MODELING THE IMPACT OF POLICIES AND DESIGN ELEMENTS ON INDIVIDUAL’S TRAVEL SWITCHING BEHAVIOUR TOWARDS TRANSIT, WALKING, AND CYCLING

CASE STUDY OF THE MIDDLE RING NEIGHBOURHOODS OF THE CITY OF CALGARY

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INTRODUCTION

Trip making behaviour is affected by various interrelated factors such as: the characteristics of the built environment, supporting demand management policies, as well as the characteristics of the public transport.

Mixed land use neighbourhoods and supporting demand management policies aim at changing travel behaviour in terms of lower trip frequency, more use of “green” modes and shorter non-work travel distances. Cervero, 2002 has shown that higher land use density, more pedestrian-friendly neighbourhood and better transit service quality would decrease the share of driving a private vehicle to work and increase the proportions of trips made by public transit, biking, and walking. Zhang and Guindon (2006) also showed that the provision of local facilities and services might reduce travel distance and increase the proportion of short journeys capable of being travelled by non-motorized modes. Parking availability is also shown to affect travel behaviour. Cervero and Kockelman (1997), Zhang and Guindon (2006) and Barnes (2001) found that neighbourhoods with limited on-street parking abutting commercial establishment tended to have on average less drive-alone travel.

On the other hand, elements of the transit service itself play a key role in defining transit quality and attracting riders from the auto mode. Recently, the concept of Customer Oriented Transit Service (COTS) has been promoted to further support high quality transit, with the ultimate goal of attracting auto users to transit and maintaining acceptable levels of transit ridership. COTS is characterized by fast and reliable service, passenger information systems, attractive vehicle design (both interior and exterior), distinctive and attractive station design, electronic fare collection, etc.

Conventional methods of sustainable community development are plagued with many problems. They are generally aggregate, hence more appropriate for regional planning than community/neighbourhood planning. Conventional mode choice models often produce inaccurate forecasts of demand shift to transit, and they are generally poorly sensitive to customer-oriented service elements (e.g. passenger information provision, ITS technologies that improve reliability, rail vs. bus attraction, etc.). Many researchers have highlighted those methodological limitations (Winston (2000), Beimborn et al. (2003), Flyvbjerg et al. (2005), Quentin and Hong (2005), Cantillo et al. (2007) and Domarchi et al. (2008)). Additionally, those tools have been built in platforms that are not conducive for interactive input by stakeholders and for public consultation. The need for new methodologically sound and interactive tools to support the planning of sustainable communities and design of COTS cannot be overstated.

In addition, existing mode choice models (estimated on RP data) fail to capture habit, inertia and other socio-psychological factors that act as barriers to transit usage. At the same time, there is still limited understanding on how transit service in urban neighbourhoods can be modified such that not only retain existing riders, but also attract people who are currently using private automobile. Improved understanding of customers’ behaviour and attitude is crucial to fine-tune resource-constrained transit services to attract maximum ridership. Thus,
the success of any customer-first transit service requires customers’ choices and attitudes to be explicitly represented.

Given that bus transit systems are most frequently accessed via walking or biking, an increase in transit ridership is likely associated with increase in biking and cycling trips. While modelling the shift towards transit is an important step to estimate a significant portion of the active modes, it is not sufficient from a community viewpoint. From a community perspective, the quality of urban life is greatly affected by the level of pedestrian and cycling activities in a community. However, modelling the shift towards walking and/or cycling is still a topic that has had little exploration in the literature.

**OBJECTIVES AND SCOPE**

In this research, a model will be developed to adequately forecast people’s mode switching behaviour towards more sustainable modes of travel such as walking, cycling, and high quality transit, in response to changes in various transit and land use design as well as travel demand attributes. The specific aim of this work is to develop proper analytical tools to assess the effects of:

1. Sustainable neighbourhood design elements (e.g. high density and mixed use, TOD, connectivity, street pattern, improved street walkability, provision of bike paths, etc.).
2. High-quality transit modes and service characteristics (LRT, BRT, real time information, travel time, connectivity with other modes, reliability, etc.)
3. Supporting transportation policies, such as parking policies (e.g. restrictions, rates, etc.)

In September 2009, the City of Calgary Council approved “Plan It Calgary”, which is an integrated Municipal Development Plan (MDP) and Calgary Transportation Plan (CTP). Plan It Calgary proposes policies that focus on developing resilient neighbourhoods through intensifying and diversifying urban activities around transit stations and routes, more intensive development, mixed land-uses, encouraging non-motorized trips and reinforcing comfortable, safe, and walkable streets (Plan It Calgary, 2009).

