Modal Shift Forecasting Model for Transit Service Planning:
Survey Instrument Design

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ABSTRACT
While being useful to explain current modal split, mode choice models developed by using only Revealed Preference (RP) data often suffer from many problems. Evidence in the literature shows that RP data based mode choice models fail to accurately forecast modal shift in response to new improvements in the transit services. Further, it is often difficult to accommodate attributes of emerging systems, such as passenger information systems, ITS technologies that improve reliability, etc in conventional mode choice models because detailed information of such attributes are often missing in traditional household based RP travel survey data. In addition, traditional logit mode choice models are criticized for their weak characterization of several behavioural aspects, contributing in part to their misleading modal shift estimation. This is a critical issue in transit service design where improving service to facilitate modal shift towards transit is targeted.

As opposed to traditional mode choice models based on RP data, mode shift models will be developed using state-of-the-art methodology of combining Revealed Preference (RP) and Stated Preference (SP) information. Our proposed methodological approach incorporates two main stages. The first deals with designing and implementing an innovative socio-psychometric survey about personal attitudes and habit formation of Toronto commuters regarding shifting to different transit technologies of varying characteristics. The second stage focuses on developing an econometric choice model of mode-switching behaviour towards public transit. However, this paper only reports on the first stage.

In addition to collecting common socioeconomic, demographic and modal attributes, the survey is intended to collect data on the revealed mode choice behaviour as well as the stated mode switching preferences to public transit considering some important preference attributes such as advance information provision, ITS technologies and rail vs. bus attraction. Moreover, the survey will gather psychological information regarding habit of auto driving, affective appraisal and personal attitudes. Different psychometric tools will be used to capture psychological factors affecting mode choice. Further, the survey sets up a stated choice experiment based on efficient experimental design techniques to maximize the information gained from different hypothetical scenarios. The survey respondents will be asked to identify their propensity to perform their work trip by a non-existing transit service in the future. In an attempt to maintain practical attribute level ranges in the stated choice experiment, best practices in transit service planning will be utilized in terms of service accessibility standards, service frequency and headway standards and service reliability standards.

The data collected through such novel survey will develop a better understanding of commuters’ preferences and mode switching behaviour towards public transit in response to changes in transit service design attributes.

KEYWORDS
Habitual Behaviour, Mode Choice, Mode Shift, Revealed Preference, Stated Choice, Transit Service Design
INTRODUCTION

The growth of nations and the need to meet mobility have significantly accelerated urban motorization and increased the reliance on the private automobile as a travel alternative. In turn, such increment in auto dependency has provided unprecedented levels of mobility and liberty to motorists. However, the adverse effects associated with the extensive use of private cars in urban areas cannot be overstated. Obviously, the unlimited use of single occupancy vehicle has raised resource consumption, traffic congestion, and emissions. Further, it reduced the economic, social and environmental viabilities of urban communities (Garber and Hoel 2002; Litman and Laube 2002; Vuchic 2005).

Consequently, aiming at providing a better quality movement of people, transport planners’ focus has been directed, in the early 1970’s, towards managing the increasing travel demand rather than boosting supply, which is known as Transport Demand Management (TDM). In general, numerous TDM policies (e.g., congestion pricing, parking management, and public transit provision) have been adopted to achieve such objective by changing individuals travel behaviour from extensive automobile usage towards the use of more sustainable means of transport (Meyer 1999).

In essence, there has been a growing interest in promoting sustainable communities that incorporate compact, mixed-use development and pedestrian-friendly street network design to support walking, biking and high-quality transit. Such form of development is commonly referred to as Transit Oriented Development (TOD). While TOD is essential to support high-quality transit, it is not sufficient alone to achieve this goal, as elements of the transit service itself play a key role in defining transit quality. 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 (Hale 2009). 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.

As noted above, the main objective of COTS is to attract and retain transit ridership while making transit a viable competitor to auto driving. COTS is now considered an integral part of sustainable transportation and community development programs. However, planning sustainable communities and designing COTS are not very straightforward tasks. The success of any sustainable community planning and COTS design relies on how the policies and design elements affect peoples’ travel choices and behaviour. Hence, without proper analytical tools of evaluating the impacts of alternative sustainable transportation policies (such as TDM policies, transit-oriented land use policies, etc.) and COTS elements (some of which are qualitative) on travel behaviour, it becomes prohibitive to assess and develop effectively successful TOD plans and COTS designs.

