise a progressively increasing number of trips.

4.2 Sensitivity Testing

This study has involved the analysis of more data points and more trips than most other studies previously completed. For instance, the study by Parkany et al (2006) analysed 4,494 trips over a period of 10 days. By comparison, this study involved over 170,000 trips over a period of six months. This is a result of the fact that this study uses raw data logs from a carshare program, as opposed to the explicit selection of drivers through formal study participant selection procedures. This is differentiated by the fact that formal selection procedures would involve the issuance of a GPS unit to the participant for the duration of the study and have typically involved additional inputs (such as trip purpose and car occupancy). However, the data set for this study involves raw data which has been collected by the carshare program for operational purposes in order to allow the calculate usage charges for drivers.

Due to the large amount of data that was required to be processed for this study, the execution of the programming code took a substantial amount of time to complete. Due to the amount of time involved in executing the programming code, it was not feasible to consider assessing the sensitivity of the cut-off durations for the dwell times as part of the identification of trip ends. These dwell times determined the minimum dwell time for which it would not be reasonable to assume a trip had ended, and the maximum dwell time for which a trip could be assumed to have ended.

It is reasonable to expect that the number of trips identified, particularly in the context of a large data set, could be particularly sensitive to the cut-off durations utilised for dwell time. As a result of this, it is suggested that future studies consider the sensitivity testing of these cut-off durations. This will assist in improvising the validity of the results, particularly in the context of the unique characteristics of Sydney in terms of network and congestion. These unique characteristics have the potential to impact upon the magnitude of any cut-off durations and may differ from those utilised in previous (overseas) studies, such as Du and Aultman-Hall (2007).

4.3 Upgrade of the M2 Motorway

The data set in this study completely overlapped with the period during which the M2 Motorway upgrade works were undertaken. These upgrade works involved the closure of lanes in order to permit construction works that would provide additional lanes post-construction. As a result, it is possible the small number of trips recorded on the M2 Motorway from the data set is a consequence of motorist aversion to the potential increased delays from construction related activity.

However due to the ongoing collection of data by the carshare program, it would be possible to undertake studies in future which consider the M2 Motorway corridor post-upgrade. Anecdotal evidence suggests that travel times on the M2 Motorway are noticeably improved from pre-upgrade travel times. Furthermore, the toll on the M2 Motorway has increased following the completion of upgrade works.

As a result, there are two potential further studies that can be undertaken. The first additional study could consider a replication of this study with the inclusion of more data, and thus more trips. This would enable a more accurate determination of the Value of Travel Time Savings. The second additional study would involve a comparative study of the Value of Travel Time Savings (VTTS) between the pre-upgrade scenario and the post-upgrade scenario. Given the anecdotal evidence suggests that travel times and reliability of travel times have improved on the M2 Motorway, it is possible a different VTTS will be determined.

4.4 Ghost Tolls on Tolled Motorways

Given the low VTTS determined by this study, another potential extension of this study would involve assessing the viability of paying so-called "ghost tolls" for motorway use. The concept of ghost tolls is comparable to the arrangement the NSW Government has with the AirportLink train line, whereby the NSW Government pays the "Station Access Fee" for passengers travelling to Mascot and Green Square Railway Stations.

This further study would involve assessing whether the carshare program should incentivise drivers to use motorways by offering to pay for the cost of the toll. The motivation behind this further study is that the low VTTS determined by this study would suggest that drivers are not overly concerned with the cost of travelling. As a result, drivers may take a route with longer distance and / or travel time, therefore increasing the amount of fuel consumed and the long term maintenance costs for the vehicles. In addition to this, consideration can also be given to the impact of carbon emissions from these longer journeys.

Based upon the above, this further study would assess whether the cost to the carshare program from these longer trips outweighs the cost of paying the toll for drivers. As such, it has the potential to provide direct advice to the carshare program regarding the viability of paying ghost tolls.

4.5 Non-Linear Utility Specifications

Hensher, Greene and Li (2011) utilised non-linear utility functions in their analysis of stated preference results to determine the VTTS for motorists in Brisbane, Australia. Their study was able to conclude that the model standard errors and the explanatory power of the model were significantly improved. However, they were unable to provide a definitive conclusion regarding which non-linear specification was best.

