A Gender-based Analysis of Work Trip Mode Choice of Suburban Montreal Commuters Using Stated Preference Data

Submitted: 1 August 2004
Word Count: 6,374

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ABSTRACT

Transportation literature suggests that men and women have different characteristics with respect to commuting patterns, as well as with respect to their propensity to switch between travel options. In North America, women are expected to have an increasing impact on travel demand. As such, differences in female responses to travel demand management strategies are likely to become increasingly important as governments try to curtail travel demand in the future. This paper uses a 1994 stated preference (SP) survey of suburban commuters in Montreal to: determine whether there is evidence for differences between men and women in the factors that affect work trip choices; quantify those differences; and suggest what these differences imply for travel demand management in the future in Montreal. The main conclusions of this paper. are as follows. First, women and men should be modeled separately with respect to mode choice. Second, three main differences that appear from the econometric models: women are less likely to choose public transit than men; women are more likely to choose to rideshare and; women are less time sensitive when it comes to commuting than men are.

INTRODUCTION

The transportation literature suggests that men and women have different characteristics with respect to commuting patterns as well as with respect to their propensity to switch between travel options. At the same time, women have been (and continue to) making up a larger part of traffic demand because of their increasing labor participation rates as well as the fact that a larger proportion of women have drivers licenses. Women are expected to continue their contribution to traffic demand into the future. As such, and for the purposes of traffic demand management, it is worthwhile to understand the factors that affect travel demand and the degree to which these factors might be different between men and women. This paper endeavors to do just that.

Using a 1994 stated preference data set of suburban Montreal work trips, this paper develops a mode choice model for men and women and then tests to see whether men and women ought to be modeled separately. As it turns out, there is strong evidence that they should be modeled separately. Models for men and women are then developed separately.

The paper begins with a short background and literature review, then continues to describe stated preference methodologies and the data used in the analysis. A section on discrete choice modeling is followed by a presentation of the results of the models developed, beginning with results from the entire sample and continuing with the results for men and women seaparately. The paper is ended with a section on conclusions and policy implications.

LITERATURE REVIEW

It has been noted that women behave differently from men when it comes to commuting behaviour. First, women's overall commuting travel patterns are different than men's [12]. This has been noted in a number of different dimensions. For instance, women travel for shorter distances between work and home, and make more trips due to their pivotal role in home and family activities. Wachs also reports that lower income women are more likely to use public transit, whereas upper and middle income women are less likely to use public transit. Levinson [7] also reports that women make more linked trips than men do.

Second, there are difference in how women's travel patterns react to changes in family or travel circumstances. For instance, Mokhtarian [9] reports that women are more likely than men to change their travel behaviour as a result of congestion. Moreover, women are more likely to adopt work schedule changes (thereby affecting their travel patterns) than men are. Finally, differences between men and women have been identified with respect to their willingness to change commuting patterns for non-economic reasons. For example, Matthies, Kuhn & Klockner [10] report that women are more willing than men to reduce car use (because of being more likely to switch to public transport and to switch travel other modes).

At the same time, two important demographic trends have emerged in North America in the past few decades: increasing numbers of women are obtaining driver's licenses [12], and the proportion of women in the work force has been increasing [7]; two important factors affecting travel demand. These same trends have also been identified in Quebec and are expected to continue, albeit at a decreasing rate into the future [11]. As a result of these trends, women will make up an important share of future demand growth in Quebec.

If it is indeed the case that women have different travel patterns, and perhaps more importantly, different propensities to shift commuting patterns and modes, knowing and understanding this will be important in the development of future travel demand management in increasingly congested cities. Luckily, a 1994 stated preference commuter choice survey for suburban commuters in Montreal affords the opportunity to test for differences in the response of women and men to policies aimed at reducing the proportion of solo-driver journeys to work.

STATED CHOICE METHODOLOGIES

Stated Choice Methods are now a well understood and accepted technique (see [8]) whereby respondents express preferences by choosing an outcome from a set of alternatives that has been generated according to a particular experimental design. The main advantage of this approach is that it can incorporate both existing and proposed outcomes in choice sets. Once the experimental choice sets have been designed, and respondent choices have been elicited, these can then be analyzed statistically to produce estimates of, among other things, the probabilities of respondents choosing between alternatives, under differing circumstances and differing choice options. The current study uses a stated preference dataset focusing on Montreal suburban commuter mode choice.

DATA

Information on this section comes from [2]. The data for this analysis come from a 1994 suburban Montreal commuter survey of 882 respondents. The survey was originally designed as part of a larger research project whose goal was to better understand suburban commuter vehicle choice, as well as the potential to decrease the number of peak period solo-driver work trips of suburban Montrealers. The survey data are very rich, with a large amount of information on individual respondent characteristics including standard characteristics such as age and income, as well as less common ones relating to ethnic background, vehicle preferences, average commuting time and even the amount for which a respondent's last car was sold.

Of 5,751 households originally contacted, 1,503 were eligible to participate in the survey and 882 actually responded to the survey. The households themselves were located in suburban communities of Montreal, or in what were deemed to be suburban neighborhoods within the city of Montreal. A smaller subset of responses from these people were used in the actual analysis because some relevant information was missing for particular variables and were thus dropped. As well, because the population of peak period solo drivers were deemed to be the most important since it is they whose habits would be of the most interest in this study, only observations on those respondents were used. As such information on around 500 respondents was used of which 57% were men and 43% were women.

The SP experiment asked respondents to choose between nine commuter choice options. Each of the nine choices involved choosing between six alternatives, namely: solo automobile, ridesharing and public transit during the peak period, as well as these three options during the off-peak period. For each of the choices, the respondents were given different commuting time and monetary cost combinations designed to simulate changes either in information about commuting options or changes in policy scenarios (e.g. peak period tolling). An example of the types of questions asked can be found in Table 1.

