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An SEM Approach of Travel Mode Choice and Trip Chaining: A Study on Dhaka City

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Abstract: Mode choice and trip chaining behavior of developing cities are becoming more complex gradually due to rapid urbanization and economic growth. This paper investigates the relationships among the major attributes that affect mode choice and trip chaining by Structural Equation Modeling (SEM) approach. In this study, 15 attributes regarding mode choice and trip chain are employed to develop SEM models for 978 respondents. Among the developed models, the best model is selected by using different statistical significance. These models investigate negative and positive influences of attributes' on overall mode choice. The best model result shows that among all attributes waiting time at stations, comfort level, parking availability, travel by bus/cng, and trip chain influence user's choice of mode significantly. The results of this study are expected to help policymakers to predict user's future mode choice and trip chaining behavior, and facilitate development of relevant transportation policies for assessing infrastructure investments.

Keywords: Mode choice, Trip chain, Structural Equation Modeling.

1. INTRODUCTION

Mode choice is usually an application of users' decision making process of choosing different modes for particular types of trips. The choice of mode is one of the most important classic models in transportation planning. It is closely associated with the commuters' choice making process which is one of the most important aspects of the transportation modeling in order to predict the choice behavior for travel decisions. This is because of the key role played by transport in policy making (Ortúzar and Willumsen, 2001). The important concept of travel mode choice models is to understand the relationship between traveler's motivation to choose a mode and the underlying attributes of the choice, such as service quality of modes, accessibility, cost, travel time, waiting time, number and ease of transfers, comfort, etc. (Ben-Akiva and Lerman, 1985; Koppleman and Wen, 2000).

Mode choice models for forecasting travel demand have been developed by several researchers in the last few decades (Ben-Akiva and Lerman, 1985; Train, 1998). Habib (2002) developed a four step travel demand model for Dhaka city (Dhaka urban transport model, DUTM). The results showed that they were counterintuitive with positive sign of the coefficients or time and cost parameters. In his study, it was found that coefficient for comfort is greater than that of time and cost which is not normal for developing country like Bangladesh. A mode choice model for the work trips of middle income group of Dhaka city was developed by

Aftabuzzaman et al. (2010). Result showed a rise in the modal share of bus and fall in the share of rickshaw and auto rickshaw. Gopinath (1995) presents latent class models for mode choice behavior and shows that different segments of population have different decision protocols before the choice process as well as different sensitivities for time and cost.

Trip chain may be defined as a sequence of trips that starts at home, involves visits one or more other places, and ends at home (Timmermans et al. 2003; Ye et al. 2007; Primerano et al. 2008). Lee et al. (2007) suggest that a trip chain comprise at least two out-of-home activities that are connected by travel after leaving home until returning home in a single 24-h day. Trip chain may be classified into two categories depending on the number of visits during a trip chain: simple and complex. Simple trip chain may be considered as a trip for a single work with only one stopover; however a trip with more than one stopover may be considered as complex tour. Examples of simple and complex trip chains are: Simple chain: home - shop - home and Complex chain: home - work - shop - home. Trip chain analysis symbolizes the travel behavior in a better way and provides various frameworks that may help to examine different transportation issues (Strathman & Dueker, 1995).

Hensher and Reyes (2000) observed that trip chains are interconnected to work trips. As the researches in examining trip chaining issues become more popular, greater attention is drawn towards enhancing the statistical models to determine the correct relationship between factors. Due to days with full of activities and lack of free time individuals trip chaining behavior are becoming more complex (Currie and Delbosc 2011). The ability to do multiple activities in a trip chain is more convenient and useful than a single stop simple chain (Hensher et al., 2000). Trip chaining behavior also increases individual transport usage such as car and thus increases the congestion and urban peak hours (Ye et al. 2007; Habib et al. 2009; Yun et al. 2014). Women trip chain is more complex and varied than man because of their multipurpose work including employment, home, baby caring, the elderly or other persons in need (MacDonald, 1999). To fulfill the task in limited time budget leads to the growing tendency of chaining more trips in home - home or home - work trip chains, where the end location and start location can be both home or either home or working place (McGuckin and Nakamoto 2004; Kitamura and Susilo, 2006). Another study was carried out by Sydney Metropolitan area about the mode choice perspective, showed that 45% of the trip makers using car or public transport were involved in making complex trips (Hensher and Reyes, 2000).

SEM methodology has been applied widely in several fields of research such as Psychology and Social Science, Natural Science, and especially in the field of Economy and Statistics, and in recent years it has started to be most frequently used in the field transport planning. Andreassen (1995) and Karlaftis et al. (2001) adopted SEM specifically for describing customer perception in public transport services. Shiftan et al. (2008) used SEM to identify simultaneously travelers' attitudes, travel behavior and relationship between travelers' socioeconomic profile and their attitude toward travel and how they choose trips. SEM has been used empirically to examine the relationship of residential neighborhood type to travel behavior, incorporating attitudinal, lifestyle and demographic variables (Bagley and Mokhtarian 2002) and recently to explore whether changes in neighborhood characteristics bring about changes in travel choice (Aditjandra et al 2012).

Rapid industrialization and socialization led to higher growth rates, higher income and excessive demand for mobility in developing cities. Increasing transports cause congestion, environmental problems that create disrupt in traffic condition like delay, accidents resulting significant economic loss every year. Nowadays traffic congestion is a matter of great concern for the inhabitants of Dhaka resulting in user's annoyance, lengthier travel times, and air.

Users have diverse sensitivity concerning the service related attributes of modes. It is essential comprehending user's motivations for using a particular mode for implementing suitable transport strategies aimed at resolving the congestion, and to identify the sensitivity towards the attributes and associated trade-offs for various travel attributes. Furthermore developing cities like Dhaka barely explores the reasons for choosing different modes and often employed the mode choice models that are used in developed countries which do not represent the different scenario actually exist in there. Thus the objectives of this study is to investigate the relationships among the major attributes that affect mode choice and trip chaining by Structural Equation Modeling (SEM) approach.

