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Unraveling the Relationship between Trip Chaining and Mode Choice using Structural Equation Models

by

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DEDICATION

To My Parents

ABSTRACT

Trip chaining and mode choice are two important travel behavior decisions in activity-based travel demand modeling system. The hierarchy of these two decisions influences model's predictive capability and policy sensitivity. This thesis is aimed at investigating the hierarchical relationship between these decisions and also the effects of socio-demographic characteristics on them. Structural Equation Modeling (SEM) technique is used for this investigation. A six week travel diary data collected in Thurgau, Switzerland in 2003 is used for model estimation. Model estimation results show that for work-tour, trip chain and mode choice decisions are simultaneous and it remains consistent across the six weeks. For weekday's non-work tour, mode choice precedes trip chain whereas for weekend's non-work tour trip chain precedes mode choice. The investigation of the effect of a number of socio-demographic characteristics on trip chaining and mode choice behaviors is also found useful for better understanding of these behaviors.

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CHAPTER 1

INTRODUCTION

1.1 Background

Various studies and survey results show that peoples' travel patterns are becoming more complex day by day because of individual's desire for activity fulfillment with minimum amount of travel (David and Kumar, 1996; Hensher and Reyes, 2000; McGuckin, et al., 2005; Ye, et al., 2007). Peoples' desire of minimizing travel time may lead to the propensity of linking single trip of various activities together in a single journey rather than making a number of unlinked trips for each of the activities separately (Shiftan, 1998; Hensher and Reyes, 2000).

The analysis of trip chaining or trip linking behavior is important for better understanding of peoples' travel behavior and transportation policy sensitivity analysis (Strathman and Dueker, 1995). A significant amount of research works have been conducted on travelers' trip chaining behavior, sometimes called stop making behavior (Adler and Ben-Akiva, 1979; Strathman et al., 1994; Bhat, 1997; Bhat, 1999; Golob, 2000; Chu, 2003; Chu, 2004; Lee, 2007; Ye et al., 2007; Ye, 2010). These literatures reveal no commonly accepted definition of trip chain. A good summary of the various commonly used definitions of trip chain in travel behavior research is presented by Primerano et al. (2008). The trip chain, also known as tour, is defined as a sequence of trips that begins at home, involves visits to one or more places, and ends at home. Several reasons are described by Primerano et al. (2008) as to why home-to-home type of trip chain definition is adopted in almost all literatures. Depending on the presence or absence of work place within the trip chain, it can be classified as work-related trip chain or non-work-related trip chain. Furthermore, a number of categorizations of each type of trip chain can be made based on the number of non-home stops made within the trip chain. This trip chaining phenomenon is especially prevalent for workers, due to their time constraints to perform non-work activities. Workers have a tendency to link various non-work activity related trips during their morning and evening commutes in weekdays. Thus, many studies have been carried out which focused on investigating only workers trip chaining behaviors (Bhat, 1997; Wegmann and Jang, 1998; Bhat, 1999; Bhat and Singh, 2000; Kuppam and Pendyala, 2001, Chu, 2003, Chu, 2004). However, most of the existing literatures classify trip chain as simple or complex. Simple chains or tours can be defined as those that involve one out-of-home stop within the chain or tour, and complex chains can be defined as those that involve two or more out-of-home stops within the chain.

Trip chaining has important implications in transportation policy analysis and travel demand management (Ye et al., 2007; Lee et al., 2007). Complex trip chain patterns may lead to the tendency of more auto usage and corresponding more auto traffic on the road network because of its more flexibility to stop in multiple locations in a single journey than public transit (Ye et al., 2007;

Strathman and Dueker, 1995; Wallace et al., 2000). The ability to make complex trip chain is limited in case of public transit because of constraints imposed by its routes, frequency, uncertainty etc (Hensher and Reyes, 2000). Commuters' tendency of linking non-work activity related trips in their morning and evening work commutes may lead to a spreading of morning and evening peak periods (Ye et al., 2007).

It is now widely accepted that there is a close relationship between mode choice and trip chaining behavior of travelers. This relationship has caused the shifting of mode choice behavior research from trip-based to tour-based approach in activity based travel demand modeling (Ben-Akiva et al., 1998; Millar et al., 2005). Several studies show that the complex tours may tend to be more auto-oriented (Strathman and Dueker, 1995; Wallace et al., 2000). However, the directionality of the causality between mode choice and trip chain patterns is not quite understood. One may first decide to make particular trip chain pattern based on his/her personal and household need and then choose a mode that is convenient for making the selected trip chain. On the other hand, one may first choose a mode and then based on the flexibility and convenience offered by that mode, he/she may plan his trip chain pattern.

The hierarchical relationship between trip chain and mode choice has important application in developing activity based travel demand modeling. Activity based travel demand models are based on the conception that travel is a derived demand which arises from the need to participate in various out-of-home activities. Trip chain arises in the process of activity scheduling and rescheduling. In ALBATROSS, an activity scheduling model, mode choice is incorporated in activity scheduling process itself. This model first defines the mode for primary work activities and later defines mode for trip chains (Arentze and Timmermans, 2004). TASHA, another activity scheduling model also includes tour-based mode choice model, but the sequence of choices is activity generation, activity location choice, activity scheduling, household level tour mode choice and finally trip assignment (Miller and Roorda, 2003). Kitamura et al. (2000) assume the sequence of travel decisions as activity type choice, activity duration choice, activity location choice and travel mode choice as last step in their proposed micro-simulator for the generation of daily activity-travel patterns. FAMOS, developed by Pendyala et al. (2005), is another activity based travel demand model where sequence of submodels is activity type choice models, activity duration models, and destination and mode choice model. CEMDAP, developed by Bhat, et al. (2004), defines the trip chain first and then model the mode choice for the selected trip chain.

It is found from most of the activity based travel demand models that, mode choice is considered after formation of trip chain or activity scheduling. Obviously, the assumed hierarchy of decisions in an activity-based travel demand model influences its predictive capacity and policy sensitivity. Clear understanding of the underlying mechanism of travelers' decision process during making a trip is important for accurate and reliable application of the travel demand models. People's activity scheduling or trip chaining pattern and mode choice are two very important decisions, the sequence of which need to be clearly understood for realistic travel demand modeling. Thus, it is useful to empirically test the hierarchy regarding the decisions of trip chain formation and mode choice.

Some trip chaining studies assumed mode choice as an exogenous (explanatory) variable and trip chaining as decision variable (Strathman et al., 1994; Chu, 2003; Chu, 2004). These studies found that mode has significant effect on trip chaining behavior. Some other studies assumed both trip chain and mode choice as decision variables and showed that there is a strong correlation between mode choice and trip chaining (Bhat, 1997, Bhat and Singh, 2000). But, these studies don't confirm the hierarchy of the choice decisions between trip chain and mode choice. A very few studies have focused on investigating the directionality of trip chain and mode choice decisions (Strathman and Dueker, 1995; Ye et al., 2007; Ye, 2010).

Strathman and Dueker (1995) used a nested logit (NL) model to investigate the causal relationship between mode choice and trip chaining. Their result suggests that trip chain precedes mode choice. However, NL does not provide parameters directly measuring causal effects. Also, the NL model has restriction on inclusive value parameter coefficient. Ye et al. (2007) investigated the causal relationship between mode choice and trip chaining patterns using recursive bivariate probit modeling framework and simultaneous logit model. They found that trip chaining precedes mode choice for non-work tours. For work-tour, the relationship is less conclusive. They used 2000 Swiss Travel Microcensus data for their investigation. However, they considered a simplified classification of trip chain pattern and mode type. Also weekdays versus weekends travel behavior is not investigated. Ye (2010) also investigated the relationship between mode choice and non-work tour by using two-stage semi-nonparametric method. His results imply that travelers who have plan to make a complex tour will heavily consider the flexibility and convenience of auto mode use, but travelers already using automobiles will only consider the flexibility in making multi-stop tour as an additional benefit but not an urgent requirement. However, data set used for the study is also weekdays and weekend aggregated non-work tour extracted from the 2000 Swiss Travel Microcensus. Estimation of the model was limited information maximum likelihood.

From the above discussions it is clear that the mode choice and trip chaining behavior has a lot of implications in the development of activity-based travel demand model, transportation policy analysis, travel demand forecasting and travel demand management. It is also clear that there is still lack of understanding regarding the interrelationship between these two important travel behavior decisions. This thesis is aimed at further investigation of the hierarchical relationship of workers' trip chaining and mode choice behavior. A very rigorous investigation is performed by estimating a series of structural equation models. The availability of six week travel diary data provides the privilege to investigate the relationship for weekdays and weekends separately compared to traditional one-day trip diary data. It is more realistic to analyze workers' travel behavior separately for weekdays and weekend because weekday's travel behavior is likely to be influenced by the time constraint imposed by work time and duration. A much detailed trip chain patterns and mode types are considered to capture the complex trip chain and mode choice behavior. After an extensive literature review Structural Equation Modeling (SEM) technique is found to be the most appropriate for investigating such interrelationship.

1.2 Objectives

Above discussions clearly show the necessity of examining the causal relationship between trip chain pattern and mode choice for various transportation policy analyses and activity based travel demand modeling. The specific objectives of this thesis can be summarized as follows:

- Investigating whether trip chaining influences mode choice or mode choice influences trip chaining or both are decided simultaneously.
- Testing the consistency of the relationship among weekdays, weekends, work related trip chains and non-work-related trip chains.
- Testing the consistency of the causal relationship across the weeks.
- Checking the justification of the detailed classification of trip chain patterns and mode type made.

- Investigating the effects of socio-demographic and land use characteristics on trip chain pattern and mode choice.

1.3 Methodology

Structural Equation Modeling (SEM) technique is found to be the most suited technique for fulfilling the objectives of this thesis. Also, SEM can be estimated with readily available software. Model estimation in this thesis is performed by using LISREL software. SEM technique has been extensively applied in social science research to investigate the causal relationships. SEM technique has become increasingly popular in travel behavior research in the recent time because of its flexibility for analysis of complex causal relationship among a large number of exogenous and decision variables (Roorda and Ruiz, 2008). In this thesis, two latent variables: trip chaining utility and mode choice utility are used in the specified model structure. Trip chain patterns are used as indicator variables for the former latent variable and mode types are used as indicator variables for latter one. It is hypothesized that socio-demographic characteristics affect the trip chain and mode choice utilities, which define peoples' trip chaining pattern and mode choice. Detail description of the methodology is provided in chapter 3.

1.4 Thesis Outline

The thesis consists of six chapters. Chapter 2 presents a literature review on trip chaining behavior and mode choice behavior. It reviews the relevant papers available that use Structural Equation Modeling (SEM) technique as well as other methodology for analyzing trip chaining and mode choice behavior. A description of SEM technique and its goodness of fit are also provided at the end of this chapter.

Chapter 3 presents a description of the conceptual modeling framework for the causal relationship to be tested and the hypotheses that are being tested in this thesis.

Chapter 4 presents a brief description of six week travel diary data collected in Switzerland and describe how the data is processed for model estimation. It also provides preliminary statistical characteristics of the dataset.

Chapter 5 presents the details of all empirical models estimation results with discussion.

Finally, Chapter 6 summarizes the main findings of the thesis with some recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Outline

This chapter presents an extensive review of literatures that deal with trip chaining and mode choice behavior. After a brief description of the importance of trip chaining and mode choice behavior research in the next section, this chapter summarizes the available literature on trip chaining and mode choice in general along with the inherent limitations of these studies. Then, it introduces the Structural Equation Modeling (SEM) technique which has been extensively used in social science. Application of SEM in travel behavior research is briefly summarized at the end which shows the potential of using this technique for this thesis.

2.2 Importance of Trip Chaining and Mode Choice

The trip chain, also known as tour, is defined in this thesis as a sequence of trips that begins at home, involves visits to one or more places, and ends at home. As peoples' travel patterns are becoming more complex day by day, trip chaining phenomenon has received great attention to the researchers. Former trip-based analysis of travel behavior is now being replaced by tour-based analysis in activity-based travel demand modeling (Ben-Akiva et al., 1998; Dissanayake and Morikawa, 2002). It is now believed that if, for example, someone makes a home to work trip, he/she does not consider this trip in isolation, rather he/she plans for the complete tour and makes all related decisions prior making the tour. Thus, trip chain or tour analysis may provide a better understanding of travelers' behavior compared to trip analysis. The analysis of trip chaining or trip linking behavior is important for transportation policy sensitivity analysis and travel demand management (Strathman and Dueker, 1995). Trip chaining phenomenon is found more prevalent for workers because of their tendency to link non-work activity related trips in their morning and evening work commutes. This may lead to the spreading of morning and evening peak periods (Ye et al., 2007). Thus, trip chaining has important implications in travel demand management as well as traffic operation and control field.

Mode choice and trip chaining are two very important travel decisions that are found closely related from various studies (Bhat, 1997; Bhat and Singh, 2000). This results the shifting of travel behavior analysis from trip-based to tour-based approach (Ben-Akiva et al., 1998; Millar et al., 2005). The hierarchical relationship of mode choice and trip chain has important application in developing activity based travel demand modeling. In activity-based travel demand modeling, travelers' travel related all decisions are modeled following a sequence of the decisions. Without being able to capture the actual sequence of travelers' decisions in the model, it is not expected to obtain a model with good forecasting capacity. Most of the activity-based travel demand models assume trip chain/ activity scheduling precedes mode choice. The assumed hierarchy of decision influences its predictive capacity and policy sensitivity. Clear understanding of the underlying mechanism of travelers' decision process during making a trip is important for accurate and reliable application of the travel demand models for transportation policy analysis and travel demand forecasting.

The hierarchical relationship between trip chain and mode choice has important implication also for public transport service providers. If mode choice decision precedes activity scheduling or trip chain pattern decision, then public transport service providers have a greater chance to attract riders by improving service quality, frequency, accessibility, safety and security, and comfort. On the other hand, if the activity scheduling precedes mode choice decision, then the public transport industry has a greater challenge to attract riders. (Ye et al., 2007)

2.3 Trip Chain and Mode Choice Research

Trip chaining behavior analysis in existing literature can be classified into two groups. One group of studies is focused on predicting the number of stops made within the chain especially the number of stops made by the commuters during their morning and evening commute between home and work (Adler and Ben-Akiva, 1979; Bhat, 1997; Bhat, 1999; Bhat and Singh, 2000; Chu, 2003; Chu, 2004). Other group of studies is focused on defining trip chaining or tour pattern of travelers and investigated the effect of various socio-demographic characteristics on it. A number of studies show that complex trip chains are likely to be auto-oriented (Strathman et al., 1994; Wallace et al., 2000). Hensher and

Reyes (2000) showed that trip chaining acts as a barrier to the propensity to use public transit. However, these studies do not indicate the directionality of the causal relationship between trip chain and mode choice decisions. A very few studies have focused on investigating the directionality of trip chain and mode choice (Strathman and Dueker, 1995; Ye, 2007; Ye, 2010).

Adler and Ben-Akiva (1979) developed a multinomial logit model based on random utility maximization (RUM) theory and taking account of the trade-offs involved in the choice of multiple-stop chains. A household's choices of daily travel patterns are derived from this theoretical model. The authors described optimum travel pattern by the number of chains (tours) traveled on a given day and by the number of stops made on each of those chains. Their result suggests the necessity of considering trip chaining behavior in travel demand forecasting model.

Golob (1986) presented a nonlinear canonical correlation analysis to investigate the relationship between trip chain, socioeconomic and socio-demographic characteristics of the trip makers. Twenty types of home-based trip chains were identified based on the sequence of away-from-home activities. This study was only focused on trip chain pattern analysis. Mode choice corresponding to the trip chain pattern was not taken into account.

Strathman et al. (1994) developed a logit model to analyze the effect of household structure and travel characteristics on trip chaining and allocation of household non-work trips to alternative work and non-works chains using 24-hours data collected in weekday from Portland, Oregon. In their study, chains were classified as simple work, complex work, simple non-work and complex non-work. Mode choice is used as an exogenous variable in their model rather than considering it as dependent or decision variable. Results suggest that tendency to form complex work chain is significantly higher for women, people who drive alone to work, workers from higher income household.

David and Kumar (1996) performed a comparative study to see the change in people's travel pattern using 1968 and 1987-88 metropolitan Washington, DC household travel surveys. They showed that in 1988, 15 percent home to work trips are linked, having stoppage on the way for non-work purposes, and 31 percent trips from work to home are linked. These figures were 1.5 percent and 9 percent in 1968. This clearly shows that people's travel behaviors are becoming more complex day by day. This complexity may arise from the increased auto-ownership, improvement of technology or because of the increased spatial accessibility.

Bhat (1997) developed a joint model of work mode choice and number of non-work activity stops during the work commute. A multinomial logit model is used for mode choice and ordered-response formulation is used for modeling number of stops. Result shows a strong correlation between the random components influencing mode choice and stop-making tendency. However, it does not show whether the correlation is unidirectional or reciprocal.

Shiftan (1998) developed a system of logit models that distinguishes between two main types of tours: a tour that includes one or more work destinations is defined as a work-related tour (WRT); all other tours are defined as nonwork-related tours (NWRT). The model takes a hierarchical structure with auto ownership at higher level and frequency of WRT at next level. Based on the frequency of WRT, frequency of NWRT is modeled.

Bhat (1999) applied standard ordered-response logit (ORL) model and random coefficients heteroscedastic ordered response logit (RCHORL) model to analyze the number of stops made by individuals during work-to-home commute. He estimated two models using multiple-weekdays activity diary data collected from San Francisco Bay area to capture the variation in stop-making propensity across individuals due to (a) observed individual, land-use, and work-related characteristics such as sex, income, work duration, (b) unobserved individual characteristics such as lifestyle/mobility preferences and (c) sensitivity differences to work-related attributes such as differences in responsiveness to work duration. However, this study does not consider the mode of travel, which may have significant effect on stop making behavior.

Bhat and Singh (2000) developed a joint model of evening commute work mode choice (unordered discrete variable), number of evening commute stops (ordered discrete variable), and number of post home arrival stops (ordered discrete variable). Their model shows strong correlation between the random components of the three choice decisions. However, their finding does not show any hierarchy of the three decisions.

Hensher and Reyes (2000) used multinomial logit, nested logit and random parameter logit models to improve the understanding of trip chaining as a barrier to the propensity to public transport use. They found that as trip chain moves from simple to complex in nature, the relative utility gained from using public transport decreases. However, they didn't investigate the hierarchical relationship between trip chain and mode choice decisions.

Wallace et al. (2000) presented a negative binomial regression model using travel diary data to identify the factors influencing traveler's trip chaining behavior. The study suggests that household characteristics variables like household size and income has negative impact on complex trip chaining tendency. Among the individual level characteristics only gender tends to have significant impact. However, a limited number of individual level characteristics were tested in their study. Though their result suggests that car users are likely to link more trips in a trip chain, it does not confirm the directionality of influence.

Chu (2003) developed a set of stop frequency models to predict the number of non-work activity stops made by the adult worker during morning commute, evening commute and during their work hours. Mode choice is used as exogenous variable in the model.

Chu (2004) used a multivariate probit model to predict workers' stop-making propensity and the potential interaction in stop-making over different time periods in a working day. The model considers four types of explanatory variables: individual and household socio-demographics, land use measures, transportation related attributes and work schedule attributes. Model result suggests that stop-making propensity among different time periods is interrelated. However, mode choice is used as exogenous variable in the model.

McGuckin, et al. (2005) investigated work related trip chaining trends in the United States using data from the 1995 nationwide personal transportation survey and the 2001 national household travel survey. Results show that home to work trip chain increased by 21 percent and chain in both directions increased by more than 12 percent. However, work to home trip chaining stayed about the same.

Lee et al (2007) presents simultaneous doubly-censored tobit models to examine time allocation patterns within household-level trip chaining. This study also investigates the effect of household socio-demographic characteristics on trip chain behavior. By the term trip chain behavior, they refer duration of subsistence, mandatory and discretionary out-of-home activities.

Some of the papers discussed above either assumed mode type as exogenous variable or didn't consider mode type to analyze the trip chaining or stop making behavior. Others assumed both mode type and trip chain pattern as decision variables and found that they are correlated. But, neither of these papers confirms any hierarchy of the decision process. A very few studies focused on investigating the directionality of trip chain and mode choice decisions are discussed below.

Strathman and Dueker (1995) used a nested logit (NL) model to investigate the causal relationship between mode choice and trip chaining. They considered seven work and non-work trip chain patterns and two types of mode (car and public transport) in their analysis. Using a sequential modeling approach between trip chain type choice and mode choice, their result suggests that trip chain precedes mode choice. However, NL does not provide parameters directly measuring causal effects. Also, the NL model has restriction on inclusive value parameter coefficient (Ye et al., 2007).

Ye et al. (2007) investigated the relationship between mode choice and trip chaining patterns using recursive bivariate probit modeling framework and simultaneous logit model. They found that trip chain precedes mode choice for non-work tours. For work-tour, either trip chain precedes mode choice or both are simultaneous. They used 24-hrs 2000 Swiss Travel Micro-census data which was collected through-out the year. However, their analysis does not differentiate between weekdays versus weekend travel behavior and worker versus non-worker travel behavior. Only two types of trip chain patterns and auto versus non-auto mode classification is used in the analysis.