As mentioned above, respondents were able to choose between six work trip options. In order to get a sense of the raw data, the frequencies of travel work trip choices have been tabulated first simply by sex and then by sex and income and sex and age. It should be noted that these are stated preferences and as such are not actually how people traveled, but rather how they said they would travel given the relative characteristics of the different commuting options. Table 1shows the breakdown of the frequency of the chosen modes by sex. As can be seen, men more often chose solo automobile as their stated choice relative to women with men choosing solo automobile 55% of the time and women 46% of the time. As well, women are more likely to choose ridesharing (47% vs. 38% for men) and slightly more likely to choose public transit (7% vs. 6%).

When considering differences by age and sex the patterns above are particularly pronounced for younger (18-24) and older (55-65) women relative to men with respect each of the different mode choices particularly during the peak period (see Table 2). For example, whereas 18% of 18-24 year old males chose solo automobile travel in the peak, only 6% of women did and 76% of males 55-65% chose driving vs. 22% of women.

With respect to how these commuting choices break down by income, as people get wealthier, the proportion of women who chose to drive declines, whereas the proportion of men who chose to drive increases (see Table 3 and Table 4). For example for women who earned less than $30,000, 63% of them chose to drive whereas only 60% of men did. For men who earned more than $100,000, however, 70% of them drive, whereas only 46% of women do. Other travel option shares adjust to this general pattern with ridesharing and public transit use for women increasing with income and decreasing for men.This particular pattern for women is strange since one would expect the proportion of women choosing to drive to increase with income based on revealed preferences (as described above). This is perhaps a result of the fact that these are stated preference choices and thereby a reminder to be cautious in the interpretation of stated preference data.

PREVIOUS ANALYSIS

An initial analysis of this data [2] was done. It consisted of separating the data into three different subsets (peak period solo drivers, peak period ride-sharers, and off-peak commuters) and conducting multinomial logit analysis of the different subsets, regressing the chosen work trip options on three alternative specific constants (public transit, off-peak commuting and ridesharing) and commuting time and commuting cost. The results of these regressions were reported and then used to conduct simulations of commuting choice using different assumptions about time and monetary costs under different scenarios.

A further "fully specified" multinomial logit model was estimated which included the interaction terms between individual characteristic data with variables in the scaled down models. . Some evidence was found suggesting that women had different preferences towards ridesharing and responded differently to commuting costs.

The work presented in this paper extends previous analysis by trying to systematically determine whether there are statistically significant and meaningful differences between men and women in this data set with respect to factors affecting commuting choices. Before continuing with the analysis of the data, a short section on the statistical analysis of discrete choice data is presented below.

DISCRETE CHOICE STATISTICAL ANALYSIS

This discussion borrows from [8], [1] and [5]. The workhorse and standard for the modeling of discrete choice data is the conditional multinomial logit model (MNL), also referred to as McFadden's Logit model. The simple conditional MNL is founded in random utility theory. Essentially it says that people are rational and so in a choice context (here commuting mode choice) individual q will choose alternative j that maximizes their utility for the given mode j as a subset of C for all m not equal to j:

$$j \subset C_q if U_{jq} \geq U_{mq} \forall m \neq j \quad (1)$$

However, it is not possible to observe someone's utility, but we can observe people's choices. As such random utility theory supposes that a person's utility is a combination of a systematic portion and a random portion. This is normally denoted as:

$$U_{jq} = V_{jq} + \varepsilon_{jq} \quad (2)$$

where V_{jq} is the systematic (estimable) component of the utility and ε_{jq} is the random component. With this, it can then be derived that the probability that an individual will choose one mode over another is:

$$P_{jq} = P(U_{jq} \geq U_{mq}) \forall m \neq j \in A \quad (3)$$

and more importantly

$$P_{jq} = P(\varepsilon_{jq} - \varepsilon_{mq} \leq V_{mq} - V_{jq}) \forall m \neq j \in A \quad (4)$$

The errors are assumed to be identically and independently distributed (IID) with a Type I Extreme Value distribution. As a result, the cumulative density of the difference between them is distributed as a logistic distribution giving rise to the logistic model.

Using these assumptions, the systematic proportion of the utility function can be estimated by maximum likelihood estimation resulting in the probability of choosing one mode over another as:

$$P_{jq} = \frac{\exp(V_{jq})}{\sum_{m=1}^{M} \exp(V_{mq})} \quad (5)$$

The IID assumption of the model also implies the independence of irrelevant alternatives. This means that if another mode or choice is introduced to the model, it will not affect the relative probabilities of the other choices already present. This is a convenient assumption because of the fact that a) it allows for the derivation of the MNL and b) allows one to estimate the potential market share of a new choice without including it in the estimation of the model.

At the same time it is quite restrictive. Even worse is the fact that if the different choices are not independent, the model can produce questionable results such as those from the famous red bus, blue bus problem. This has implications for the type of model that is used to estimate mode choice. In the case of the present data, one might reasonably be suspect of this assumption for several reasons. For example, does it not make sense that the choices of solo automobile driving and ridesharing might not be independent if people prefer automobiles, or on the other hand do not like public transit? If this is the case, then using the standard MNL to estimate these models would be inappropriate. One method by which to alleviate these problems is the nested logit model (NL).