2. LITERATURE REVIEW

Mode choice has direct impact in policy making because of its important influence in transportation planning. Mode choice models are closely linked with individual's mode choice behavior which continues to attract attention for further exploration of the choice making process (Sekhar, 2014). Travelers' mode choice decisions and the influencing factors have been investigated in many studies (Train and McFadden, 1976; 1978; Bordagaray et al., 2014). Logit models have been widely employed on mode choice decisions in previous literatures (Anas, 1983; Ben-Akiva, 1999; Walker, 2001). Disaggregated demand models are used to reveal the variables that influence user's choice and to ascertain the probability of choosing different available options used (McFadden, 1981; Schakenbos et al., 2016). The majority of the models developed for travel behavior functions are based on random utility theory (McFadden, 1974; Domencich and McFadden, 1975; Manski, 1977; de Dios Ortúza and Willumsen, 2001), which presumes that the preference of choice of an alternative is considered by utility, and decision of selection is done based on the most satisfactory choice (Taniguchi et al., 2014). The essential concept of travel mode choice models is to understand the relationship between traveler's choice and the contributing factors, such as the social-economic level and service level of modes (Ding and Zhang, 2015).

A review of previous research has identified the impact on trip chaining patterns. The majority of these studies have focused on socio-economic factors contributing to the number of stops within a trip chain, such as sex (Strathman et al, 1995; Strathman et al, 1994), age (Bhat, 1997; McGuckin et al, 2005; Schmöcker et al, 2010), income per month (Adler et al, 1979; Hensher et al 2000), number of children (Hensher et al 2000; Noland and Thomas, 2007). Other researchers have focused on the effects of technology advancements (Strathman et al, 1994) and Trip-specific features such as trip distance have been examined by Schmöcker et al. (2010), length of travel time and cost was analyzed by Bhat (1997) and parking availability along with day of the trip was observed by Primerano et al, (2008).

Modern life is becoming busier and has lack of free time that makes the peoples' trip chaining behavior more complex (Currie and Delbosc 2011). Women trip chain is more complex and varied than man because of their multipurpose work including employment, home, baby caring, the elderly or other persons in need (McDonald, 1999). To fulfill the task in limited time budget leads to the growing tendency of chaining more trips in home - home or home - work trip chains, and the origin and destination of the trips can be both home or either home or working place (McGuckin and Nakamoto 2004; Kitamura and Susilo 2006). The ability to do multiple activities in a trip chain is more convenient and useful than a single stop simple chain (Hensher et al., 2000). Trip chaining behavior also increases individual transport usage such as car and thus increases the congestion and urban peak hours (Ye et al. 2007; Habib et al. 2009; Yun et al. 2014).

SEM was adopted in several fields of research and generalized by Joreskog and Wiley (Joreskog 1973; Wiley 1973). Application of SEM in travel behavior research initiates the analysis of complex causal relationship among individual's travel decisions. Travel behavior investigators applied SEM in their research in order to analyze complex causal relationship among travel-related variables, such as trip frequency, travel time or travel distance, activity duration, etc. Kitamura et al. (1992) and Golob et al (1994) are the first known application of SEM to joint activity duration and travel time data. Kitamura (1996) gave an overview that includes discussions of the role of SEM in activity and time-use modeling. Lu and Pas (1997) revealed in home activities, out-of-home activities (by type), and travel (measured various ways), conditional on socioeconomic variables by SEM.

Golob and McNally (1997) present an SEM of the interaction of household heads in activity and travel demand, with data from Portland. Activities are divided into three types, and SEM results are compared using maximum likelihood (ML) and generalized least squares (GLS) estimation methods. They conclude that GLS methods should be used to estimate SEM when it is applied to activity participation data.

Fuji and Kitamura (2000) studied the latent demand effects of the opening of new freeways. The authors used an SEM to determine the effects of commute duration and scheduling variables on after work discretionary activities and their trips by using data for Osaka-Kobe Region of Japan. Golob (2000) estimated a joint model of work and non-work activity duration using Portland data. Kuppam and Pendyala (2000) presented three SE models estimated by GLS using data from Washington, DC. The models concentrated on relationships between: activity duration and trip generation, durations of in-home and out-of-home activities, and activity frequency and trip chain generation. Simma and Axhausen (2001) developed an SEM that captured relationships between male and female heads of household with regard to activity and travel demands. The dependent variables included car ownership, distances traveled by males and females, and male and female trips by two types of activities using data from the upper Austria. Meka and Pendyala (2003) investigated the interaction between two adults in one household in their travel and activity time allocation by SEM using Southeast Florida data. This is the first attempt to relate mode choice and trip chains by using SEM for developing countries like Bangladesh.

3. METHODOLOGY

A two-step methodology was adopted for this study. The first part was the data collection approach incorporating purpose built questionnaire survey. The questionnaire contains three sections. The first part was about the respondent's socio-economic information. The second part involved information about trip chain of work related days and non-work related days and final part involved about trip characteristics.

The second step addresses SE model development. For each empirical model, the process of model development follows the approach of trial and error in terms of shuffling various exogenous, endogenous and latent variables as well as observing overall goodness of fit of them. For testing parameter estimation a two-tailed t-test with a critical value of 1.64 for 95% confidence level is considered.

3.1 Sample

SEM is a large sample technique (usually sample size>200) (Lei et al. 2007). One of the strengths of SEM is its flexibility, which permits examination of complex associations of various types of data (e.g., categorical, dimensional, censored, count variables), and comparisons across alternative models. However, general guidelines and requirements are difficult to develop because of these features of SEM (MacCallumc et al., 1999). Despite this, various rules-of-thumb have been practiced. Boomsma (1982, 1985) adopted a minimum sample size of 100 or 200 while Bentler and Chou (1987) approached 5 or 10 observations per estimated parameter, and 10 cases per variable (Nunnally, 1967). Model characteristics such as the level of communality across the variables, sample size, and degree of factor determinacy affect the accuracy of the parameter estimates and model fit statistics, which raises doubts about applying sample size rules-of-thumb to a specific SEM (MacCallum et al., 1999). The sample size for this research was 978, which is adequate.