In a recent effort to promote sustainable communities, the PlanYourPlace (PYP) project, sponsored by GEOIDE (Geomatics for Informed Decisions) and supported by the Neptis foundation, adopted a user-centered design approach that brings together planning tools founded on practical, academically-sound principles that are designed to educate and stimulate interest in the development of future communities within the Middle Ring neighbourhood in the City of Calgary. Calgary's “middle ring” is comprised of neighbourhoods that were developed between the 1950s and 1970s. The dominant pattern of each of these neighbourhoods consists of a warped grid and crescent blocks organised around a central school and recreation field(s). Commercial development within the neighbourhood unit typically takes the form of auto-oriented strip malls with a large grocery store anchor and large surface parking lots. In general, the PYP project’s goal is to develop a
process and guidelines that assist the City in transitioning these "middle ring"
eighbourhoods into a sustainable future.

In particular, the intent of PlanYourPlace project is to help change existing lifestyle choices
and allow communities to switch to options that promote sustainable living where compact,
mixed-use, pedestrian-friendly street network, and design are integrated to support walking,
cycling, and high-quality transit. Such form of development is commonly referred to as TOD
(Transit Oriented Development).

The specific aim of this project is to investigate how transportation policies, TOD and various
design elements (specifically related to the built environment and to transit service) might
affect an individual’s travel switching behaviour towards transit, walking, and cycling in
selected communities in the middle ring neighbourhoods of the City of Calgary. Proper
analytical tools to assess the effects of alternative sustainable policies and urban street
characteristics on changing traveller’s behaviour have been developed to adequately
forecast people’s mode switching behaviour towards such sustainable modes of travel.

**RESEARCH METHODOLOGY:**

Our proposed methodological approach includes a number of key tasks including design and
implementation of a travel survey and the development of econometric choice model of
mode-switching behaviour towards transit and active modes such as walking and biking at
the community level. The survey is intended to collect data on revealed mode choice
behaviour as well as on sensitivity of mode switching preferences to walking, cycling, and
public transit considering some important preference attributes such as advance information
provision, ITS technologies and rail vs. bus attraction. In addition, built environment variables
like neighbourhood densities, mixed-use levels will also be included in the survey. Particular
emphasis will be given to the impact of adverse weather conditions in the modal shifting
model towards the active modes. Some of the key preference attributes (such as
technological preferences, habit of auto driving, inertia to use transit etc.) are not easy to
capture in Revealed Preference (RP) data. Therefore, a systematically designed Stated
Preference (SP) experiment is unavoidable. In this project, we developed an innovative
survey tool combining RP mode choice information with SP experiments called RP-pivoted
SP survey.

The data collected through such novel survey was then used to develop econometric model
of mode shift, with emphasis on capturing the behaviour of switching to transit and active
modes. The econometric model was a hybrid discrete choice model, where a revealed mode
choice model was be combined with a stated mode switching probability model.

The outcome from this research will be useful for evaluating transit oriented land use
planning policies and alternative transit infrastructure development strategies (e.g. LRT, BRT,
new transit lines, etc.). The resulting framework will also assist in evaluating active
community land use planning policies (e.g., pedestrian and bicycle trails and facilities) and
alternative transit infrastructure development strategies (e.g., LRT, BRT and new transit
lines).
CITY OF CALGARY CASE STUDY

As mentioned, this study was designed to further educate and stimulate interest in the development and redevelopment of communities within the Middle Ring neighbourhood in the City of Calgary; neighbourhoods that were developed between the 1950s and 1970s. The maps below show the Middle Ring neighbourhoods in Calgary and the approximation used in collecting the survey data by using Forward Sortation Areas.

Calgary’s Middle Ring

Study Area Equivalent using Forward Sortation Areas (FSAs)

SAMPLING STRATEGY

The following is the sampling strategy for a web-based travel survey used to measure the impact of policies and design elements on individual's travel switching behaviour towards transit, walking and cycling.