This discussion comes primarily from [3] and [4]. The NL is a generalization of the MNL that allows groups of alternatives to be similar to each other in an unobserved way, i.e. it allows the variances of the random components to vary across subsets of alternatives. This is done by specifying a structure that partitions similar alternatives into groups or nests. They can be generalized to various nesting levels by grouping the alternatives within such a nest into subsets and so on. In the current example, it might be the case that individuals, instead of choosing initially between all six alternatives, choose initially between public modes and non-public modes and then between the remaining alternatives. Such a nesting structure could then be visualized as in Figure 1.

Assuming for simplicity a two level nesting structure with J alternatives and K nests $N_1, N_2, \ldots, N_k$, suppose $y \in \{1,2,\ldots, j, \ldots J\}$ is the choice outcome. Now, if alternative j is an element of nest N_k, then the probability of y=j can in general be decomposed into:

$$P(y = j) = P(y \in N_k) \cdot P(y = j \mid \in N_k) \quad (6)$$

if we drop the individual subscript from (2) without loss of generality, and continue to assume that the error of (2) is Type I extreme value distributed, the resulting outcome probabilities are:

$$P(y = j \mid y \in N_k) = \frac{e^{\frac{1}{\tau_k} v_j}}{e^{IV_k}} \quad (7)$$

Where V_j denotes the deterministic part of the utility, and

$$P(y \in N_k) = \frac{e^{\tau_k IV_k}}{\sum_m e^{\tau_m IVm}}, \quad (8)$$

with the inclusive value IV_k defined as

$$IV_k = \ln \sum_{l \in N_k} e^{\frac{1}{\tau_k} V_l}. \quad (9)$$

The marginal probability of the outcome j according to equation (6) is under these assumptions equal to:

$$P(y=j)=\frac{e^{\frac{1}{\tau_k}V_j}}{e^{IV_j}}\cdot\frac{e^{\tau_k IV_k}}{\sum_m e^{\tau_m IVm}} . \quad (10)$$

The parameters τ_k are called IV or dissimilarity parameters. They represent the degree of dissimilarity between the alternatives within one nest. The standard MNL follows in the special case of τ_k=1 $\forall k=1,...,K$. This NL is consistent with the random utility model if all τ lie in the unit interval. Because of the fact that this model is consistent with RUM it is the one that was used to do the modeling for this paper (as opposed to the non-normalized nested logit which is sometimes used in this type of analysis). This was done using the nlogitrum command in STATA as opposed to the standard nlogit command which is not RUM consistent (see [3] as well as [6]).

Before moving to less restrictive NL models, tests for the violation for the IIA condition should be undertaken. The most common test (as described in [8]) is that proposed by Hausman and McFadden (1984). Essentially, should the IIA assumption hold between the choice alternatives, then the presence or absence of an alternative preserves the ratio of the probabilities associated with other alternatives in the choice set (i.e. P_i/P_j is unaffected by changes in characteristics of alternatives k). The Hausman-McFadden test for the violation of the IIA assumption is then to estimate the model with all of the alternatives and compare the coefficient estimates to those of a model where a subset (whose random components are suspected of being different from the rest of the set of alternatives). The test statistic under the alternative hypothesis of the IIA violation is:

$$q=[b_u-b_r]'[V_r-V_u]^{-1}[b_u-b_r]$$

where 'u' and 'r' indicate unrestricted and restricted models and V is an estimated variance matrix for the estimates.

METHODOLOGY

First violation of the IIA assumption across different subsets of alternatives was tested. Before this could be done, it was necessary to develop standard MNL models. This was done by generating a large number of interaction variables between individual characteristics and the alternative specific constants (public transit, ridesharing and work trips done in the off-peak) as well as the continuous variables of travel time and travel cost. The significance of these variables was tested first by including all variables and then removing them, either in groups after testing the joint significance of several variables, or toward the end individually if only one variable was insignificant. This methodology was followed until all the variables were significant. The exception to this was the inclusion of the travel cost variable which was often insignificant, yet important enough to be included in the models.

Once an MNL model was developed, it was then possible to test, first whether there were differences in coefficient estimates between men and women. This was done by interacting all of the remaining variables with female dummy variables and testing for their joint insignificance using likelihood ratio tests. This resulted in a chi-square statistic of 147 with 29 degrees of freedom suggesting rejection of the hypothesis of joint insignificance of the female interaction terms at 1%level of significance and that it was justified, if not necessary, to estimate the models of women separately from men. Once these tests were done, MNL models for men and women were separately estimated. Once these models were estimated, tests for nested structures were undertaken on the entire sample as well as for men and women separately.

Testing for nests was undertaken using the Hausman-McFadden test described above to test for violation of the IIA condition in the absence of several sets of alternatives representing different potential nesting structures. In fact, three different nests were tested.

The first nest was for peak and off-peak decisions. Essentially, for differences in the estimated coefficients in the absence of off-peak options the question being asked is whether people first make the decision to undertake work trips during the peak or off-peak period and then given this first decision, what mode to take thereafter. The second nest to be tested was between public and non-public modes. Essentially, the intuitive question being asked was whether people first decide whether or not to use public transit or not and then what mode (or what time period) to travel by. The third nest that was tested was that between traveling alone and traveling with others. Intuitively, it is supposed that people first decide whether they would like to travel alone and given this decision, what mode they would finally choose.

After the IIA assumption was tested over different subsamples, overall nesting structures were tested. This was necessary when more than one of the structures above could not be rejected e.g. if both the public/private option as well as the peak/off-peak could not be rejected as violating the IIA assumption. Once these final nesting structures were arrived at, the final models were developed. It should be noted that because of the way that the survey choice structure was developed (i.e. that the peak and off-peak options were included as part of the structure – e.g. solo automobile during the peak or off peak), it was not possible to develop a nesting structure that could incorporate this decision while incorporating other potential nests (e.g. public/private) because of the fact that the options themselves would not be mutually exclusive between the different nesting levels. It should also be mentioned that STATA had trouble producing estimates (even when only very few variables were used in the regressions) of descriptive statistics (e.g. standard errors) for many of the coefficient estimates when more than two levels of nests were modeled. For this reason, it was not possible produce models with more than two levels, despite the fact that these may be preferable to MNL or other nested models presented below.