3.2 Statistical Analysis

A series of models are developed to identify the relationship of mode choice and trip chaining for work trips in Dhaka city. The target is to reveal the variables that influence mode choice and trip chaining. At the end, all the proposed candidate models are compared and the optimal one is found out. The optimal model is the most representative one of the actual scenario. In this study STATA 13 software is used for modeling. STATA 13 uses ML (maximum likelihood) estimate method among the various parameter estimation methods. To cope with complexity of SEM model more than one model should be introduced to define the goodness of fit of the models. Standardized Root Mean Squared Residual (SRMR), Root Mean Squared Error of Approximation (RMSEA), Tucker-Lewis index (TLI) and Comparative fit Index (CFI) are some measures that are used to define fitness of good. According to Steiger (1990) a RMSEA value .05 or less designates very good fit and value below 0.10 designates good fit. Browne and Cudeck (1993) introduce that value of 0.08 or less is always reasonable. A value of SRMR less than .10 indicates a good fit of the data in Empirical SEM models (Lance et al. 2000). CFI values range between 0.0 and 1.0 with values closer to 1.0 indicating a good fit (Hooper et.al 2008).

3.3 Mode choice Attributes

15 mode choice attributes are used in this study. For building models these attributes are used as endogenous, exogenous variables and some latent variables. List of Variables and Their Roles in the Proposed SEM Models are shown in Table 1. Explanation of 15 attributes is as follows:

- Parking availability (explains workplace have parking facilities or not and the condition of parking facilities)
- Trip distance (explains the home to work and work to home distance)

- Change of mode (explains how many times respondents change their mode to make a trip)
- Travel by bus/train/tempo, travel by bicycle/rickshaw, travel by private car, travel by motorcycle, travel by taxi (explains how many times in a month respondents use these mode of transport)
- Waiting time at station (explains how long respondents wait at the station for a transport)
- Time take to reach the destination (explains travel time of the respondents to reach their desired destination)
- Comfort level of mode (explains the comfort level of the transports)

In this research 4 types of trip chains are introduced to build models. Figure 1-4 shows schematic diagrams of trip chains.

1) Simple home to work ; work to home (h-w-(-w-)-h) trip chain

Figure 1. (h-w-(-w-)-h) trip

2) One non-work stop from home to work and one non-work stop from work to home (h-nw-w-(-w-)-nw-h) trip chain

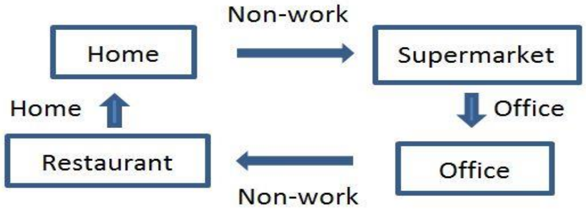

Figure 2. (h-nw-w-(-w-)-nw-h) trip

3) No non-work stop from home to work but one non-work stop from work to home (h-w(-w-)-nw-h) trip chain

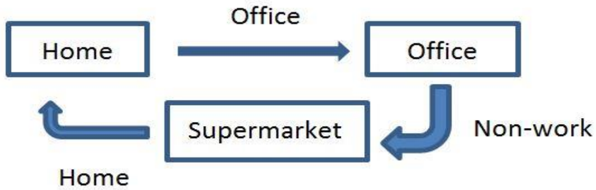

Figure 3. (h-w(-w-)-nw-h)

4) No non-work from home to work but more than two non-work stop from work to home (h-w(-w-)-nw-nw-(-nw-)-h) trip chain

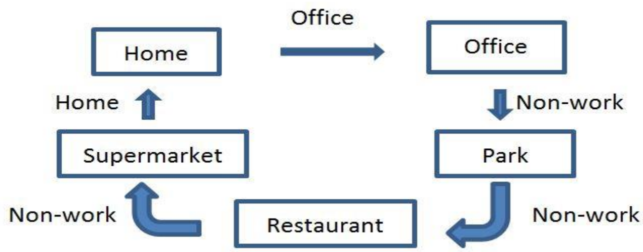

Figure 4. home (h-w(-w-)-nw-nw-(-nw-)-h) trip

Table 1. List of Variables and Their Roles in the Proposed SEM Models

Item no	Description	Model 1		Model 2		Model 3		Model 4	
		Type	Notation	Type	Notation	Type	Notation	Type	Notation
1	Parking Availability	Ex.	X_1	Ex.	X_1	En.	y_1	En.	y_1
2	Trip Distance	Ex.	X_2	Ex.	X_2	En.	y_2	En.	y_2
3	Change of Mode	P.	Z	P.	Z	En.	y_3	En.	y_3
4	Simple home to work-work to home trip	Ex.	X_4	Ex.	X_3	En.	y_4	En.	y_4
5	One non-work from home to work and one non-work stop from work to home trip	Ex.	X_5	Ex.	X_4	En.	y_5	En.	y_5
6	No non-work from home to work but one non-work stop from work to home trip	Ex.	X_6	Ex.	X_5	Ex.	y_6	En.	y_6
7	No non-work from home to work but more than two non-work stop from work to home trip	Ex.	X_7	Ex.	X_6	En.	y_{15}	En.	y_{13}
8	Travel by bus/train/tempo	Ex.	X_{10}	Ex.	X_7	En.	y_{14}	En.	y_7
9	Travel by bicycle/rickshaw	Ex.	X_8	Ex.	X_{10}	En.	y_{10}	En.	y_{10}
10	Travel by private car	Ex.	X_{12}	Ex.	X_8	En.	y_{13}	En.	y_8
11	Travel by taxi	Ex.	X_{11}	N/A	N/A	En.	y_{12}	N/A	N/A
12	Travel by motor cycle	Ex.	X_9	Ex.	X_9	En.	y_{11}	En.	y_9
13	Waiting time at the station	En.	Y_2	En.	Y_1	En.	y_9	En.	y_{11}
14	Time taken to reach the station	En.	Y_1	En.	Y_2	En.	y_8	En.	y_{12}
15	Comfort level of the mode	Ex.	X_3	En.	Y_3	En.	y_7	En.	y_{14}
16	Trip Characteristics	N/A	N/A	N/A	N/A	Lt.	η_1	N/A	N/A
17	Trip chain of work related days	N/A	N/A	N/A	N/A	Lt.	η_2	N/A	N/A
18	Trip chain of non-work related days	N/A	N/A	N/A	N/A	Lt.	η_3	N/A	N/A
19	Trip Behavior	N/A	N/A	Lt.	η	N/A	N/A	Lt.	η_1
20	Trip chain	N/A	N/A	N/A	N/A	N/A	N/A	Lt.	η_2

Ex. = Exogenous variables; En. = Endogenous variables; Lt. =Latent variables; N/A= Not applied in this model; P. = Overall Perceived variable

4. DATA COLLECTION

6 surveyors did face to face interview survey at 14 locations of Dhaka city starting from 4th March 2016 to 9th April 2016. The target was collecting 1000 data. Out of the 1000 questionnaire administered, twenty two (22) were discarded due to their incompleteness; hence the usable sample size for the model was 978.