Unfortunately, classical methods of sustainable community development and transit service planning tools are plagued with many problems. They are generally aggregate, hence more appropriate for regional planning than community/neighbourhood planning. Moreover, conventional mode choice models often overestimate shift to transit and are not sensitive to customer-oriented service elements (e.g., passenger information provision, ITS technologies that improve reliability, rail vs. bus attraction, etc.) (Winston 2000; Beimborn et al. 2003; Flyvbjerg et al. 2005; Quentin and Hong 2005; Cantillo et al. 2007; Domarchi et al. 2008).

In an attempt to contribute to this research problem, the main objective of the presented work is to develop demand forecasting tools for transit investments that usually target auto users. Unlike traditional mode choice models, adequate mode shift models will be developed to accurately forecast transit ridership. Such objective will be achieved by studying people’s decision making behaviours rather than their choices among alternatives. Our proposed methodological approach is twofold. The first deals with designing and implementing an innovative survey about personal attitudes and habit formation of Toronto commuters regarding shifting to different transit technologies of varying characteristics. The second stage focuses on developing an econometric choice model of mode-switching behaviour towards public transit. However, this paper only reports on the first stage.

MODE SHIFT MODELLING

In general, increasing modal shift from single occupancy vehicles towards public transit is a desirable objective of modern society (Ogilvie et al. 2004; Nurddien et al. 2007; Vedagiri and Arasan 2009; Vermote and Hens 2009; Hamer 2010). However, an effective implementation of mode switching strategies requires proper evaluation of the proposed approach on changing travel behaviour a prior to the actual application (Tanadung et al. 2005).

Traditionally, the classical four-stage sequential demand forecasting model has been developed to predict the number of trips made within an urban area. The standard practice in the study of the choice of the mode of travel makes use of the mode choice concept, the third phase in the four-stage model. Commonly, mode choice models are based on the Random Utility Maximization (RUM) framework originating in microeconomics, assuming that utilities are random to the modeller and choice strategies are deterministic from the trip maker’s perspective. Under this framework, choice decisions can be conceptualized where a passenger selects the best option, based on his/her preferences, from a set of travel alternatives according to his/her socio-economic/demographic characteristics and the relative attractiveness of the available modes (McFadden 1974; Banister 1978; Ben-Akiva and Boccara 1995).
Most mode choice studies include some socioeconomic and demographic attributes of the trip maker and other factors representing the relative attractiveness of the available options as predictors of mode choice (Eriksson et al. 2008). Of the trip maker characteristics, car ownership and availability are usually considered the major determinants of mode choice (Williams 1978; Barff et al. 1982). On the other hand, travel cost and time play a bigger role in determining mode choice than others that characterize the attractiveness of the competing modes (Beesley 1965; Quarmby 1967; Williams 1978). A variety of mode choice studies have examined the tradeoff between travel cost and time where their importance have been demonstrated (Hensher 2001a; Hensher 2001b).

Further, the characteristics of the trip itself have an influence on the choice of mode. For example, research has shown that transit is a closer substitute to the automobile for commuters or business trips than for leisure travel (Storchmann 2001).

Over the decades, research has continuously improved mode choice models on an analytical viewpoint in an effort to make them better explain modal split. Nevertheless, research showed that such models fail to forecast modal shifts in response to new improvements in the transit service (Winston 2000; Beimborn et al. 2003; Flyvbjerg et al. 2005; Forsey et al. 2011). Such failures are generally attributed to the lack of tools that can adequately forecast the behaviour of the potential ridership. This in turn induces a poor knowledge of the demand for the new service and a subsequent difficulty in designing an economically sustainable system.

Evidence in the literature shows that traditional mode choice models tend to overestimate the attractiveness of transit for choice users which leads to over predicting transit ridership (Winston 2000; Beimborn et al. 2003; Flyvbjerg et al. 2005). In addition, conventional mode choice models are criticized for their weak characterization of several behavioural aspects (e.g., attitude and habit formation) which would be considered a contributing factor to the misleading modal shift estimation (Quentin and Hong 2005; Cantillo et al. 2007; Domarchi et al. 2008).