TARGET POPULATION

The target population in this study is all individuals in the employed labour force, 15 years and over, having a usual place of work in the city of Calgary, Canada. According to the Place of Work and Commuting to Work data released by Statistics Canada in 2006, the target population is estimated as 498,030 commuters distributed among different modes of travel as shown in Table 1.
Table 1: Number and percentage of commuting work trip by mode

<table>
<thead>
<tr>
<th>Mode of Transportation</th>
<th>Trips</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car, truck, van as driver</td>
<td>335,720</td>
<td>67.41%</td>
</tr>
<tr>
<td>Car, truck, van as passenger</td>
<td>36,475</td>
<td>7.32%</td>
</tr>
<tr>
<td>Public transit</td>
<td>85,700</td>
<td>17.21%</td>
</tr>
<tr>
<td>Walked</td>
<td>28,900</td>
<td>5.80%</td>
</tr>
<tr>
<td>Bicycle</td>
<td>6,980</td>
<td>1.40%</td>
</tr>
<tr>
<td>Other method</td>
<td>4,255</td>
<td>0.85%</td>
</tr>
<tr>
<td><strong>Total - Mode of transportation</strong></td>
<td><strong>498,030</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

**SAMPLE SIZE DETERMINATION:**

In order to maintain an efficient and adequately sized sample, this study uses the Simple Stratified Random Sampling method where survey population is divided into homogeneous mutually exclusive strata before selecting independent Simple Random Samples from each stratum.

The sample size is determined to maintain a margin of error of ±0.05 at a 95% confidence level for estimates of the whole population. Given the preliminary estimates of mode choice proportions in Table 1, the variability in the population (P) is selected to be 0.6741 (max. variability).

1. Calculate the initial sample size, \( n_1 \):

\[
 n_1 = \frac{z^2 P(1 - P)}{e^2}
\]

\[
 n_1 = \frac{(1.96)^2 \times 0.6741(1 - 0.6741)}{(0.05)^2} = 338
\]

2. Adjust the sample size to account for the size of the population:

\[
 n_2 = n_1 \frac{N}{N + n_1}
\]

\[
 n_2 = 338 \times \frac{498,030}{498,030 + 338} = 338
\]
3. Adjust the sample size for the effect of the sample design:

\[ n_3 = \text{deff} \times n_2 \]
\[ n_3 = 3 \times 338 \approx 1,000 \]

Note that for stratified random sampling, usually deff < 1. However, selecting sampling frame based on e-mail addresses may impose clustering effect (i.e., clustering based on e-mail availability before stratifying based on mode choice). Given that no estimate of deff is available in this study, setting deff > 1 should have the effect of producing a more conservative (i.e., larger) sample size estimate.

**TRAVEL SURVEY INSTRUMENT DESIGN**

This section presents the design of an innovative Revealed Preference (RP) and Stated Preference (SP) survey for mode shift modelling. The main objective of the developed survey is to provide a better understanding of commuters' mode choice preferences (e.g., car driver, car passenger, carpool, etc.) and willingness to switch to public transit and active modes (bike and walk) in response to changes in transit service attributes and neighbourhood design.

The proposed survey will be administered among a random sample of commuters in Calgary's Middle Ring Neighbourhoods to collect detailed information about daily commuting work trips that constitute an increasingly large proportion of urban trips in the City of Calgary and, therefore, have a significant impact on traffic congestion and emissions. Although it might suffer from low response rate, the web-based mode of data collection is adopted in this research. One reason for using such data collection method is the tremendous time and cost savings associated with eliminating printing and mailing the survey instrument. In addition, a major advantage of web-based surveys is that the interviews can be tailored for each individual participant based on his/her earlier responses in the questionnaire (Cobanoglu et al. 2001; Kwak and Radler 2002; Kaplowitz et al. 2004).

In general, the survey intends to gather socio-demographic characteristics of respondents (e.g., age, gender, income, auto ownership and availability), as well as their factual and stated choice experience (e.g., travel cost, parking cost, travel time, and waiting time) associated with different travel options. The questionnaire is divided into three sections, as shown in Figure 1. Section A gathers revealed information regarding daily commuting work trips and current travel options. In particular, this section asks questions about trip origin and destination, trip start time, primary mean of commuting as one of the following options: car driver, car passenger, carpool, public transit, cycle, walk or other. Further, transit users are also asked to provide information about their access mode as one of the following options: ride all way, park and ride, kiss and ride, carpool and ride, or cycle and ride. After identifying the primary mode of travel, additional mode specific information is gathered. Car drivers are asked about travel time, travel cost, parking cost, car type (i.e., sedan, SUV, coupe, van or truck), make, model, year and either conventional, hybrid or electric. Information about travel time, travel cost is collected from both car passengers and carpoolers in addition to the number of passengers in the carpool for the later. Public transit users are asked about
the number of transfers they make, in addition, detailed data about their modal combination is collected by allowing them to unrestrictedly choose between bus, BRT and LRT. Transit users are also asked about transit fare and payment method (i.e., cash, tickets, or transit pass) and whether it is paid by their employer. Moreover, special consideration is given to each of the transit trip time components by asking explicit questions about access, waiting, in-vehicle, transfer, and egress times. Finally those who use non-motorized (active) modes (i.e., walk and bike) are asked about travel time as well as the months of year they usually use these options. After that, the survey collects information about secondary means of commuting that is used in case of unavailability of the primary option to have a clearer idea about the hierarchies within the choice set. Finally, the last part in this section gathers information about non-transit users’ perceptions about public transit service in terms of transit fare, access, waiting, in-vehicle, and egress time as well as technological preferences (e.g., rail vs. bus attraction) and frequency of past use.
Figure 1 Innovative Commuting Survey for Mode Shift Modelling