Ye (2010) also investigated the relationship between mode choice and non-work tour by using two-stage semi-nonparametric method. His results imply that travelers who have plan to make a complex tour, heavily consider the flexibility and convenience of auto mode use but travelers already using automobiles only consider the flexibility in making complex tour as an additional benefit but not an urgent requirement. However, the data set used for the study was also weekdays and weekend aggregate non-work tour extracted from the 2000 Swiss Travel Microcensus. Both trip chain choice and mode choice are modeled as binary choice. Estimation of the model was limited information maximum likelihood.

It is clear from the above discussion that there is still a lack of understanding regarding the interrelationship the trip chain and mode choice decisions. A detailed disaggregate level investigation of these two choices decision may provide a stable hierarchical relationship between them.

2.4 SEM Technique in Transportation Research

Structural Equation modeling (SEM) technique has been extensively applied in social sciences, political sciences, biological sciences, psychology and in market research. Most of these research areas deal with human behavior. This technique is used in these research fields in order to investigate the relationship between human responses and their characteristics. This technique has become increasingly popular in travel behavior research in the recent time because of its flexibility for analysis of complex causal relationship among a large number of exogenous and decision variables. After being introduced in travel behavior research in 1980s, SEM is becoming widely used in the analysis of travel demand and many other component of transportation research. Golob (2003) presents an excellent review of SEM application in travel demand modeling, using both cross-sectional and panel data, activity-based travel demand modeling, driver behavior analysis and other related component of travel behavior.

Kuppam and Pendyala (2001) applied SEM with frequency of complex trip chain formation as decision variable and activity participation and socio-demographic characteristics as exogenous variables. A 24-hour revealed preference survey data of commuters in metropolitan area of Washington, DC was used to estimate the model. Trip chain was classified as simple work, complex work, simple non-work and complex non-work. Model results suggest that elderly commuters make fewer complex trip chains. Higher income commuters tend to make a greater number of complex trip chains. However, mode type was not considered in the model.

Golob (2000) used SEM to investigate relationship among decision variables of work and non-work activity duration, trip chain and travel time. Household characteristics and accessibility indices are used as exogenous variables. A two-day activity diary data collected from Portland, Oregon was used to estimate the model. All home based trip chain (tours) was classified into four categories. These were: work only (simple and complex), work-nonwork, simple non-work and complex nonwork tours. The model used counts of trip chain made by all household members. Mode choice is not considered in trip chain analysis.

Lu and Pas (1999) used SEM technique to investigate the interrelationship among socio-demographics, activity participation and travel behavior. A 48-hour period data obtained from Oregon-Southwest Washington activity and travel survey of 1994/95 was used for model estimation. In activity participation they considered time allocation on subsistence, maintenance, recreation and other activities. Travel behavior related variables included number of trips, travel time, car mode share and number of trip chains.

Jang (2003) used a structural equation model to investigate the joint relationships among travel mode choice, activity participation and travel pattern using a 24-h travel day data collected from Jeonju city of Korea. In his study, travel patterns were classified as simple and complex trip chain. But mode choice data was not tour-based rather it was trip-based.

Apart from trip chain analysis discussed above, SEM technique is being used in investigating the various causal relationships in transportation field. A brief summary is discussed below.

Golob (1989) applied SEM for modeling the causal relationships among income, car ownership, and trip generation by mode at the household level. Kitamura (1989) used SEM to examine the causal relation between car ownership and transit use. Dutch national mobility panel survey data was used to estimate the model. Results suggest that increase in car use, which results from increased car ownership, may not be suppressed by improving public transit. Golob (1990) developed a dynamic SEM to link car ownership, travel time per week by car, travel time by public transit, and travel time by nonmotorized modes with household characteristics. Wissen and Golob (1992) used SEM to investigate the relationship between car mobility and the choice of alternative-fuel versus gasoline cars. Golob et al. (1996) applied SEM for investigating how households use different types of vehicles. Golob and McNally (1997) used SEM to explain activity interaction between heads of households and to explain household demand for travel. Fujii and Kitamura (2000) presented an SEM system to investigate the effect of transportation control measures on commuters' daily activity pattern after work hours. Parameters were estimated using one-day activity diary data collected from Osaka-Kobe metropolitan area. Golob and Regan (2000) applied SEM to investigate the freight industry attitudes towards policies to reduce congestion. Golob and Regan (2001) used SEM to explore how road congestion adversely affects trucking operations. Golob (2001) used SEM for jointly modeling people's attitudes and behavior to explain how both mode choice and attitudes regarding the congestion pricing project differ across the population. Roorda and Ruiz (2008) applied SEM technique to explore the long and short-term dynamics in activity scheduling. Four model structures were estimated to investigate the dynamics of the propensity of mode choice, activity duration choice. Xu, et al. (2010) used SEM to examine and analyze the relationship among travelers' intentions of accepting travel information, trust in travel information, perceived usefulness of travel information, perceived ease of use and other related variables. Yang (2010) applied SEM to investigate the relationship between socio-demographics, activity participation and trip chaining between household heads. Martínez et al. (2010) used SEM to analyze interaction of various land use and accessibility factors as well as household socioeconomic and attitudinal characteristics to examine residential area satisfaction.

2.5 Structural Equation Model

A full structural equation model, also called simultaneous equation model, is composed of three set of equations (or three sub-models): (1) a measurement model for the decision (dependent) variables (2) a measurement model for exogenous (independent) variables and (3) a structural model. However a full SEM is rarely applied in practice. An SEM measurement model is used to specify a set of latent (unobserved) variables as linear functions of other observed decision or exogenous variables. In a full SEM, structural model is used to capture the causal influences among the latent exogenous and latent decision variables. If no measurement model is used, structural model capture directly the causal influences of the observed exogenous variables on the observed decision variables and the causal influences among observed decision variables. SEM, that have measurement model only for observed decision variables, structural model involves latent decision variables rather than observed decision variables. Similarly for SEM with measurement model only for observed exogenous variables, structural model involves latent exogenous variables rather than observed exogenous variables. In this thesis, SEM with a structural model and a measurement model for the decision variables is used. The typical path diagram of the corresponding SEM is shown in Figure 3.2.

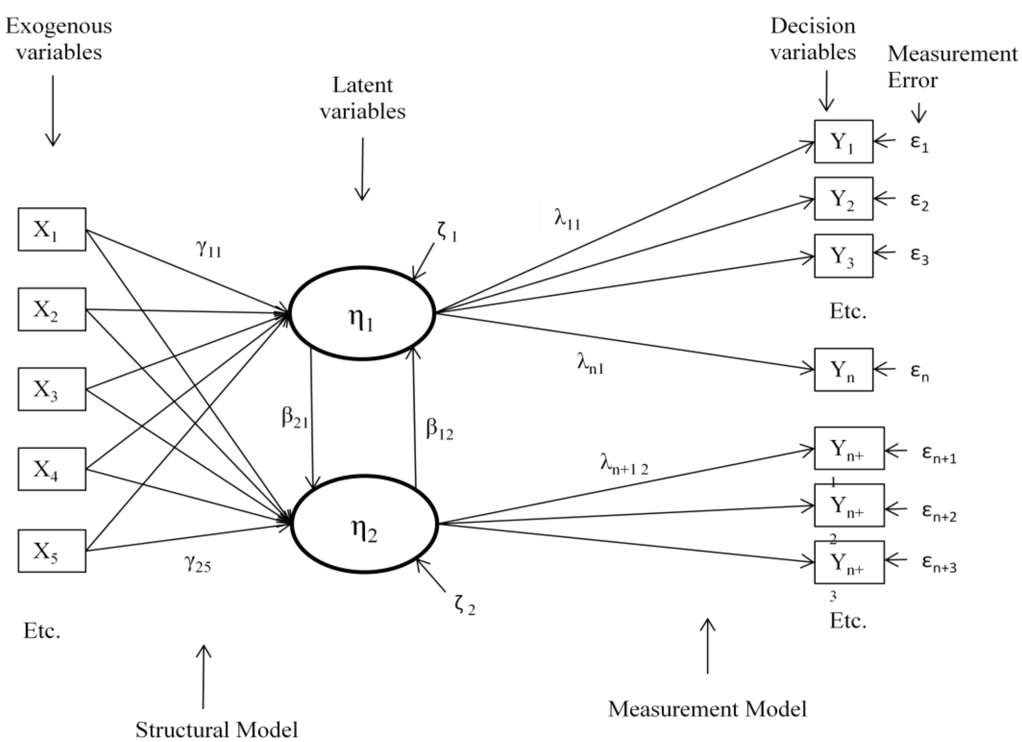

Figure 2.1: Typical SEM path diagram

Corresponding equations can be written as follows:

Structural equations:

$$\eta = \mathrm{B}\eta + \Gamma X + \zeta \qquad (1)$$

$$\begin{bmatrix}\eta_1\\ \eta_2\end{bmatrix} = \begin{bmatrix}0 & \beta_{12}\\ \beta_{21} & 0\end{bmatrix}\begin{bmatrix}\eta_1\\ \eta_2\end{bmatrix} + \begin{bmatrix}\gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{14} & \dots\dots\\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{24} & \dots\dots\end{bmatrix}\begin{bmatrix}X_1\\ X_2\\ X_3\\ \cdot\\ \cdot\\ \cdot\\ \cdot\end{bmatrix} + \begin{bmatrix}\zeta_1\\ \zeta_2\end{bmatrix}$$

Measurement equations:

$$\mathrm{Y} = \Lambda_{\mathrm{y}}\eta + \varepsilon \qquad (2)$$

$$\begin{bmatrix}Y_1\\ Y_2\\ Y_3\\ Y_4\\ \cdot\\ \cdot\\ \cdot\end{bmatrix} = \begin{bmatrix}\lambda_{11} & 0\\ \lambda_{21} & 0\\ \lambda_{31} & 0\\ \cdot & 0\\ \cdot & 0\\ 0 & \lambda_{n+12}\\ 0 & \lambda_{n+22}\\ 0 & \cdot\end{bmatrix}\begin{bmatrix}\eta_1\\ \eta_2\end{bmatrix} + \begin{bmatrix}\varepsilon_1\\ \epsilon_2\\ \epsilon_3\\ \cdot\\ \cdot\\ \cdot\\ \cdot\end{bmatrix}$$

From equation (1) and (2),

$$\mathrm{Y} = \Lambda_{\mathrm{y}}(I - B)^{-1}(\Gamma X + \zeta) + \varepsilon \qquad (3)$$

Where,

X = vector of exogenous variables,

Y = vector of decision variables

η = vector of latent dependent or decision variables Y

ε = vector of measurement errors in Y

B = matrix of coefficients of the η-variables in the structural relationship.

ζ = vector of equation errors (random disturbances) in the structural relationship between η and X.

Γ = matrix of coefficients of the X-variables in the structural relationship.

Λ_y = matrix of coefficients of the regression of y on η

Two decision latent variables: trip chain utility and mode choice utility are used in the proposed SEM framework. In measurement model trip chain utility latent variable has indicator variables of specified trip chain patterns and mode choice utility variable has indicator variables of specified types of mode choice. Each types of trip chain patterns and mode choice variables represents the day level counting of each chains patterns and mode type observed in the data.

Structural equation model is estimated based on covariance analysis, also known as method of moments, where the difference between the sample covariance matrix and the model implied covariance matrix is minimized (Bollen, 1989). The fundamental assumption is that, the population covariance matrix of observed variables can be expressed as a function of unknown parameters θ (Lu and Pas, 1999). This can be expressed in the following way,

$$\Sigma = \Sigma(\theta)$$

Where,

Σ is the population covariance matrix of observed variables

θ is the vector of the unknown parameters of the model

$\Sigma(\theta)$ is the covariance matrix expressed as a function of θ

Variance-covariance matrix of the combined set of decision and exogenous observed variables is defined in the following way (Golob, 2000):

$$S = \begin{bmatrix} S_{YY} & S_{YX} \\ S_{YX}^{/} & S_{XX} \end{bmatrix}$$

Where S_{YY} denotes the variance-covariance matrix of the decision variables, S_{YX} denotes the covariance matrix between decision and exogenous variables, and S_{XX} denotes the variance-covariance matrix of the exogenous variables. The variance-covariance matrix implied by the model (1) can be written as (Jöreskog and Sörbom, 1996-2001)

$$\Sigma = \begin{bmatrix} \Sigma_{YY} & \Sigma_{YX} \\ \Sigma_{YX}^{/} & \Sigma_{XX} \end{bmatrix}$$

Where,

$$\Sigma_{YY} = \Lambda_Y \Omega \Lambda_Y^{/} + \Theta_\epsilon$$

$$\Sigma_{YX} \Sigma_{XX}^{-1} == \Lambda_Y (\mathrm{I} - \mathrm{B})^{-1} \Gamma$$

Ω is covariance matrix of η

Θ_ϵ is the covariance matrix of ϵ, which is a diagonal matrix here.

An important step before model estimation is to ensure that each component of the model is identified. Structural equation model is basically a set of simultaneous linear equations. To obtain correct parameter estimates, the set of equations must be identified regardless of the sample size. Model identification problem can be resolved by imposing some constraint on model parameters. This restriction can be imposed by fixing some parameter's value to a pre-defined value or fixing some error terms to zero. If the reliability of the measurement of an observed variable is known, error term for that variable can be defined as (1-reliabilty) times variance of the variable (Jöreskog and Sörbom, 1996-2001). A very detailed discussion on SEM identification can be found in Hayduk (1996), Bollen (1989) and O'Brien (1994).

The unknown parameters of the model are estimated so that the model implied covariance matrix, $\sum$ is as close as possible to the sample covariance matrix, S.

A number of parameter estimation methods can be used for structural equation model which includes: Maximum Likelihood (ML), Two-Stage Least Square (TSLS), Generalized Least Squares (GLS), Unweighted Least Squares (ULS), Weighted Least Squares (WLS), and Diagonally Weighted Least Squares (DWLS). LISREL 8.8, which is used here for model estimation, has all of these estimation methods. However, in this study, ML estimation method is used. This method provides the most precise estimators and is relatively robust against violations of the normal distribution assumption. Several research studies showed that ML estimation method provides quite well and consistent parameters estimate under violation of multivariate normality (Golob and McNally, 1997; Boomsma, 1987).

For a given sample data, ML maximizes the likelihood of the parameters which is equivalent to minimizing fitting function (F) (Kelloway, 1998).

$F_{ML} = \log|\sum(\theta)| + \mathrm{tr}(S\sum^{-1}) - \log|S| - (p+q)$

Where, p is the number of decision variables and q is the number of exogenous variables.

2.6 SEM Goodness of Fit

There are numerous goodness of fit indices available to test the fit of the model to the observed data. Some of the important indices are described here:

Chi-square value is a commonly reported index for model goodness of fit. This value is sensitive to sample size and very sensitive to departures from multivariate normality of the observed variables (Jöreskog & Sörbom). Since, this measure is a direct function of sample size, almost any model is likely to be rejected if the sample is large enough (Anderson 1987) whereas models having large misspecification are accepted when small samples are used (Hox, 1995). To address these issues, a number of alternative assessments of fit that are less dependent on sample size have been introduced.

Root mean squared residual (RMR) is the root square of the mean of the squared discrepancies between the model implied and the observed covariance matrices. However this value is sensitive to the scale of measurement of the model variables. To avoid scaling effect standardized root mean squared residual (SRMR) is introduced for testing goodness of fit. Both RMR and SRMR are used in this thesis for evaluating model goodness of fit. A value of SRMR less than 0.10 indicates a good fit of the data (Vandenberg and Lance, 2000)

Root mean squared error of approximation (RMSEA) is another widely reported fit index which is not affected by the scale of the variables. Steiger (1990) recommends that values below 0.10 indicate a good fit to the data and values below 0.05 a very good fit to the data. Browne and Cudeck (1993) suggest that a value of 0.08 or less is reasonable.

In this study, a comparative index is also used to check the goodness of fit of the models. Comparative index implied how well is the model compared to null model (no relationship among variables). Comparative index used here is comparative fit index (CFI) proposed by Bentler (1990).

It is important to mention here that model fit is a necessary but not sufficient condition for the validity of the hypothesis or theory. Goodness of fit within reasonable value implies that the data under consideration support the hypothesis.

2.7 Summary

The hierarchy of trip chaining and mode choice decisions has important application in development of activity based travel demand modeling. Besides, their relationship is important for better understanding of peoples' travel behavior and for transportation policy analysis. After an extensive review of literatures it is found that numerous studies have been conducted to analyze peoples' trip chaining behavior and mode choice behavior independently. Some trip chaining studies assumed mode choice as exogenous variables or even didn't consider mode choice for analysis. Others assumed both trip chain and mode choice as decision variables and found that they are correlated. These studies do not confirm any hierarchy of the decision process. Very few studies have focused on the hierarchical relationship between trip chain and mode choice. However, there is still lack of understanding regarding this interrelationship. These hierarchical relationship investigation studies classified trip chain as simple or complex and mode choice as auto or non-auto. Weekdays versus weekend travel behavior is not investigated in these studies. It is found from the literatures that SEM technique is extensively used mainly for investigating casual relationship which perfectly matches with the objective of the thesis. This technique is especially appropriate in case of investigating causal relationships among a large number of exogenous and decision variables. In addition to a large number of exogenous variables, this thesis considered ten types of trip chain patterns and six mode types. SEM technique is especially appropriate for investigating the relationships for such large number of variables. One alternative approach of causal relationship analysis could be the use Nested Logit (NL) model. However, it does not provide parameters directly measuring the causal effect. Also, the NL model has restriction on inclusive value parameter coefficient.

CHAPTER 3

METHODOLOGY

3.1 Outline

This chapter presents the overall methodology of the investigation performed in this thesis. Structural Equation Modeling (SEM) technique is used for investigating the hierarchical relationship between trip chain and mode type and the effect of exogenous variables on them. First section describes the conceptual framework of the Structural Equation Model. Subsequent sections describe the empirical specification of the SEM along with the hypotheses to be tested in this thesis.

3.2 Conceptual Framework

Figure 1 shows the conceptual modeling framework used for this thesis. It is hypothesized that the trip chaining pattern choice, in other word activity scheduling and mode type choice are governed by various extrinsic and intrinsic behavior of people. We do not know exactly why an individual chooses a particular trip chain pattern and mode type. We observe various individual, household and land use characteristics. There might have other factors that contribute in peoples' choice behavior. In general, it is assumed that peoples' choice behavior is determined by some latent variables. These latent variables are influenced by many factors some of which are individual, household and land use characteristics.

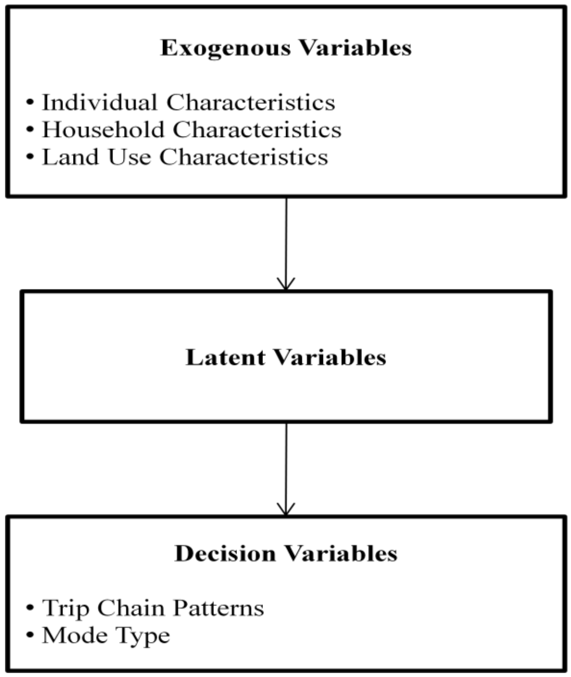

Figure 3.1: Conceptual modeling framework

3.3 Empirical Specification of the SEM

Figure 3.2 shows the general framework of the SEM path diagram estimated in this thesis. The SEM structure consists of a structural equation model and a measurement model for the decision variables. Trip chaining utility and mode choice utility are two decision latent variables in the model. It is hypothesized that the exogenous variables affect the individuals' trip chaining utility and mode choice utility, which define the trip chain choice and mode choice of that individual. A number of individual, household and land use characteristics are used as exogenous variables of the model. One of the key challenges in finalizing the model specification is to find a set of exogenous variables that can be used to predict the latent variables: Trip Chaining Utility and Mode Choice Utility. Number of exogenous variables in the final model is obtained by testing their statistical significances on representing the latent variables. Trip chain patterns are classified into ten categories and mode types into six categories based on the observed data. These are used as decision variables of the model.