Research referred the reluctance to modal shift to the formation of habits which could lead to the domination of a specific mode even in cases where the rational choice favours another. In a recent study, Diana (2010) has quantitatively showed that habits and cognitive attitudes have an importance, compared to that of the transport services performances, even if only these latter are routinely considered. Further, it was found that the role of self-related factors further increased when travellers are less familiar with the technological background and the subsequent operation of a new service. In particular, self-related factors such as attitudes, lifestyles or personality traits seem to play a greater role in the decision making context where information on the new alternatives is incomplete. This is a critical issue in transit service design where improving service to facilitate modal shift towards transit is targeted. Therefore, the key point towards developing adequate tools to forecast transit ridership seems to be more the study of changing behaviours and less that of the choices among alternatives (Cantillo et al. 2007; Behrens and Mistro 2010).

Numerous research attempts have been made to capture the effects of behavioural aspects by introducing them as explanatory variables within the classical mode choice models in addition to the conventional personal and modal service attributes (Johansson et al. 2006; Cantillo et al. 2007; Domarchi et al. 2008; Habib et al. 2010). While being useful and insightful, the previous research efforts were focused on studying mode choice without giving proper attention to mode switching. What is unique to mode shift compared to the classical mode choice scenario, where the different modes are equally considered before the choice, is that the choice task is not cognitively symmetric since people had to consider switching from an option which they are familiar with to a new alternative (Diana 2010). Therefore, further research is suggested to investigate people’s mode switching behaviour rather than studying their mode choice decisions.

Since the attractiveness of any transit service relies mainly on the way design factors affect peoples’ travel choices, behaviour and subsequently mode switch, this research effort aims at developing a better understanding of commuters’ preferences and mode switching behaviour towards public transit in response to changes in transit service design attributes. The premise of the presented work is to improve the demand forecasting tools for transit investments that usually target auto users.

In opposed to the classical mode choice concept, this research pays more attention to some behavioural issues such as personal attitudes, habit formation and affective meaning that seem to play an important role in the mode shift decision making process.

In general, mode shift can be looked at as a special case of mode choice where choice tasks are not cognitively symmetric. Therefore, studying people’s mode choice decision making process can help us investigating their mode switching behaviour. In essence, research in social psychology has shown the importance of studying several behavioural aspects (e.g., habit formation, affective meaning, and personal attitude) to understand the decision making process underlying mode choice behaviour (Sheth 1976; Goodwin 1977; Aarts et al. 1997).

As an early indication for the effect of habit formation on mode choice decisions, Sheth (1976) stated that people tend to stay with the mode they are already accustomed even though other modes may be more appropriate for them. The previous argument was further supported by Goodwin (1977) which showed that habits may prevail even in cases where the more deliberate choice favours another mode. In addition, Aarts et al. (1997) argued that
mode choice decisions like many other routine behaviours are supposed to be often made in a habitual mindless fashion.

In light of the above, the effect of habit formation on mode choice and subsequently mode shift cannot be overstated and should be incorporated within choice models (Ajzen 1991; Gärling et al. 1998; Fuji & Kitamura 2003; Gärling and Axhausen 2003). Social psychologists claim that habitual behaviour can be identified given its invariability, repetition and persistence (Golledge and Brown 1967; Banister 1978). One way of measuring habitual behaviour is through the response-frequency measure (Verplanken and Aarts 1999). The response-frequency measure of habit presents participants with a number of habit related situations (e.g., to go to work, to go shopping) and asks them to respond as quickly as possible to generate the mode of travel they associate with that situation (e.g., car, public transit). The proportion of these responses serves then as a measure of habit formation (Verplanken et al. 1997; Verplanken et al. 1998).

Another behavioural aspect that affects people choices is affective appraisal (affective attitude). In general, affective factors refer to personal emotions evoked in response to a specific stimulus (e.g., place, object or event). Frequently facing this particular stimulus originates an emotional disposition which creates a long-term tendency to consistently respond to such arousing situations (Anable and Gatersleben 2005; Reeve 2005). In order to quantify affective appraisal, Osgood’s semantic differential is used (Osgood et al. 1957; Osgood et al. 1971). This measure corresponds to a bipolar rating scale intended to capture the hidden meaning of a particular concept. According to their first impression, respondents are asked to state the position of the concept they adopt (chosen mode) in every semantic scale where perfect antonym adjectives are located at each end. The rating of the concept in each of these scales allows the construction of a semantic space where different attitudinal objects can be compared based on their relative locations. Further, different groupings of the semantic scales define certain affective dimensions (axis of the semantic space) (Domarchi et al. 2008).