Majority (86%) of the respondents are male and only 14% are female. In the case of occupation, 73% are service holder, 23% are businessman, and 4% are from other occupation. Educational qualification of respondents shows that 63% of the respondents had graduation, 7% below elementary, 27% elementary/diploma/intermediate and only 1% had doctoral degree. Age distribution shows that 30%, 43% and 27% respondent's were within 21-30, 31-40 and above 40 years group respectively. Family monthly income shows that 36% had more than 40000 BDT (80 BDT= 1$) monthly family income. 1%, 20%, and 43%, respondents were within 5000-10000, 10000-20000, and 20000-40000 BDT monthly family income range respectively. 9% of the respondents monthly travel expenditure is less than 500 BDT while 11 % respondents had above 10000 BDT. 19%, 23% and 38% respondents were within 500-2000, 6000-10000 and 3000-5000 taka monthly household travel expenditure group respectively. Distances of trip from house were less than 1 km, 1-3 km, 3-5 km, and above 5 km as reported by 14%, 36%, 26%, and 24% respectively. 79% respondents reported that they didn't change their mode to reach their destination. Once, twice and three times change of mode to reach destination had been reported by 18%, 2% and 1% respondents respectively.

5. RESULT ANALYSIS

A series of structural equation models are developed to find out the correlation among the mode choice attributes. The target is to identify which parameters are more important for choosing a particular mode. At the end all the models are compared to obtain an optimal model which may be the most representative for the actual scenario.

Four different models are developed revealing the relationships of different variables with mode choice. Fifteen observed variables are used to develop the models. Total 15 observed variables are used as exogenous and endogenous variables and latent variable are also introduced in the models. Table 1 shows the variables that are used in different models.

Model 1 is developed without any latent variable. Two endogenous variables as "Time taken to reach each destination, (Y_1)" and "Waiting time, (Y_2)" are used to construct model 1 (Figure 5). "Time to reach destination" describes trip characteristics and trip chains constructed with seven exogenous variables (item 1-item 2; item 4-item 7; item 15; Table 1). Waiting time signifies mode specific features described by five exogenous variables (item 8-item 12; Table 1). "Time to reach destination" is one of the important variables that influence mode choice positively because users always want to reach their destination as quick as possible. However, the result of model 1 (-0.097; Table 2) shows that "Time taken to reach destination" is an insignificant variable. Also, it influences passenger's mode choice negatively which does not match the actual case. Shortest travel time allows the respondent to arrive at work earliest. Nevertheless congestion characterizes common scenario of everyday life in Dhaka city especially for rush commuting hours. The results indicate that users are likely to select alternatives that allow them to reach at a lower cost and are not really influenced whether the alternative takes longer travel time or not. Furthermore, the results show some other inconsistencies such as “Parking availability”, “One non-work from home to work and one non-work stop from work to home trip”, “No non-work from home to work but more than two non-work stop from work to home trip” influences negatively (-0.12, -0.032, -0.047; Table 2). Waiting time influences mode choice negatively (-0.055; Table 1) which also does not match with the real scenario. “Travel by private car” and “Travel by motor cycle” influence “Waiting time” negatively (-0.2, -0.19; Table 2). Exogenous variables “Trip distance”, “Comfort level”, “Simple home to work; work to home trip”, and “No non work from home to work but one non-work stop from work to home trip” are significant and influence positively (0.59, 0.058, 0.046; Table 2). With some unconventionalities M1 has poor fit indices (CFI= 0.817, RMSEA= 0.066, SRMR= 0.051), M2 is developed.

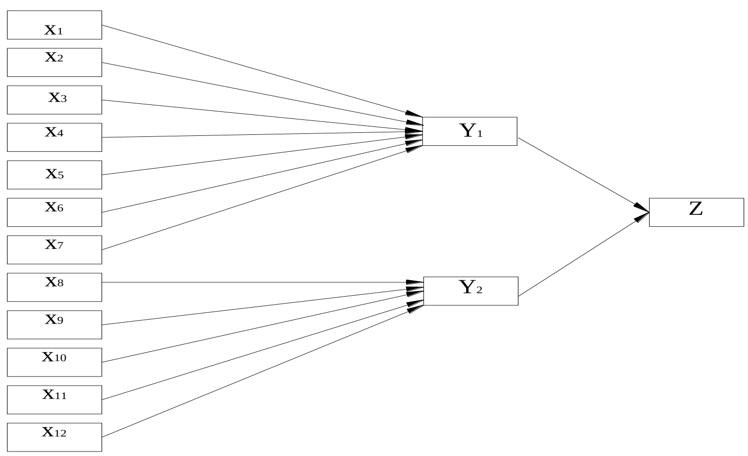

Figure 5. Generalized path diagram of model 1

Model 2 is constructed with one latent variable introducing all variables by trip behavior (η). Trip behavior (η) is calibrated by three endogenous variables characterizing time and comfort of mode (item 13-item 15; Table 1). The latent variable is calibrated with ten exogenous variables (item 1-item 2; item 4-item 10; item 12; Table 1). Model 2 (Figure 6) shows that “Waiting time” and “Time taken to reach destination” influences “Change of mode to reach destination” positively (0.045, 0.91; Table 2) which is reasonable and match with the real scenario because waiting time and time taken to reach destination significantly influence users to choose a particular mode. However, comfort level of mode influences change of mode negatively (-0.041; Table 2) which is not expected because comfort is always preferable by the passengers especially for long distance. Model 2 results show some other irrelevancies with the real scenario. For example, “Simple home to work; work to home, No non-work from home to work but more than two non-work stop from work to home trip, Travel by private car, Travel by motor cycle have negative influence trip behavior. Parking availability, trip distance, one non-work from home to work and one non-work stop from work to home trip, no non work from home to work but one non-work stop from work to home trip, travel by bus/train/tempo, and travel by bicycle/rickshaw influence trip behavior positively. With some irregularities M2 has good fit indices (CFI= 1.00, RMSEA= 0.000, SRMR= 0.012), M3 is developed.