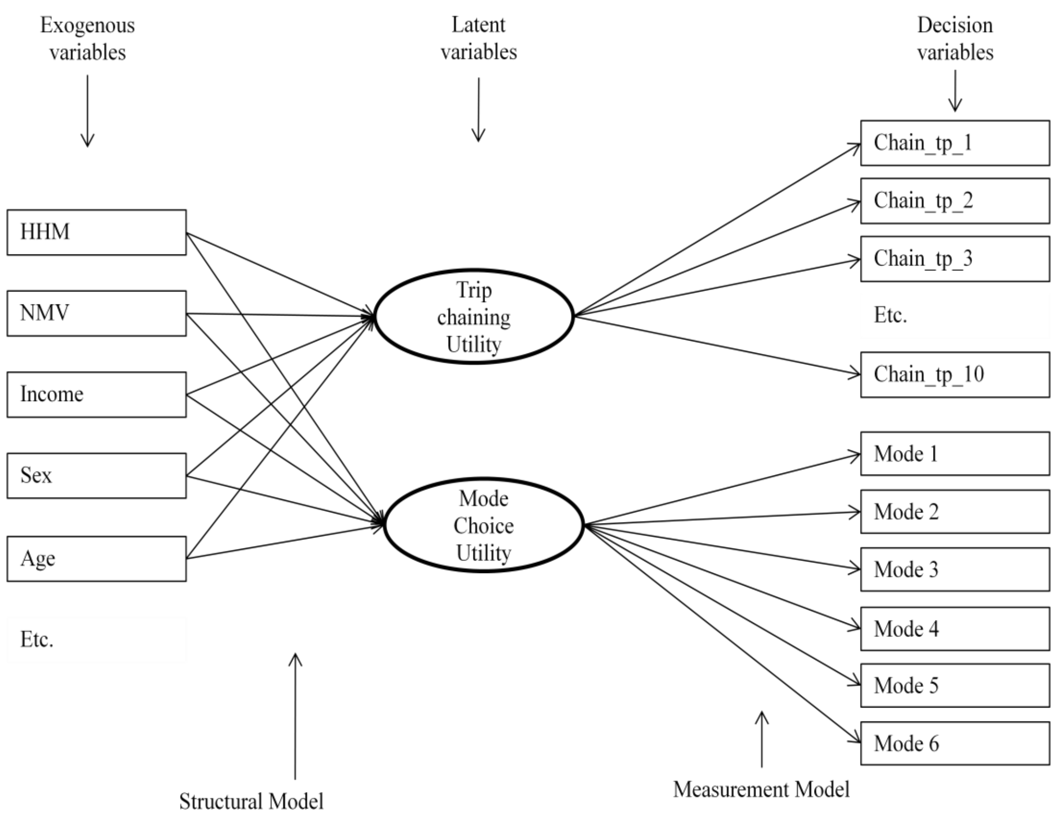

Figure 3.2 Hypothetical path diagram of SEM

3.4 Hypotheses to be Tested

The prime question this thesis intended to answer is the hierarchy of peoples' trip chain and mode choice decisions. For the purpose of thorough understanding of the relationship between trip chain and mode choice, all the possible relationships between these two choice decisions have been investigated in this study.

Trip chaining utility ($\eta_{1)}$ and mode choice utility (η_2) can be correlated in four different ways. All of these four relationships have been investigated step by step. Followings are the four hypotheses have been tested statistically to investigate the possible correlation between trip chain pattern and mode choice:

Hypothesis 1:

H_1: η_1 and η_2 have X as common causes (spurious correlation)

Hypothesis 2:

H_2: η_1 influences η_2

Hypothesis 3:

H_3: η_2 influences η_1

Hypothesis 4:

H_4: η_1 and η_2 influence each other reciprocally.

The causal relationships in work-related trip chain may be different from those in non-work related trip chain. Also, weekday travel behavior can be different from that of weekends. This is because the presence of a work activity may impose a certain amount of spatial and temporal rigidity on the activity scheduling related to that tour (Ye et al., 2007). For these reasons, hypotheses are tested for six weeks pooled weekday and weekend data separately. For weekdays, the investigation is again made for each weekly data separately to see consistency of the relationship across the weeks and also with the pooled data. Other two models are estimated for weekday's work-related and non-work related trip chain separately. In case of weekend pooled data, model is estimated only for nonwork-related trip chain because this comprises substantial observations. Separate models are also estimated for each of the six weekend data but are not reported here because of not getting consistent results. Inconsistency may result from having a small number of observations for single weekends.

3.5 Model Estimation

A number of SEM programs are available for model estimation. The most popular SEM programs are LISREL, AMOS and EQS. Linear Structural Relationships (LISREL) is used in this thesis for estimation of the specified model. Seven estimation methods are available in LISREL 8.8. Maximum Likelihood (ML) estimation method is used in this thesis. The advantages of ML method are that it provides the most precise estimators and is relatively robust against violation of the normal distribution assumption. It is also found from literature that ML estimation provides quite well and consistent parameters estimate under violation of multivariate normality (Boomsma, 1987; Golob and McNally, 1997). One of the prerequisite condition of model estimation is that model has to be identified. For measurement model to be identified, at least one element of each column of the loading matrix (Λ) has to be fixed to a non-zero value. In this case, for elements of loading matrix corresponding to Trip Chain Type 1 and Mode Type 1 are fixed to unity. Error terms of Trip Chain Type 1 and Mode Type 1 are fixed equal to the (1-reliability) times corresponding variance. Reliability is assumed as 85 percent for these two variables (Jöreskog and Sörbom, 1996-2001). The structural part of the model is made identified following the procedure described by Bollen (1989). For evaluation of the model goodness of fit a number of fit indices are used as described in Chapter 2.

3.6 Summary

This thesis investigates the hierarchical relationship between trip chain and mode choice decisions along with the effect of various individual, household and land use characteristics on them. Structural Equation Modeling (SEM) technique is found to be the most suited for this investigation. The SEM framework is based on the conception that the exogenous variables will affect the individuals' trip chaining utility and mode choice utility, which will define the trip chain patterns and mode choice of that individual. A number of individual, household and land use characteristics are used as exogenous variables and trip chain patterns and mode types as decision variables of the model. The four hypotheses tested in this thesis are 1) trip chain and mode choices have exogenous variables as common cause 2) trip chain influences mode choice 3) mode choice influences trip chain and 4) trip chain and mode choice are simultaneous.

CHAPTER 4

DATA DESCRIPTION AND PRELIMINARY STATISTICS

4.1 Outline

This chapter presents a brief description of the data sample used for this thesis. It also describes the data preparation process and preliminary statistical results. This preliminary analysis helped in the classification of trip chain patterns and mode type for final model development.

4.2 Survey Description

The dataset used in this thesis is extracted from a six week travel diary data collected in Switzerland in autumn and winter 2003. The travel diary dataset consists of pre-paid envelope survey of a total of 230 members of 99 households in the City of Frauenfeld and in the countryside with small villages north of Frauenfeld between Thur and Bodensee/Rhine. Households with children over the age of ten were selected for the survey. The respondents were asked to fill out a travel diary for every single day for the entire survey span of six consecutive weeks. After each week, respondents were asked to return the forms. In addition to travel diary, the survey also collected socio-demographic characteristics of households and its members by face to face interview (LöchI et al., 2005).

It is a common practice to use cross-sectional travel survey data for travel behavior analysis and modeling. This is mainly because of high cost and big reporting burden for the respondents associated with longitudinal survey data. The dataset used here is one of the very few multi-week travel diary dataset that include all trip purposes and transport modes. A total 36761 trips are recorded in the entire survey along with trip purpose, start time, travel time, mode type etc. The dataset also consists of very large number of individual and household characteristics. Among the 230 respondents associated in the survey, 130 are workers and 100 are non-workers. Only the workers data is used for investigation made in this thesis. From the huge number of information related to trips made by individuals, this thesis extracts all the trip purpose and corresponding mode choice to get trip chain or tour and tour level mode choice. Among the socio-demographic and land use characteristics available in the dataset, those found relevant with trip chain and mode choice decisions are used in the models. The next section describes the variables found to be statistically significant in the final models.

4.3 Variables Definition

Raw data includes all the trips made by individuals in a given day with trip start time, trip purpose and travel mode. These trips and corresponding modes are arranged sequentially in a day level according to the time of the day the trips were made. This arrangement of data shows the trip chaining patterns of individuals in day level along with the travel modes used for the trip chains. All the home based trips chains are then divided into two major groups: work-related trip chains and non-work related trip chains depending on the presence or absence of work activity within the trip chain. Work-related trip chains are coded to represent a number of trip chain patterns. Finally eight types of work-related trip chains patterns are found to have significant number of observations to carry out the econometric analysis. Non-work related trip chains are divided into simple and complex tours based on the number of out-of-home stops made within the trip chain. Six types of tour level modes are found to have significant number of observations. Detail of trip chain patterns and mode choices are presented in the subsequent sections.

For the purpose of investigating trip chain and mode choice behavior SEM technique is used in this thesis, the detail of which is presented in Chapter 3. The model consists of two sets of decision variables and a number of socio-demographic characteristics. Table 4.1 presents the trip chain pattern and mode choice related decision variables along with socio-demographic characteristics included in the final model. Decision variables represent the day level counting of various trip chain pattern and mode type choice.

Table 4.1
Exogenous and decision variables definition

Decision Variables	
Chain_tp_1	Number of trip chain pattern 1 chosen by an individual per day
Chain_tp_2	Number of trip chain pattern 2 chosen by an individual per day
Chain_tp_3	Number of trip chain pattern 3 chosen by an individual per day
Chain_tp_4	Number of trip chain pattern 4 chosen by an individual per day
Chain_tp_5	Number of trip chain pattern 5 chosen by an individual per day
Chain_tp_6	Number of trip chain pattern 6 chosen by an individual per day
Chain_tp_7	Number of trip chain pattern 7 chosen by an individual per day
Chain_tp_8	Number of trip chain pattern 8 chosen by an individual per day
Chain_tp_9	Number of trip chain pattern 9 chosen by an individual per day
Chain_tp_10	Number of trip chain pattern 10 chosen by an individual per day
Mode 1	Number of mode type 1 chosen by an individual per day
Mode 2	Number of mode type 2 chosen by an individual per day
Mode 3	Number of mode type 3 chosen by an individual per day
Mode 4	Number of mode type 4 chosen by an individual per day
Mode 5	Number of mode type 5 chosen by an individual per day
Mode 6	Number of mode type 6 chosen by an individual per day

Exogenous variables	
HHM	Number of members in the household
HHA	Number of adults in the household
MV	Number of motorized vehicles in the household
License	Number of driving licenses in the household
Walk_bus	Bus stop within 10 min walking time=1, otherwise=0
Walk_rail	Rail station within 10 min walking time=1, otherwise=0
Income	Household income categories
Gender	Male=1, female=0
Age	Person's age
Partner	Life partner/long term relationship=1, otherwise=0
Work_status	Full time employed=1, otherwise=0
N_o_wh	Number of working hours per week
W_schedule	Working hour schedule, Non flexible=1, otherwise=0
Education	Secondary=1, high school=2
Ps_at_wp	Parking space at work place, yes=1, otherwise=0

4.4 Trip Chain Classification

Trip chain patterns are classified into ten categories as described in the next paragraph. First eight patterns are for work-related trip chain and the last two are for nonwork-related trip chain. These ten categorizations of trip chain patterns are based on the preliminary statistics and investigation. In this thesis, the term trip chain refers to home based trip chain, a series of trips that begins from home, involves traveling one or more places and finally ends at home. Work-related trip chain involves at least one work stop within the trip chain. Non-work-related trip chain involves no work stop within the chain. Classification of work-related trip chain patterns are based on the number of stop made from home to work and from work to home journey. Nonwork-related trip chains are classified as simple and complex. Simple nonwork-related trip chains have only one nonwork stop within the chain. Complex nonwork-related trip chains have more than one stop within the chain.

1) Simple home to work to home trip chain. No non-work stops from home to work and from work to home journey. h-w(-w-)-h
2) One non-work stop from home to work journey and one non-work stop from work to home journey. h-nw-w(-w-)-nw-h
3) No non-work stops from home to work journey but one non-work stops from work to home journey. h-w(-w-)-nw-h
4) No non-work stops from home to work journey but two non-work stops from work to home journey. h-w(-w-)-nw-nw-h

5) No non-work stops from home to work journey but more than two non-work stops from work to home journey. h-w(-w-)-nw-nw-(-nw-)-h
6) One non-work stop from home to work journey but no non-work stops from work to home journey. h-nw-w(-w-)-h
7) More than one non-work stops between home to work journey but no non-work stops from work to home journey. h-nw-(-nw-)-w(-w-)-h
8) Others (Multiple non-work stops from home to work journey and from work to home journey not covered in trip chain pattern 1 to 7)
9) Simple non-work trip chain. Trip chain involves only one non-work activity and no work activity. h-nw-h
10) Complex non-work trip chain. Trip chain involves more than one non-work activity and no work activity. h-nw-(-nw-)-h

h: home, w: work, nw: non-work. The bracketed terms represent additional trips that may be in the chain.

This classification of trip chain pattern doesn't consider the midday work-based trip chain, as was considered by Strathman & Dueker (1995). However, unlike their classification, this classification consider more detail trip chain patterns based on the number of stops made from home to work and from work to home journey. Also, six types of mode are considered here as described below as opposed to their two types of mode.

4.5 Mode Types

All of the previous study on trip chaining pattern considered only two or three types of mode. The dataset used in this study gives the opportunity to consider following six types of mode in the analysis. This modal classification was based on the preliminary statistics and investigation. In most of the cases, single mode was prevalent for a given trip chain. In cases where multiple modes were used within the trip chain, a single mode was assigned depending on which mode was used from departing home.

1) Auto driver
2) Auto passenger/park and ride/others
3) Transit (Bus/Rail)
4) Bi-cycle
5) Walk
6) Motorcycle

4.6 Preliminary Statistics of Weekdays' Data

Total 36761 numbers of trips were reported in the survey. The survey consists of 130 workers and 100 non-workers. In this thesis, only worker data are used which consists of 3317 person-days data. Table 4.2 presents the socio-demographic characteristics of workers. Workers' data is divided into workers' weekdays and workers' weekends. The trip dataset is aggregated into tour level dataset. All the household and person characteristics are merged into the tour level dataset. Trip chain patterns are classified into ten categories as described in above section. In most of the cases, single mode was used for a given chain. In cases, where multiple modes were used, a single mode is assigned based on the mode used while departing from home. A maximum of six tours were reported by a person in a given day. Decision variables of trip chain patterns and mode choice type represent day level counting of each type of chain patterns and modes type. Table 4.3 shows final data for each of the six weeks. Weekday's data are also segregated into work-related trip chain and nonwork-related trip chain data. Data has 2316 person-days observations of work-related trip chain and 1627 person-days observations of nonwork-related trip chain.

Table 4.2
Characteristics of exogenous variables

Average HHM	2.84
Average HHA	2.00
Average MV	2.12
Average License	2.02
Walk_bus	Bus stop within 10 min walking time =104, otherwise=26
Walk_rail	Rail station within 10 min walking time =33, otherwise=97
Gender	Male=79, Female=51
Average Age	43.43
Partner	Yes=98, No=32
Work_status	Full time employed=98, othetwise=32
Average N_o_wh	40.92 hours
W_schedule	Non flexible=48, otherwise=82
Education	Secondary=103, high school=27
Ps_at_wp	Yes=95, otherwise=35

Table 4.3
Weekly number of observations of worker-workdays data

Week	Person-days
1st week	587
2nd week	572
3rd week	593
4th week	584
5th week	528
6th week	453
Total	**3317**

Table 4.4 presents the number of trip chain made per day for the worker-weekdays sample. Figure 4.1 shows the trip chaining frequency in graphical form. Around 50 percent of the observations have more than one trip chain per day. This clearly shows the complex travel behavior of peoples. In most of the cases, among the trip chains made in a day, one trip chain is related to work activity.

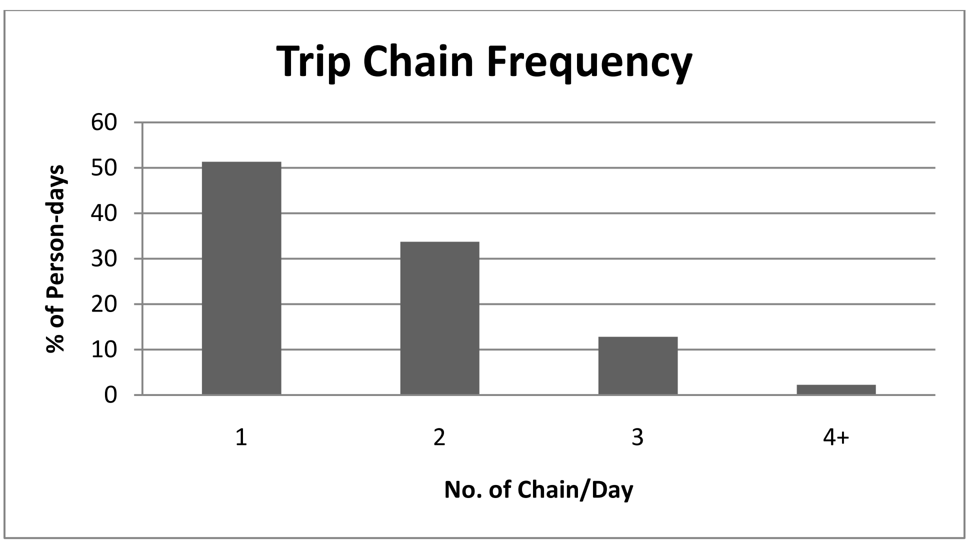

Figure 4.1: Trip chaining frequency for pooled weekday's data

Table 4.4
Trip chaining frequency for the sample

No of Trip Chain/day	Person-days	Percentage
1	1701	51.3
2	1119	33.7
3	424	12.8
4+	73	2.2
Total Observation	**3317**	**100.0**

Table 4.5 presents the distribution of trip chain pattern and mode choice. It shows that trip chain type 9 and 10, which correspond to non-work related trip chain, together is around 43 percent of total trip chain formation. This indicates that people make a substantial number of non-work related trip chains in the weekdays. However, around 57 percent of trip chains are work related of which 44 percent are simple work related trip chains. Among the 13 percent of work-related complex trip chains, around 9 percent involves non-work activities during the evening commute. Commuters are more likely to make non-work activities during their evening commute than morning commute and that may be the reason why some studies focused on stop making behavior of commutes especially during evening work-to-home commute (Bhat, 1997). It is found that around 77 percent trip chains are simple chain of which 44 percent are work-related and 32 percents are nonwork-related trip chain. In terms of mode use, about 70 percent trip chains involves auto mode of which about 62 percent is auto driver. Figure 4.2 and 4.3 present the trip chains and mode choices distribution respectively in aggregated form. It shows that 24 percent of the total trip chains are complex in nature. For 70 percent cases trip chain is made of either auto driver mode or auto related mode.

Table 4.5
Trip chain pattern and mode choice distribution of the worker-weekdays sample

Tour Type	**Mode Type**						**Total**	Percent
	1	**2**	**3**	**4**	**5**	**6**		
1	1609	112	275	181	233	41	**2451**	44.4
2	22	6	0	4	4	12	**48**	0.9
3	270	40	38	19	15	2	**384**	7.0
4	52	0	15	7	0	0	**74**	1.3
5	42	2	3	0	0	0	**47**	0.9
6	69	6	5	18	3	0	**101**	1.8
7	15	2	1	5	0	0	**23**	0.4
8	19	2	1	2	0	0	**24**	0.4
9	916	255	132	165	222	85	**1775**	32.2
10	371	88	68	29	19	13	**588**	10.7
Total	**3385**	**513**	**538**	**430**	**496**	**153**	**5515**	100.0
Percent	61.4	9.3	9.8	7.8	9.0	2.8	100	

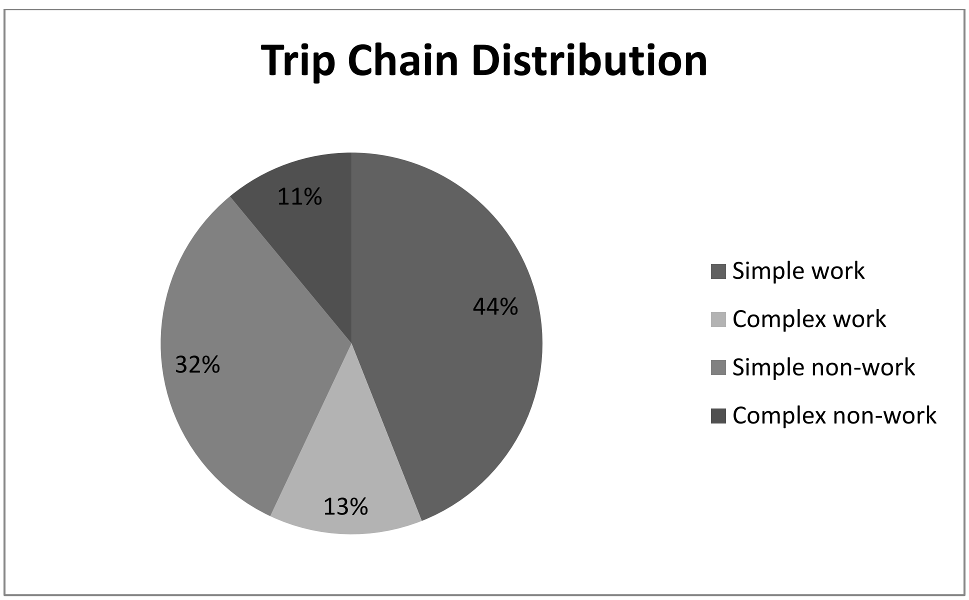

Figure 4.2: Trip chain distribution of the pooled weekday's data

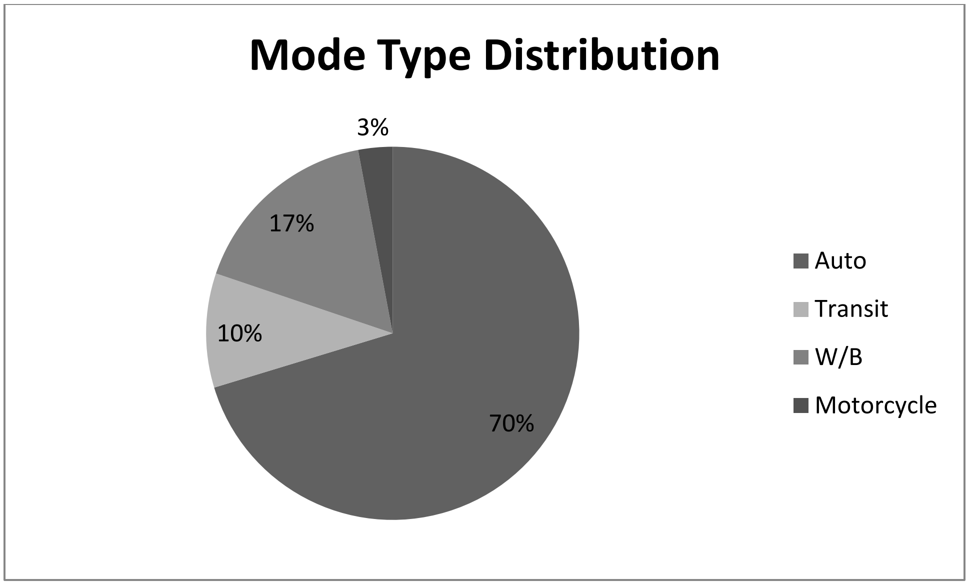

Figure 4.3: Mode choice distribution of the pooled weekday's data

To get a more clear idea of trip chain and mode use distribution, Table 4.6 presents trip chaining and mode choice in a more aggregated form. It shows auto usage is higher both for work and non-work related complex trip chains compared to simple trip chains. In terms of mode choice, it is found that transit users make simple trip chain more than complex both for work and non-work trip chains.