In addition to habitual behaviour and affective appraisal, personal attitudes are of importance. Cognitive attitudes refer to the accumulated evaluation of the choice which has a magnitude and a direction (Ajzen 1991). Depending on the expectancy-value theory, the magnitude of an attitude depends on two components which are the expectations that an individual has regarding the results of the behaviour, and the values that he/she assigns to these possible results. Furthermore, the direction of an attitude represents whether the trip maker is for or against a specific behaviour (Triandis 1977; Gärling et al. 1998).

In this research, different psychometric tools are used to capture psychological factors affecting mode shift. In particular, the proposed survey gathers psychological information regarding habit of auto driving, affective appraisal and personal attitudes. Habitual behaviour is measured using Verplanken’s response-frequency questionnaire. Affective meaning is indirectly estimated using the Osgood's semantic differential scale. A five-point Likert scale is used to measure attitude.

**STATED CHOICE EXPERIMENT DESIGN**

Modelling discrete choice behaviour relies mainly on travel data collection to elicit people preferences. In principle, two methodologies are commonly utilized for quantifying people propensities; namely, Revealed Preference (RP) and Stated Preference (SP) or Stated Choice (SC) methods (Ben-Akiva et al. 1994). The revealed preference approach uses information collected about actual choices made by individuals to estimate statistical demand models. Accordingly, such an approach is limited to analyzing the effect of existing factors in the transport system (Gunn et al. 1992). Obviously, collecting RP data from the field is challenging if the proposed transit service does not exist or if it is not well known by potential users (Diana 2010). In such cases, SP experiments where respondents are directly asked about their preferences for hypothetical options may be more efficient. (Louviere et al. 2000; Arasan and Vedagiri 2011).

In this research, a mixed RP/SP survey has been designed to collect some behavioural factors that affect passengers’ mode shift decisions in addition to common socioeconomic, demographic, and modal characteristics. The design of SP experiments, originated at marketing and economics, have lately received increasing attention in the transportation field. Generally, the main purpose of conducting SP experiments is to determine the independent influence of design attributes (variables or factors) such as transit service design characteristics on an observed outcome (e.g., mode shift) made by sampled respondents undertaking the experiment (Louviere and Hensher 1983; Louviere and Woodworth 1983).

In a typical SP survey, a number of choice tasks (hypothetical scenarios) are presented to each respondent where he/she is asked to select one or more alternatives from amongst a finite set of options. Such alternatives are defined by a number of different factors described by pre-specified factor levels that are drawn from some underlying experimental design. Conceptually, an experimental design might be thought of as a matrix of values that represent factor levels, where the rows and columns of the matrix represent factors and choice situations corresponding to different alternatives, respectively. Nevertheless, the way the levels of the design factors are distributed within the experiment plays a major role in determining the independent contribution of each attribute to the observed choices. Moreover, the allocation of the different factor levels within the experimental design may also affect the
Statistical power of the experiment and its ability to detect statistical relationships that may exist within data (Rose and Bliemer 2009; Cooper et al. 2011).

In light of the above, the issue of how to allocate attribute levels to the design matrix is crucial to SP experimental designs. Over the years, research has relied upon orthogonal experimental designs to generate the hypothetical choice tasks shown to respondents. In general, orthogonal designs relate to the correlation structure between design attributes such that all correlations between attributes are equal to zero (Louviere et al. 2000; Bliemer et al. 2008; Bliemer and Rose 2011). Recently, researchers put the relevance of orthogonal design-based SP experiments in question, claiming that orthogonality is unrelated to the desirable properties of the econometric models used to analyse SP data (e.g., logit and probit models) (Huber and Zwerina 1996; Kanninen 2002; Kessels et al. 2006). The previous claim was further supported by Train (2003) who argued that whilst orthogonality is an important criterion to determine independent effects in linear models, discrete choice models are not linear. In fact, the correlation structure between the attributes is not what matters in models of discrete choice, but rather the correlations of the differences in the attributes (Train 2003; Bliemer et al. 2008).

This lead to the emergence of a class of designs, known as efficient or optimal designs, that is considered a recent advancement in SP experimental designs. Efficient or optimal designs have been considered by researchers as the current best practice of designing SP experiments. Unlike orthogonal designs, efficient designs do not merely try to minimize the correlation between the attribute levels in the choice situations, but rather aim to find designs that are statistically efficient in terms of estimating parameters with the smallest asymptotic standard errors. Accordingly, such designs would either improve the reliability of the parameters estimated from SP data at a fixed sample size or reduce the sample size required to produce a fixed level of reliability in the parameter estimates (Huber and Zwerina 1996).