Start

Trip Origin and Destination
Full Address (Optional)
Postal Code
City

Trip Start Time

Primary Mode
Car Driver
Travel Time
Travel Cost
Parking Cost
Car Type
Car Make
Car Model
Car Year
Transmission Type
Secondary Choice

Car Passenger
Travel Time
Travel Cost
Primary Mode
Secondary Choice

Carpool
Travel Time
Number of Carpoolers
Travel Cost
Secondary Choice

Other
Mode
Travel Time
Travel Cost
Parking Cost
Months of Year
Secondary Choice

Cycle
Travel Time
Months of Year
Secondary Choice

Walk
Travel Time
Months of Year
Secondary Choice

Public Transit
Access Mode
Technology (Worst)
Payment Method
Reimbursement
Number of Transfers
Access Time
Waiting Time
In-Vehicle Time
Egress Time
Fare
Secondary Choice

Perception about Public Transit
Access Time
Waiting Time
In-Vehicle Time
Egress Time
Transit Fare
Transit Technology
Frequency of Past Use

Modes Description
Choice Tasks
In each of the six presented hypothetical scenarios, select the travel alternative that you would use to make your work trip based on the given situation, mode features, and LOS attributes

Willingness to Comply to the SP Choice

Gender
Age
Marital Status
Occupation
Dwelling Unit Type

Household Occupancy (Older than 18 and under 18 Explicitly)
Car Ownership
Driver’s License Holding
Personal Annual Income

End
The data collected in the first section of the survey will allow us to match factual experiences with personal views concerning the trip under investigation and current travel options. Further, the web-based data collection will provide us with an opportunity to customise the SP experiment based on earlier responses entered by the participants. For example, asking non-transit users about their perception of the transit service will help us to generate reasonable attribute levels for each respondent while customising the SP scenarios in section B of the questionnaire.

Section B sets up a SP experiment, which is considered a key component of the proposed mode shift model. The proposed experiment measures participants’ stated mode switching preferences towards public transit and active modes given some policy changes. The stated choice experiment asks respondents to rate their propensity to perform the same trip (their work trip) by a non-existing transit service or active option in the future. A total of six hypothetical scenarios are presented to each respondent where he/she is asked to choose between his/her primary option (revealed earlier in the questionnaire), shift to a new hypothetical option or other alternative that is identified by the respondent. Two extremes of the new transit service are proposed in the experiment. First, new services that can be easily figured out by the respondents. Second, new services and/or technologies that are more innovative on a technological point of view and that have little chance of having been experienced in the past by the survey respondents.

As opposed to common SP surveys, and since it is hard for respondents to make a clear choice between the mode they are already accustomed to and a new alternative that has not been experienced before, respondents were not asked to make a clear choice between the presented alternatives but instead they are asked to express their willingness to switch modes using a Likert scale. Such scale will be used to decrease the measurement error of the response (Diana 2010).

Factors such as travel time, travel cost, and parking cost for the car option are considered in the experiment. Further, different components of the transit trip travel time are included as well as transit fare for the public transit alternative. In addition, various transit service design factors are considered such as service accessibility in terms of access/egress to public transit stops/stations as well as park-and-ride availability; service frequency and headway in terms of the expected waiting time; and service reliability standards in terms of transit schedule delay (on-time performance). Moreover, the experiment is sensitive to crowding effects and some important preference attributes such as advance information provision, ITS technologies and rail vs. bus attraction. Furthermore, given the effect of neighbourhood design on changing people’s travel mode choices (especially for active modes of travel), the availability of pathways/bike lanes, street furniture, and vegetation/trees is considered in the experiment.