Table 4.6
Trip chain pattern and mode choice distribution in aggregated classification

Chain Type	Mode Type					
	Auto	Transit	W/B	Motorcycle	**Total**	Percent
Simple work	1721	275	414	41	**2451**	44
Complex work	547	63	77	14	**701**	13
Simple non-work	1171	132	387	85	**1775**	32
Complex non-work	459	68	48	13	**588**	11
Total	**3898**	**538**	**926**	**153**	**5515**	100
Percent	71	10	17	3	100	

Row Percent

Chain Type	Mode Type				
	Auto	Transit	W/B	Motorcycle	Total
Simple work	70.2	11.2	16.9	1.7	100
Complex work	78.0	9.0	11.0	2.0	100
Simple non-work	66.0	7.4	21.8	4.8	100
Complex non-work	78.1	11.6	8.2	2.2	100

Column Percent

Chain Type	Mode Type			
	Auto	Transit	W/B	Motorcycle
Simple work	44.2	51.1	44.7	26.8
Complex work	14.0	11.7	8.3	9.2
Simple non-work	30.0	24.5	41.8	55.6
Complex non-work	11.8	12.6	5.2	8.5
Total	100	100	100	100

4.7 Preliminary Statistics of Weekends' Data

Weekend Dataset has a total 1320 person-days observations for workers. After removal of incomplete trip chain and other noises, 1185 person-days observations were found. This includes both work and non-work trip chains. It is found that work related chains for worker are few in weekend. Finally considering only the non-work related trip chain, 1150 person-days data was obtained. Figure 4.4 shows the number of chain per days. It is found that for around 45 percent person-days, number of trip chains per day is greater than one. Figure 4.5 and 4.6 show the distribution of trip chain pattern and mode choice respectively. Table 4.7 also shows the distribution of trip chain patterns and mode choice. It is found that 71 percent trip chains patterns are simple. Auto usage is higher for complex trip chain pattern than simple trip chain.

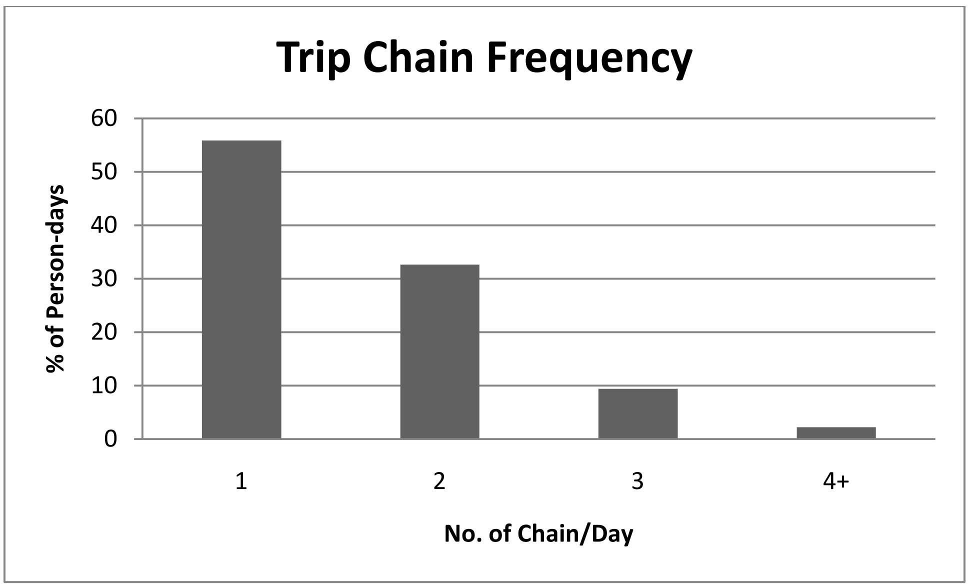

Figure 4.4: Trip chaining frequency for pooled weekend's data

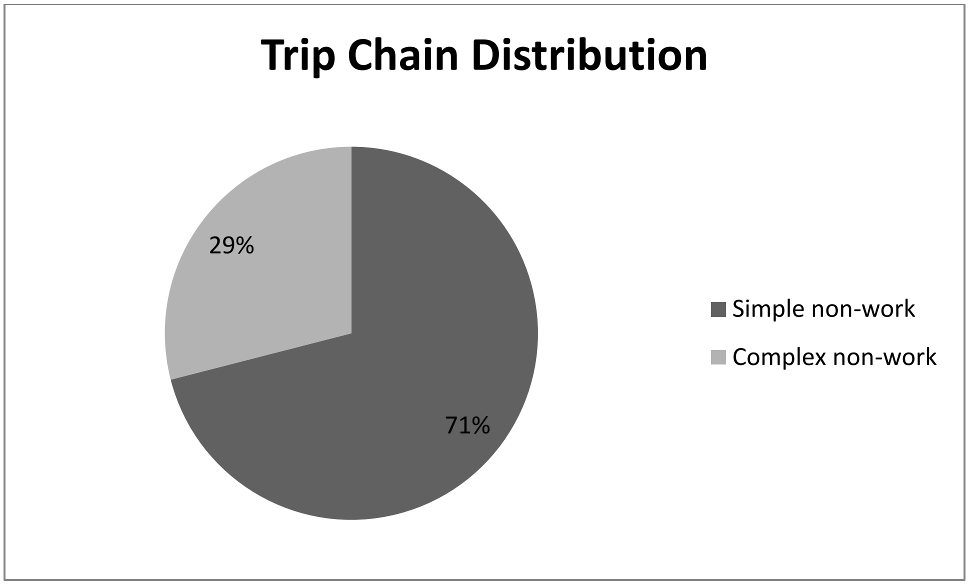

Figure 4.5: Trip chain distribution of the pooled weekend's data

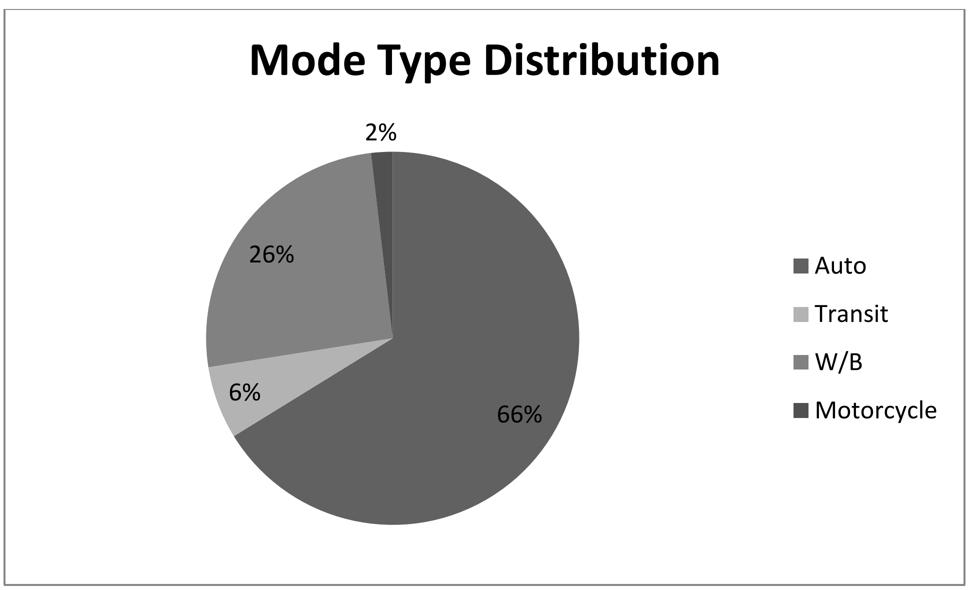

Figure 4.6: Mode choice distribution of the pooled weekend's data

Table 4.7
Distribution of trip chain and mode choice for weekend data

Tour Type	**Mode**							
	1	2	3	4	5	6	**Total**	Percentage
Simple non-work	600	186	81	122	284	30	**1303**	71
Complex non-work	314	107	34	29	32	4	**520**	29
Total	**914**	**293**	**115**	**151**	**316**	**34**	**1823**	100
Percentage	50	16	6	8	18	2	100	

Row percentage

Chain Type	Mode Type						
	1	2	3	4	5	6	Total
Simple non-work	46	14	6	9	22	2	100
Complex non-work	60	21	7	6	6	1	100

Column percentage

Chain Type	Mode Type					
	1	2	3	4	5	6
Simple non-work	66	63	70	81	90	88
Complex non-work	34	37	30	19	10	12
Total	100	100	100	100	100	100

4.8 Summary

The data used in this thesis is extracted from a six week travel diary data collected in the city of Frauenfeld and in the countryside with small villages north of Frauenfeld between Thur and Bondensee/Rhine in Switzerland in the year of 2003. The dataset consists of prepaid envelope survey of a total 230 members of 99 households along with a face to face interview data of socio-demographic characteristics. This thesis only used a subset of the data that consists of 130 workers. Trip-based raw data is aggregated into home-based tour level data by sequencing the trips according to the time of the day as they occurred. All the socio-demographic and land use characteristics are merged into tour level data. After a preliminary investigation and statistics ten types of trip chain patterns and six types of mode are selected for econometric analysis. Among the trip chain patterns eight are related to work related activity and two are for non-work related activity. After removing some incomplete trip chain and other noise, total 3317 observations were found for weekdays and 1150 observations for weekend. Weekdays observations are separated into work related trip chain and non-work related trip chain for separate model estimation. It is found that around 49 percent of people make more than one trip chain per day that reflect the complex travel behavior of people. Auto usage rate is higher both for work and non-work related complex trip chains compared to that of simple trip chains. Transit users are used to make simple chain more than complex trip chain.

CHAPTER 5

EMPIRICAL MODEL AND DISCUSSION

5.1 Outline

This thesis is aimed at investigating the hierarchical relationship between trip chain and mode choice along with the effect of socio-demographic characteristics on them. The relationship is investigated for pooled data, work-related data and non-work related data separately. For non-work related trip chain investigation is made for the weekdays and weekend trip chains separately. To test the consistency of the relationship, separate models are estimated for each of the six weeks' data. This chapter presents the detail results of all the final estimated models and discusses the results.

5.2 Model Result for Weekdays Work- Non-work Pooled Data

First model is estimated for pooled data of six weekdays' which contains both work and non-work trip chains. All the possible correlations between the trip chain and mode choice is investigated by testing the four hypotheses as stated in Chapter 3. Appendix A shows the four hypotheses plotted in LISREL interface. Final model is obtained by systematic testing of these hypotheses. The decision variables of the model remain the same for all the hypotheses testing, but the exogenous variables are selected by trial basis to get a stable and only the statistically significant variables. T-statistics value of 1.64 (Two-tail 90 percent confidence interval) is used as critical value. However, some variables with T-statistics less than the critical value are also reported here. It is presumed that these variables would be statistically significant for larger dataset. Overall goodness of fit is found reasonable. Root mean squared error of approximation (RMSEA) of the final model is 0.059; root mean squared residual (RMR) is 0.095; standardized root mean squared residual (SRMR) is 0.057 and comparative fit index (CFI) is 0.777. From the critical values of fit indices presented in chapter 2, we can say that the data reasonably support the model structure. Table 5.1 shows the estimation results of the four hypotheses. Result shows that the first hypothesis is rejected because correlation coefficient (ψ_{12}) of the error terms of trip chaining utility (η_1) and mode choice utility (η_2) latent variables is statistically significant. This means that there exists a definite correlation between trip chaining and mode choice rather than having a spurious correlation between them. Estimation results of second and third hypothesis are also statistically significant. These indicate that neither of the hypotheses can be rejected, nor can one be preferred over the other from statistical point of view. Result of fourth hypothesis indicates that the causal relationship between η_1 and η_2 is reciprocal as the effects of both mode choice on trip chaining and trip chaining on mode choice are statistically significant. Thus, for the pooled data, it is found that the hypothesis that assumes trip chaining and mode choice decisions are simultaneous is statistically significant. This means that people are likely to make their trip chain pattern and mode choice decisions simultaneously without any hierarchical order of decision making. Table 5.2 shows the detailed model estimation result for the modeling structure where trip chain and mode choice decisions are simultaneous. Results of other three hypotheses are presented in Appendix B. It is found that all the indicator variables of trip chaining and mode choice utilities are statistically significant. This justifies the broader classification of trip chain pattern and mode choice rather than traditional classification of simple versus complex trip chain and auto versus non-auto mode type. However, from Table 5.2 it is difficult to interpret the results. It is convenient to perceive and interpret the effects of exogenous variables on decision variables. The effects of exogenous variables on decision variables are presented in Table 5.3.

Table 5.1
Results of four hypotheses for weekday's work-nonwork pooled data

Hypothesis	Description	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.145	13.22
H2	Trip chain utility influences mode choice utility	0.371	13.90
H3	Mode choice utility influences trip chain utility	0.225	13.61
H4	Trip chain utility influences mode choice utility	0.581	4.99
	Mode choice utility influences trip chain utility	-0.157	-1.74

Table 5.2
Model results for weekday's work-nonwork pooled data

Measurement model	**Decision variable**	**Latent variable**	**Estimates**	**T- Stat**
Variable related with trip chaining utility	Chain_ tp_ 1	Trip chaining utility	1.00	---
	Chain_ tp_ 2		-0.0201	-5.54
	Chain_ tp_ 3		-0.1087	-11.20
	Chain_ tp_ 4		-0.0252	-5.62
	Chain_ tp_ 5		-0.0163	-5.09
	Chain_ tp_ 6		-0.0183	-3.40
	Chain_ tp_ 7		-0.0076	-2.95
	Chain_ tp_ 8		-0.0101	-3.82
	Chain_ tp_ 9		-0.2483	-11.29
	Chain_ tp_ 10		-0.1385	-11.59
Variables related with mode choice utility	Mode 1	Mode choice utility	1.00	---
	Mode 2		-0.0866	-9.64
	Mode 3		-0.1905	-24.04
	Mode 4		-0.097	-9.51
	Mode 5		-0.1293	-10.81
	Mode 6		-0.0571	-8.63
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chaining utility	HHM	Trip chaining utility	-0.0912	-6.23
	HHA		0.0431	1.55
	MV		0.0991	6.68
	License		-0.0801	-4.07
	Walk_bus		0.0637	1.54
	Gender		0.2718	7.12
	Age		0.0071	4.22
	Partner		0.2359	5.69
	Work_status		0.1512	2.81
	N_o_wh		-0.0031	-1.61
Variables related with mode choice utility	MV	Mode choice utility	0.0545	4.33
	License		0.1696	7.72
	Walk_bus		-0.1074	-2.16
	Walk_rail		-0.1533	-4.21
	Income		-0.0837	-6.15
	Gender		-0.3239	-6.65
	Age		0.0108	6.64
	Partner		0.1866	4.04
	Work_status		0.0717	1.61
	Education		0.2011	4.92
Direct effect within latent variables				
	Chain to mode		0.581	4.99
	Mode to chain		-0.157	-1.73

Table 5.3
Total effect of exogenous variables on decision variables for weekday's work-nonwork pooled data

Decision variables	Exogenous variables											
	HHM	HHA	MV	Walk_bus	Walk_rail	Income	Gender	Age	Partner	Work_ status	N_o_wh	Educa-tion	License
Chain_ tp_ 1	-0.0835	0.0395	0.083	0.0738	0.022	0.012	0.2957	0.005	0.1894	0.1283	-0.0028	-0.0289	-0.0978
Chain_ tp_ 2	0.0017	-0.0008	-0.0017	-0.0015	-0.0004	-0.0002	-0.0059	-0.0001	-0.0038	-0.0026	0.0001	0.0006	0.002
Chain_ tp_ 3	0.0091	-0.0043	-0.009	-0.008	-0.0024	-0.0013	-0.0321	-0.0005	-0.0206	-0.0139	0.0003	0.0031	0.0106
Chain_ tp_ 4	0.0021	-0.001	-0.0021	-0.0019	-0.0006	-0.0003	-0.0075	-0.0001	-0.0048	-0.0032	0.0001	0.0007	0.0025
Chain_ tp_ 5	0.0014	-0.0006	-0.0014	-0.0012	-0.0004	-0.0002	-0.0048	-0.0001	-0.0031	-0.0021	0.00004	0.0005	0.0016
Chain_ tp_ 6	0.0015	-0.0007	-0.0015	-0.0013	-0.0004	-0.0002	-0.0054	-0.0001	-0.0035	-0.0023	0.0001	0.0005	0.0018
Chain_ tp_ 7	0.0006	-0.0003	-0.0006	-0.0006	-0.0002	-0.0001	-0.0023	-0.00004	-0.0014	-0.001	0.00003	0.0002	0.0007
Chain_ tp_ 8	0.0008	-0.0004	-0.0008	-0.0007	-0.0002	-0.0001	-0.003	-0.0001	-0.0019	-0.0013	0.00003	0.0003	0.001
Chain_ tp_ 9	0.0207	-0.0098	-0.0206	-0.0183	-0.0055	-0.003	-0.0734	-0.0012	-0.047	-0.0319	0.0007	0.0072	0.0243
Chain_ tp_ 10	0.0116	-0.0055	-0.0115	-0.0102	-0.0031	-0.0017	-0.041	-0.0007	-0.0262	-0.0178	0.0004	0.004	0.0135
mode1	-0.0485	0.0229	0.1027	-0.0646	-0.1405	-0.0768	-0.1522	0.0137	0.2966	0.1462	-0.0016	0.1843	0.1129
mode2	0.0042	-0.002	-0.0089	0.0056	0.0122	0.0066	0.0132	-0.0012	-0.0257	-0.0127	0.0001	-0.016	-0.0098
mode3	0.0092	-0.0044	-0.0196	0.0123	0.0268	0.0146	0.029	-0.0026	-0.0565	-0.0278	0.0003	-0.0351	-0.0215
mode4	0.0047	-0.0022	-0.01	0.0063	0.0136	0.0074	0.0148	-0.0013	-0.0288	-0.0142	0.0002	-0.0179	-0.0109
mode5	0.0063	-0.003	-0.0133	0.0084	0.0182	0.0099	0.0197	-0.0018	-0.0383	-0.0189	0.0002	-0.0238	-0.0146
mode6	0.0028	-0.0013	-0.0059	0.0037	0.008	0.0044	0.0087	-0.0008	-0.0169	-0.0083	0.0001	-0.0105	-0.0064

It is found from the above table that as the number of household member increases, simple work trip chain decrease, but as the number of adult increases, simple work trip chain increases which are obvious. As the number of auto in the household increases, auto mode choice also increases. People having transit stops within 10 min walking distance are likely to choose transit mode. However, still there is a difficulty to interpret the effects of all the variables because of analyzing work-nonwork trip chain together. Basically the purpose of analyzing work-nonwork trip chains together is to see the correlation between trip chain and mode choice decisions and to compare the result with the results of separate investigation of work and non-work trip chains. This will reveal whether combined analysis overlooks any critical relationship that actually exists.

5.3 Model Result for Weekdays Work-related Pooled Data

It is more realistic to estimate separate models for these two trip chain patterns to investigate the relationship between them which may be overlooked by aggregate estimation. Again same as the previous model estimation, all the four hypotheses are tested systematically. Table 5.4 presents the results of four hypotheses. Goodness of fit indices of final model are found as: RMSEA is 0.060, SRMR is 0.055 CFI is 0.772. Results clearly show that the relationship between trip chaining and mode choice decisions is simultaneous. This finding partially complies with the finding of Ye et al. (2007) where they found the relationship is either simultaneous or trip chain precedes mode choice.