Given that the standard error is calculated as the root of the diagonal of the Asymptotic Variance-Covariance (AVC) matrix of the parameters, prior information about the parameter estimates are required in order to generate efficient designs. Such prior parameter information can be estimated from similar studies or pilot tests. An efficient experimental design yields data that enables parameter estimation with the lowest possible standard errors. Generally, the efficiency of an experimental design can be derived from the AVC matrix. However, instead of assessing a whole AVC matrix, it is easier to assess a design based on a single value. Hence, numerous efficiency measures have been developed in order to calculate such efficiency value representing an efficiency error that should be minimized (Rose et al. 2008).

By taking the determinant of the AVC matrix based only on a single respondent, the D-error is the most widely used efficiency measure in the literature. Although it is hard to find in practice, the design with the lowest D-error is called D-optimal design. Alternatively, it is more common to look for a design with a sufficiently low D-error, or in other words the D-efficient design. Depending on the available information on the prior parameters $\beta$, different types of D-error have been developed such as the $D_{c}$-error (‘$c$’ from ‘zero’) where no information is available (not even the sign of the parameters, $\beta=0$); the $D_{p}$-error (‘$p$’ from ‘priors’) where relatively accurate information is available with good approximations of $\beta$; and $D_{b}$-error (‘$b$’ from ‘Bayesian’) where information is available with uncertainty about the approximations of $\beta$ (Hensher et al. 2009).

In general, efficient designs always outperform orthogonal designs when prior information about the parameters (even only the sign) is available. Unfortunately, since the purpose of the SP experiment is to estimate the parameters of the specified model, they are unknown. However, given that some attributes (e.g., transit fare) are typically negatively perceived while others (e.g., transit frequency) are positively perceived, it should be always possible to obtain some information on the parameters (at least the signs), even without estimating them relying on reasoning alone. Further, prior parameter estimates can be obtained by referring to similar surveys. Otherwise, conduct a small pilot study might be useful to get an initial idea about the parameter values (Rose and Bliemer 2009).

In efficient designs, prior parameter estimates are required to compute utilities that are essential to obtain more information from each choice task. Maximizing information gained from each choice situation is achieved by optimizing utility balance (i.e., avoiding situations having alternatives that are clearly dominating the choice set). For example, consider a choice situation between two unlabelled transport alternatives. The first option has both a lower travel time as well as a lower travel cost, making it clearly the preferred alternative. The first option therefore clearly dominates in this choice situation, and therefore no information will be gained. In contrast, a different choice situation where there is no clear dominant alternative (i.e., the respondent has to make a clear tradeoff between travel time and cost), will provide useful information. As illustrated in the example above, balancing the utilities of alternatives is a desirable property of efficient designs (Huber and Zwerina 1996).

In addition, research has shown that many features of the SP experiments can influence the efficiency of the resulting parameter estimates. Of which, number of attribute levels, attribute level ranges, and the number of choice tasks provided to each respondent are of importance. Transport researchers have been questioning the ability of respondents to comprehend and respond to complex designs that involve many alternatives, attributes, and choice situations (treatments). In general, the lesser the number of attributes and attribute levels, the more
convenient for the respondent the design is. Commonly, the number of attribute levels depends on the model specification. If a certain attribute is expected to have nonlinear effects, then more than two levels are needed for this attribute to be able to capture these nonlinearities. However, if dummy attributes are included, then the number of levels required for these attributes is predetermined. Moreover, the number of attribute levels used impact the resulting number of choice situations such that the more levels used, the higher the number of choice situations is. In addition, mixing the number of attribute levels for different attributes is not desirable as it may also yield a higher number of choice situations in order to maintain attribute level balance (Rose and Bliemer 2009).