In order to ensure practical attribute level ranges, best practices in transit service design are utilized in the design. According to (Mistretta et al. 2009), service design standards refer to specific goals, objectives and policies that a transit agency sets for itself in various areas of transit service design to maintain an acceptable balance between operating cost and service quality. In general, service design standards deal with all facets of a transit system that affects both the passengers and the operator. In this research, more attention is given to service design standards that affect mode shift towards public transit from the passenger’s
viewpoint. In particular, the proposed SP experiment considers factors such as service accessibility, frequency and headway, directness and reliability.

Service accessibility standards ensure a reasonable passenger utilization of the transit service. In general, standards for service accessibility address several aspects of the transit system that affect the utilization of the service such as service coverage, route layout and design, stop location and spacing. As an important measure of service accessibility, service coverage identifies the extent to which the defined service area is being served. Service coverage is commonly measured by the percentage of the population that resides within a suitable access distance from a transit stop. Typically, physical access to a transit stop is achieved by walking, riding a bicycle or driving a short distance in an automobile. Based on assumed average walking speed of about 1.3 m/s, 400 meters (5 minutes) walk is often considered reasonable for local transit service, which can be increased up to 800 meters for express or rapid transit service (Murray et al. 1998; Murray 2003; Murray and Wu 2003). Another important measure of service accessibility involves the availability of park-and-ride facilities, which extend the use of the transit system to include automobile users. Commonly, park-and-ride facilities should be provided at appropriate stops on rapid and express services to serve transit users from medium- and low-density residential areas. At park-and-ride facilities, it is typical that off-street auto parking is provided to accommodate the total parking demand. Park-and-ride facilities may be provided at any suitable location which can be shown to attract 200 autos per day for express service and 150 autos per day for limited stop service (Highway et al. 2004; Deakin et al. 2006).

Service frequency and headway are often used interchangeably to provide guidance on the schedule design functions of a transit system. Generally, service frequency refers to how often transit units arrive at a particular stop/station, whereas headway refers to the time interval between the arrivals/departures of two successive transit units at a transit stop/station. The common practice in service design is to have a more frequent service during peak periods and less frequent service during off-peak periods. However, headways are not usually allowed to exceed a specified threshold or a policy headway that defines the transit system policy and represents the minimum level of service with respect to time of day or day of the week. In general, policy service levels are identified as a compromise between economic efficiency and the functionality of the system. Given that service levels past 30 minutes are generally unacceptable from the passenger’s perspective and are not enough to develop a solid and a consistent base of ridership, a widely used policy headway is 30 minutes during peak hours and can reach 60 minutes during off-peak hours. Moreover, headways for night, Saturday, and Sunday service usually match the off-peak headways or may be even longer. In addition, policy headways can also be altered according to the offered service technology. For example, BRT should combine a much higher service frequency by utilizing advanced technologies such as transit signal priority, off-board payment, and queue-jump lanes to increase the speed of the service (Vuchic 2005).

Transit travel should be as competitive as possible with private auto travel in order to provide attractive and convenient service. One measure of such competitiveness is service directness, which refers to the degree to which a route deviates from the shortest path between the origin and destination points of the route. In practice, agencies measure service
Crowding effects can be expressed in terms of the loading standards that are created to maintain acceptable passenger loads on transit units. In practice, the load factor indicates the extent of crowding or the need for additional transit units/vehicles. It is expressed as the ratio of passengers actually carried versus the total seating capacity of a transit unit/vehicle (Katz and Rahman 2010; Li and Hensher 2011)

In light of the above, the assignment of levels to each SP attribute conditional on the RP levels is straightforward. Except for some fixed values, the attribute levels are set as proportions relative to those associated with a current trip identified earlier in the RP prior to the application of the SP experiment, or designated values estimated based on the deference in average operating speed between various transit technologies. However, if the RP trip had a zero level for an attribute, which is possible for one or more factors (e.g., parking cost), suitable values were estimated based on the origin-destination matrix running in the background of the survey.

Given the mode specific information indicated by the respondent earlier in the questionnaire, auto in-vehicle travel time is decreased by 10% then increased by 50% and 75%. Transit in-vehicle travel time on the other hand is first estimated based on the offered transit service, based on the deference in average speed between transit technologies, before being decreased by 10%, 20%, then increased by 10%. Three transit technologies are considered in the experiment based on the expected developments in Calgary’s Middle Ring neighbourhoods as follows: regular bus, Bus Rapid Transit (BRT), and Light Rail Transit (LRT). Travel and parking costs for car are increased by 25%, 50% and 75%, whereas transit fare is increased by 10%, 20% and 30%. Given 5 min as a typical standard, Access/Egress times are decreased by 50% (2.5 min) and increased by 100% (10 min). It should be clear that access time corresponds to the walking, cycling, or time spent in a car depending on the participant’s access mode (ride all way, cycle and ride, carpool and ride, kiss and ride, or park and ride, etc.).