Once tests had been done for the violation of IIA and thereby for the use of nests, nested models were developed, beginning with using the entire sample of men and women. These models were then used to test for differences in coefficient estimates between men and women, a hypothesis that could not be rejected. Likelihood ratio tests were used for this as with the MNL above, however the results are omitted in order to save space. As such, in addition to models for the entire sample, nested models were also developed for men and women separately. Finally, the nested models were compared with the MNL models and the final models were arrived at. As will be explained below, the MNL version of the models was considered to be superior in all of the three cases.

RESULTS

Entire Sample

For the three types of nesting structures tested, it was impossible to reject the hypothesis of IIA for any of them. Testing for a peak/off-peak nest using the Hausman test discussed above resulted in a chi-square statistic (with 15 degrees of freedom) of 126 which is significant at 1% level of significance suggesting that a nest for peak/off-peak would be desirable. Testing for the public/private and alone/not-alone nests using the more generalized SUEST command resulted in a chi-square statistic for the public/private nest (with 31 degrees of freedom) of 68, and for the alone/not-alone nest (with 35 degrees of freedom) of 677, both of which are significant at 1%. These suggest that nests for peak/off-peak and public/private and alone/not-alone would be desirable.

As such, four different nesting structures were tested and compared. As mentioned above, attempts were made to estimate more complicated multilevel structures, but STATA was not able to produce estimates for descriptive characteristics of many of the coefficient estimates with even a few variables, not to mention if many variables were used. As a result, the most complicated structures to be evaluated were two level structures. These were compared to a multinomial logit model. The three nested models estimated were models with initial nests respectively of peak/off-peak, public/private and alone/not-alone. The results of these models can be found in Table 7.

After comparing the four models, the MNL model was chosen to the best of the models. The problem with the first two models is that both of them have estimated IV parameters outside of the unit interval (with their 95% confidence intervals also falling outside of the unit interval as well). The third model has one IV parameter that falls outside of the unit interval but whose confidence interval (IV Private) falls within the unit interval. However, the fact that this IV parameter is so close to 1 suggests this type of nest may not be justified. Moreover, when considering the maximum value of the log of the likelihood function, the value for the MNL model is higher. As well, doing a likelihood ratio test, testing whether there is indeed a statistically significant difference between the maximum values of the LLF (namely whether the LLF of the MNL actually is larger) revealed a chi-square statistic of 19.06 and 2 degrees of freedom which (5% critical value of 5.99). As such the null of no difference in explanatory power between the two models can be rejected. Based on this the MNL was chosen.

The model produces coefficient estimates that are, for the most part, intuitive and significant at the 5% level as well as having respectable pseudo R-squares around 20%. Both the public transit and ridesharing alternative specific constants are negative suggesting that, all else equal, people would rather drive solo than take either of the other options.

The coefficient estimates from logistic regressions are the logarithm of the odds ratio. As a result, it is often helpful for interpretation to take the exponent of the coefficient. The exponent of the coefficient times the change in the variable of interest produces the odds ratio. For example, the coefficient value of -2.32 for public transit implies that all else equal, the odds of an individual choosing transit are 0.10 times the odds of driving alone during the peak. Similarly, the coefficient value of -1.077 for ride sharing implies that all else equal, the odds of an individual choosing rideshare are 0.34 times the odds of driving alone.

Examination of the continuous variables (monetary cost and time) reveals an interesting pattern. While the coefficient for time is negative and significant in the MNL as well as all of the other models, this is not the case for travel cost. Of the four models included here, three of the estimated coefficients for travel cost are insignificant, and one of them is significant but postitive instead of having an expected negative sign. For time, however, the coefficient of -0.031 implies that if travel time were to increase by ten minutes (all else equal), this ten minute increase would multiply the odds of an individual choosing the slower alternative by 0.73. In other words, people do seem to be quite time sensitive. On the other hand, the fact that the cost coefficient is insignificant (i.e. possibly not different from 0), implies that people may not be that sensitive to costs associated with work trips. The fact that in one of the models this coefficient is positive seems counterintuitive and is suspect. This may be due to an omitted variable bias, as might the fact that the coefficient in the other models is insignificant.

The rest of the variables used in the models are interacted variables (Table 7). They basically try to account for how different characteristics of the respondents affect their likelihood of choosing one mode over another. There are several types of characteristics that are interacted with the alternative specific constants (ASC) and continuous variables – home location, length of drive home, how long a respondent generally keeps a car, the age of the respondents, the language they speak at home, their income, and the next type of car they expect to buy.

A couple of examples should suffice to give a sense of the type of inferences that can be drawn from the estimates. The coefficient of -1.176 for the variable vaudshare (resident of Vaudreuil interacted with the rideshare ASC) implies that the odds of someone from Vaudreuil choosing to rideshare are 0.31 the odds of someone from Montreal ridesharing. Note that Montreal refers here to people who live in suburban areas of Montreal as opposed to other municipalities considered as suburbs. Another interesting result is that the coefficients for the effect of income on time suggest that higher income earners are more sensitive to increases in time than lower income earners. For example the coefficients for time interacted with high and middle income suggest a) that both these categories of people are more sensitive to time costs than the lowest income category and b) that high income respondents are more sensitive than middle income respondents. Since the main interest of this paper is developing models to see how sensitive people might be to switching traveling alternatives, these interaction variables should be seen mainly as control variables. As a result, the focus of the analysis is on the ASCs and the continuous variables.