Table 5.4
Results of four hypotheses for weekdays work-related pooled data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.085	10.79
H2	Trip chain utility influences mode choice utility	0.27	1.83
H3	Mode choice utility influences trip chain utility	0.34	11.99
H4	Trip chain utility influences mode choice utility	-0.13	-1.92
	Mode choice utility influences trip chain utility	0.47	6.89

Table 5.5 presents the detailed results of the final model parameters. Results of other hypotheses are provided in Appendix C. It is found from Table 5.5 that all the indicator variables of trip chaining utility and mode choice utility are statistically significant. In most of the literatures on trip chaining and mode choice classified trip chain pattern into simple and complex and mode choice into auto versus non-auto and sometimes auto, transit and non-motorized vehicle. This result suggests the necessity of doing more detailed investigation of people's trip chaining pattern and mode choice for getting better idea about people's travel behavior. However, the effects of exogenous variables and sign of indicator variables are not understandable through this table. It is more interpretable to see the effect of exogenous variables on decision variables rather than that on latent variables. The total effect of exogenous variables on decision variables is the sum of direct and indirect effect. In the case of the modeling structure specified in the thesis, total effect equals to indirect effect. LISREL, the software package used for this investigation, provides these effects in its output file.

Table 5.5
Model result for weekdays work-related pooled data

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.000	
	Chain_ tp_ 2		-0.042	-8.10
	Chain_ tp_ 3		-0.279	-21.60
	Chain_ tp_ 4		-0.061	-9.23
	Chain_ tp_ 5		-0.046	-8.83
	Chain_ tp_ 6		-0.054	-7.10
	Chain_ tp_ 7		-0.014	-4.10
	Chain_ tp_ 8		-0.021	-5.59
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.000	
	Mode 2		-0.092	-9.13
	Mode 3		-0.279	-25.88
	Mode 4		-0.130	-9.95
	Mode 5		-0.151	-11.06
	Mode 6		-0.039	-5.76
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	MV	Trip chaining utility	0.043	4.59
	License		-0.084	-4.99
	Walk_bus		-0.089	-2.05
	Gender		0.206	5.88
	Partner		0.144	4.18
	Work_status		-0.147	-3.80
	Education		-0.092	-2.64
	W_Schedule		0.162	5.55
	Ps_at_wp		-0.324	-5.33
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.088	-6.45
	HHA		0.142	4.96
	MV		0.074	6.25
	Walk_bus		-0.132	-2.83
	Walk_rail		0.149	4.83
	Income		-0.036	-2.68
	Age		0.010	7.92
	Partner		0.066	1.73
	Work_status		0.172	3.34
	N_o_wh		-0.007	-3.70
	Education		0.104	2.92
	W_Schedule		-0.079	-2.53
	Ps_at_wp		0.808	24.16
Direct effect within latent variables				
	chain to mode		-0.134	-1.92
	mode to chain		0.472	6.89

Table 5.6
Total effect of exogenous variables on decision variables for weekday's work-related pooled data

Decision variables	Exogenous variables														
	HHM	HHA	MV	License	Walk_ bus	Walk_rail	Income	Gender	Age	Partner	Work_ status	N_o_wh	W_schedule	Education	Ps_at_wp
Chain_ tp_ 1	-0.039	0.063	0.073	-0.079	-0.142	0.066	-0.016	0.194	0.005	0.165	-0.062	-0.003	0.117	-0.04	0.054
Chain_ tp_ 2	0.002	-0.003	-0.003	0.003	0.006	-0.003	0.001	-0.008	-0.0002	-0.007	0.003	0.0004	-0.005	0.002	-0.002
Chain_ tp_ 3	0.011	-0.018	-0.02	0.022	0.04	-0.018	0.004	-0.054	-0.001	-0.046	0.017	0.001	-0.033	0.011	-0.015
Chain_ tp_ 4	0.002	-0.004	-0.004	0.005	0.009	-0.004	0.001	-0.012	-0.0003	-0.01	0.004	0.0003	-0.007	0.002	-0.003
Chain_ tp_ 5	0.002	-0.003	-0.003	0.004	0.007	-0.003	0.001	-0.009	-0.0002	-0.008	0.003	0.0004	-0.005	0.002	-0.002
Chain_ tp_ 6	0.002	-0.003	-0.004	0.004	0.008	-0.004	0.001	-0.01	-0.0002	-0.009	0.003	0.0004	-0.006	0.002	-0.003
Chain_ tp_ 7	0.001	-0.001	-0.001	0.001	0.002	-0.001	0.0004	-0.003	-0.0001	-0.002	0.001	0.0004	-0.002	0.001	-0.001
Chain_ tp_ 8	0.001	-0.001	-0.002	0.002	0.003	-0.001	0.0001	-0.004	-0.0001	-0.003	0.001	0.0001	-0.002	0.001	-0.001
Mode 1	-0.083	0.134	0.064	0.011	-0.113	0.14	-0.034	-0.026	0.009	---	0.18	-0.006	-0.094	0.109	0.8
Mode 2	0.008	-0.012	-0.006	-0.001	0.01	-0.013	0.003	0.002	-0.001	---	-0.017	0.001	0.009	-0.01	-0.073
Mode 3	0.023	-0.037	-0.018	-0.003	0.031	-0.039	0.009	0.007	-0.003	---	-0.05	0.002	0.026	-0.03	-0.223
Mode 4	0.011	-0.017	-0.008	-0.001	0.015	-0.018	0.004	0.003	-0.001	---	-0.024	0.001	0.012	-0.014	-0.104
Mode 5	0.013	-0.02	-0.01	-0.002	0.017	-0.021	0.005	0.004	-0.001	---	-0.027	0.001	0.014	-0.017	-0.121
Mode 6	0.003	-0.005	-0.002	0.0004	0.004	-0.005	0.001	0.001	0.00004	---	-0.007	0.00003	0.004	-0.004	-0.031

Table 5.6 presents the effect of personal, household and land use characteristics on trip chaining and mode choice behavior. Most of the effects are found having expected sign. In terms of household total members and household adult members, it is found that individual with higher total household members make more complex work-related trip chain, but individual with higher adult households make more simple work trip chain. As the model is estimated for worker data, it is obvious that there will be more home-work-home simple trip chains as the number of adults in the household increase. However, increase of other member categories for example child may lead to increase of pick-up, drop-off type of non-work related trips linking with the work trip. If household auto ownership increases individual has greater freedom to make simple trip chain because of availability of auto. Complex trip chain may result from the constraint imposed by non-availability of motor vehicle. The effect of the number of licenses in the household on trip chaining is found less intuitive. Individual having bus stop access within 10 min walking time tends to choose complex trip chain pattern whereas Individual having rail stop access within 10 min walking time tends to choose simple trip chain pattern. This may because of the fact that rail route has less spatial accessibility compared to bus route. People tend to use rail for simple work trip chain. As income increases, individual is more likely to make complex trip chain. This may because of their involvement of various economic activities other than work. This finding is complied with the finding of Hensher and Reyes (2000). Female are more likely to make complex trip chains. Age is found positively related with simple trip chain. Individuals having partners tend to make simple work chain. This may happen due to task allocation between them which reduce the necessity to link non-work trip with the work trip. Those who work full time are more inclined to link non-work trip with work trip which may because of their time constraint to make separate non-work trip in working days. The same explanation is true for those who work more hours in the weekdays. Individual with non-flexible office hours tends to make simple work trip rather than complex. Higher educated people are more likely to make complex trip chain. This may because of their more involvement of various activities compared to lower educated people. Those who have parking space at work place are likely to make simple trip chain.

In terms of mode choice, as number of household members increase, auto mode use decrease which may result from the non-availability of auto for all the members. Household adults are more likely to use auto. This seems logical because for worker data set, adults are basically workers. Auto mode choice increases with increase in number of auto and number of license in the households. Individual with bus stop access within 10min walking distance is less likely to choice auto mode. The effect of rail accessibility is found positively related with auto mode choice which is less intuitive. Household income is found negatively related with auto mode choice. Female are more inclined to use auto mode than male. Age and auto mode choice are found to be positively related. Full-time workers are likely to choose auto. Number of work hours and non-flexible work schedule are found negatively related with auto mode. Higher educated people are likely to choose auto mode. Individuals having parking space at work place are more likely to use auto mode.

5.4 Model Result for Weekdays Nonwork-related Pooled Data

This section presents the model estimation results for non-work trip chains. Table 5.7 presents the estimation results of four hypotheses. Goodness of fit indices of final model are found as: RMSEA is 0.077, SRMR IS 0.072 and CFI is 0.791. It is found from the results that mode choice influence trip chaining is statistically significant for non-work related trip chain in weekdays. One may conjecture that worker has time constraints in the weekdays which may impose restriction to freely plan for non-work related trip chain before mode choice. Thus people tend to choose mode first and then plan their trip chain pattern accordingly. Table 5.8 presents the detailed results of the model structure where mode choice precedes trip chain pattern. Results of all other hypotheses are presented in Appendix D. Result shows that all the indicator variables are statistically significant. Table 5.9 presents the effects of exogenous variables on decision variables.

The table shows that in case of trip chain pattern, as household total members as well as number of adults increase, trip chains are more likely to be simple. These findings comply with the findings of Ye et al. (2007) and strathman and Dueker (1994). However, for work-related trip chain household member and simple trip chain are negatively related. As household auto ownership and number of license increases, trip chains are more likely to be simple rather than complex. Individual having bus stop and rail station access with 10min walking distance tends to make simple non-work trip. Higher income people tend to make complex non-work trip chain. Gender is found to have insignificant effect on weekdays non-work related trip chaining. People with higher age are likely to make simple trip chain. Full-time workers are less likely to make complex trip chain. Weekly working hour and parking space availability at work place are found positively related with simple trip chain. Higher educated people are likely to make complex trip chain.

In case of mode choice, household auto ownership and number of licenses, individual's age, partnership, number of work hour and parking place at work place are positively related with auto mode choice. For work-related trip chain, number of work hour is found negatively related. These results suggest that those who work more hours are less likely to use auto mode for work-related trip chain, but more likely to use auto for non-work-related trip chain. Rail station access within 10min of walking time seems to be negatively related with auto mode choice. Income, full-time work status, non-flexible office hours are found to have negative relation with auto mode choice.

Table 5.7
Results of four hypotheses for weekday's non-work related pooled data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.08	6.54
H2	Trip chain utility influences mode choice utility	0.18	6.76
H3	Mode choice utility influences trip chain utility	0.23	7.44
H4	Trip chain utility influences mode choice utility	-0.009	-0.10
	Mode choice utility influences trip chain utility	0.19	2.81

Table 5.8
Model result for weekday's non-work related pooled data

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chain utility	Chain_ tp_9	Trip chaining utility	1.000	
	Chain_tp_10		-0.448	-24.37
Variable related with mode choice utility	Mode 1	Mode choice utility	1.000	
	Mode 2		-0.188	-11.14
	Mode 3		-0.136	-11.83
	Mode 4		-0.123	-8.16
	Mode 5		-0.116	-7.57
	Mode 6		-0.103	-7.73
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain utility	HHM	Trip chaining utility	0.023	1.31
	HHA		0.081	2.23
	Walk_bus		0.215	3.70
	Walk_rail		0.167	3.71
	Gender		0.070	1.61
	Partner		-0.108	-2.21
	Work_status		-0.259	-3.71
	N_o_wh		0.003	1.49
	Education		-0.097	-2.01
	W_schedule		0.047	1.16
Variable related with mode choice utility	MV	Mode choice utility	0.033	2.79
	License		0.102	4.41
	Walk_rail		-0.170	-4.09
	Income		-0.089	-6.23
	Gender		-0.156	-3.72
	Age		0.007	4.44
	Partner		0.265	5.46
	Work_status		-0.081	-1.30
	N_o_wh		0.005	2.50
	W_schedule		-0.086	-2.21
	Ps_at_wp		0.212	4.53
Direct effect within latent variables				
	chain to mode		---	---
	mode to chain		0.232	7.45

Table 5.9
Total effect of exogenous variables on Decision variables for weekday's nonwork-related pooled data

Decision variables	Exogenous variables														
	HHM	HHA	MV	Walk_ bus	Walk_ rail	Income	Sex	Age	Partner	Work_s tatus	N_o_w h	W_sche dule	Ps_at_w p	Educati on	License
Chain_tp9	0.023	0.081	0.008	0.215	0.128	-0.021	---	0.002	---	-0.277	0.005	---	0.049	-0.097	0.024
Chain_tp10	-0.01	- 0.036	-0.003	-0.096	-0.057	0.009	---	-0.001	---	0.124	-0.002	---	-0.022	0.044	-0.011
Mode1	---	---	0.033	---	-0.17	-0.089	-0.156	0.007	0.265	-0.081	0.005	-0.086	0.212	---	0.102
Mode2	---	---	-0.006	---	0.032	0.017	0.029	-0.001	-0.05	0.015	-0.001	0.016	-0.04	---	-0.019
Mode3	---	---	-0.005	---	0.023	0.012	0.021	-0.001	-0.036	0.011	-0.001	0.012	-0.029	---	-0.014
Mode4	---	---	-0.004	---	0.021	0.011	0.019	-0.001	-0.032	0.01	-0.001	0.01	-0.026	---	-0.012
Mode5	---	---	-0.004	---	0.02	0.01	0.018	-0.001	-0.031	0.009	-0.001	0.01	-0.024	---	-0.012
Mode6	---	---	-0.003	---	0.017	0.009	0.016	-0.001	-0.027	0.008	-0.001	0.009	-0.022	---	-0.01

5.5 Model Result for Weekly Work-related Data

Specified model structure is also estimated for six week work-related data separately to see whether the relationship between trip chain pattern and mode choice is consistent across the weeks and also with the pooled data. For all the weekly data, four hypotheses are tested systematically. Results of the four hypothesis test are presented in Table 5.10 to Table 5.15. These tables show that the relationship remains consistent for most cases and it complies with the result obtained for the model estimated with weekday's work-related pooled data. Results show that trip chain and mode choice decisions are simultaneous. As the pooled data is predominated by work-related trip chain, the relationship between trip chain and mode choice for non-work trip chain may be overlooked in pooled analysis. Detailed results are presented in Appendix E. All the results that are found consistent with the results of pooled work-related data.

Table 5.10
Results of four hypotheses for 1st week work-related data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.16	3.41
H2	Trip chain utility influences mode choice utility	0.19	3.50
H3	Mode choice utility influences trip chain utility	0.25	3.49
H4	Trip chain utility influences mode choice utility	-0.27	-1.99
	Mode choice utility influences trip chain utility	0.57	3.86

Table 5.11
Results of four hypotheses for 2nd week work-related data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.16	3.48
H2	Trip chain utility influences mode choice utility	0.19	3.58
H3	Mode choice utility influences trip chain utility	0.27	3.56
H4	Trip chain utility influences mode choice utility	-0.09	-1.04
	Mode choice utility influences trip chain utility	0.38	4.20

Table 5.12
Results of four hypotheses for 3rd week work-related data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.20	4.36
H2	Trip chain utility influences mode choice utility	0.23	4.55
H3	Mode choice utility influences trip chain utility	0.33	4.54
H4	Trip chain utility influences mode choice utility	-0.44	-2.54
	Mode choice utility influences trip chain utility	0.72	4.55

Table 5.13
Results of four hypotheses for 4th week work-related data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.17	3.93
H2	Trip chain utility influences mode choice utility	0.23	4.55
H3	Mode choice utility influences trip chain utility	0.33	4.54
H4	Trip chain utility influences mode choice utility	-0.40	-2.54
	Mode choice utility influences trip chain utility	0.78	4.55

Table 5.14
Results of four hypotheses for 5th week work-related data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.13	6.41
H2	Trip chain utility influences mode choice utility	0.37	7.17
H3	Mode choice utility influences trip chain utility	0.49	7.10
H4	Trip chain utility influences mode choice utility	-0.72	-1.91
	Mode choice utility influences trip chain utility	1.07	4.72

Table 5.15
Results of four hypotheses for 6th week work-related data

Hypothesis	Parameter	Estimate	T-statistic
H1	Correlation in error components between Trip chain utility and mode choice utility	0.08	4.36
H2	Trip chain utility influences mode choice utility	0.28	4.61
H3	Mode choice utility influences trip chain utility	0.37	4.58
H4	Trip chain utility influences mode choice utility	0.02	0.16
	Mode choice utility influences trip chain utility	0.35	2.17

5.6 Model Result for Weekend Non-work related Pooled Data

The dataset used in this study gives us an opportunity to estimate separate model for weekdays and weekend. For weekend data, only non-work related trip chain patterns are considered as the work-related trip chains are negligible for weekend. Table 5.16 shows the results of four hypotheses that have been tested. Goodness of fit indices of the final model are found as: RMSEA is 0.09, SRMR is 0.085 and CFI is 0.683. These fit indices are slightly higher than previous models, but still they are within the critical values specified in Chapter 2. Small number of observations in weekend may cause little higher fit indices.

Results show that for weekend, non-work related trip chain and mode choice relationship is reverse of that for weekday's non-work related trip chain and mode choice. Here, model structure where trip chain pattern precedes mode choice is statistically significant. One can surmise that the absence of work activity in weekend provides workers more flexibility to plan their trip chain pattern freely. Thus, they first choose the trip chain pattern and then choose mode for the chain. Table 5.17 provides detail result of estimated the final model. Table 5.18 presents the effect of exogenous variables on decision variables for the final model. Results of other hypotheses are presented in Appendix F.

It is found that number of household adults, age and male are positively related with simple trip chain pattern. Higher educated people are likely to make complex trip chain. In terms of mode choice, it is found that number of household adults, household auto ownership, male and age are positively related with auto mode choice whereas, number of household members, rail accessibility, individual's income and educations are negatively related with auto mode choice. One interesting finding here is that male are negatively related with auto mode in the weekdays but positively related with auto in the weekend. This reflects peoples' variation in travel behavior from weekdays to weekends.

Table 5.16
Results of four hypotheses for weekend non-work related pooled data

Hypothesis	Parameter	Estimate	T-stat
H1	Correlation in error components between Trip chain utility and mode choice utility	0.23	10.17
H2	Trip chain utility influences mode choice utility	0.30	11.23
H3	Mode choice utility influences trip chain utility	0.32	11.32
H4	Trip chain utility influences mode choice utility	0.29	2.61
	Mode choice utility influences trip chain utility	0.02	0.17

Table 5.17
Model result for weekend's non-work related pooled data

Measurement model	**Decision variable**	**Latent variable**	**Estimates**	**T- Stat**
Variable related with trip chain	Chain tp- 9	Trip chain utility	1	---
	Chain tp_10		-0.33	-19.8
Variable related with mode choice	Mode 1	Mode choice utility	1	---
	Mode 2		-0.17	-10.25
	Mode 3		-0.09	-8.45
	Mode 4		-0.1	-7.03
	Mode 5		-0.13	-7.39
	Mode 6		-0.03	-4.24
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain pattern	HHA	Trip chain utility	0.063	1.76
	Gender		0.077	1.39
	Age		0.005	2.13
	Education		-0.085	-1.27
Variable related with mode choice	HHM	Mode choice Utility	-0.048	-2.4
	MV		0.073	4
	Walk_rail		-0.251	-4.63
	Income		-0.05	-2.43
	Gender		0.341	6.67
	Age		0.007	3.15
	Partner		0.102	1.6
Direct effect within latent variables				
	chain to mode		0.30	11.23
	mode to chain		---	---

Table 5.18
Total effect of exogenous variables on Decision variables for weekend's nonwork-related pooled data

Exogenous variables	Exogenous variables								
	HHM	HHA	MV	Walk_rail	Income	Sex	Age	Partner	Education
Chain_tp_9	---	0.063	---	---	---	0.077	0.005	---	-0.085
Chain_tp_10	---	-0.021	---	---	---	0.025	-0.002	---	0.028
Mode1	-0.048	0.019	0.073	-0.251	-0.05	0.364	0.008	0.102	-0.026
Mode2	0.008	-0.003	-0.013	0.044	0.009	-0.063	-0.001	-0.018	0.004
Mode3	0.004	-0.002	-0.007	0.022	0.005	-0.033	-0.001	-0.009	0.002
Mode4	0.005	-0.002	-0.007	0.024	0.005	-0.035	-0.001	-0.01	0.002
Mode5	0.006	-0.003	-0.01	0.034	0.007	-0.049	-0.001	-0.014	0.003
Mode6	0.001	-0.001	-0.002	0.007	0.001	-0.01	-0.0004	-0.003	0.001

5.7 Summary

The hierarchical relationship between trip chaining and mode choice is thoroughly investigated by applying Structural Equation Modeling (SEM) technique. It is mentioned in the earlier chapter that trip chain and mode choice can be correlated in four ways: i) they have exogenous variables as common cause, ii) trip chain precedes mode choice, iii) mode choice precedes trip chain and, iv) both are simultaneous. A series of models are specified and estimated to thoroughly investigate all of these possible relationships between trip chain and mode choice. Separate models have been estimated for weekdays versus weekend data and for work-related versus non-work related data to see the variation of the relationship across them. Consistency of the relationship is tested by estimating models for each of the six weekly data. This chapter presents only the final models results and discussion on the results. It is found that for weekday's work-nonwork pooled data the relationship is simultaneous. For weekdays work-related pooled data the relationship is simultaneous whereas for weekday's non-work related pooled data mode choice precedes trip chain. As the weekday's work-nonwork pooled data is dominated by work-related data, it overlooks the relationship between non-work data in aggregate investigation. Model estimations for each of the six weekly work-related data show that the relationship is simultaneous and it remains consistent across the weeks. For weekend's non-work related pooled data it is found that trip chain precedes mode choice. In terms of investigating the effect of socio-demographic characteristics, a number of variables are tested. Though the variables with t-stat value greater than 1.64 (One tail 95% confidence level) are mostly reported, some variables with less t-stat are also reported presuming that they would be significant for larger dataset. Most of the effects of exogenous variables are found consistent with the expectations. Some of the variables like number of working hours and gender are found to have opposite relation with auto mode choice from weekdays to weekends.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Study Summary

Trip chaining and mode choice are two very important travel decisions the interaction of which has lots of implications in transportation policy analysis and travel demand management. The hierarchical relationship of mode choice and trip chain has important application in developing activity-based travel demand modeling. Most activity-based travels demand models consist of hierarchical structure where trip chaining or activity scheduling precedes mode choice decision. The assumed hierarchy of decisions in an activity-based travel demand model has direct influence on its predictive capacity and policy sensitivities. Proper understanding of the underlying mechanism of travelers' decision process is important for development of the travel demand models. The hierarchy of decision between trip chain and mode choice also have important implications in sustainable transportation policy implementation. Thus, it is useful to empirically test the hierarchy regarding the decisions of trip chain formation and mode choice.