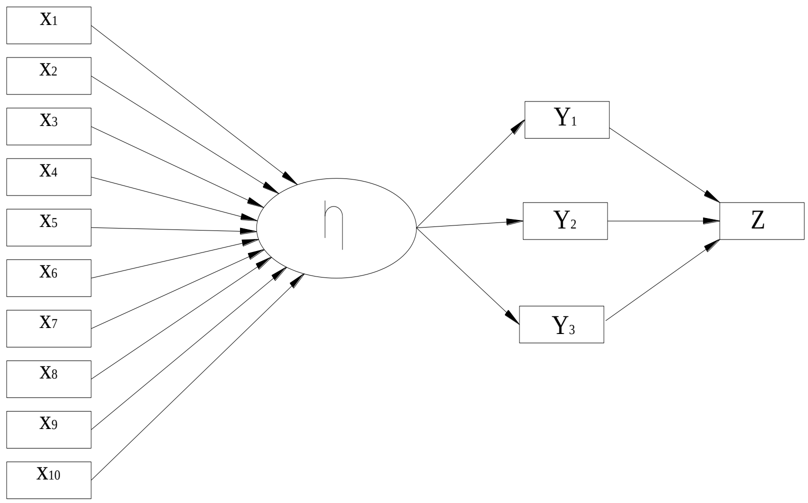

Figure 6. Generalized path diagram of model 2

Model 3 introduces three latent variables obtained by splitting all the variables into three parts; Trip characteristics (η_1), Trip chain of work related days (η_2) and trip chain of non-work related days (η_3). "Trip characteristics" was calibrated with three endogenous variables (item 1– item 3; Table 1), "Trip chain of work related days" was calibrated by four endogenous variables (item 4-item 6;item 7; Table 1) and "Trip chain of non-work related days" was calibrated by nine endogenous variables (item 7- item 15). Endogenous variable "No non-work from home to work but more than two non-work stop from work to home trip" was introduced in this model which was calibrated with two latent variables "Trip chain of work related days, (η_2)" and "Trip chain of non-work related days". The path connecting Trip characteristics (η_1) and Trip chain of work related days (η_2) has the parameter of 0.36 (Z value 2.67). The path connecting Trip characteristics (η_1) and Trip chain of non-work related days (η_3) has the parameter of 2.5 (Z value 1.68) and Trip chain of work related days (η_2) and Trip chain of non-work related days (η_3) has the parameter of .49 (Z value 1.67). These parameters indicate that latent variables are connected with each other strongly which is rational. Among the three latent variables "Trip characteristics, (η_1)" influences "Parking availability" negatively (-.12; Table 2) and "Trip distance" and "Change of mode to reach destination" positively (.59 and .99; Table 2). No of change of mode to reach destination has is substantial influence trip characteristics which highlights the lack of connectivity of transportation system in Dhaka. Trip chain of work related days (η_2) influences "Simple home to work; work to home trip" and "No non work from home to work but one non-work stop from work to home trip" positively (.058, .046; Table 2) and "One non-work from home to work and one non-work stop from work to home trip" negatively (-.032; Table 2). Trip chain of non-work related days (η_3) influences nine endogenous variables. Trip chain of work related days (η_2) influences "No non-work from home to work but more than two non-work stop from work to home trip" negatively (-.06; Table 2) and Trip chain of non-work related days (η_3) influences "No non-work from home to work but more than two non-work stop from work to home trip" positively (.039; Table 2). From the results of model 3 (Figure 7), it is seen that "Trip chain of non-work related days" influences comfort level positively which is anticipated. Also the "Trip chain of non-work related days" influences waiting time negatively which does not represent actual scenario as users prefer to make trips in shorter time. With some anomalies fit indices of M3 are within range (CFI= 1.00, RMSEA= 0.000, SRMR= 0.000), indicating a good model. M4 is developed.

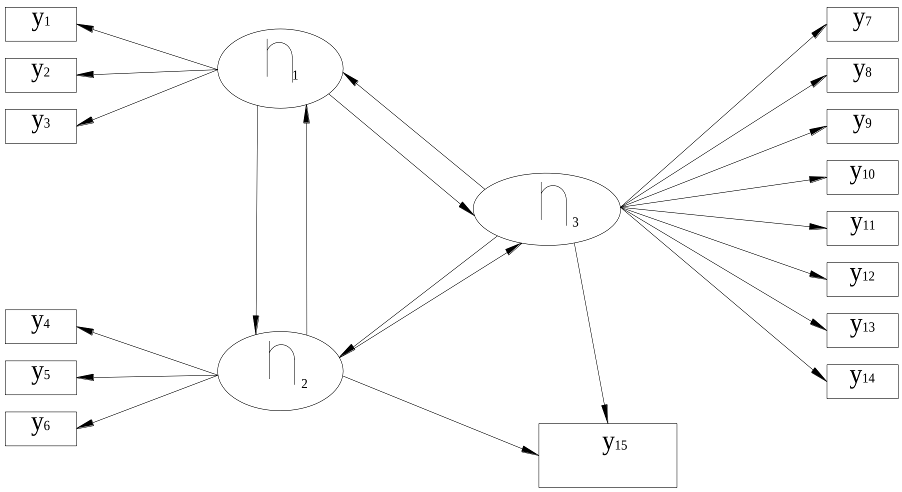

Figure 7. Generalized path diagram of model 3

To get best model, model 4 is developed, where two latent variables are introduced. "Trip behavior, η_1)" is calibrated by seven endogenous variables (item 1- item 7; Table 1) and "Trip chain, η_2" is calibrated by seven endogenous variables (item 8-item 10; item 12-item 15; Table 1). The latent variables "Trip behavior" and "Trip chain" both significantly influences each other. The endogenous variables "Parking availability", "Trip distance", "Change of mode to reach destination", "Simple home to work-work to home trip", "One non-work from home to work and one non-work stop from work to home trip", "No non work from home to work but one non-work stop from work to home trip", "No non-work from home to work but more than two non-work stop from work to home trip"; have positive influence (0.69, 0.05, 0.94,0.024 , 0.01,0.032, 0.18; Table 2) on trip behavior that represents the actual scenario. The latent variable "Trip chain" has positive relation with the endogenous variables (item 8-item 10; item 12-item 15; Table 1) which is reasonable. Two latent variables, η_1 and η_2 are connected with each other and the correlation is significant with coefficient value of 2.5. Although last three models have good fit indices, model 4 (Figure 8) can be considered as the best model considering its relevance with practical scenario.

