Abstract: This paper investigates socio-psychometric data measured in a semantic scale to explicitly capture attitudes, affective appraisal and habit formation and their influences on commuting mode choice. The dataset was collected in 2009-2010 in Edmonton, Alberta. In addition to common socioeconomic, demographic and modal attributes, the survey gathered psychological information regarding habitual behaviour, affective appraisal and personal attitudes. Different psychometric tools are used to capture psychological factors affecting mode choice. Habitual behaviour is measured by using Verplanken’s response-frequency questionnaire. Affective appraisal is indirectly estimated using the Osgood’s semantic differential scale. A five-point Likert scale is used to measure attitude. The Structural Equation Modelling (SEM) approach is used to investigate the effects of psychological factors measured by means of semantic scales on mode choice behaviour. SEM captures the latent nature of psychological factors and uses path diagram to identify the directionality as well as intensity of the relationships. The investigation reveals that passengers have positive emotions towards their chosen mode. Further, evidence of the superiority of the car as a travel alternative was established in terms of strong habit towards it, such that passengers would use the car for almost every single trip.

Keywords: Affective Appraisal, Attitudes, Habit, Latent Variables, Structural Equation Models.
1. INTRODUCTION

Random Utility Maximization (RUM)-based mode choice models are extensively used to analyze the choice of an alternative mode from a set of mutually exclusive options. The underlying assumption of such models is that a traveller chooses the alternative mode that maximizes his/her utility of mode choice. Utility in RUM-based models is specified by assigning weights to the different attributes characterizing each of the available options as well as those of the individual traveller (McFadden 1974; Banister 1978; Barff et al. 1982; Ben-Akiva and Boccara 1995; Eriksson et al. 2008). Among such characteristics, auto ownership, auto availability, travel time and travel cost are considered the major determinants of mode choice (Quarmby 1967; Williams 1978; Barff et al. 1982). The simplest form of mode choice model is a multinomial logit (MNL) model, which assumes that the random errors of the utility functions are independently and identically distributed (iid). More advanced models include the nested logit (NL) model, tree logit model, GEV model and mixed logit models (Barff et al. 1982; Chih-Wen 2005).

All conventional mode choice models have been criticized for their inability to pay appropriate attention to some psychological constructs such as habit, attitude and affective factors. In most cases, such psychological factors are not directly observable, but they greatly influence individuals’ choices (Heinen et al. 2010). There have been compelling arguments to consider behavioural psychological factors directly in the mode choice models (Banister 1978; Aarts et al. 1997; Gärling et al. 1998; Fujii and Kitamura 2003; Gärling and Axhausen 2003; Mackett 2003). Numerous research attempts have been made to capture the intricacies of the choice process by including socio-psychological aspects as explanatory variables within the traditional mode choice models in addition to the conventional personal and modal service variables (Morikawa 1994; Bradley and Daly 1997; Cantillo et al. 2007).

It is clear that mode choice is a complex process, which is strongly influenced by different socio-psychological factors. It is also established that incorporating psychological factors in the utility functions of the mode choice model improves its goodness of fit (Domarchi et al. 2008). Although a number of attempts have been made to incorporate psychological factors directly within the mode choice analyses, in most cases the direct effects of psychological variables are incorporated through the inclusion of alternative-specific constants or dummy variables without any causal relationships between latent variables (Johansson et al. 2006; Temme et al. 2008; Habib et al. 2010; Galdames et al. 2011). In order to address this critical issue, this paper adopts a multivariate statistical modelling approach to investigate the causal relationships between the underlying psychological aspects affecting mode choice such as habit, attitude and affective factors. Further, the Theory of Interpersonal Behaviour (TIB), by Triandis (1977), is utilized as the theoretical foundation of the adopted approach.