Men

For the three types of nesting structures tested it was not possible to reject the hypothesis of IIA for any of them. Testing for a peak/off-peak nest using the Hausman test discussed above resulted in a chi-square statistic (with 15 degrees of freedom) of 147, which is significant at 1% suggesting that a nest for peak/off-peak would be desirable. The same test statistic for testing for the public/private nest resulted in a chi-square statistic of 65 with 30 degrees of freedom, also significant at 1%. Testing for an alone/not-alone nest using the more generalized test using the SUEST command resulted in a chi-square statistic (with 35 degrees of freedom) of 925, significant at 1%. As a result, nesting structures for all three possible nests were tested.

As with the model for the entire sample, two of the three nested structures tested produced IV parameters that were outside of the unit interval and as such were rejected. The private/public nested structure because of the fact that one of its IV parameters (Private) was outside of the unit interval was rejected as well, leaving the MNL as the preferred model about which several things are worth mentioning.

First, it is worth noting that the off-peak ASC was not significant and so was not included in the final regression, leaving four other variables of interest. Of these variables and as with the coefficient estimates for the whole sample, all of them were significant apart from the continuous monetary cost variable. Of the other ones, the public transit ASC is a little less than half the absolute value of the coefficient for the whole sample suggesting that men are somewhat less averse to taking public transit than the population as a whole.

The rideshare ASC is a bit more negative than for the population as a whole suggesting that men are less likely to rideshare. The coefficient for the effect of time on travel choice is very similar for men as for the population as a whole with a coefficient of -0.035 as opposed to -0.031. Finally, the travel cost coefficient is insignificant.

Women

For the three types of nesting structures tested it was possible to reject the hypothesis of IIA for only one of them – alone/not-alone nest. Testing for a peak/off-peak nest using the Hausman test discussed above resulted in a chi-square statistic (with 2 degrees of freedom) of 0.00 which is not significant, suggesting that a nest for peak/off-peak would not be necessary. Testing for a public/private nest resulted in a chi-square statistic (with 20 degrees of freedom) of 1.42 also suggesting that no nest would be needed. Testing for the alone/not-alone nest using the more generalized test using the SUEST command resulted in a chi-square statistic for the alone/not-alone nest (with 28 degrees of freedom) of 516, which is significant at 1% suggesting a nest for alone/not-alone would be appropriate. As a result, a model with an alone/not-alone nest was developed and was compared to a standard MNL.

Despite the fact that tests suggested violation of IIA in the alone/not-alone structure, the multinomial logit model seems to provide the best fit to the data given the alternatives available (please see Table 7). Although the NL has IV parameters that are on the unit interval (providing evidence that the nesting structure is suitable), the log of the likelihood function is highest not for the NL but for the MNL and by quite a margin as well. In fact, using a likelihood ratio test with the null hypothesis that there is no difference between the maximum logs of the likelihood function of the two models produced a chi-square (with 2 degrees of freedom) 53.73, significant at 1% suggesting that there is indeed a difference between the LLFs of the two different models.

With respect to coefficient estimates, as with the other two models discussed, the offpeak ASC was not included and the travel cost coefficient is insignificant (although negative). The most interesting results from this model concern the other three coefficients. The public transit coefficient of -3.501 of MNL was twice as large (in absolute value) than that of NL model for both males and females.. . It suggests an odds ratio of 0.03 (i.e. that all else equal the odds of a woman choosing to take public transit are 0.03 times the odds of taking their car). This is quite a dramatic result and suggests that using the stated preference data, women exhibit a serious dislike of public transit relative to men. The second interesting result is the time cost coefficient. With an estimated value of -0.026, it is 25% larger than for men. As an example, if there were a 10 minute increase in one way commuting time, the effect of that increase would multiply the odds of choosing the slower option for men by 0.7 and that of women by 0.78. In other words, women are less time-sensitive than men. This is perhaps unsurprising given differences in wages between men and women. One final difference of interest is in the rideshare ASC. Whereas the rideshare coefficient for men is -1.454, for women it is only -0.554. This suggests that women are less averse to ridesharing than men. In fact, these coefficients suggest that the odds ratio for ridesharing for women is 0.23, less than half that of men's (0.57).

CONCLUSIONS AND POLICY IMPLICATIONS

The above presentation of results provides two main areas of discussion involving: differences in the commuting habits of men and women and policy implications thereof, as well as ways in which the present analysis could be furthered and improved.

Consistent with the literature on female travel patterns and behaviour, this study finds that women do indeed differ from men with respect to the factors (and the degree to which those factors) affect women's commuting mode choices in this sample of suburban Montreal commuters. This was established by testing the joint significance of coefficients interacted with female dummy variables in models that included the entire sample of peak period solo automobile commuters, as well as by estimating models separately for men and women resulting in models with slightly different sets of variables.

The estimation of separate models for men and women of this sample resulted in three interesting conclusions: women are more likely than men to rideshare, women are less likely than men to use public transport, and women seem to be less time sensitive than men. These three conclusions have potential implications for policy directed at travel demand management, especially considering the increasing importance that women are having and will continue to have in their contribution to travel demand.

The most striking difference is the fact that women prefer the public transit option much less than men do. This is likely due to the fact that suburban women commuters have other tasks to do revolving around family life which forces them to link trips (see [7]), thus making public transit less attractive due to the more complicated travel patterns that result. Perhaps there are other reasons such as perceived safety of transit facilities. It is also possible, seeing as this result is contrary to much revealed prerference data that this is a result of the use of this SP dataset suggesting perhaps required caution in the conclusions drawn from these results.