Fit indices of M4 are (CFI= 1.00, RMSEA= 0.000, SRMR= 0.000). All of the fitting indicators are within the recommended range. Therefore, the model has a good fit.

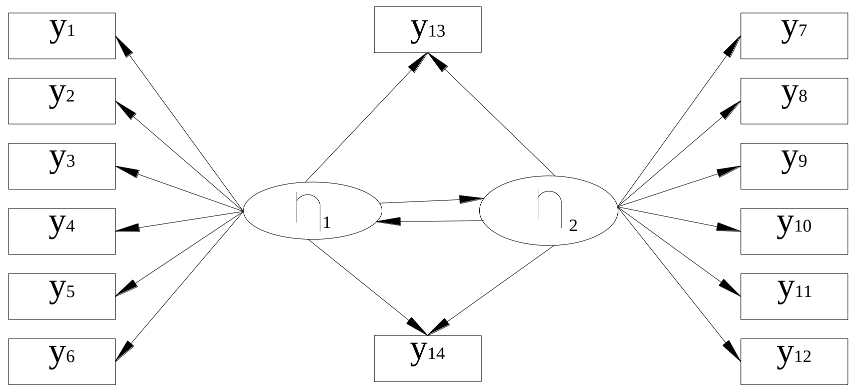

Figure 8. Generalized path diagram of model 4

Table 2 represents the parameters value of all variables (exogenous, endogenous and latent) that are used to build the models.

Table 2. Estimated parameters for different models

Observed variables	Model 1 estimates	Model 2 estimates	Model 3 estimates	Model 4 estimates
Parking Availability	-*.12*(0.00)	.0032(.650)	-.12(.169)	.69(.745)
Trip Distance	.59(0.00)	.15(.001)	*0.59*(.244)	.05(0.00)
Change of Mode	.99(0.00)	.98(.224)	0.99(.198)	.94(.177)
Simple home to work-work to home trip	.058(0.00)	-*.019*(.580)	0.058(.130)	.024(.096)
One non-work from home to work and one non-work stop from work to home trip	-*.032*(.204)	.048(0.00)	*-0.032*(.136)	.01(.0125)
No non-work from home to work but one non-work stop from work to home trip	.046(.065)	.12(0.00)	*.0.046*(.194)	.032(.003)
No non-work from home to work but more than two non-work stop from work to home trip	-*.047*(.060)	-.042(0.00)	-0.06(0.00) , 0.039(.306)	*.18*(.004)
Travel by bus/train/tempo	.39(0.00)	.87(0.00)	*.9*(0.00)	.88(0.00)
Travel by bicycle/rickshaw	.06(.030)	.077(0.00)	.51(0.00)	.48(0.00)
Travel by private car	-*.2*(0.00)	-.49(0.00)	.12(0.00)	.57(0.00)
Travel by taxi	.022(0.030)		-.68(0.00)	
Travel by motor cycle	-*.19*(0.00)	-.49(0.00)	.42(0.00)	.7(0.00)
Waiting time at the station	-*.055*(.004)	.045(.192)	-*.31*(0.00)	.67(0.00)
Time taken to reach the station	-*.097*(0.00)	.91(0.00)	.1(0.00)	*.33*(0.00)
Comfort level of the mode	.095(0.00)	-*.041*(0.00)	.32(.003)	.86(0.00)
Latent Variables				
Trip Characteristics	-	-	.992	-
Trip chain of work related days	-	-	*.258*	-
Trip chain of non-work related days	-	-	.611	-
Trip Behavior	-	*.71*	-	*.0058*
Trip chain	-	-	-	.068

Italic numbers indicate 1.00= t state < 1.64

The model fit indices of model 1, 2, 3 and 4 are shown in Table 3.

Table 3. Fit indices of models

Fit Indices	**Model 1**	**Model 2**	**Model 3**	**Model 4**
		Absolute fit indices		
Root man squared of approximation (RMSEA)	0.092	0.00	0.00	0.00
Standardized root mean square residual (SRMR)	0.040	0.012	0.00	0.000
		Incremental fit indices		
Comparative fit index (CFI)	0.823	1.00	1.00	1.00
Tucker-Lewis index (TLI)	0.725	0.758	0.824	0.95
		Parsimony fit indices		
Akaike's information criterion (AIC)	34468.13	35906.74	35783.13	35872.14

CONCLUSION

In this study an effort has been made to investigate the relationship of mode choice attributes and trip chaining for Dhaka city. The users' stated their preferences which are employed to find out the set of parameters which affect the choice of mode. In this research, four models are developed by SEM and compared them with the standardized values to find out the best model. SEM is an advanced technique which permits latent constructs that are used in this study to develop and compare four different SEMs.

Three out of four models are well fitted; all of which were developed with latent variables for instance trip characteristics, trip chains, and trip behavior. Model 2 revealed that among the three endogenous variables time taken to reach destination is the most influential attribute that affect the choice of mode. In this model trip behavior is used as a latent variable and among the ten exogenous variables trip distance affect the latent variable most. In model 3, three latent variables are introduced and they have very strong relationship among each other. Trip characteristics, trip chains in work related days and trip chains in non-work related days are introduced as latent variable in model 3 having strong correlation with the endogenous variables parking availability, simple home to work - work to home trip, travel by car. For the final proposed model it was revealed that all endogenous variables are positively related with latent variables. Two latent variables trip chain and trip behavior are introduced in this model. Final proposed model had good fit indices and could explain actual scenario of mode choice attributes; hence it may be considered as the best model.