Further, the wider the attribute level ranges, the higher the efficiency of the design is. Research have shown that having wide attribute level range (e.g., waiting time= 2 min – 12 min) is statistically preferable to having a narrow range (e.g., waiting time= 1.5 min – 2 min) as this will lead to better parameter estimates (i.e., smaller asymptotic standard error). However, using extremely wide ranges might result in choice tasks with dominated alternatives which in turn would affect the choice probabilities obtained from the design. Moreover, using too narrow attribute level ranges will result in alternatives which are largely indistinguishable. Hence, there should be a trade-off between the statistical preference for a wide range and the practical limitations that may limit the range while maintaining attribute levels within limits that make sense to the respondents. Another important property that significantly impact the potential efficiency of the design is maintaining attribute level balance (i.e., all attribute levels appear equally in the dataset). Although imposing attribute level balance may result in sub-optimal designs, it is generally considered a desirable property. Balancing attribute levels ensures that the parameters are estimated on the whole range of levels, instead of having data points at few of the attribute levels, and hence provides a good basis for estimation (Causade et al. 2005; Scarpa and Rose 2008; Bliemer and Rose 2009).

In terms of the number of choice situations, research did not provide evidence of any systematic relationship between the value of the design parameter and the number of treatments (Hensher 2001b). Furthermore, it has been shown that generally efficient designs with a small number of treatments perform just as good (or even better) than a more complex design (Bliemer and Rose 2011).

In light of the above, 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 D_p error. In order to ensure more reliable parameter estimates, we conducted a small-scale pilot survey among a random sample of students and staff members of the University of Toronto, Canada, based on orthogonal design. Such pilot survey will be used to obtain the prior parameter estimates for the actual experimental design. Based on the number of attributes and their levels, the orthogonal design for the SP experiment generated 72 rows to ensure attribute level balance. Obviously, it is too large to give all the 72 choice situations to a single respondent. Hence, we blocked the orthogonal design into 12 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 12 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 72.

In particular, a block (b) is randomly drawn from blocks 1, 2, 3, …, and 12 and assigned to respondent 1. Then the rest of blocks are assigned as follows: block [(b mod 12) + 1] to respondent 2, block [((b+1) mod 12) + 1] to respondent 3, …, block [((b+10) mod 12) + 1] to respondent 12. We then go to block 1 for the next set of 12 respondents. For example, if the first respondent faces block 11 of the design, the next respondents will receive blocks 12, 1 and 2 and so on. Once all blocks are assigned, a number from 1 to 12 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 12, 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.

TRAVEL SURVEY INSTRUMENT DESIGN

This paper presents an innovative socio-psychometric survey for mode shift modelling. We combine both RP and SP data in order to take advantage of their strengths and minimize their individual drawbacks. On one hand, it is established that RP data may have substantial amount of noise that result from many factors such as measurement error. For example, an individual self-report of an actually made choice is likely to be uncertain. Such uncertainty probably increases as the time between the actual choice and the report of that choice increases. On the other hand, SP experiments are usually generated by some systematic and planned design process in which the attributes and their levels are pre-defined without measurement error and varied to create preference or choice alternatives. Nevertheless, SP responses are stated and not actual, and hence are uncertain because individuals may not actually choose the alternatives that they select during the experiment. Hence, both methods may have potential for error. Therefore, mixing RP and SP data may be more beneficial (Morikawa 1994; Dosman and Adamowicz 2006).

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).

Within the context of mode shift modelling, the focus of the proposed survey is to gather socioeconomic and demographic characteristics of respondents, their factual as well as their stated experiences with travel mode choice and other psychological aspects that reflect their tendency to mode switch. In particular, the survey will collect information related to the trip maker (e.g., age, gender, income, auto ownership and availability), the competing travel alternatives (e.g., travel cost, parking cost, travel time, and waiting time). In addition, psychological factors have shown to have a great effect on the human decision making process.

The proposed survey will be administered among a random sample of commuters in the city of Toronto to collect detailed information associated with their daily commuting work trips. A market research company is hired to recruit a representative sample from a panel of individuals (Canadians) to conduct the survey among them. There are two reasons for our emphasis on work trips as a trip purpose. First, work trips constitute an increasingly large proportion of urban trips in the city of Toronto and, therefore, have a significant impact on traffic congestion and emissions. Second, since habits can be identified by their repetition and persistence, the behavioural factors in question are likely to have greater effects on people’s behaviour when commuting to work than they do for pursuing non-work trips.

The questionnaire is divided into four sections. 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 as shown in Figure 1. Further, transit users are also asked to provide information about the 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 made, in addition, detailed data about their modal combination is collected by allowing them to unrestrictedly choose between streetcar, bus and subway. Also, they are asked about transit fare and payment method (i.e., cash, tickets, tokens or PRESTO card) 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 tend to use this option. After that, the survey collects information about secondary mean 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.