As for waiting and transfer times, both are decreased by 50% then increased by 50%. The number of transfers is altered as 0, 1, and 2 or more. Three factor levels are used to indicate the crowding level as uncrowded (seats available), moderately crowded (no seats available), and overcrowded (wait for next transit unit). Similarly, three factor levels are used to
represent the schedule delay as early (more than 1 min early), on-time (between 1 min early & 5 min late), and late (more than 5 min late). Moreover, the availability of park-and-ride facilities, schedule information, and real-time information is considered as Yes/No attributes. Further, pathways/bike lanes availability is represented by three factor levels as follows: no travel can be on pathways/bike lanes, some (<50%) of travel can be on pathways/bike lanes, and most (>50%) of travel can be on pathways/bike lanes. Similarly, street furniture availability is represented using the following factor levels: no street furniture (arcades, canopies, water fountains, and/or benches) are present, less than five items of street furniture (arcades, canopies, water fountains, and/or benches) are present, and greater than five items of street furniture (arcades, canopies, water fountains, and/or benches) are present. Finally, the availability of vegetation/trees is considered using the following factor levels: there is no vegetation or trees along the route, there are trees along the route providing some shade, and there are trees along the route that provide shade across the entire street.

The D-efficient design is adopted in this research to develop the stated choice experiment. The Ngene software package is used to generate the design that maintains the utility balance and maximizes the information gained from each hypothetical scenario while minimizing the Dp-error. In order to ensure more reliable parameter estimates, a small-scale pilot survey will be conducted among a random sample of commuters based on orthogonal design. Such pilot survey will be used to obtain prior parameter estimates for the actual experimental design.

Based on the number of attributes and their levels, the SP experimental design generated 108 scenarios that maintain attribute level balance. Obviously, it is too large to give all the 108 choice situations to a single respondent. Hence, we blocked the orthogonal design into 18 blocks of 6 choice tasks each, defining block 1 as the first 6 rows of the design, block 2 as the second 6 rows and so on. Importantly, each of the 18 blocks is not orthogonal by itself, but rather the combination of all blocks is orthogonal. As such, each respondent will be faced with a random block of 6 choice tasks instead of 108. In particular, a block (b) is randomly drawn from blocks 1, 2, 3, ..., and 18 and assigned to respondent 1. Then the rest of blocks are assigned as follows: block [(b mod 18) + 1] to respondent 2, block [((b+1) mod 18) + 1] to respondent 3, ..., block [((b+10) mod 18) + 1] to respondent 18. We then go to block 1 for the next set of 18 respondents. For example, if the first respondent faces block 17 of the design, the next respondents will receive blocks 18, 1 and 2 and so on. Once all blocks are assigned, a number from 1 to 18 is drawn and the block sequence is repeated again. The advantage of the previous procedure is that as long as the number of respondents is a multiple of 18, we will have a symmetrical representation of each block (having exactly the same number of respondents in each block) and yet a complete orthogonality in model estimation is guaranteed (Hensher 2001a). Furthermore, in order to eliminate the order effect in the SP experiment, the 6 choice tasks within the same block are assigned to each respondent at random.

Finally, Section D collects information regarding common socioeconomic and demographic characteristics such as gender, age, marital status, occupation, dwelling unit type, number of persons in the household, number of cars in the household, driver's license availability, and annual income.
The data collected through such novel survey will then be used to develop econometric mode shift models, with emphasis on capturing mode switching behaviour towards public transit and active modes. The proposed econometric models will be hybrid discrete choice model, where a revealed mode choice model is combined with a stated mode switching probability model. The proposed approach presents a new methodologically sound tool for evaluating the impacts of alternative transit and neighbourhood designs on travel behaviour.

**SURVEY RESULTS**

**DEMOGRAPHIC CHARACTERISTICS OF SURVEY RESPONDENTS**

As part of the survey, demographic characteristics were asked of the respondents. These characteristics included gender, age, relationship status, residence type, vehicle ownership, and income. Below is a graphical representation of the key demographic characteristics of the survey respondents.