The remainder of the paper is arranged as follows: the next section provides a review of the psychological aspects affecting mode choice and a description of the methodology used in the analysis. Section three includes a description of the data used in this research. This is followed by the modelling process in Section four. Finally, conclusions are reported in Section five.
2. Utilizing the Theory of Interpersonal Behaviour as the Theoretical Foundation of SEM Analysis

Structural equation models (SEMs), also known as simultaneous equation models, refer to a statistical technique for linear-in-parameters multivariate (i.e., multi-equation) regression models representing causal relationships between variables in the model. In addition, the response variable in one regression equation may appear as a predictor in another equation. Hence, variables in SEM can affect one another either directly or indirectly. Further, in addition to the inclusion of observed exogenous and endogenous variables, a SEM can incorporate unobservable latent variables, also called constructs or factors, that are not measured directly but rather indirectly through their effects (indicators) or observable causes. Such latent variables are modelled by specifying a measurement model and a structural model. The measurement model specifies the relationships between the observed indicators and the latent variables while the structural model specifies the relationships amongst the latent variables themselves. Furthermore, what differentiates SEM from other conventional multivariate linear models is that it requires specification of a model in terms of a system of unidirectional effects between variables based on theory and research. Therefore, SEM is considered a confirmatory rather than exploratory method (Hoyle 1995; MacCallum and Austin 2000).

In general, a full SEM consists of three sub models; namely, a measurement model for the endogenous variables, a measurement model for the exogenous variables and a structural model for latent variables. Nevertheless, one or both of the measurement models can be eliminated in practice. Hence, SEM analyses can be classified in one of the following three categories. An SEM with both measurement and structural models is called an SEM with latent variables. On the other hand, an SEM with no measurement models is called an SEM with observed variables, whereas a measurement model alone is typically a confirmatory factor analysis (Golob 2003).

Within the structural equation modelling framework, cause and effect relationships are commonly expressed in the form of a causal graph or a path diagram. Path diagrams provide a graphical representation of the SEM such that circles or oval shapes enclose the unobservable (latent) variables. Rectangular boxes, on the other hand, enclose directly observed variables, whereas the disturbances and error terms are not enclosed. Further, unidirectional straight arrows indicate the linear impact of the exogenous variables, at the base of the arrows, on the endogenous variables, at the head of the arrows. Bidirectional curved arrows represent non-causal linear covariance (correlation) between exogenous variables and also between disturbances/errors. Compared to other modelling techniques, the SEM has major advantages in behaviour modelling given its capabilities in dealing with latent variables with multiple indicators, modelling mediating factors and dynamic phenomena such as habit and inertia in mode choice (Golob 2003).

In light of the above, the objective of this research is to identify the causal effects of several psychological aspects on mode choice behaviour using the SEM approach. As a first step for achieving this objective, the path diagram that represents the hypothesized relationships between all latent and
observed variables is specified using a psychological theory as the theoretical framework describing the underlying interaction between latent variables and final behaviour (mode choice).

In general, research in social psychology has suggested that the decision making process underlying mode choice can be better understood by modelling the relationship between attitude and behaviour. Numerous psychological theories have studied such interaction between attitude and behaviour such as the Theory of Planned Behaviour (TPB) by Ajzen (1985), and the Theory of Interpersonal Behaviour (TIB) by Triandis (1977).

In essence, this paper utilizes the elements of the theory of interpersonal behaviour, which has an advantage over other theories by accounting for the role of the frequency of past behaviour (habits) in mediating the final behaviour, as the socio-psychological theoretical framework for SEM analysis.

According to Triandis (1977), observed behaviour is generally assumed to succeed both intention and habit that respectively represent the motivation to perform a specific action and the past frequency of a specific behaviour, while being mediated by contextual facilitating conditions.

The theory of interpersonal behaviour assumes that intention is guided by three major determinants; namely attitudinal, social and affective factors. First, attitudinal factors refer to the degree to which an individual has a favourable or unfavourable appraisal of the behaviour under consideration (Ajzen 1991). In other words, attitude is considered as the accumulated evaluation of the choice which has a magnitude and a direction. Based 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 decision maker is for or against a specific behaviour (Triandis 1977; Gärling et al. 1998; Domarchi et al. 2008).

The second determinant of intention is the social factors which include social norm, social role and self-concept. Social norms are the social rules about what should and should not be done, whereas social roles are sets of behaviours that are considered appropriate for persons holding particular status in a group. On the other hand, self-concept refers to the idea that an individual has of his/herself, the goals that it is appropriate for the person to pursue or to eschew, and the behaviours that the person does or does not engage in.