The specific objectives of this thesis can be summarized as i) investigating whether trip chaining precedes mode choice or mode choice precedes trip chaining or both are decided simultaneously ii) testing the consistency of the relationship among weekdays, weekends, work related trip chains and non-work-related trip chains iii) testing the consistency of the causal relationship across the weeks iv) checking the justification of a very detailed classification of trip chain pattern and corresponding tour-level mode choice made and, v) investigating the effects of socio-demographic and land use characteristics on trip chain pattern and mode choice.

It is found from literature review that numerous studies have been conducted to analyze peoples' trip chaining behavior and mode choice behavior independently. Some trip chaining studies assumed mode choice as exogenous variables or even didn't consider mode choice for analysis. Others assumed both trip chain and mode choice as decision variables and found that they are correlated. These studies didn't not investigate the hierarchy of the decisions between trip chain and mode choice process. Very few studies have focused on the hierarchical relationship between trip chain and mode choice. However, there is still lack of understanding regarding this interrelationship. These hierarchical relationship investigation studies classified trip chain as simple or complex and mode choice as auto or non-auto. Weekdays versus weekend travel behavior is not investigated in these studies.

Literatures also show that SEM technique is being extensively used mainly for investigating casual relationship which perfectly matches with the objective of the thesis. This technique is especially appropriate in case of investigating causal relationships among a large number of exogenous and decision variables. In addition to a large number of exogenous variables, this thesis considered ten types of trip chain patterns and six mode types. SEM technique is especially appropriate for investigating the relationships for such large number of variables. One alternative approach of causal relationship analysis is found as Nested Logit (NL) model. However, it does not provide parameters directly measuring the causal effect. Also, the NL model has restriction on inclusive value parameter coefficient.

For thorough investigation of the causal relationship between trip chain and mode choice, all the possible correlations between them are investigated in this thesis. Four hypotheses are being tested for this purpose: i) they have exogenous variables as common cause, ii) trip chain precedes mode choice, iii) mode choice precedes trip chain and, iv) both are simultaneous.

The dataset used for this analysis is extracted from six week travel diary data collected from Switzerland in autumn and winter 2003. Only the workers subset of data is used in this thesis. This unique dataset provides the opportunity to estimate a series of models to test the consistency of the causal relationship between trip chain and mode choice. To capture the complex travel behavior, trip chain pattern is classified into ten categories and six types of tour level mode choice are considered in the analysis. Relationship is investigated for weekdays versus weekends and for work-related tour versus non-work-related tour.

As a first step, model is estimated for weekday's work-nonwork pooled data. The result suggests that the hypothesis that assumes trip chain and mode choice decisions as simultaneous is statistically significant. In second steps two models are estimated by segregating the weekday's work-nonwork pooled data into work-related pooled data and non-work-related pooled data. For work-related data, trip chain and mode choice decisions are found simultaneous whereas for non-work-related data mode choice precedes trip chaining is found statistically significant. To test the consistency of the relationship, separate models are estimated for each of the six weeks work-related trip chain data. It is found that trip chain and mode choice decisions are simultaneous. This relationship remains consistent across the weeks. For weekends, only the non-work-related trip chains are considered for analysis as the work-related trip chains are found negligible. Result shows that trip chain pattern precedes mode choice for non-work-related tour in weekend.

Effects of a number of socio-demographic characteristics on trip chaining and mode type choice are also investigated. It is found that household size, number of household members, household auto ownership, number of driving licenses, household income, gender, age, work status, number of working hours, work schedule, educational status, parking space at work place and transit accessibility have significant effects on trip chain and mode choice behavior.

6.2 Limitations and Future Research

This thesis is intended for investigating the casual relationship between trip chain and mode choice behavior. The results of the thesis provide new insight into the understanding and development of activity-based travel behavior. One of the future researches can be the incorporation of the findings of this thesis into the activity-based travel demand modeling such as one presented by Habib, (2009). The intra-household and inter-household travel behavior may have significant effect on people's trip chaining and mode choice behavior. Inclusion of these effects on analysis may provide better understanding of travel behavior provided that data with these information are available. This thesis didn't consider the midday work-based trip chaining in the analysis because of not having enough observations. Based on the midday work-based trip chaining, trip chain pattern can be expanded into more categories.

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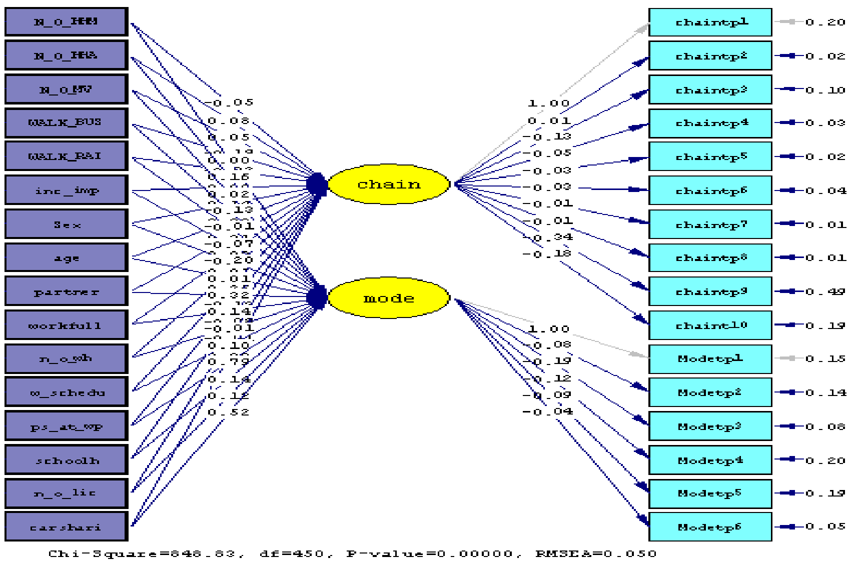
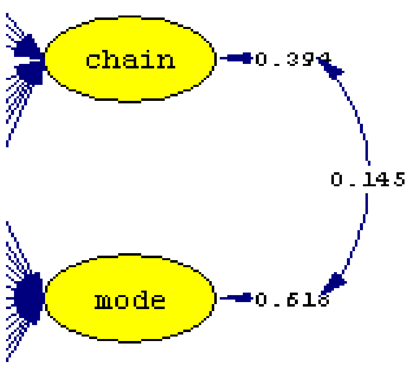
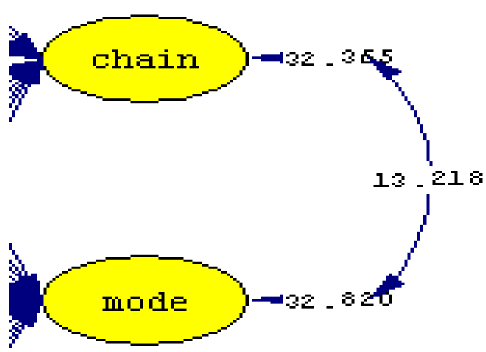
APPENDICES

Appendix A: Graphical presentation of hypotheses

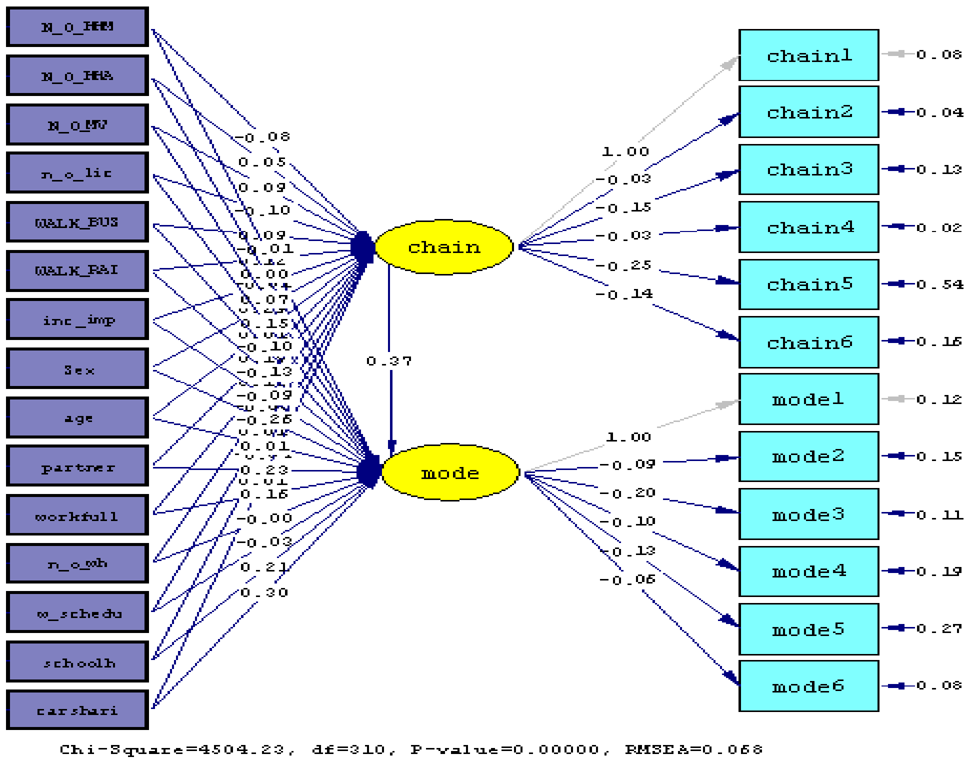
Hypothesis H1







Hypothesis H2



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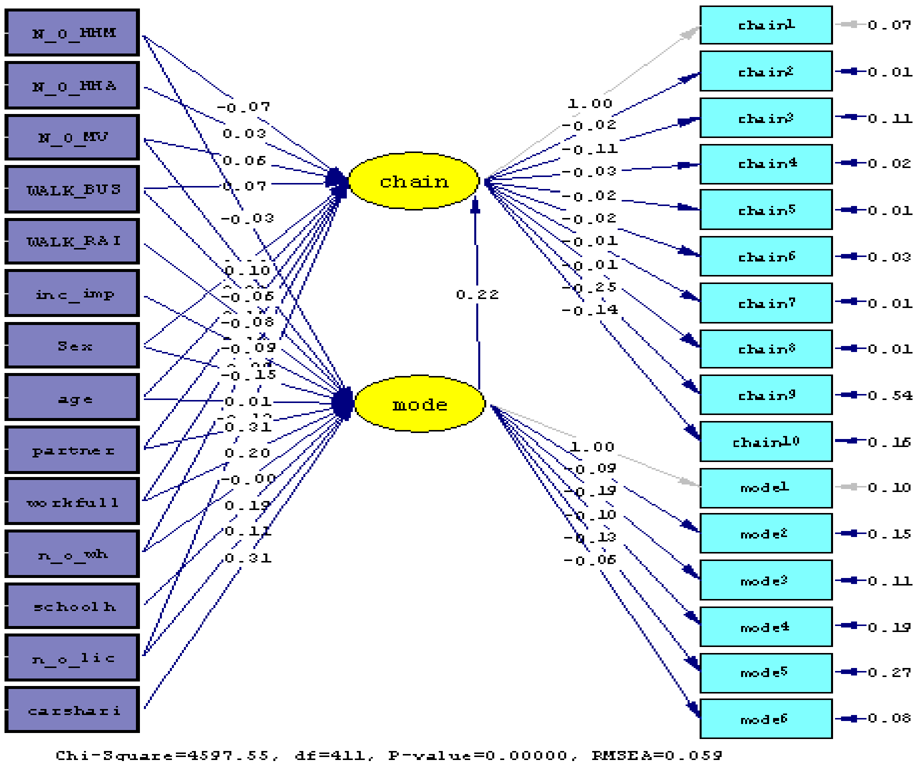
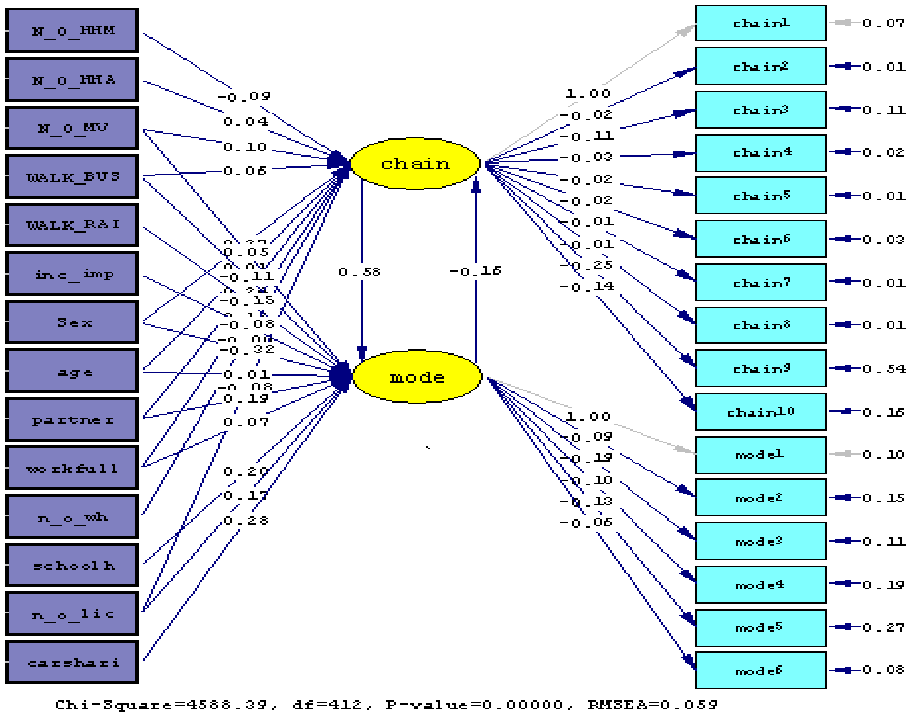


Hypothesis H4



Appendix B: Model Results for Weekdays Work-Nonwork Pooled Data

Table I: Hypothesis H1 result for weekdays work and non-work related trip chain

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chaining utility	Chain_ tp_ 1	Trip chaining utility	1.00	---
	Chain_ tp_ 2		-0.0201	-5.54
	Chain_ tp_ 3		-0.1087	-11.21
	Chain_ tp_ 4		-0.0252	-5.62
	Chain_ tp_ 5		-0.0163	-5.09
	Chain_ tp_ 6		-0.0183	-3.39
	Chain_ tp_ 7		-0.0076	-2.95
	Chain_ tp_ 8		-0.0101	-3.82
	Chain_ tp_ 9		-0.2486	-11.31
	Chain_ tp_ 10		-0.1383	-11.57
Variables related with mode choice utility	Mode 1	Mode choice utility	1.00	---
	Mode 2		-0.0867	-9.66
	Mode 3		-0.1906	-24.07
	Mode 4		-0.0967	-9.50
	Mode 5		-0.1291	-10.80
	Mode 6		-0.057	-8.61
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chaining utility	HHM	Trip chaining utility	-0.0816	-6.47
	HHA		0.0342	1.36
	MV		0.086	7.57
	License		-0.0999	-6.57
	Walk_bus		0.0667	1.72
	Gender		0.2978	9.10
	Age		0.0051	4.47
	Partner		0.2032	5.92
	Work_status		0.1377	2.73
	N_o_wh		-0.0028	-1.54
Variables related with mode choice utility	HHM	Mode choice utility	-0.031	-2.18
	MV		0.1023	7.86
	License		0.113	5.94
	Walk_bus		-0.0676	-1.38
	Walk_rail		-0.1244	-3.51
	Income		-0.0873	-6.30
	Gender		-0.1513	-3.71
	Age		0.0139	9.42
	Partner		0.3092	7.19
	Work_status		0.2095	3.15
	N_o_wh		-0.0044	-1.89
	Education		0.2074	5.10
Correlation Coefficient between latent variables			0.1454	13.22

Table II: Hypothesis H2 result for weekdays work and non-work related trip chain

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chaining utility	Chain_ tp_ 1	Trip chaining utility	1.000	---
	Chain_ tp_ 2		-0.020	-5.49
	Chain_ tp_ 3		-0.109	-10.96
	Chain_ tp_ 4		-0.025	-5.51
	Chain_ tp_ 5		-0.016	-5.01
	Chain_ tp_ 6		-0.018	-3.35
	Chain_ tp_ 7		-0.008	-2.93
	Chain_ tp_ 8		-0.010	-3.77
	Chain_ tp_ 9		-0.248	-11.05
	Chain_ tp_ 10		-0.140	-11.49
Variables related with mode choice utility	Mode 1	Mode choice utility	1.000	---
	Mode 2		-0.087	-9.43
	Mode 3		-0.196	-23.97
	Mode 4		-0.097	-9.26
	Mode 5		-0.129	-10.48
	Mode 6		-0.058	-8.52
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chaining utility	HHM	Trip chaining utility	-0.080	-6.27
	HHA		0.046	1.74
	MV		0.085	7.48
	License		-0.097	-6.34
	Walk_bus		0.088	2.23
	Walk_rail		0.117	3.98
	Gender		0.292	8.91
	Age		0.005	4.39
	Partner		0.187	5.40
	Work_status		0.116	2.24
	N_o_wh		-0.003	-1.42
	Education		-0.040	-1.18
Variables related with mode choice utility	MV	Mode choice utility	0.066	6.11
	License		0.153	8.22
	Walk_bus		-0.092	-1.93
	Walk_rail		-0.130	-3.67
	Income		-0.090	-6.77
	Gender		-0.263	-6.67
	Age		0.012	8.60
	Partner		0.232	5.57
	Work_status		0.159	2.45
	N_o_wh		-0.003	-1.45
	Education		0.206	5.00
Direct effect within latent variables				
	Chain to mode		0.371	13.90
	Mode to chain		--	---

Table III: Hypothesis H3 result for weekdays work and non-work related trip chain

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chaining utility	Chain_ tp_ 1	Trip chaining utility	1	---
	Chain_ tp_ 2		-0.0201	-5.54
	Chain_ tp_ 3		-0.1089	-11.22
	Chain_ tp_ 4		-0.0252	-5.62
	Chain_ tp_ 5		-0.0163	-5.09
	Chain_ tp_ 6		-0.0183	-3.40
	Chain_ tp_ 7		-0.0076	-2.96
	Chain_ tp_ 8		-0.0101	-3.82
	Chain_ tp_ 9		-0.2493	-11.34
	Chain_ tp_ 10		-0.1381	-11.55
Variables related with mode choice utility	Mode 1	Mode choice utility	1	---
	Mode 2		-0.0868	-9.66
	Mode 3		-0.1906	-24.04
	Mode 4		-0.0967	-9.48
	Mode 5		-0.1288	-10.76
	Mode 6		-0.0571	-8.62
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chaining utility	HHM	Trip chaining utility	-0.0702	-5.68
	HHA		0.0323	1.28
	MV		0.0649	5.80
	License		-0.1276	-8.56
	Walk_bus		0.0699	1.86
	Gender		0.3363	10.55
	Age		0.0022	1.94
	Partner		0.1532	4.57
	Work_status		0.1208	2.47
	N_o_wh		-0.0024	-1.40
Variables related with mode choice utility	HHM	Mode choice utility	-0.0289	-2.02
	MV		0.1029	7.91
	License		0.1137	5.97
	Walk_bus		-0.0591	-1.20
	Walk_rail		-0.0808	-2.21
	Income		-0.0883	-6.17
	Gender		-0.1545	-3.78
	Age		0.0139	9.41
	Partner		0.3051	7.08
	Work_status		0.2018	3.02
	N_o_wh		-0.0044	-1.87
	Education		0.1933	4.61
Direct effect within latent variables				
	Chain to mode		--	---
	Mode to chain		0.225	13.61