As shown, 52% of the respondents were female; the majority of respondents were age 51-60 (36%), and 45% of the respondents were single. The predominant residence type was a house (52%); 45% of the respondents had one vehicle and 38% of the respondents had two vehicles. The income distribution showed a majority of respondents with an income of $100,000 or higher (21%), with the next highest income category being $50,000 - $59,999 (15%).
The existing behaviours and characteristics of the respondent’s work trips were asked in significant detail as part of the survey. The comparison below shows the study area responses adjacent to the citywide travel-to-work behaviour. Respondents in the Middle Ring study area demonstrated a lower mode share to car, truck, van as a driver. This lower mode share was made up by other modes of travel to work, such as walking, biking, and public transit use.

The demographic characteristic and existing travel-to-work behaviours of the respondents within the Middle Ring communities in Calgary was then cross-tabulated to reveal unique travel behaviours. The results of the cross-tabulation are shown in the graphs that follow.
There were a number of existing travel behaviours of the respondents that were revealed in the survey. As shown, men drove all the way to work more than females; with females being car passengers and using park and ride more than men. Drive All Way was less common in younger adults and Cycle All the Way was most common amongst respondents between the age of 41-50 years. Also, adults under 40 years of age used transit more than over 40 years of age. The respondents that were Married, Divorced, and Widowed chose to Drive All Way more than Single Adults; with approximately 19% of Single Adults walking to work.

Adults living in a Townhouse or Apartment drive less and use Active Transportation and Transit as a mode choice more than adults living in single-family dwelling units. In addition, adults living in a household with 1 or 2 people in the household use active transportation more than households of larger size. Finally, use of Active Transportation and Transit use was shown to decline with an increase in vehicle ownership.

Non-work trip travel behaviours were also asked of the survey respondents. The non-work trip types were: Visiting Friends, Visiting Family, Going Shopping, Going with Family to a Restaurant, Going to Play Sports, Visiting a Park, Going Fishing on the Weekend, Going to the Movies, and Going to a Party. As shown below, Active Transportation was found to be more prevalent for trips to parks, shopping, and playing sports. Additionally, Transit use was more prevalent for trips to visit friends, playing sports, going to the movies, and going to a party.
This section presents a SP Mode Shift Model for car drivers. Data used in the analysis comes from a small-scale pilot survey conducted among a random sample of commuters in Calgary’s Middle Ring Neighbourhood. The developed model has the following six alternatives: Car Driver, Shared Ride (Car Passenger/Carpool), Transit with Auto Access, Transit with Non-Motorized (NMT) Access, Bike, and Walk. In general, the estimated model is sensitive to various Level of Service (LOS) attributes related to the competing options as well as the socioeconomics and demographics of passengers.

The following table shows the model estimation results. It is worth noting that the specification of the final model is derived based on the accommodation of variables with proper signs and statistical significance; however, some parameters with t-statistics values lower than the acceptable critical value are retained in the model because the corresponding variables provide considerable insight into the behavioural process.
### SP Mode Shift Model for Calgary's Middle Ring Commuters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mode</th>
<th>Parameter</th>
<th>t test</th>
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</thead>
<tbody>
<tr>
<td>Log Likelihood of Mode Shift Model</td>
<td></td>
<td>-479.55</td>
<td></td>
</tr>
<tr>
<td>Log Likelihood of Null Model</td>
<td></td>
<td>677.28508</td>
<td></td>
</tr>
<tr>
<td>Rho-Squared Value</td>
<td></td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td><strong>Variable</strong></td>
<td><strong>Mode</strong></td>
<td><strong>Parameter</strong></td>
<td><strong>t test</strong></td>
</tr>
<tr>
<td>Alternative Specific Constant</td>
<td>Car Driver</td>
<td>6.0276</td>
<td>7.406</td>
</tr>
<tr>
<td></td>
<td>Shared Ride (Car Passenger/Carpooler)</td>
<td>4.6393</td>
<td>6.151</td>
</tr>
<tr>
<td></td>
<td>Transit Auto Access (TAA)</td>
<td>4.1298</td>
<td>5.284</td>
</tr>
<tr>
<td></td>
<td>Transit NMT Access (TNMTA)</td>
<td>3.3847</td>
<td>4.146</td>
</tr>
<tr>
<td></td>
<td>Bike</td>
<td>4.7160</td>
<td>5.436</td>
</tr>
<tr>
<td></td>
<td>Walk (Base)</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Travel Distance</td>
<td>Bike</td>
<td>-0.2395</td>
<td>-4.223</td>
</tr>
<tr>
<td></td>
<td>All Motorized</td>
<td>-0.0733</td>
<td>-2.359</td>
</tr>
<tr>
<td>Parking Cost</td>
<td>Car Driver, Shared Ride, and TAA</td>
<td>-0.0291</td>
<td>-2.286</td>
</tr>
<tr>
<td>In-Vehicle Travel Time (Access + Egress)</td>
<td>All Motorized Modes</td>
<td>-0.0135</td>
<td>-2.499</td>
</tr>
<tr>
<td>Schedule Information: Yes</td>
<td>All Transit Options</td>
<td>-0.0051</td>
<td>-1.771</td>
</tr>
<tr>
<td>Vehicle Crowding Level: Uncrowded (Seats</td>
<td>Transit NMT Access (TNMTA)</td>
<td>0.5243</td>
<td>1.301</td>
</tr>
<tr>
<td>Access + Egress) Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parking Crowding Level: Overcrowded (No</td>
<td>Transit Auto Access</td>
<td>-0.3887</td>
<td>-1.079</td>
</tr>
<tr>
<td>spots (P&amp;R) are available)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street Furniture: Less than five items</td>
<td>Bike</td>
<td>0.4223</td>
<td>0.970</td>
</tr>
<tr>
<td>of street furniture, arcades, canopies,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water fountains, and/or benches are</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>present</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation: There are trees along the</td>
<td>Bike</td>
<td>0.2896</td>
<td>0.668</td>
</tr>
<tr>
<td>route providing some shade</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Given the presented rho-squared value of 0.29, the model has an acceptable goodness of fit and explanatory power. The examination of traditional variables within the model shows that travel distance, travel cost, parking cost, and different trip time components have correct (negative) signs that match expectations. Further, the primary investigation of the model parameters shows that traditional attributes (e.g., travel cost and time) are of lower importance (given their low parameter values) to mode switching behaviour compared to other transit design factors and technologies (e.g., vehicle crowding level, parking crowding level, and schedule information).