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**Figure 1 Means of Commuting.**
In general, the data collected in the first section of the survey allows us to match factual experiences with personal views concerning the trip under investigation and current travel options. Further, the web-based data collection allows us to customise the SP experiment based on earlier responses entered by the participants. For example, asking non transit users about their perception about the transit service helps us to generate reasonable attribute levels for each respondent while customising the SP scenarios in section B of the questionnaire. Respondents are allowed to skip such set of questions if they are completely unaware of the transit service or if the service does not exist. However, an origin-destination matrix that resides in the background of the survey is used to estimate such missing information if those questions are skipped by the respondent (given the OD of the respondent). This matrix is calculated based on an EMME/2 model for the case study region.

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 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 in the future. Given that the resulting mode shift model specification has alternatives with alternative-specific parameters, respondents are asked to choose between labelled alternatives in the experiment (e.g., auto driver, streetcar, subway). 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 such as streetcar, bus and/or subway services. 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 such as Bus Rapid Transit (BRT) and/or Light Rail Transit (LRT), as shown in Figure 2.

**CHOICE (SCT.B)**

If the current choice is no longer available, please consider the following alternative choices and select the one that you would use to make your current work trip based on mode features presented in the table below.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Current Choice</th>
<th>Alternative Choice</th>
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<tbody>
<tr>
<td></td>
<td>Public Transit</td>
<td>Public Transit</td>
</tr>
<tr>
<td></td>
<td>Bus Rapid Transit (BRT), ROW B</td>
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</tr>
<tr>
<td>Travel Cost (Face to Face)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Auto Parking Cost</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Access Time</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>Walking &amp; Transfer Time</td>
<td>6</td>
<td>7.5</td>
</tr>
<tr>
<td>In-Vehicle Travel Time</td>
<td>13</td>
<td>7.2</td>
</tr>
<tr>
<td>Ears Time</td>
<td>18</td>
<td>5.3</td>
</tr>
<tr>
<td>Total Trip Time</td>
<td>33</td>
<td>22.3</td>
</tr>
<tr>
<td>Parking Availability</td>
<td>--</td>
<td>No</td>
</tr>
<tr>
<td>Cost (Low, Medium, High)</td>
<td>--</td>
<td>Unspecified (Costs available)</td>
</tr>
<tr>
<td>Number of Transfers</td>
<td>0</td>
<td>2 or more</td>
</tr>
<tr>
<td>On-Time Performance</td>
<td>--</td>
<td>On Time</td>
</tr>
<tr>
<td>Schedule Information</td>
<td>--</td>
<td>Yes</td>
</tr>
<tr>
<td>Real-Time Information about Service Level</td>
<td>--</td>
<td>No</td>
</tr>
</tbody>
</table>

Given the alternative modal characteristics presented above, which option would you choose?

- **Shift to public transit (Bus Rapid Transit (BRT), ROW B)**
- **Shift to Other Mode, please specify:**

In the future, what would be your propensity to make your work trip using the selected hypothetical service instead of the transport means you are currently using?

- **Click on the button that matches your personal agreement, indicating how much you are willing to switch.**

<table>
<thead>
<tr>
<th>Willingness to make shift</th>
<th>Very Weak</th>
<th>Moderately Weak</th>
<th>Neutral</th>
<th>Moderately Strong</th>
<th>Very Strong</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
In opposed to common SP surveys, and since it is hard for respondents to make a clear choice between the mode the 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, 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. Sufficient off-street auto parking should be provided at park-and-ride facilities 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; Deakien 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 below 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, Bus Rapid Transit (BRT) should combines 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 directness using different methods. One measure of service directness is the number of transfers required for a passenger to reach his/her final destination. Obviously, the more transfers required in a system, the longer total travel time will be and consequently the less desirable the service is.

Service reliability, also known as punctuality, involves the direct impact of the transit service’s on-time performance on the passengers and the way they perceive it. In general, the transit system should be designed and
operated to maximize schedule adherence. On-time performance in the transit industry is defined as the percentage of trips that arrive/depart within a specified timeframe at a specific scheduled time point. The majority of the systems define a route as being late if it is late over 5 minutes, whereas they define a route as early even if it is 1 minute early. In other words, some standards define “on-time” as arriving from one minute early to five minutes late.