Appendix C: Model Results for Weekdays Work-related Pooled Data

Table I: Hypothesis H1 result for weekdays' work related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.00	---
	Chain_ tp_ 2		-0.042	-7.98
	Chain_ tp_ 3		-0.2812	-21.39
	Chain_ tp_ 4		-0.0616	-9.13
	Chain_ tp_ 5		-0.0463	-8.73
	Chain_ tp_ 6		-0.054	-7.00
	Chain_ tp_ 7		-0.0143	-4.03
	Chain_ tp_ 8		-0.021	-5.51
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.00	---
	Mode 2		-0.0884	-8.34
	Mode 3		-0.2995	-26.16
	Mode 4		-0.1211	-8.75
	Mode 5		-0.1497	-10.34
	Mode 6		-0.0372	-5.23
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHM	Trip chaining utility	-0.0353	-2.53
	HHA		0.0791	2.80
	MV		0.0612	4.92
	License		-0.0762	-4.54
	Walk_bus		-0.1148	-2.54
	Walk_rail		0.1130	3.59
	Gender		0.1646	4.41
	Age		0.0035	2.73
	Partner		0.144	4.18
	Work_status		-0.1218	-3.08
	Education		-0.0731	-2.09
	W_Schedule		0.1206	3.93
	Ps_at_wp		0.065	1.87
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.0755	-5.86
	HHA		0.1238	4.68
	MV		0.0625	5.60
	Walk_bus		-0.0992	-2.32
	Walk_rail		0.1402	4.86
	Income		-0.0359	-2.93
	Sex		-0.0878	-2.49
	Age		0.0105	8.68
	Partner		0.0453	1.32
	Work_status		0.195	3.99
	N_o_wh		-0.0055	-3.18
	Education		0.0956	2.83
	W_Schedule		-0.0964	-3.37
	Ps_at_wp		0.8103	25.37
Correlation Coefficient between latent variables			0.0848	10.79

Table II: Hypothesis H2 result for weekdays' work related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.00	---
	Chain_ tp_ 2		-0.042	-7.98
	Chain_ tp_ 3		-0.2814	-21.40
	Chain_ tp_ 4		-0.0616	-9.13
	Chain_ tp_ 5		-0.0464	-8.73
	Chain_ tp_ 6		-0.054	-7.00
	Chain_ tp_ 7		-0.0143	-4.01
	Chain_ tp_ 8		-0.021	-5.51
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.00	---
	Mode 2		-0.0885	-8.35
	Mode 3		-0.2994	-26.15
	Mode 4		-0.1211	-8.74
	Mode 5		-0.1498	-10.35
	Mode 6		-0.0375	-5.27
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHM	Trip chaining utility	-0.0356	-2.55
	HHA		0.0803	2.84
	MV		0.0601	4.82
	Walk_bus		-0.1158	-2.57
	Walk_rail		0.1127	3.58
	Gender		0.1648	4.41
	Age		0.0035	2.68
	Partner		0.1518	4.19
	Work_status		-0.1231	-3.12
	W_schedule		0.1217	3.96
	Ps_at_wp		0.0635	1.83
	Education		-0.0714	-2.04
	License		-0.0704	-4.08
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.0654	-5.21
	HHA		0.1002	3.91
	MV		0.0506	4.64
	Walk_bus		-0.0665	-1.60
	Walk_rail		0.1126	3.99
	Income		-0.0356	-2.98
	Gender		-0.1294	-3.74
	Age		0.0099	8.65
	Work_status		0.2293	4.89
	N_o_wh		-0.0056	-3.23
	W_Schedule		0.7996	25.90
	Ps_at_wp		0.1079	3.31
	Education		0.808	24.16
Direct effect within latent variables				
	chain to mode		0.254	11.28
	mode to chain		---	---

Table III: Hypothesis H3 result for weekdays' work related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.00	---
	Chain_ tp_ 2		-0.0421	-7.99
	Chain_ tp_ 3		-0.2811	-21.36
	Chain_ tp_ 4		-0.0615	-9.12
	Chain_ tp_ 5		-0.0463	-8.72
	Chain_ tp_ 6		-0.0541	-7.01
	Chain_ tp_ 7		-0.0144	-4.04
	Chain_ tp_ 8		-0.021	-5.51
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.00	---
	Mode 2		-0.0887	-8.37
	Mode 3		-0.2992	-26.14
	Mode 4		-0.1209	-8.73
	Mode 5		-0.1502	-10.38
	Mode 6		-0.0372	-5.23
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	MV	Trip chaining utility	0.0488	5.56
	Walk_bus		-0.0879	-2.05
	Walk_rail		0.0636	2.06
	Gender		0.1979	5.67
	Partner		0.1571	4.69
	Work_status		-0.1476	-3.86
	W_schedule		0.1469	5.06
	Ps_at_wp		-0.233	-5.77
	Education		-0.0868	-2.60
	License		-0.0809	-4.92
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.0751	-5.85
	HHA		0.1313	5.03
	MV		0.0616	5.52
	Walk_bus		-0.0975	-2.28
	Walk_rail		0.1413	4.89
	Income		-0.0343	-2.80
	Gender		-0.0838	-2.38
	Age		0.0108	9.30
	Work_status		0.1867	3.90
	N_o_wh		-0.0055	-3.14
	W_Schedule		-0.1005	-3.51
	Ps_at_wp		0.8163	25.76
	Education		0.0912	2.72
Direct effect within latent variables				
	chain to mode		---	---
	mode to chain		0.3546	12.18

Appendix D: Model Results for Weekdays Nonwork-related Pooled Data

Table I: Hypothesis H1 result for weekday's non-work related trip chain

Measurement model	**Decision variable**	**Latent variable**	**Estimates**	**T- Stat**
Variable related with trip chain utility	Chain_ tp_9	Trip chaining utility	1.000	---
	Chain_tp_10		-0.4394	-24.49
Variable related with mode choice utility	Mode 1	Mode choice utility	1.000	---
	Mode 2		-0.1879	-10.68
	Mode 3		-0.1415	-11.86
	Mode 4		-0.1248	-7.99
	Mode 5		-0.114	-7.17
	Mode 6		-0.1067	-7.68
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain utility	HHM	Trip chaining utility	0.0277	1.55
	HHA		0.0738	2.03
	Walk_bus		0.204	3.45
	Walk_rail		0.1141	2.53
	Income		-0.0216	-1.35
	Work_status		-0.2407	-3.62
	N_o_wh		0.0039	1.74
	Education		-0.0809	-1.63
	License		0.0432	1.87
Variable related with mode choice utility	MV	Mode choice utility	0.0311	2.63
	Walk_rail		-0.1777	-4.33
	Income		-0.0901	-6.36
	Gender		-0.1729	-4.35
	Age		0.0067	4.54
	Partner		0.2832	5.99
	N_o_wh		0.0034	2.35
	W_schedule		-0.0918	-2.41
	Ps_at_wp		0.2041	4.44
	License		0.1002	4.39
Correlation Coefficient between latent variables			0.0848	6.54

Table II: Hypothesis H2 result for weekday's non-work related trip chain

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chain utility	Chain_ tp_9	Trip chaining utility	1.000	---
	Chain_tp_10		-0.4393	-24.49
Variable related with mode choice utility	Mode 1	Mode choice utility	1.000	---
	Mode 2		-0.188	-10.69
	Mode 3		-0.1417	-11.88
	Mode 4		-0.1243	-7.96
	Mode 5		-0.1137	-7.16
	Mode 6		-0.1067	-7.68
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain utility	HHM	Trip chaining utility	0.0298	1.64
	HHA		0.0739	2.01
	Walk_bus		0.2021	3.37
	Walk_rail		0.1147	2.54
	Income		-0.0231	-1.44
	Work_status		-0.2499	-3.71
	N_o_wh		0.0041	1.82
	Education		-0.0702	-1.39
	License		0.0434	1.89
Variable related with mode choice utility	MV	Mode choice utility	0.0251	2.14
	Walk_rail		-0.1877	-4.63
	Income		-0.0883	-6.31
	Gender		-0.1714	-4.32
	Age		0.0066	4.52
	Partner		0.2713	5.74
	N_o_wh		0.0039	2.7538
	W_schedule		-0.0874	-2.30
	Ps_at_wp		0.2134	4.64
	License		0.0914	4.05
Direct effect within latent variables				
	chain to mode		0.181	6.76
	mode to chain		---	---

Table III: Hypothesis H4 result for weekday's non-work related trip chain

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chain utility	Chain_ tp_9	Trip chaining utility	1.000	---
	Chain_tp_10		-0.4393	-24.49
Variable related with mode choice utility	Mode 1	Mode choice utility	1.000	---
	Mode 2		-0.188	-10.68
	Mode 3		-0.1418	-11.88
	Mode 4		-0.1243	-7.96
	Mode 5		-0.1137	-7.16
	Mode 6		-0.1067	-7.68
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain utility	HHM	Trip chaining utility	0.0297	1.64
	HHA		0.0744	2.00
	Walk_bus		0.2022	3.36
	Walk_rail		0.1131	2.38
	Income		-0.0237	-1.3932
	Work_status		-0.2518	-3.60
	N_o_wh		0.0042	1.79
	Education		-0.0699	-1.38
	License		0.0452	1.60
Variable related with mode choice utility	MV	Mode choice utility	0.0249	2.09
	Walk_rail		-0.1881	-4.63
	Income		-0.0882	-6.3
	Gender		-0.1715	-4.32
	Age		0.0066	4.51
	Partner		0.2713	5.73
	N_o_wh		0.0039	2.74
	W_schedule		-0.0875	-2.2993
	Ps_at_wp		0.2135	4.63
	License		0.0911	4.00
Direct effect within latent variables				
	chain to mode		-0.0089	-0.10
	mode to chain		0.1874	2.81

Appendix E: Model Results for weekly Weekdays Work-related Data

Table I: Hypothesis H4 result for 1st week work-related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.000	
	Chain_ tp_ 2		-0.081	-3.65
	Chain_ tp_ 3		-0.279	-9.83
	Chain_ tp_ 4		-0.07	-4.41
	Chain_ tp_ 5		-0.046	-3.88
	Chain_ tp_ 6		-0.053	-3.74
	Chain_ tp_ 7		-0.016	-1.80
	Chain_ tp_ 8		-0.043	-3.57
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.000	
	Mode 2		-0.072	-3.42
	Mode 3		-0.289	-10.88
	Mode 4		-0.113	-3.68
	Mode 5		-0.217	-5.81
	Mode 6		-0.045	-2.45
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHA	Trip chaining utility	-0.0835	-1.48
	MV		0.0486	1.66
	Walk_bus		-0.147	-1.60
	Income		0.0322	1.07
	Gender		0.328	4.26
	Partner		0.266	3.20
	N_o_wh		-0.007	-1.95
	W_Schedule		0.218	2.92
	Ps_at_wp		-0.373	-3.19
	License		-0.139	-3.48
Variable related with mode choice pattern	HHA	Mode choice pattern	0.0645	1.23
	MV		0.0476	1.79
	Walk_bus		-0.139	-1.54
	Gender		-0.135	-1.65
	Age		0.018	5.94
	Partner		0.13	1.45
	Work_status		0.355	2.95
	N_o_wh		-0.009	-2.03
	Ps_at_wp		0.537	7.12
Direct effect within latent variables				
	chain to mode		-0.27	-1.99
	mode to chain		0.57	3.86

Table II: Total effect of exogenous variables on Decision variables for 1st week work-related trip chain: Hypothesis H4

Decision variables	**Exogenous variables**											
	HHA	MV	Walk_bus	Income	Gender	Age	Partner	Work_status	N_o_wh	W_schedul	Ps_at-wp	License
Chain_ tp_ 1	---	0.066	-0.196	0.028	0.217	0.009	0.295	0.176	-0.01	0.189	---	-0.12
Chain_ tp_ 2	---	-0.003	0.009	-0.001	-0.011	-0.0004	-0.014	-0.009	0.0005	-0.009	---	0.006
Chain_ tp_ 3	---	-0.018	0.055	-0.008	-0.0561	-0.003	-0.082	-0.049	0.003	-0.053	---	0.034
Chain_ tp_ 4	---	-0.005	0.014	-0.002	-0.015	-0.0006	-0.021	-0.012	0.0007	-0.013	---	0.008
Chain_ tp_ 5	---	-0.003	0.009	-0.001	-0.01	-0.0004	-0.014	-0.008	0.0005	-0.0088	---	0.0056
Chain_ tp_ 6	---	-0.004	0.011	-0.002	-0.012	-0.0005	-0.016	-0.009	0.0005	-0.01	---	0.0064
Chain_ tp_ 7	---	-0.001	0.003	-0.0005	-0.004	-0.0001	-0.005	-0.003	0.0002	-0.003	---	0.002
Chain_ tp_ 8	---	-0.003	0.008	-0.001	-0.009	-0.0004	-0.013	-0.008	0.0004	-0.008	---	0.0051
Mode 1	0.075	0.03	-0.087	-0.008	-0.193	0.0158	---	0.308	-0.0064	-0.05	0.5523	0.0322
Mode 2	-0.005	-0.002	0.006	0.0005	0.014	-0.0011	---	-0.022	0.0005	0.0036	-0.0397	-0.0023
Mode 3	-0.022	-0.009	0.025	0.0022	0.0056	-0.0046	---	-0.0888	0.0019	0.0146	-0.1596	-0.0093
Mode 4	-0.009	-0.003	0.01	0.0008	0.0218	-0.0018	---	-0.0347	0.0007	0.0057	-0.0624	-0.0036
Mode 5	-0.016	-0.007	0.019	0.0016	0.042	-0.0034	---	-0.0668	0.0014	0.011	-0.12	-0.007
Mode 6	-0.003	-0.001	0.004	0.0003	0.009	-0.0007	---	-0.0138	0.0003	0.0023	-0.0247	-0.0014

Table III: Hypothesis H4 result for 2nd week work-related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.000	
	Chain_ tp_ 2		-0.032	-3.28
	Chain_ tp_ 3		-0.29	-9.83
	Chain_ tp_ 4		-0.074	-4.48
	Chain_ tp_ 5		-0.041	-3.38
	Chain_ tp_ 6		-0.076	-3.99
	Chain_ tp_ 7		-0.012	-1.57
	Chain_ tp_ 8		-0.026	-3.00
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.000	
	Mode 2		-0.082	-3.59
	Mode 3		-0.293	-10.71
	Mode 4		-0.104	-2.96
	Mode 5		-0.229	-5.66
	Mode 6		-0.038	-2.04
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHA	Trip chaining utility	0.108	2.66
	Walk_rail		0.231	3.47
	Income		-0.042	-1.45
	Partner		0.203	2.62
	Education		-0.147	-1.96
	License		-0.174	-4.99
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.046	-1.79
	HHA		0.127	1.67
	MV		0.073	3.26
	Walk_bus		-0.086	-1.24
	Walk_rail		0.072	1.12
	Age		0.007	2.81
	Partner		0.127	1.67
	Ps_at_wp		0.688	10.26
Direct effect within latent variables				
	chain to mode		-0.09	-1.04
	mode to chain		0.38	4.20

Table IV: Total effect of exogenous variables on Decision variables for 2nd week work-related trip chain: Hypothesis H4

Decision variables	**Exogenous variables**										
	HHM	HHA	MV	Walk_bus	Walk_rail	Income	Age	Partner	Ps_at_wp	Education	License
Chain_ tp_ 1	-0.017	0.132	0.027	-0.031	0.25	-0.04	0.0026	0.243	0.252	-0.142	-0.169
Chain_ tp_ 2	0.0005	-0.0042	-0.0009	0.001	-0.008	0.0013	-0.0001	-0.0077	-0.0088	0.0045	0.0054
Chain_ tp_ 3	0.0048	-0.038	-0.0078	0.0091	-0.072	0.012	-0.0008	-0.0703	-0.0728	0.0411	0.0488
Chain_ tp_ 4	0.0012	-0.0097	-0.002	0.0023	-0.018	0.003	-0.0002	-0.0179	-0.0185	0.0105	0.0124
Chain_ tp_ 5	0.0007	-0.0054	-0.0011	0.0013	-0.0103	0.0017	-0.0001	-0.01	-0.0104	0.0059	0.007
Chain_ tp_ 6	0.0013	-0.01	-0.002	0.0024	-0.0189	0.0031	-0.0002	-0.0184	-0.0191	0.0108	0.0128
Chain_ tp_ 7	0.0002	-0.0016	-0.0003	0.0004	-0.003	0.0005	-0.00004	-0.0029	-0.003	0.0017	0.002
Chain_ tp_ 8	0.0004	-0.0034	-0.0007	0.0008	-0.0065	0.0011	-0.0001	-0.0063	-0.0066	0.0037	0.0044
Mode 1	-0.044	0.0613	0.071	-0.083	---	---	0.0069	0.1054	0.6662	---	---
Mode 2	0.0036	-0.005	-0.0058	0.0068	---	---	-0.0006	-0.0087	-0.0547	---	---
Mode 3	0.0129	-0.018	-0.021	0.0243	---	---	-0.002	-0.0309	-0.1954	---	---
Mode 4	0.0046	-0.0064	-0.0074	0.0086	---	---	-0.0007	-0.011	-0.0695	---	---
Mode 5	0.01	-0.014	-0.0163	0.019	---	---	-0.0016	-0.0242	-0.1527	---	---
Mode 6	0.0017	-0.0023	-0.0027	0.0031	---	---	-0.0003	-0.004	-0.0252	---	---

Table V: Hypothesis H4 result for 3rd week work-related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.000	
	Chain_ tp_ 2		-0.0345	-3.42
	Chain_ tp_ 3		-0.333	-10.83
	Chain_ tp_ 4		-0.0395	-3.21
	Chain_ tp_ 5		-0.0282	-3.05
	Chain_ tp_ 6		-0.047	-2.65
	Chain_ tp_ 7		-0.017	-2.37
	Chain_ tp_ 8		-0.0163	-2.26
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.000	
	Mode 2		-0.078	-3.18
	Mode 3		-0.3313	-12.39
	Mode 4		-0.1113	-3.74
	Mode 5		-0.1578	-4.77
	Mode 6		-0.0283	-1.89
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHA	Trip chaining utility	0.0473	1.01
	Gender		0.1679	1.88
	Age		-0.0059	-1.59
	Partner		0.1121	1.29
	Work_status		-0.2163	-1.79
	N_o_wh		0.0107	2.71
	W_schedule		0.3076	4.37
	Education		-0.3058	-3.59
	License		-0.092	-2.40
	Ps_at_wp		-0.3533	-2.66
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.0727	-2.34
	HHA		0.1501	2.16
	MV		0.1011	3.44
	Walk_rail		0.1632	2.08
	Income		-0.0608	-1.7031
	Age		0.0115	3.57
	Partner		0.153	1.62
	Ps_at_wp		0.7391	9.31
Direct effect within latent variables				
	chain to mode		-0.44	-2.54
	mode to chain		0.72	4.55

Table VI: Total effect of exogenous variables on Decision variables for 3rd week work-related trip chain: Hypothesis H4

Decision variables	**Exogenous variables**													
	HHM	HHA	MV	Walk_rail	Income	Gender	Age	Partner	Work_status	N_o_wh	W_schedule	Ps_at_wp	Education	License
Chain_ tp_ 1	-0.0398	0.1181	0.0554	0.0894	-0.0333	0.1275	---	0.1689	-0.1643	0.0082	0.2336	0.1365	-0.232	-0.070
Chain_ tp_ 2	0.00114	-0.0041	-0.0019	-0.0031	0.0011	-0.0044	---	-0.0058	0.0057	-0.0003	-0.0081	-0.0047	0.008	0.002
Chain_ tp_ 3	0.0133	-0.0394	-0.0184	-0.0298	0.0111	-0.0425	---	-0.0563	0.0547	-0.0027	-0.0778	-0.0455	0.077	0.023
Chain_ tp_ 4	0.0016	-0.0047	-0.0022	-0.035	0.0013	-0.005	---	-0.0067	0.0065	-0.0003	-0.0092	-0.0054	0.009	0.003
Chain_ tp_ 5	0.0011	-0.0033	-0.0016	-0.0025	0.0009	-0.0036	---	-0.0048	0.0046	-0.0002	-0.0066	-0.0038	0.007	0.002
Chain_ tp_ 6	0.0019	-0.0055	-0.0026	-0.0042	0.0016	-0.006	---	-0.0079	0.0077	-0.0004	-0.011	-0.0064	0.011	0.003
Chain_ tp_ 7	0.0007	-0.002	-0.0009	-0.0015	0.0006	-0.0022	---	-0.0029	0.0028	-0.0001	-0.004	-0.0023	0.004	0.001
Chain_ tp_ 8	0.0006	-0.0019	-0.0009	-0.0015	0.0005	-0.0021	---	-0.0027	0.0027	-0.0001	-0.0038	-0.0022	0.004	0.001
Mode 1	-0.0552	0.0982	0.0767	0.124	-0.0461	-0.056	0.0107	0.0788	0.0722	-0.0036	-0.1026	0.6792	0.102	0.031
Mode 2	0.0043	-0.0077	-0.006	-0.0097	0.0036	0.0044	-0.0008	-0.0061	-0.0056	0.0003	0.008	-0.053	-0.008	-0.002
Mode 3	0.0183	-0.0325	-0.0254	-0.0411	0.0153	0.0186	-0.0035	-0.0261	-0.0239	0.0012	0.034	-0.225	-0.034	-0.010
Mode 4	0.0061	-0.0109	-0.0085	-0.0138	0.0051	0.0062	-0.0012	-0.0088	-0.008	0.0004	0.0114	-0.0756	-0.011	-0.003
Mode 5	0.0087	-0.0155	-0.0121	-0.0196	0.0073	0.0088	-0.0017	-0.0124	-0.0114	0.0006	0.0162	-0.1072	-0.016	-0.005
Mode 6	0.0016	-0.0028	-0.0022	-0.0035	0.0013	0.0016	-0.0003	-0.0022	-0.002	0.0001	0.0029	-0.0192	-0.003	-0.001