Interestingly, car drivers’ willingness to shift to public transit increases with the availability of schedule information at transit stops/stations. In addition, the model shows that the
tendency to mode shift from private car to public transit with auto access decreases with higher crowding levels at park-and-ride facilities. Whereas, mode shift to public transit with NMT access is more sensitive to crowding levels at transit units. As for shifting to active modes, the results show that car drivers might consider biking in cases where better street furniture (e.g. arcades, canopies, water fountains, and/or benches) and vegetation are present along the route.

**KEY FINDINGS**

Some of the key findings from the Revealed Preference portion of the survey are:

- Males use Active Transportation more than Females
- Drive All Way is less common in younger adults
- Adults under 40 years old use transit more than over 40 years old
- Married, Divorced, and Widowed drive more all the way than single adults
- Approx. 19% of single adults walk to work
- Adults living in a Townhouse or Apartment drive less and use Active Transportation and Transit as a mode choice more than adults living in single-family dwelling units
- Adults living in a household with 1 or 2 people in the household use active transportation more than households of larger size
- Use of Active Transportation and Transit use declines with vehicle ownership
- Active Transportation is more common for trips to parks, shopping, and play sports
- Transit use is more common for trips to visit friends, play sports, going to the movies, and going to a party

Key conclusions that were revealed in the Stated Preference model development are:

- Traditional attributes (e.g. travel cost and time) are of lower importance to mode switching behaviour compared to other transit design factors and technologies (e.g. vehicle crowding level, parking crowding level, and schedule information).
- Car drivers’ willingness to shift to public transit increases with the availability of schedule information at transit stops/stations.
- Tendency to mode shift from private car to public transit with auto access decreases with higher crowding levels at park-and-ride facilities.
- Mode shift to public transit with NMT access is more sensitive to crowding levels at transit units.
- Car drivers might consider biking in the case where better urban design treatments, such as street furniture (e.g. arcades, canopies, water fountains, and/or benches) and vegetation, are present along the route.
The following references contributed to the development of the methodology or model used in this study.


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Green, R.K.: Land use regulation and the price of housing in a suburban Wisconsin County. J. Housing Econ. 8, 144–159 (1999)


Long, Y. & Baran, P. (2006b) Methodology for analyzing the relationships between objective and subjective evaluations of urban environment: space syntax, cognitive maps, and urban legibility, in: Space Syntax and Spatial Cognition Workshop Proceedings. Available at http://www.space.bartlett. ucl.ac.uk/sc06/proceedings/


Shriver, K. (1997) Influence of environmental design on pedestrian travel behavior in four Austin neighborhoods, Transportation Research Record, 1587, pp. 64–75.


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