Despite this, the results regarding improvements in model explanatory power were promising. Whilst the study by Hensher, Greene and Li was applied to Stated Preferences, it is reasonable to expect that these processes could be applied to Revealed Preference studies (such as this study). As a result, it would be possible to improve the explanatory power of any VTTS model, and would also improve the robustness of the model by providing a more appropriate representation of risk aversion.

Based upon the anticipated applicability of these non-linear utility model specifications, further studies could involve the estimation of these non-linear models in order to ascertain a more valid estimation of the VTTS for drivers in Sydney.

5. Conclusion

The Value of Travel Time Savings (VTTS) can be determined through the use of a revealed preference study using GPS data. However, revealed preference studies require a representative sample of data in order to identify an unbiased result for the VTTS. This was a noted complication in this study that became evident by the completion of the study. Due to the unique demographic aspects of the carshare user group, the VTTS determined in this study of $12.15 / hour is specific to the carshare user group.

Similarly, it is possible to determine the Value of Reliability (VOR) and relevant cross elasticities using the same methodology. This determined the Value of Reliability to be $8.70 / hour, Cross-Elasticity of Travel Time Savings to the Cost of Time to be $22,822.77 / hour, Cross-Elasticity of Travel Time Savings to the Cost of Distance to be $1,043.95 / hour, Cross-Elasticity of the Cost of Time to the Cost of the Toll to be $0.0005 / hour and the Cross-Elasticity of the Cost of Distance to the Cost of the Toll to be $0.01 / hour.

These values are so vastly different compared to those obtained in previous studies as a result of the unique characteristics of carshare programs compared to private vehicle drivers. This is such that carshare program participants are required to overcome many hurdles regarding the need to pre-book vehicles, estimate the duration of the return trip and return the vehicle to the designated parking space. This need to estimate the duration of the return trip at the booking stage also introduces uncertainty into the prospective driver. Due to the potential financial penalties involved in under-booking a vehicle, drivers are more willing to utilise roads with high travel time savings (such as tolled routes) in order to minimise the amount of time they are required to book the vehicle. On balance, the cost of the toll may be outweighed by the time charge for the booking.

However, these values determined for VTTS, VOR and cross-elasticity are based upon an assumption of risk-neutrality in the drivers. Given that this is unlikely, the model specification should include a risk parameter to correct these output values. This risk parameter should take the form of either Constant Absolute Risk Aversion or Constant Relative Risk Aversion. This will enable for a more accurate determination for the Value of Travel Time Savings (for carshare users). In addition to this, non-linear specifications for utility can be utilised in order to generate more realistic results.

Finally, additional data on tolled routes would assist in improving these estimates.

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7. Presenter's Bio

7.1 Vinayak DIXIT

Dr. Dixit is a Senior Lecturer in the School of Civil and Environmental Engineering at The University of New South Wales (UNSW). He joined UNSW after serving as the Associate Director of Research for the Gulf Coast Centre for Evacuation and Transportation Resiliency at Louisiana State University. His key research interest lies in studying risk in the transportation infrastructure system as it relates to highway safety, travel time uncertainty, as well as natural and man-made disasters. He was the supervisor of the paper being submitted for presentation.

7.2 John TRIEU

John Trieu is an undergraduate studying civil engineering at The University of New South Wales (UNSW). He is also working as an Undergraduate Engineer at Cardno in the Traffic and Transport team in their St Leonards office. John recently completed an honours thesis as part of his civil engineering degree at UNSW. This thesis, titled "Use of GPS Data to Determine Value of Travel Time Savings for Motorists in Sydney" is the subject of this paper. This thesis required the development of a choice model to isolate the VTTS based upon GPS data provided by a carshare company.

7.3 Sisi JIAN and Xun LI

Sisi Jian and Xun Li are PhD candidates at The University of New South Wales with an interest in research regarding carshare users and the applicability of GIS data to transport modelling. They were both involved in the extraction of travel time data from ArcGIS for this paper.