The third determinant of intention is the affective factors which refer to the emotional response that an individual has towards or against a specific mode of travel. Affect is more or less unconsciously evoked such that it is governed by instinctive behavioural responses to particular situations.

Finally, facilitating conditions (contextual factors) refer to the ease or difficulty of performing the behaviour in terms of several attributes representing the socioeconomic and demographic characteristics of the decision maker, and relative attractiveness of the competing alternatives such as mode availability,
level of service, travel time and cost.

As discussed, the TIB provides a detailed description of the decision making process starting from the initial determinants of the behavioural response and moving forward till reaching the final observed outcome. The theory indicates that attitude and behaviour are positively correlated and can be described such that the more favourable the attitude, social and affective factors, the stronger should be an individual’s intention to perform the behaviour in question. Such intention interacts with habit and contextual aspects producing the final behaviour.

In light of the TIB, this research models the way decisions are made using the SEM approach. However, the proposed approach starts from the final observed mode choice behaviour and moves backward till reaching the determinants of such choice. In other words, the suggested path diagram of SEM analysis models the relationship and the correlation between the unobservable behavioural factors and their observable indicators, as shown in Figure 1.

As shown in Figure 1, intention is represented by a latent variable which in turn is affected by a set of three constructs; namely, attitude, social and affective factors. Each of the three factors is indirectly measured through its indicators as suggested by the theory of interpersonal behaviour. In addition, habit is represented by a latent variable which is indirectly measured through the frequency of past behaviour as its effect. Finally, intention, habit and facilitating conditions interact together to produce the observed mode choice behaviour.
3. DATA DESCRIPTION

The paper uses a dataset which was collected in 2009-2010 in Edmonton, Canada (Dogar 2010). The dataset is collected through socio-psychometric survey investigating the behavioural factors affecting travel mode choice. The survey technique follows an innovative procedure where habit, affective and attitudinal factors were measured using a semantic scale (Domarchi et al. 2008). Further, the survey was conducted using face-to-face random intercept interviews at transit stops/stations, shopping malls and restaurants in the central business district during the afternoon lunch period.

The survey questions referred to the home-to-work commuting trips and gathered socioeconomic and demographic data, as well as level of service and cost information for the used transport mode. In addition, the respondents were also asked to give information regarding some psychological factors that would affect their choices such as habitual behaviour, affective meaning and personal attitudes. Different psychometric tools were used to measure such psychological factors in semantic scales that explicitly capture attitudes, affective appraisal and habit formation. Attitudes towards car and transit were 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). The affective factor on the other hand was indirectly estimated using the Osgood’s semantic differential scale by comparing 14 pairs of antonym words. Further, habitual behaviour was measured using Verplanken’s response-frequency questionnaire based upon 9 hypothetical situations.

A total sample of 176 records was initially collected. This number was reduced to only 141 records with 88 records of car users and 53 records of transit riders that were available for the model estimation after a process of cleaning the dataset. In addition, people walking or using other means of transportation were excluded from the analysis. With respect to gender, 79.4% were males and 20.6% were females. The average age was 37.8 years old, with a standard deviation of 9.8 years.

4. MODEL ESTIMATION AND ANALYSIS

This paper focuses on the interaction between the psychological precursors of the observed mode choice behaviour, utilizing the theory of interpersonal behaviour as the theoretical foundation of the analysis. In particular, the analysis models the interaction between habitual inertia and those aspects affecting intention; namely attitudinal and affective factors. Although social factors are not studied in this research, it is suggested that they should be considered in future work. Alternative SEM specifications were estimated and tested against one another till reaching the final models. The covariance analysis method (method of moments) is used to estimate the proposed models using the Linear Structural RELation (LISREL) software version 8.80. Furthermore, in order to determine the goodness of fit of the estimated models to the observed data, several statistical tests were performed such as Chi-square statistics, Normed Fit Index (NFI), Comparative Fit Index (CFI),
and Root Mean Square Error of Approximation (RMSEA). In practice, the recommended acceptance of a good fit to a model requires that the obtained NFI and CFI value should be in range from 0 to 1, with higher values indicating better model fit and a recommended value of 0.90 or greater for model acceptance. On the other hand, RMSEA values below 0.05 indicate good fit, while those ranging from 0.08 to 0.10 indicate mediocre fit whereas those greater than 0.10 indicate poor fit (Long et al. 2011). However, it is important to note that although model fit is necessary, it is not a sufficient condition for the validity of the hypothesis or theory. Goodness of fit within reasonable values implies only that the data under consideration support the hypothesis. Nevertheless, a conceptual model that guides the specification process, especially the paths between latent and observed variables, is required.