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, different attribute level ranges are set up as upper and lower bounds of service characteristics based on the technological differences between the current and the proposed transit services. Further, the proposed survey utilizes the previous standards to maintain reasonable attribute levels in the SP experiment. 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. 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 will be estimated based on the origin-destination matrix running in the background of the survey.

In addition to the detailed information about the trip and the selected travel option, the survey also gathers some latent constructs that affect respondents’ choices. Section C collects unobservable psychological information regarding habit of auto driving, affective appraisal and personal attitudes. Such information allows us to match factual experiences with personal views concerning the trip under investigation. Different psychometric instruments are added to the questionnaire to measure psychological factors affecting mode choice.

Verplanken’s response-frequency measure of habit is used for measuring habitual frequency. A list of 9 non-working activities (e.g., to go shopping, to go to a park, etc.) are given to respondents, who were asked to provide the mode they would eventually use among the following options (car driver, car passenger, carpool, streetcar, bus, subway, cycle, walk or other) in order to accomplish those activities. A 10-point car use habit index is then computed by counting how many times the respondent had mentioned each mode to develop different activities. In order to reduce the effect of cognitive components on the choices, work-related activities were excluded from the response-frequency questionnaire, taking advantage of the expected context independence of habitual behaviour.

Moreover, four dimensions of the semantic differential are used, namely, evaluation, potency, activity, and control. Evaluation refers to feelings of goodness or badness elicited by a concept, potency is associated with feelings of being strong or weak, activity is related to whether the feeling induced by thinking about a concept is calm or lively, and control refers to feelings of being simple or complex. Each dimension contains four semantic scales ranging from -3 to +3, each one with words conveniently chosen to be perfect antonyms (e.g., good/bad, fast/slow, etc.), as shown in Figure 3. Therefore, each respondent has to be faced with 16 semantic scales that may describe the mode of transport they usually take to work, in addition to 8 semantic scales that may describe public transit.
Furthermore, attitudes towards car and transit are measured using five-point Likert scales for all the respondents (i.e., regardless of being a user or not), as a combination of expectation (e.g., public transport is a good mode for work trips), and value (e.g., public transit service is important for work trips) to consider the expectancy-value theory. Cognitive attitude are then computed as the product of these two scores, thus giving two attitudinal indexes (one for car and one for public transport), ranking from 1 to 25.

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 an econometric mode shift model, with emphasis on capturing the attitude and mode switching behaviour towards public transit. The proposed econometric model will be a hybrid discrete choice model, where a revealed mode choice model is combined with a stated mode switching probability model.

Obviously, the proposed approach is more desirable for transit service design than the previous ones and can aid in precisely estimating transit ridership, as it presents a new methodologically sound tool for evaluating the impacts of alternative transit service designs on travel behaviour.

CONCLUSIONS
Mode shift modelling is complicated by the fact that various behavioural elements related to the decision maker; in addition to common socioeconomic, demographic and modal attributes; must be considered in the modelling process. Without proper analytical tools of evaluating the impacts of alternative sustainable transportation policies on changing travel behaviour, it becomes prohibitive to assess and develop effectively successful plans and designs.

The main objective of this research is to develop a better understanding of commuters’ preferences and mode switching behaviour towards public transit in response to changes in transit service design attributes using efficient experiment design techniques.

In attempt to contribute to this problem, an innovative RP/SP survey is presented in this paper. The proposed survey is intended to collect data on the revealed mode choice behaviour as well as the stated mode switching preferences to public transit considering some important preference attributes such as advance information provision, ITS technologies and rail vs. bus attraction. The survey is divided into the following four sections. Section A gathers information on the daily commuting work trip and current travel options; Section B asks about willingness to make the same work trip using a new transit service; Section C gathers information regarding habit formation, emotional response and personal attitudes towards different travel options; and, Section D collects socioeconomic and demographic characteristics.

Data collected through the presented survey can answer two main research questions. First, what are the perceived importance of service quality and cost in the mode shifting process? Second, how do trip makers make tradeoffs among the previous attributes when shifting to a new travel option?

Further, it is suggested for future work to use the collected dataset data to develop econometric models of mode shift, with emphasis on capturing the attitude and mode switching behaviour of respondents towards public transit. The developed models will help us understand how trip makers actually make tradeoffs among the previously mentioned attributes.

REFERENCES


Osgood, C. E., G. J. Suci, et al. (1957). The measurement of meaning, Univ of Illinois Pr.