One interesting aspect of the above analysis suggests that even if women do tend to have an aversion to transit, they are not as time sensitive and that thereby time might not be as important to women in their mode choice decisions relative to transit. In any case, if authorities would like to get more women traveling by transit, they will likely have to consider the factors affecting this perceived relative aversion to transit by women. Alternatively, this could also suggest that publicity campaigns be oriented more towards men since they seem to dislike transit less. That men are more time sensitive than women suggests that gains made in reducing transit travel times could well encourage them to take to transit more than women.

The other potentially important conclusion is that since women are less likely to dislike ridesharing relative to solo commuting, it might be easier to convince them to participate in ridesharing, thereby reducing travel demand. This suggests the possibility of ridesharing encouragement programs focused at women.

With respect to further work in this area there are several things to mention. First of all, due to the way in which survey was designed, it seems that it might be impossible to develop a nesting structure to account for intragroup variance for which there is evidence that it exists. Namely, it seems that for men, a nesting structure might be required for a peak/off-peak nest, a public/private nest and an alone/not-alone nest. However, since the peak/off-peak dichotomy cannot be modeled mutually exclusively between levels, a 'perfect' nesting structure might not be achievable. Related to this is the fact that STATA was not able to produce reliable results for three-level nesting structures that included the public/private and alone/not-alone nests and as such it may have been possible to arrive at a 'better', more complicated model had results been obtainable. This suggests the possibility of continuing this work using other software that uses different searching algorithms than does STATA.

Finally, given the nature of the data and the fact that the survey was designed explicitly with the idea of testing the degree to which traffic could be shifted away from single occupant vehicle peak period commuting, the models developed here, or models that might be developed further down the road with more complicated structures could be used in the same way as they were used in [2] to produce simulations of the effect that altering travel costs and time could have on commuter mode split in Montreal.

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Figure 1 – Possible Nesting Structure for Suburban Commuter Choice

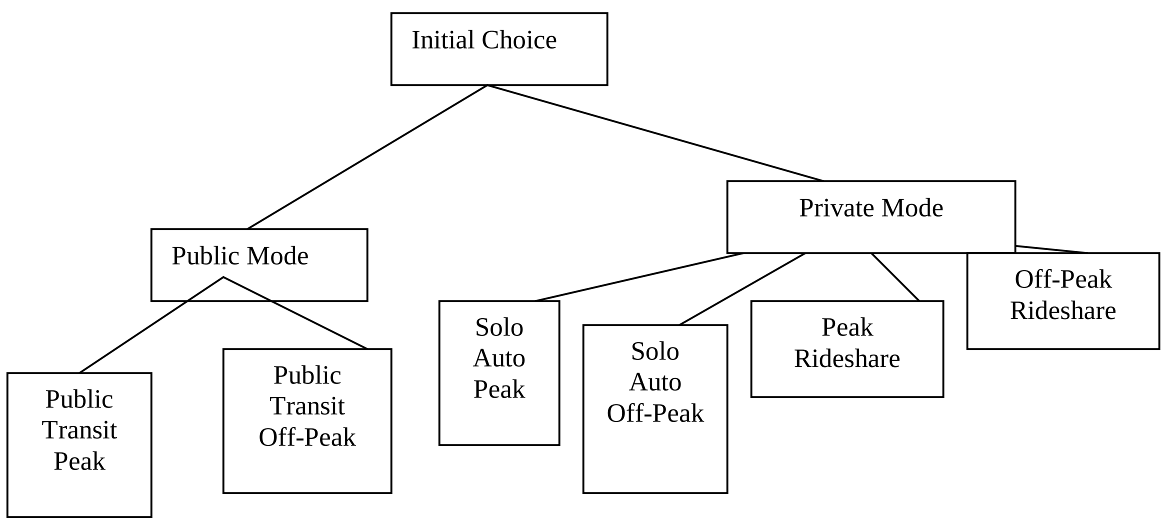

Table 1 – Examples of Questions in the Original SP Survey

Check which one of the three alternatives you would choose.

	Alone	Share	Transit
Commuting Travel & Parking Cost (Weekly)	$35	$18	$22
Commuting Travel Time (One-Way)	15 min	9 min	30 min

In this case, which one would you choose?

	Alone	Share	Transit
Commuting Travel & Parking Cost (Weekly)	$35	$18	$22
Commuting Travel Time (One-Way)	15 min	12 min	40 min

Table 2 – Breakdown of Commuting Alternative Chosen by Sex

Men	
Alternative Chosen	**Percent**
Peak	
Solo Automobile	23
Rideshare	20
Public Transit	4
Off-Peak	
Solo Automobile	33
Rideshare	18
Public Transit	2
Total	100
Women	
Alternative Chosen	**Percent**
Peak	
Solo Automobile	18
Rideshare	26
Public Transit	6
Off-Peak	
Solo Automobile	28
Rideshare	21
Public Transit	1
Total	100

Table 3 - Breakdown of Commuting Alternative Chosen by Age (Men)

Men by Age						
	18-24	**25-39**	**40-54**	**55-65**	**>65**	**% of Total**
Peak						
Solo Automobile	18%	21%	23%	44%	33%	23%
Rideshare	26%	23%	16%	9%	0%	20%
Public Transit	2%	4%	5%	2%	0%	4%
Off-Peak						
Solo Automobile	16%	33%	37%	32%	67%	33%
Rideshare	37%	18%	15%	12%	0%	18%
Public Transit	1%	1%	5%	1%	0%	2%
Total	8%	48%	38%	5%	0%	100%