8. Appendix A

Table 3 Summary of Data Analysed

Route	Direction	Time of Day	Total Trips	Mean Travel Time (mins)	Standard Deviation of Travel Time (mins)
M2	East	00:00 – 07:00	1	N/A	N/A
		07:00 – 10:00	2	25.95	36.68
		10:00 – 15:00	10	31.61	11.53
		15:00 – 19:00	9	71.51	54.93
		19:00 – 00:00	4	34.81	12.61
Epping Road	East	00:00 – 07:00	0	N/A	N/A
		07:00 – 10:00	2	34.28	36.58
		10:00 – 15:00	14	49.31	67.58
		15:00 – 19:00	14	30.01	19.91
		19:00 – 00:00	9	34.24	27.19
M2	West	00:00 – 07:00	0	N/A	N/A
		07:00 – 10:00	5	50.21	21.99
		10:00 – 15:00	9	32.81	22.22
		15:00 – 19:00	3	68.73	20.27
		19:00 – 00:00	1	N/A	N/A
Epping Road	West	00:00 – 07:00	0	N/A	N/A
		07:00 – 10:00	8	49.59	26.28
		10:00 – 15:00	35	30.77	20.27
		15:00 – 19:00	17	46.29	36.04
		19:00 – 00:00	5	30.76	16.85
M4	East	00:00 – 07:00	13	26.79	12.89
		07:00 – 10:00	14	77.26	42.28
		10:00 – 15:00	139	49.36	34.94
		15:00 – 19:00	251	68.81	41.61
		19:00 – 00:00	101	52.16	43.06
Parramatta Road	East	00:00 – 07:00	2	27.07	5.37
		07:00 – 10:00	3	39.15	15.87
		10:00 – 15:00	31	39.76	23.79
		15:00 – 19:00	32	41.18	23.33
		19:00 – 00:00	7	55.10	35.30
M4	West	00:00 – 07:00	12	44.63	18.59
		07:00 – 10:00	149	60.08	25.36
		10:00 – 15:00	264	57.87	32.22
		15:00 – 19:00	29	73.69	47.16

Route	Direction	Time of Day	Total Trips	Mean Travel Time (mins)	Standard Deviation of Travel Time (mins)
		19:00 – 00:00	38	38.64	26.71
Parramatta Road	West	00:00 – 07:00	1	N/A	N/A
		07:00 – 10:00	16	48.54	27.03
		10:00 – 15:00	45	44.87	27.72
		15:00 – 19:00	18	57.92	45.42
		19:00 – 00:00	7	43.69	15.05

9. Appendix B

9.1 Table of Variables

Table 4 List of Variables

Variable Name	Units	Variable Description
Choice	N/A	› Binary variable which models the "choice" of the driver between the "motorway" and "(untolled) arterial road" › Equals "1" if the driver chose the motorway › Equals "0" if the driver chose the "(untolled) arterial road"
Age	Years	› Age of the driver of the vehicle
Experience	Years	› Number of years the vehicle's driver has held their driver's licence
Traveltime (sic)	Days	› Total travel time for the trip › The units for this variable was set as "days" as it is the base unit for time in Microsoft Excel
Distance	Metres	› Total distance for the trip
tt_sect_avg	Minutes	› Average travel time on the sector analysed (See Section 3.2) › The units for this variable was set as "minutes" as it is the base unit for time in ArcGIS
tt_sect_sd	Minutes	› Standard deviation of travel times on the sector analysed (See Section 3.2) › The units for this variable was set as "minutes" as it is the base unit for time in ArcGIS
tt_diff_avg	Minutes	› Difference in average travel time for the sector analysed (See Section 3.2) › The units for this variable was set as "minutes" as it is the base unit for time in ArcGIS
tt_diff_sd	Minutes	› Standard deviation in the difference of travel times for the sector analysed (See Section 3.2) › The units for this variable was set as "minutes" as it is the base unit for time in ArcGIS

Variable Name	Units	Variable Description
Avgspeed	Metres / Day	› Average speed for the trip
Cost_Time	Dollars	› Cost charged by the carshare program for the duration of the vehicle hire
Cost_Dist	Dollars	› Cost charged by the carshare program for the distance travelled
Cost_Dist	Dollars	› Cost charged by the carshare program for the toll
Cost_Total	Dollars	› Total cost charged by the carshare program for the trip
Car_Own_0	N/A	› Dummy variable › Equals "1" if the driver does not own their own vehicle › Equals "0" otherwise
Car_Own_1	N/A	› Dummy variable › Equals "1" if the driver owns one (1) vehicle › Equals "0" otherwise
Car_Own_Buy	N/A	› Dummy variable › Equals "1" if the driver intends to purchase a car › Equals "0" otherwise
Car_Own_Sell	N/A	› Dummy variable › Equals "1" if the driver currently owns a car and intends to sell the vehicle › Equals "0" otherwise
Car_Own_2	N/A	› Dummy variable › Equals "1" if the driver owns two (2) or more vehicles
Car_Own_Other	N/A	› Dummy Variable › Equals "1" if the driver is not in one of the earlier categories › Equals "0" otherwise
Toll_Route	Dollars	› Equals the toll for the roads in the **corridor** › For the M2 Motorway corridor, this is equal to $4.95