Table VII: Hypothesis H4 result for 4th week work-related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.000	
	Chain_ tp_ 2		-0.067	-4.75
	Chain_ tp_ 3		-0.277	-9.12
	Chain_ tp_ 4		-0.0387	-2.97
	Chain_ tp_ 5		-0.0762	-5.04
	Chain_ tp_ 6		-0.0382	-2.40
	Chain_ tp_ 7		-0.0165	-1.98
	Chain_ tp_ 8		-0.0164	-1.96
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.000	
	Mode 2		-0.10	-3.92
	Mode 3		-0.3215	-12.05
	Mode 4		-0.0957	-3.21
	Mode 5		-0.1819	-5.15
	Mode 6		-0.0363	-2.41
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHA	Trip chaining utility	0.0701	1.44
	Income		0.0567	1.59
	Gender		0.3149	3.46
	Age		-0.0058	-1.27
	Partner		0.1341	1.54
	Work_status		-0.3572	-2.63
	N_o_wh		0.0061	1.42
	W_schedule		0.2604	3.42
	Education		-0.1483	-1.61
	License		-0.0714	1.82
	Ps_at_wp		-0.6123	-2.97
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.0503	-1.73
	HHA		0.0936	1.31
	MV		0.0769	2.89
	Walk_rail		0.1858	2.45
	Income		-0.0658	-2.22
	Age		0.013	4.26
	Partner		0.1723	1.8472
	Work_status		0.1598	1.44
	N_o_wh		-0.0071	-1.93
	W_schedule		-0.10	-1.40
	Education		0.0926	1.12
	Ps_at_wp		0.7654	10.61
Direct effect within latent variables				
	chain to mode		-0.41	-1.77
	mode to chain		0.82	3.17

Table VIII: Total effect of exogenous variables on Decision variables for 4th week work-related trip chain: Hypothesis H4

Decision variables	**Exogenous variables**													
	HHM	HHA	MV	Walk_rail	Income	Gender	Age	Partner	Work_status	N_o_wh	W_schedule	Ps_at-_wp	Education	License
Chain_ tp_ 1	-0.031	0.110	0.047	0.114	---	0.2362	0.0037	0.2065	-0.1698	---	0.1338	0.0110	---	-0.054
Chain_ tp_ 2	0.002	-0.007	-0.003	-0.008	---	-0.0158	-0.0002	-0.0138	0.0113	---	-0.0089	-0.0007	---	0.0036
Chain_ tp_ 3	0.009	-0.031	-0.013	-0.032	---	-0.0654	-0.0010	-0.0572	0.0470	---	-0.0370	-0.0031	---	0.015
Chain_ tp_ 4	0.001	-0.004	-0.002	-0.004	---	-0.0091	-0.0001	-0.0080	0.0066	---	-0.0052	-0.0004	---	0.002
Chain_ tp_ 5	0.002	-0.008	-0.004	-0.009	---	-0.018	-0.0003	-0.0157	0.0129	---	-0.0102	-0.0008	---	0.004
Chain_ tp_ 6	0.001	-0.004	-0.002	-0.004	---	-0.009	-0.0001	-0.0079	0.0065	---	-0.0051	-0.0004	---	0.002
Chain_ tp_ 7	0.001	-0.002	-0.001	-0.002	---	-0.0039	-0.0001	-0.0034	0.0028	---	-0.0022	-0.0002	---	0.001
Chain_ tp_ 8	0.001	-0.002	-0.001	-0.002	---	-0.0039	-0.0001	-0.0034	0.0028	---	-0.0022	-0.0002	---	0.001
Mode 1	-0.038	---	0.058	0.139	-0.067	-0.096	0.0115	0.0884	0.2288	-0.0072	-0.1545	0.7609	0.115	0.022
Mode 2	0.004	---	-0.006	-0.014	0.007	0.010	-0.0012	-0.0089	-0.0229	0.0007	0.0155	-0.0762	-0.012	-0.002
Mode 3	0.012	---	-0.019	-0.045	0.021	0.031	-0.0037	-0.0284	-0.0736	0.0023	0.0497	-0.2447	-0.0369	-0.0070
Mode 4	0.004	---	-0.006	-0.013	0.006	0.009	-0.0011	-0.0085	-0.0219	0.0007	0.0148	-0.0729	-0.011	-0.002
Mode 5	0.007	---	-0.011	-0.025	0.012	0.018	-0.0021	-0.0161	-0.0416	0.0013	0.0281	-0.1385	-0.021	-0.004
Mode 6	0.001	---	-0.002	-0.005	0.002	0.004	-0.0004	-0.0032	-0.0083	0.0003	0.0056	-0.0276	-0.004	-0.001

Table IX: Hypothesis H4 result for 5th week work-related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1.000	---
	Chain_ tp_ 2		-0.05	-4.15
	Chain_ tp_ 3		-0.28	-9.84
	Chain_ tp_ 4		-0.06	-3.84
	Chain_ tp_ 5		-0.02	-2.23
	Chain_ tp_ 6		-0.04	-2.16
	Chain_ tp_ 7		-0.02	-2.33
	Chain_ tp_ 8		-0.01	-1.36
Variable related with mode choice pattern	Mode 1	Mode choice utility	1.000	---
	Mode 2		-0.12	-4.72
	Mode 3		-0.27	-10.76
	Mode 4		-0.12	-4.11
	Mode 5		-0.11	-3.89
	Mode 6		-0.03	-2.09
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHM	Trip chaining utility	0.0665	1.56
	HHA		-0.1299	-1.52
	Income		0.0579	1.51
	Gender		0.325	2.96
	Age		-0.0086	-1.87
	Partner		0.1528	1.55
	Work_status		-0.2891	-2.51
	W_schedule		0.3118	3.41
	License		-0.0498	-1.12
	Ps_at_wp		-0.7693	-3.76
Variable related with mode choice pattern	HHM	Mode choice pattern	-0.0814	-1.76
	HHA		0.1949	2.03
	MV		0.061	1.48
	Walk_bus		-0.2394	-1.63
	Walk_rail		0.4134	2.70
	Income		-0.0699	-1.61
	Age		0.0121	2.86
	Partner		0.1537	1.11
	N_o_wh		-0.011	-2.12
	Ps_at_wp		0.9223	7.79
Direct effect within latent variables				
	chain to mode		-0.72	-1.91
	mode to chain		1.07	4.72

Table X: Total effect of exogenous variables on Decision variables for 5th week work-related trip chain: Hypothesis H4

Decision variables	**Exogenous variables**													
	HHM	HHA	MV	Walk_bus	Walk_rail	Income	Gender	Age	Partner	Work_status	N_o_wh	W_schedule	Ps_at-_wp	License
Chain_ tp_ 1	-0.012	---	0.037	-0.145	0.250	---	0.183	0.003	0.179	-0.163	-0.007	0.175	0.124	-0.028
Chain_ tp_ 2	0.0006	---	-0.0019	0.0075	-0.0130	---	-0.0095	-0.0001	-0.0093	0.0084	0.0003	-0.0091	-0.0064	0.0015
Chain_ tp_ 3	0.0033	---	-0.0103	0.0405	-0.0699	---	-0.0512	-0.0007	-0.0501	0.0455	0.0019	-0.0491	-0.0348	0.0078
Chain_ tp_ 4	0.0007	---	-0.0023	0.0090	-0.0155	---	-0.0113	-0.0002	-0.0111	0.0101	0.0004	-0.0109	-0.008	0.002
Chain_ tp_ 5	0.0002	---	-0.0006	0.0024	-0.0041	---	-0.0030	0.0000	-0.0029	0.0027	0.0001	-0.0029	-0.002	0.001
Chain_ tp_ 6	0.0005	---	-0.0015	0.0060	-0.0103	---	-0.0075	-0.0001	-0.0074	0.0067	0.0003	-0.0072	-0.005	0.001
Chain_ tp_ 7	0.0002	---	-0.0006	0.0025	-0.0043	---	-0.0031	0.0000	-0.0031	0.0028	0.0001	-0.0030	-0.002	0.001
Chain_ tp_ 8	0.0001	---	-0.0002	0.0008	-0.0015	---	-0.0011	0.0000	-0.0010	0.0009	0.0000	-0.0010	-0.001	0.000
Mode 1	-0.0729	0.1626	0.0343	-0.1347	0.2326	-0.0629	-0.1324	0.0103	---	0.1178	-0.0062	-0.1270	0.832	0.020
Mode 2	0.0088	-0.0196	-0.0041	0.0162	-0.0280	0.0076	0.0159	-0.0012	---	-0.0142	0.0007	0.0153	-0.100	-0.002
Mode 3	0.0199	-0.0443	-0.0094	0.0367	-0.0634	0.0172	0.0361	-0.0028	---	-0.0321	0.0017	0.0346	-0.227	-0.006
Mode 4	0.009	-0.020	-0.004	0.017	-0.029	0.008	0.0163	-0.0013	---	-0.0145	0.0008	0.0157	-0.103	-0.003
Mode 5	0.008	-0.019	-0.004	0.015	-0.026	0.007	0.015	-0.001	---	-0.013	0.001	0.014	-0.095	-0.002
Mode 6	0.002	-0.005	-0.001	0.004	-0.008	0.002	0.004	0.000	---	-0.004	0.000	0.004	-0.027	-0.001

Table XI: Hypothesis H4 result for 6th week work-related trip chain

Measurement model	Endogeous variable	Latent variable	Estimates	T- Stat
Variable related with trip chain Utility	Chain_ tp_ 1	Trip chaining utility	1	---
	Chain_ tp_ 2		-0.0148	-1.21
	Chain_ tp_ 3		-0.2758	-8.23
	Chain_ tp_ 4		-0.0734	-4.16
	Chain_ tp_ 5		-0.0581	-3.83
	Chain_ tp_ 6		-0.0669	-3.24
	Chain_ tp_ 7		-0.0205	-1.68
	Chain_ tp_ 8		-0.0129	-1.36
Variable related with mode choice pattern	Mode 1	Mode choice utility	1	---
	Mode 2		-0.0871	-3.07
	Mode 3		-0.3303	-11.02
	Mode 4		-0.117	-3.77
	Mode 5		-0.1879	-4.34
	Mode 6		-0.0099	-1.07
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain Utility	HHA	Trip chaining utility	0.0717	1.12
	MV		0.036	1.37
	Walk_bus		-0.2162	-2.32
	Gender		0.2186	2.96
	Partner		0.1944	2.18
	W_schedule		0.2819	4.07
	Education		-0.1437	-1.65
	License		-0.1076	-2.45
	Ps_at_wp		-0.3773	-2.73
Variable related with mode choice pattern	HHA	Mode choice pattern	0.1047	1.92
	Walk_rail		0.0796	1.10
	Income		-0.0864	-2.76
	Age		0.0069	2.46
	Partner		0.1262	1.4856
	Work_status		0.3496	3.04
	N_o_wh		-0.0132	-3.49
	Ps_at_wp		0.6947	8.21
Direct effect within latent variables				
	chain to mode		0.0213	-0.16
	mode to chain		0.3475	2.1691

Table XII: Total effect of exogenous variables on Decision variables for 6th week work-related trip chain: Hypothesis H4

Decision variables	**Exogenous variables**													
	HHA	MV	Walk_bus	Walk_rail	Income	Gender	Age	Partner	Work_status	N_o_wh	W_schedule	Ps_at-_wp	Education	License
Chain_ tp_ 1	0.1089	0.0363	-0.2178	---	-0.0303	0.2202	0.0024	0.24	0.1224	-0.0046	0.284	-0.1369	---	-0.0839
Chain_ tp_ 2	-0.0016	-0.0005	0.0032	---	0.0004	-0.0032	---	-0.0035	-0.0018	0.0001	-0.0042	0.002	---	0.0012
Chain_ tp_ 3	-0.03	-0.01	0.0601	---	0.0083	-0.0607	-0.0007	-0.0662	-0.0338	0.0013	-0.0783	0.0378	---	0.0232
Chain_ tp_ 4	-0.008	-0.0027	0.016	---	0.0022	-0.0162	-0.0002	-0.0176	-0.009	0.0003	-0.0208	0.01	---	0.0062
Chain_ tp_ 5	-0.0063	-0.0021	0.0127	---	0.0018	-0.0128	-0.0001	-0.0139	-0.0071	0.0003	-0.0165	0.0079	---	0.0049
Chain_ tp_ 6	-0.0073	-0.0024	0.0146	---	0.002	-0.0147	-0.0002	-0.0161	-0.0082	0.0003	-0.019	0.0092	---	0.0056
Chain_ tp_ 7	-0.0022	-0.0007	0.0045	---	0.0006	-0.0045	---	-0.0049	-0.0025	0.0001	-0.0058	0.0028	---	0.0017
Chain_ tp_ 8	-0.0014	-0.0005	0.0028	---	0.0004	-0.0028	---	-0.0031	-0.0016	0.0001	-0.0037	0.0018	---	0.0011
Mode 1	0.107	---	---	0.0802	-0.0871	---	0.0069	0.1313	0.3522	-0.0133	---	0.6918	0.2392	0.068
Mode 2	-0.0093	---	---	-0.007	0.0076	---	-0.0006	-0.0114	-0.0307	0.0012	---	-0.0603	-0.0208	-0.0059
Mode 3	-0.0353	---	---	-0.0265	0.0288	---	-0.0023	-0.0434	-0.1163	0.0044	---	-0.2285	-0.079	-0.0225
Mode 4	-0.0125	---	---	-0.0094	0.0102	---	-0.0008	-0.0154	-0.0412	0.0016	---	-0.0809	-0.028	-0.008
Mode 5	-0.0201	---	---	-0.0151	0.0164	---	-0.0013	-0.0247	-0.0662	0.0025	---	-0.13	-0.0449	-0.0128
Mode 6	-0.0011	---	---	-0.0008	0.0009	---	-0.0001	-0.0013	-0.0035	0.0001	---	-0.0068	-0.0024	-0.0007

Appendix F: Model Results for Weekends Nonwork-related Pooled Data

Table I: Hypothesis H1 result for weekend's non-work related trip chain

Measurement model	**Decision variable**	**Latent variable**	**Estimates**	**T- Stat**
Variable related with trip chain pattern	Chain tp- 9	Trip chain utility	1	---
	Chain tp_10		-0.33	-19.8
Variable related with mode choice	Mode 1	Mode choice utility	1	---
	Mode 2		-0.17	-10.25
	Mode 3		-0.09	-8.45
	Mode 4		-0.1	-7.04
	Mode 5		-0.13	-7.39
	Mode 6		-0.03	-4.24
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain pattern	HHA	Trip chain utility	0.07	1.93
	Gender		0.08	1.42
	Age		0.004	2.09
	Education		-0.07	1.15
Variable related with mode choice	HHM	Mode choice Utility	-0.04	-2.16
	MV		0.08	4.15
	Walk_rail		-0.25	-4.67
	Income		-0.05	-2.45
	Gender		0.36	6.78
	Age		0.004	3.61
	Partner		0.11	1.71
Direct effect within latent variables				
	chain to mode		---	---
	mode to chain		---	---
Correlation Coefficient between latent variables			0.23	10.17

Table II: Total effect of exogenous variables on Decision variables for weekend's nonwork-related trip chain: Hypothesis H1

Exogenous variables	Exogenous variables								
	HHM	HHA	MV	Walk_rail	Income	Sex	Age	Partner	Education
Chain_tp_9	---	0.07	---	---	---	0.08	0.004	---	-0.07
Chain_tp_10	---	-0.02	---	---	---	-0.03	-0.003	---	0.02
Mode1	-0.043	---	0.077	-0.251	-0.05	0.36	0.01	0.11	---
Mode2	0.008	---	-0.013	0.042	0.01	-0.06	-0.001	-0.02	---
Mode3	0.004	---	-0.008	0.022	0.004	-0.03	-0.001	-0.01	---
Mode4	0.006	---	-0.007	0.024	0.004	-0.03	-0.001	-0.01	---
Mode5	0.007	---	-0.01	0.033	0.007	-0.05	-0.001	-0.01	---
Mode6	0.001	---	-0.002	0.008	0.002	-0.01	-0.0004	-0.004	---

Table III: Hypothesis H3 result for weekend's non-work related trip chain

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chain pattern	Chain tp- 9	Trip chain utility	1	---
	Chain tp_10		-0.33	-19.80
Variable related with mode choice	Mode 1	Mode choice utility	1	---
	Mode 2		-0.17	-10.25
	Mode 3		-0.09	-8.44
	Mode 4		-0.1	-7.03
	Mode 5		-0.13	-7.38
	Mode 6		-0.03	-4.23
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain pattern	HHA	Trip chain utility	0.09	1.96
	MV		-0.02	-1.16
	Walk_rail		0.10	1.74
	Income		0.03	1.26
	Partner		-0.07	-1.02
	Education		-0.09	-1.31
Variable related with mode choice	HHM	Mode choice Utility	-0.04	-2.10
	MV		0.07	3.85
	Walk_rail		-0.25	-4.37
	Income		-0.05	-2.21
	Gender		0.33	5.40
	Age		0.01	3.74
	Partner		0.10	1.45
Direct effect within latent variables				
	chain to mode		---	---
	mode to chain		0.32	0.11.32

Table IV: Total effect of exogenous variables on Decision variables for weekend's nonwork-related trip chain: Hypothesis H3

Exogenous variables	Exogenous variables								
	HHM	HHA	MV	Walk_rail	Income	Sex	Age	Partner	Education
Chain_tp_9	-0.01	0.09	---	---	---	0.11	0.004	---	-0.09
Chain_tp_10	0.004	-0.03	---	---	---	-0.04	-0.003	---	0.03
Mode1	-0.043	---	0.073	-0.25	-0.05	0.33	0.008	0.10	---
Mode2	0.008	---	-0.014	0.042	0.01	-0.06	-0.001	-0.02	---
Mode3	0.004	---	-0.008	0.022	0.004	-0.03	-0.001	-0.01	---
Mode4	0.004	---	-0.007	0.024	0.004	-0.03	-0.001	-0.01	---
Mode5	0.006	---	-0.01	0.033	0.006	-0.04	-0.001	-0.02	---
Mode6	0.001	---	-0.002	0.007	0.002	-0.01	-0.0004	-0.004	---

Table V: Hypothesis H4 result for weekend's non-work related trip chain

Measurement model	Decision variable	Latent variable	Estimates	T- Stat
Variable related with trip chain pattern	Chain tp- 9	Trip chain utility	1	---
	Chain tp_10		-0.33	-19.8
Variable related with mode choice	Mode 1	Mode choice utility	1	---
	Mode 2		-0.17	-10.24
	Mode 3		-0.09	-8.44
	Mode 4		-0.1	-7.03
	Mode 5		-0.13	-7.38
	Mode 6		-0.03	-4.23
Structural equation model	**Exogenous variable**	**Latent variable**	**Estimates**	**T-Stat**
Variable related with trip chain pattern	HHA	Trip chain utility	0.05	1.56
	Work_status		0.09	1.45
	Age		0.005	1.91
Variable related with mode choice	HHM	Mode choice Utility	-0.04	-1.69
	N_O_MV		0.08	4.12
	WALK_RAIL		-0.25	-4.62
	HH_INCOME		-0.05	-2.21
	GENDER		0.34	6.52
	AGE		0.01	3.19
	PARTNER		0.12	1.79
Direct effect within latent variables				
	chain to mode		0.29	2.61
	mode to chain		0.02	0.17

Table VI: Total effect of exogenous variables on Decision variables for weekend's nonwork-related trip chain: Hypothesis H4

Exogenous variables	Exogenous variables								
	HHM	HHA	MV	Walk_rail	Income	Sex	Age	Partner	Education
Chain_tp_9	---	0.052	---	---	---	---	0.006	---	-0.09
Chain_tp_10	---	-0.022	---	---	---	---	-0.003	---	0.03
Mode1	-0.047	---	0.078	-0.252	-0.05	0.34	0.008	0.12	-0.03
Mode2	0.008	---	-0.014	0.043	0.01	-0.06	-0.001	-0.02	0.004
Mode3	0.004	---	-0.008	0.023	0.006	-0.03	-0.001	-0.01	0.002
Mode4	0.005	---	-0.007	0.024	0.006	-0.03	-0.001	-0.01	0.002
Mode5	0.006	---	-0.01	0.033	0.007	-0.05	-0.001	-0.02	0.003
Mode6	0.001	---	-0.002	0.008	0.002	-0.01	-0.0004	-0.004	0.001