Table 4 - Breakdown of Commuting Alternative Chosen by Age (Women)

Women by Age					
	18-24	**25-39**	**40-54**	**55-65**	**Total**
Peak					
Solo Automobile	6%	20%	17%	15%	18%
Rideshare	24%	26%	26%	33%	26%
Public Transit	5%	6%	6%	7%	6%
Off-Peak					
Solo Automobile	33%	28%	29%	7%	28%
Rideshare	31%	18%	21%	36%	21%
Public Transit	2%	2%	1%	1%	1%
Total	10%	50%	36%	4%	

Table 5 - Breakdown of Commuting Alternative Chosen by Income (Men)

Income by Men					
	<30000	**30-65k**	**65-100k**	**>100k**	
Peak					
Solo Automobile	23%	20%	23%	28%	22%
Rideshare	17%	22%	18%	17%	20%
Public Transit	2%	5%	5%	1%	4%
Off-Peak					
Solo Automobile	37%	30%	36%	42%	34%
Rideshare	17%	21%	17%	11%	18%
Public Transit	5%	2%	2%	1%	2%
Total	11%	49%	31%	10%	

Table 6 - Breakdown of Commuting Alternative Chosen by Income (Women)

Income by Women					
	<30000	**30-65k**	**65-100k**	**>100k**	
Peak					
Solo Automobile	31%	16%	17%	8%	18%
Rideshare	10%	25%	31%	31%	25%
Public Transit	9%	6%	5%	2%	6%
Off-Peak					
Solo Automobile	32%	27%	25%	38%	28%
Rideshare	18%	24%	21%	15%	22%
Public Transit	0%	1%	1%	6%	2%
Total	16%	51%	26%	8%	

MODEL RESULTS

Table 7 – Estimated NL and MNL Models

		Whole Sample				Males				Females	
		Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**	**Model 10**
Variables	**Alternatives**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Private/Public NL**	**MNL**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Public/Private NL**	**MNL**	**Alone/Not Alone NL**	**MNL**
Pub Trans ASC	Transit	-2.746	-0.31	-1.968	-2.32	-2.032	-0.234	-0.885	-1.335	-1.062	-3.501
		(7.02)**	(2.58)*	(6.46)**	(8.12)**	(4.67)**	-1.79	(2.92)**	(5.14)**	(3.31)**	(9.68)**
Rideshare ASC	Rideshare	-1.228	-0.526	-1.082	-1.077	-2.047	-0.259	-1.524	-1.454	-0.117	-0.554
		(12.84)**	(6.86)**	(10.06)**	(19.23)**	(6.67)**	(2.16)*	(6.12)**	(8.68)**	-1.35	(7.81)**
Offpeak ASC	Off Peak		0.086				0.125			-0.029	
			(2.32)*				(2.53)*			-0.37	
Travel Time	All	-0.035	0.004	-0.033	-0.031	-0.048	0.007	-0.032	-0.035	-0.012	-0.026
		(8.58)**	(2.29)*	(9.86)**	(9.52)**	(8.43)**	(2.52)*	(7.08)**	(9.06)**	(3.89)**	(5.49)**
Travel Cost	All	-0.008	0.006	-0.009	-0.007	-0.009	0.01	0.012	-0.006	0.003	-0.002
		-1.28	(2.33)*	-1.47	-1.14	-0.97	(2.56)*	-1.88	-0.95	-0.5	-0.16
Life of Car	Rideshare		0.014								
			-1.92								
Laval	Rideshare	0.585	0.683	0.508	0.495	1.735	0.71	1.213	1.183		
		(5.93)**	(7.40)**	(5.75)**	(6.64)**	(6.32)**	(7.80)**	(6.03)**	(8.49)**		
Laval	Transit		0.709			1.124	0.694		0.781		-1.276
			(7.41)**			(3.59)**	(7.29)**		(4.02)**		(4.38)**
Vaudreuil	Rideshare	-1.416	-0.686	-1.195	-1.176					-1.508	-1.773
		(3.96)**	(2.74)**	(3.81)**	(4.13)**					(4.69)**	(4.00)**
Vaudreuil	Transit		-0.966					-128.682			
			(3.85)**					(26.05)**			
South Shore	Rideshare	1.631	1.633	1.402	1.364	2.88	1.345	2.107	1.894	1.514	1.267
		(6.42)**	(8.71)**	(6.03)**	(7.40)**	(6.13)**	(6.46)**	(5.83)**	(8.02)**	(4.13)**	(4.13)**
South Shore	Transit	1.293	1.652	1.094	1.074	2.141	1.311	1.065	1.38	1.184	
		(3.38)**	(8.67)**	(3.42)**	(3.45)**	(3.43)**	(6.09)**	(2.62)**	(3.54)**	(2.86)**	
Longueuil	Rideshare		0.305			0.85		0.673	0.577		