### 4.1 SEM Measurement Models

In this research, two separate SEM measurement models were built separately for car and transit users since their choice behaviours were different. The developed models specified a set of four latent variables (i.e., habit, affective factor, attitude towards car and attitude towards transit), as linear functions of other observed exogenous indicators measured using semantic scales through an ad hoc questionnaire. Such models are considered simultaneous confirmatory factor analysis such that the measurement models contained the relationships between four factors and their indicators. Path diagrams for car and public transit users, including habit, affective and attitudinal factors, are shown in Figures 2 and 3, respectively.

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**Figure 2** Path diagram for the measurement model of car users
In an indication that car users would use the car for almost every single trip, habit is stronger and positive for the car, being negative for transit; they seldom will use public transport. On the other hand, the model shows that car users give a stronger weight to the activation and control dimensions of the affective factor compared to the potential and evaluation ones, something that might be associated with the sense of independence associated with private transportation. Further, the results show that car users give more importance to the value (important) rather than the expectation (good) component of attitude for car; whereas they give more importance to the expectation (good) rather than the value (important) component of attitude for transit. This means that they might know that transit is a good alternative but they do not perceive it as an important mode for work trips.

It is interesting to notice the negative correlation between attitudes for transit and car, for auto users. Certainly, this affects the possibility of promoting the use of transit between auto users. Besides, there is a negative correlation between affection and attitude and habit. There would not be a positive emotion towards the auto, when compared to the habit and attitude which are positively correlated. This might imply that being a frequent car user generates a positive attitude, associated with the importance of car in the daily life, but there is no connection with a positive affection itself. A car gives you independence, but there would be no attachment. This certainly provides the possibility of shifting car use through habit modification.

The previous model has a chi-square value of 32.57 with 37 degrees of freedom. The goodness of fit statistics indicates that the model has a good fit. Specifically, the RMSEA value of 0.00 indicates a perfect fit and NFI value of 0.92 and CFI value of 1.00 are considered within the acceptable range of 0 to 1.

A similar result was realized while examining the habitual behaviour of transit riders; a negative relationship with the transit option and a positive relationship with the car option, as shown in Figure 3. This might be interpreted as that transit riders are forced to use public transit, however they might shift to the car option if it is available which is considered as evidence to the superiority of the car as a mode of travel. On the other hand, transit riders give a stronger weight to the potential, control and evaluation dimensions of the affective factor compared to the activation one; that is, there is a low motivation for using public transport. Furthermore, in contrast to car users, transit riders give more weight to the expectation (good) rather than the value (important) component of attitude for car, whereas they still give more weight to the expectation (good) rather than the value (important) component of attitude for transit. In other words, they might know that transit is good and that is the reason why they use it, although it is not important for them. There is a sort of detachment toward the transit.

It is worth noticing the negative correlation between affection and habit and attitude towards transit. This reinforces what has been expressed before: people use transit because they have to, but there is no attachment. The positive correlation between habit and transit attitude might have to be with the lack of an alternative transport mode.
The positive correlation between auto attitude and affection might be implying that people have developed a positive view on private transport, not being a frequent user; there would be a strong expectation on this transport mode. This certainly might be attempting in keeping transit ridership for the analysed sample.

The previous model has a chi-square value of 34.69 with 33 degrees of freedom. The goodness of fit statistics indicates that the model has a good fit. Specifically, the RMSEA value of 0.031 is lower than the upper limit of 0.05 and NFI value of 0.840 and CFI value of 0.970 are considered within the acceptable range of 0 to 1.