Mode choice always has a negative relationship with "waiting at stations" and "time to reach destination". It is obvious that people do feel frustrated in waiting at stations and also they need access time to reach their respective modes as well. "Simple home to work and work to home" type trip chain has positive effect on the latent variable Trip behavior. Because this is a common type of trip chain for users in Dhaka city and also it takes short time.

The results match with real world scenario. It is needed to take into account that all significant variables have a role in making trip chains and mode choice. To this end a clear perception about assessing users' mode choice making according to their trip chains and household conditions is vital. The determination of the most and the least important trip chain and mode choice variables certainly helps to concentrate the limited resources of developing countries to improve users' experience.

The major limitation of this study is that experimental context is constrained due relatively small sample size. For further research more variety of data set and mode choice attributes can be included.

REFERENCES

Aditjandra, P. T., Cao, X. J., and Mulley, C. (2012). Understanding neighborhood design impact on travel behaviour: An application of structural equations model to a British metropolitan data. *Transportation research part A: policy and practice*, *46*(1), 22-32.

Adler, T., and M. Ben-Akiva. (1979). A Theoretical and Empirical Model of Trip Chaining Behavior.Journal of Transportation Research B, Vol. 13, No. 3, pp. 243-257.

Aftabuzzaman, M., Murumachi, Y., Harata, N., Ohta, K. (2010). Modeling Mode Choice Bahavior for Work-trip of a Developing City", Available at www.ut.utokyo. ac.jp/research/2010/olmd.pdf.

Anas, A. (1983). Discrete choice theory, information theory and the multinomial logit and gravity models. Transportation Research Part B, Methodological, 17(1), 13-23.

Bagley, M. N., and Mokhtarian, P. L. (2002). The impact of residential neighborhood type on travel behavior: a structural equations modeling approach. *The Annals of regional science*, *36*(2), 279-297.

Bari M. F. and Hasan M. (2001). Effect of Urbanization on Storm Runoff Characteristics of Dhaka City. Tsinghua University Press. XXIX IAHR Congress. Beijing.

Ben-Akiva, M. E. and Lerman, S. R. (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand*, The MIT Press, Cambridge, Massachusetts, USA.

Bentler, P. M., and Chou, C. P. (1987). Practical issues in structural modeling. *Sociological Methods & Research*, *16*(1), 78-117.

Bhat, C.R. Work Travel Mode Choice and Number of Non-work Commute Stops. Journal of Transportation Research B, Vol. 31, No. 1, 1997, pp. 41–54.

Boomsma, A. (1985). Nonconvergence, improper solutions, and starting values in LISREL maximum likelihood estimation. *Psychometrika*, *50*(2), 229-242.

Bordagaray, M., olio, L. d., Ibeas, A. and Cecín, P. (2014). Modelling user perception of bus transit quality considering user and service heterogeneity. Transportmetrica A, Transport Science, 10(8), 705–721.

Brown, C. H. (1993). Analyzing preventive trials with generalized additive models. *American Journal of Community Psychology*, *21*(5), 635-664.

Browne, M.W., Cudeck, R. (1993).Alternative way so assessing model fit. Sage Focus Ed.154,136–136.

Currie, G., and Delbosc, A. (2011). Exploring the trip chaining behaviour of public transport users in Melbourne. *Transport Policy*, *18*(1), 204-210.

Ding, L., and Zhang, N. (2016). A Travel Mode Choice Model Using Individual Grouping Based on Cluster Analysis. *Procedia Engineering*, *137*, 786-795.

Domencich, T. A., and McFadden, D. (1975). Urban Travel Demand. A Behavioral Analysis.Amsterdam: North-Holland.

Fuji, S. and Kitamura, R. (2000) Evaluation of Trip-inducing Effects of New Freeways Using a Structural Equations Model Systemof Commuters' Time use and Travel, Transportation Research B34, pp. 339-354.

Golob, T.F. R. Kitamura and C. Lula (1994). Modeling the Effects of Commuting Time on Activity Duration and Non-Work Travel. Presented at Annual Meeting of Transportation Research Board, Washington, D.C.

Golob, T.F. and McNally, M.G. (1997) A Model ofActivity Participation and Travel Interactions Between Household Heads, Transportation Research B31(3), pp. 177-194.

Golob, T.F (2000). A Simultaneous Model of Household Activity Participation and Trip Chain Generation. Transportation Research B34, pp. 355-376.

Gopinath, D. A. (1995). *Modeling heterogeneity in discrete choice processes: Application to travel demand*, PhD thesis, Massachusetts Institute of Technology.

Habib, K. M. N. (2002). Evaluation of Planning Options to Alliviate Traffic Congestion and Resulting Air Pollution in Dhaka City. M.Sc. Thesis, Departmet of Civil Engineering, BUET, Dhaka.

Habib, N.K., Day, N., Miller, E.J. (2009). An investigation of commuting trip timing and mode Choice in the Greater Toronto Area: application of a joint discrete-continuous model. Transp. Res. A 43(7), 639–653.

Hensher, D. A., and Reyes, A. J. (2000). Trip Chaining as a Barrier to the Propensity to Use Public Transport. Transportation, 27, 341–361.

Hooper, D., Coughlan, J., & Mullen, M. (2008). Structural equation modelling: Guidelines for determining model fit. Articles, 2.

Joreskog, K. G. (1973). Analysis of covariance structures. In P. R. Krishnaiah (Ed.), Multivariate Analysis-III ed. (pp. 263-285). New York: Academic Press.

Karlaftis, M. G., Golias, J., and Papadimitriou, E. (2001). Transit quality as an integrated traffic management strategy: Measuring perceived service. *Journal of Public Transportation*, *4*(1).

Kitamura, R., J. P. Robinson, T.F. Golob, M. A. Bradley, J. Leonard and T. van der Hoorn (1992). A comparative analysis of time use data in the Netherlands and California. In Proceedings of the 20th PTRC Summer Annual Meeting: Transportation Planning Methods, pp. 127-138.

Kitamura, R. (1996). Activity-based traveldemand forecasting and policy analysis. Presented at the TMIP Conference on Activity-Based Travel Forecasting, New Orleans, LA.