		Whole Sample				Males				Females	
		Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**	**Model 10**
Variables	**Alternatives**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Private/Public NL**	**MNL**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Public/Private NL**	**MNL**	**Alone/Not Alone NL**	**MNL**
			(3.24)**			(3.64)**		(3.82)**	(4.14)**		
Longueil	Transit		0.302								
			(3.12)**								
Montreal East	Rideshare	0.525	0.667	0.445	0.45	1.558		1.175	1.001		
		(4.17)**	(5.80)**	(3.95)**	(4.41)**	(5.32)**		(5.12)**	(6.23)**		
Montreal East	Transit		0.669								
			(5.70)**								
Time Home	Transit	0.023		0.02	0.02					0.017	0.033
		(4.01)**		(4.23)**	(4.16)**					(4.46)**	(5.11)**
Life of Car	Transit	0.11		0.089	0.093					0.075	0.175
		(3.09)**		(3.00)**	(3.13)**					(3.09)**	(3.82)**
Next Car Van	Offpeak	0.286		0.272	0.28	0.377		0.388	0.335		
		(3.11)**		(2.97)**	(3.07)**	(3.35)**		(3.20)**	(3.08)**		
Next Car Sport	Rideshare	-0.612		-0.555	-0.512	-1.008		-0.698			-0.589
		(2.72)**		(2.82)**	(2.78)**	(2.38)*		(2.22)*			(2.22)*
# registered cars	Transit	-0.572		-0.536	-0.495	-0.907	0.003	-0.479	-0.627	-0.303	
		(4.18)**		(4.77)**	(4.40)**	(4.17)**	-0.05	(3.29)**	(4.36)**	(3.21)**	
Old Age	Offpeak	-0.508		-0.579	-0.495	-0.618			-0.625	-0.347	
		(3.03)**		(3.75)**	(3.10)**	(2.59)**			(3.23)**	(2.37)*	
Prime Age	Peak	-0.418		-0.515	-0.399	-0.53			-0.514	-0.322	-0.229
		(4.47)**		(7.32)**	(4.93)**	(3.57)**			(6.43)**	(3.10)**	(1.97)*
MIdage	Peak	-0.568		-0.681	-0.544	-0.696		-0.325	-0.694	-0.312	-0.437
		(6.13)**		(9.07)**	(6.79)**	(4.78)**		(3.32)**	(8.83)**	(3.08)**	(4.84)**
Midincome	Peak	-0.226			-0.203	-0.308		-0.367		-0.347	-0.261
		(2.28)*			(2.16)*	(2.22)*		(3.43)**			(2.09)*
Avg. Income	Peak	-0.202			-0.176	-0.467		-0.532			
		(2.26)*			(2.08)*	(3.27)**		(4.78)**			
Agv. Income * Travel Cost	All	-0.029		-0.022	-0.028	-0.021		-0.019		-0.019	-0.032

		Whole Sample				Males				Females	
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Variables	**Alternatives**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Private/Public NL**	**MNL**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Public/Private NL**	**MNL**	**Alone/Not Alone NL**	**MNL**
		(7.49)**		(6.48)**	(8.06)**	(4.23)**		(4.42)**		(4.39)**	(6.79)**
Time * High Income	All	-0.029		-0.026	-0.029			-0.04			
		(2.44)*		(2.35)*	(2.63)**			(2.55)*			
Time*Mid Income	All	-0.014			-0.013					-0.018	-0.052
		(2.09)*			(2.21)*					(2.86)**	(4.69)**
West Island	Rideshare									-0.336	-0.449
										(2.37)*	(2.97)**
West Island	Transit									-0.494	-1.214
										(2.44)*	(3.36)**
Registered Cars	Share					-0.323	-0.084	-0.25	-0.197		
						(2.99)**	-1.5	(2.85)**	(2.78)**		
Vaudreuil	Offpeak					0.863			0.773		
						(2.94)**			(2.74)**		
High Incom	Peak					-0.314		-0.577			
						-1.63		(3.15)**			
Yrs in Neighbourhood	Offpeak					0.013					-0.027
						(1.99)*					(4.75)**
English	Transit										
IV Parameters											
		Alone	Peak	Private		Peak	Alone	Private		Alone	
		1.17	-0.19	1.032		1.552	-0.292	1.141		0.383	
		(12.32)**	(2.31)*	(10.02)**		(9.07)**	(2.53)*	(3.45)**		(4.72)**	
95% Confidence Interval											
		1.007637	-0.35047	0.830034		1.216321	-0.51757	0.862088		0.27721	
		1.405925	-0.02896	1.233845		1.886956	-0.06615	1.420072		0.72476	

		Whole Sample				Males				Females	
		Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**	**Model 10**
Variables	**Alternatives**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Private/Public NL**	**MNL**	**Peak/Off-Peak NL**	**Alone/Not Alone NL**	**Public/Private NL**	**MNL**	**Alone/Not Alone NL**	**MNL**
		Not-Alone	Off-Peak	Public		Off-Peak	Not-Alone	Public		Not-Alone	
		1.207	-0.115	0.62		1.56	-0.163	0.572		0.501	
		(11.88)**	(2.31)*	(4.83)**		(9.82)**	(2.53)*	(8.02)**		(4.39)**	
95% Confidence Interval											
		0.983606	-0.21321	0.3686089		1.248663	-0.28934	0.246952		0.22394	
		1.355832	-0.01745	0.8713156		1.87151	-0.03675	0.896504		0.54167	
Observations		24210	24480	24210	24210	13866	14460	14028	14028	10452	10344
Number of groups		4035	4080	4035		2311	2410	2338		1742	
LLF		-5861.62	-5993.09	-5868.8604	-5864.1	-3297.46	-3494.94	-3347.56	-3363.83	-2489.07	-2462.21
Chi-square		2634.59	2736.26	2721.778	2731.31	1686.59	1646.39	1683.14	1650.61	1264.34	1253.57
L(o)		-7178.9	-7361.2	-7229.7494	-7229.8	-4140.8	-4318.1	-4189.1	-4189.1	-3121.2	-3089
rho-square		0.183495	0.185857	0.188234602	0.188894	0.203657	0.190637	0.200894	0.197011	0.202538	0.202909
rhobar-square		0.179316	0.183411	0.18463835	0.185021	0.196412	0.187626	0.194688	0.191998	0.195169	0.196111
DF		30	18	26	28	30	13	26	21	23	21
Absolute value of z statistics in parentheses											
* significant at 5%; ** significant at 1%											

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