4.2 SEM with Latent Variables

A joint SEM with latent variables is estimated such that a structural model for the relationship between the latent variables, and two measurement models for both the endogenous (i.e., mode choice) and exogenous indicators of the psychological factors are integrated. The theory of interpersonal behaviour is utilized as the path diagram of the corresponding SEM as shown in Figure 4.
In general, the proposed model specifies the causal influences among the latent variables by incorporating both a measurement model to deal with how indicators load on the factors, and the structural model to deal with the causal relationships among factors.

As shown in Figure 4, intention is modelled as a latent variable which is indirectly measured through three constructs; namely affective factor, attitude towards car and attitude towards transit. Further, each of the three factors is indirectly measured through its effects as indicated by the measurement models. In addition, habit is modelled as a latent variable which is indirectly reflected by the frequency of past use. Finally, both intention and habit affects the observed mode choice behaviour as suggested by Triandis.

The SEM with latent variables shows similar relationships as that indicated by the measurement model for car users. In an indication that car users would use the car for almost every single trip, habit is stronger and positive for the car, being negative for transit. On the other hand, the results show that Edmonton users give a stronger weight to the activation and evaluation dimensions of the affective factor compared to the potential and control ones. Further, users give more weight to the value (important) rather than the expectation (good) component of attitude for car; whereas they give more weight to the expectation (good) rather than the value (importance) component of attitude for transit.

In addition, the SEM with latent variables shows the causal relationships among factors such that intention is reflected by affective and attitudinal factors towards car and transit. Interestingly, it can be shown that Edmonton users give a strong positive weight to the attitude towards transit whereas a negative sign is associated with the attitude towards car. It seems that
intention is guided by the attitude towards transit rather than the attitude to the car.

Further, both habit and intention integrate to influence the final observed mode choice behaviour. In an indication of the superiority of the car as a mode of travel, the final mode choice is associated with a negative habitual behaviour towards transit and a positive one towards car usage. On the other hand, intention is associated with a negative sign for car and positive sign for transit. This would be interpreted as that Edmonton users sample knows the importance of the transit service and might be motivated to use it, although the strong habit does not allow that. This could be written as there is a stated preference to use transit, but its operational and other conditions imply that the revealed preference is another: private car.

The previous model has a chi-square value of 104.36 with 51 degrees of freedom. The goodness of fit statistics indicates that this model fits the data well. Specifically, the RMSEA value of 0.086 is lower than the upper limit of 0.10 and NFI value of 0.920 and CFI value of 0.950 are considered within the acceptable range of 0 to 1.

The SEM with latent variables as studied in this paper does not allow us to estimate modal split probabilities. Nevertheless, latent variables can be obtained from the SEM, being introduced into a Logit model, helping to improve the explanatory and predictive potential of the discrete choice structure, in the fashion used by Galdames et al. (2011).

5. CONCLUSIONS

This paper adopted the structural equation modelling (SEM) approach to investigate the cause and effect relationships between the underlying psychological aspects affecting mode choice. The proposed approach focused on the psychological antecedents of mode choice behaviour following the theory of interpersonal behaviour (TIB), by Triandis (1977), as the theoretical framework.

Different psychometric tools were used to measure the effects of psychological factors such as habitual behaviour, attitudes and affective factors. Although such psychological factors were measured using different semantic scales, the SEM analysis allowed for the detection of correlation between latent variables and the determination of the importance of each latent attribute.

Several structures were proposed and estimated using LISREL software for SEM analysis. The results showed that the consideration of psychological attributes as latent variables helped explain mode choice behaviour. In addition, it was shown that users have positive emotions towards their chosen mode. Further, evidence to the superiority of the car as a travel alternative was realized such that car users would use the car for almost every single trip.
Although social factors were not studied in this research, it is suggested that their effect on intention should be considered in future work.

The impact of these findings on policy issues is a matter that should be kept in mind. The strong habit towards the auto use, associated with a positive attitude and affection to it, and the lower attitude and affection towards transit, certainly constitute a deterrent when trying to promote the use of transit facilities. Actually, demand management schema, such as road pricing, might not have the expected result given the found level of attachment to the car.

References