Variable Name	Units	Variable Description
		› For the M4 corridor, this is equal to zero › The focus on **corridors** means that, for instance, trips using Epping Road will also have a value of $4.95 in this variable.
Pref_Work_Train	N/A	› Dummy variable › Equals “1” if the driver prefers to commute to work via train › Equals “0” otherwise
Pref_Work_Bus	N/A	› Dummy variable › Equals “1” if the driver prefers to commute to work via bus › Equals “0” otherwise
Pref_Work_Bicycle	N/A	› Dummy variable › Equals “1” if the driver prefers to commute to work via bicycle › Equals “0” otherwise
Pref_Work_Walk	N/A	› Dummy variable › Equals “1” if the driver prefers to commute to work via walking › Equals “0” otherwise
Pref_Work_Car	N/A	› Dummy variable › Equals “1” if the driver prefers to commute to work via motor vehicle › Equals “0” otherwise
Pref_Work_Other	N/A	› Dummy variable › Equals “1” if the driver is not in one of the earlier categories › Equals “0” otherwise

9.2 Clarification – Dummy Variables

For the purposes of model development, the "base" dummy variables will be:

- Car Ownership
    - Car_Own_2
      This is because there only approximately ten (10) observations in this category and all observations were found to take the motorway. As such, there is perfect collinearity in this category. In order to control for this, "Car_Own_2" has been set as the base category
- Preferred Mode of Travel to Work
    - Pref_Work_Car
      This purely as a matter of convenience. Since the study focuses on carshare *drivers*, it would be prudent to utilise drivers in this category as the base category

9.3 Clarification – "Toll_Route" Variable

As stated in **Table 4**, the value each observation takes in this variable is based upon the cost of the toll on the toll road in the relevant corridor. For instance, if the driver takes the untolled Epping Road (instead of the tolled M2 Motorway), the toll of the M2 Motorway will still be reflected in this variable. As such, the observation will take the value $4.95 in this variable, even though the driver used Epping Road.

By including the value of the toll on trips utilising the untolled route, it is possible to better understand the Value of Travel Time Savings. This is because drivers using the untolled route evidently perceive the value of the travel time savings from the motorway to be less than the actual toll charged. As such, it assists in capturing the disutility perceived by the driver from the toll road.

10. Appendix C

Table 5 Preferred Model Specification and Results

Dependent Variable: Choice			
Model Type: Binary Logistic Regression			
Independent Variable	**Coefficient**	**Standard Error**	**P-Value**
Experience	-0.0155667	0.0089692	0.083
Distance	0.0000378	6.06e-6	0.000
Avgspeed	7.38e-7	1.70e-7	0.000
tt_sect_avg	-0.3124229	0.1586458	0.049
tt_sect_sd	-0.2574335	0.0497537	0.000
tt_diff_avg	0.1719585	0.1383542	0.214
tt_diff_sd	0.1230615	0.0449214	0.006
Toll_Route	-0.8489161	0.0661339	0.000
Cost_Total	-0.0004135	0.0002152	0.055
Car_Own_0	0.5595653	0.6539934	0.392
Car_Own_1	1.584125	0.7012649	0.024
Car_Own_Sell	0.1741724	0.7548663	0.818
Car_Own_Buy	-0.5285211	0.9475176	0.577
Car_Own_Other	3.255763	1.37144	0.018
Constant	0.6843814	0.7372985	0.353
Log Likelihood	-414.0949		
AIC	858.181		
SIC	935.036		
R^2	0.3358		
$\chi^2(14)$	418.79		0.0000

Note: The "AIC" refers to the Akaike Information Criterion and "SIC" refers to the Schwartz (Bayes) Information Criterion. AIC and SIC are used in the same manner as the Log Likelihood score. This is such that models with lower AIC and / or SIC results are preferred to models with higher results. They are calculated as follows:

$AIC = -2 \times \log_e(LL) + 2.k$

$SIC = -2 \times \log_e(LL) + N \times \log_e(N)$

Where:

- LL = Log Likelihood
- k = Degrees of freedom in the model (i.e. the number of variables)
- N = Number of observations