Kitamura, R., Yamamoto, T., Susilo, Y. O., & Axhausen, K. W. (2006). How routine is a routine? An analysis of the day-to-day variability in prism vertex location. *Transportation Research Part A: Policy and Practice*, *40*(3), 259-279.

Koppleman, F. S. and Wen, C. (2000). The Paired Combinatorial Logit Model: Properties, Estimation and Application", Transportation Research Record Part B: Methodological, *Journal of the Transport Research Board*, vol. 32, No. 2, pp. 75-89.

Kuppam, A.R. and R.M. Pendyala (2000). An exploratory analysis of commuters'activity and travel patterns. Presented at the 79th Annual Meeting of the Transportation research Board, Jan. 9-13, Washington, DC.

Lance, C. E., Vandenberg, R. J., and Self, R. M. (2000). Latent growth models of individual change: The case of newcomer adjustment. *Organizational behavior and human decision processes*, *83*(1), 107-140.

Lei, P. W., and Wu, Q. (2007). Introduction to structural equation modeling: Issues and practical considerations. *Educational Measurement: issues and practice*, *26*(3), 33-43.

Lu, X. and E.I. Pas (1997). A structural equations model of the relationships mong sociodemographics, activity participation and travel behavior. Presented at 76th Annual Meeting of the Transportation Research Board, January 12-16, Washington, DC.

MacCallum, R. C., Widaman, K. F., Zhang, S., & Hong, S. (1999). Sample size in factor analysis. *Psychological methods*, *4*(1), 84.

MacCallum, R. C., and Austin, J. T. (2000). Applications of structural equation modeling in psychological research. *Annual review of psychology*, *51*(1), 201-226.

MacDonald, HI. (1999). Women's employment and commuting: explaining the links. J Plan Literat 13(3), 267-283. doi: 10.1177/08854129922092397

Manski, C. F. (1977). The structure of random utility models. Theory Decision 8, 229 254. doi: 10.1007/BF00133443

McGuckin, N., & Nakamoto, Y. (2004). Trips, Chains and Tours-Using an Operational Definition. In *National Household Travel Survey Conference*.

McGuckin, N., Zmud, J., and Nakamoto, Y. (2005). Trip Chaining Trends in the U.S. Understanding Travel Behavior for Policy Making. Transportation Research Record, 1917, 199-204. doi:http://dx.doi.org/10.3141/1917-22.

Meka, S. (2003). A StructuralEquations Analysis of Within-Household Activity and Time Allocation Between Two Adults, Master Thesis, Department of Civil and Environmental Engineering, Universityof South Florida, Tampa, FL.

Nunnally, J. C., Bernstein, I. H., and Berge, J. M. T. (1967). *Psychometric theory* (Vol. 226). New York: McGraw-Hill.

Noland, R. B., and Thomas, J. V. (2007). Multivariate analysis of trip-chaining behavior. *Environment and Planning B: Planning and Design*, *34*(6), 953-970.

Ortúzar, J. de D. and Willumsen, L. G. (2001). *Modeling Transport*, 3rd Edition, John Wiley and Sons, Chichester, Sussex, England.

Primerano, F., Taylor, M. A., Pitaksringkarn, L., and Tisato, P. (2008). Defining and understanding trip chaining behaviour. *Transportation*, *35*(1), 55-72.

Schakenbos, R., L. La Paix, S. Nijenstein, K.T. Geurs (2016). Valuation of a transfer in A multimodal public transport trip. Transport Policy, 46, 72-81.

Schmöcker, J., F. Su, and R.B. Noland. (2010). An Analysis of Trip Chaining among Older London Residents. *Transportation*, Vol. 37, No. 1, pp. 105-123.

Sekhar, R. C. (2014). Mode Choice Analysis: The Data, the Models and Future Ahead. *International Journal for Traffic and Transport Engineering*, *4*(3).

Simma, A., and Axhausen, K. (2001). Within-household allocation of travel: Case of upper Austria. *Transportation Research Record: Journal of the Transportation Research Board*, (1752), 69-75.

Shiftan, Y., Outwater, M. L., and Zhou, Y. (2008). Transit market research using structural equation modeling and attitudinal market segmentation. *Transport Policy*, *15*(3), 186-195.

Strathman, J.G., K.J. Dueker, and J.S. Davis. (1994). Effects of Household Structure and Selected Travel Characteristics on Trip Chaining. Transportation, Vol. 21, No. 1, pp. 23-45.

Strathman, J. G., and Dueker, K. J. (1995). *Understanding trip chaining. Special reports on trip and vehicle attributes, 1990 NPTS reports series, publication No*. FHWA-PL-95-033, Department of transportation.

STP (2005). Strategic Transport Plan for Dhaka, Prepared by Louis Berger Group and Banndladesh Consultant Ltd.

Steiger, J. H. (1990). Structural model evaluation and modification: An interval estimation approach. *Multivariate behavioral research*, *25*(2), 173-180.

Timmermans, H., van der Waerden, P., Alves, M., Polak, J., Ellis, S., Harvey, A. S., and Zandee, R. (2003). Spatial context and the complexity of daily travel patterns: an international comparison. *Journal of Transport Geography*, *11*(1), 37-46.

Train, K. (1998). Recreation Demand Models with Taste Differences over People. *Land Economics*, vol. 74, pp. 230-240.

Wallin Andreassen, T. (1995). (Dis) satisfaction with public services: the case of public transportation. *Journal of Services Marketing*, *9*(5), 30-41.

Walker, J., L. (2001). Extended Discrete Choice Models, Integrated Framework, Flexible Error Structure, and Latent Variables. Doctor, MIT.

Wiley, D. E. (1973). The identification problem for structural equation models with unmeasured variables. In A.S. Goldberger, & O.D. Ducan (Eds.), Structural Equation Models in the Social Science (pp.69-83). New York: Seminar Press.

Ye, X., Pendyala, R. M., and Gottardi, G. (2007). An exploration of the relationship between Mode choice and complexity of trip chaining patterns. Transportation Research Part B: Methodological, 41(1), 96-113

Yun, M.P., Chen, Z.H., Liu, J.Y. (2014). Comparison of mode choice behavior for work tours And Non work tours considering trip chain complexity. Presented at the 93rd annual meeting of the Transportation Research Board, Washington.