MODELING TOUR CHOICE PATTERN OF TRANSIT COMMUTERS

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Research Motivation

Since modern life is becoming busier and people are facing more time poverty, there is an increasing tendency of people to find out opportunities to chain several activity purposes within a single tour to minimize the number of travel and to gain efficiency in activity participation. When trip making behavior becomes more complex in terms of multiple activity purposes distributed over multiple spatial locations, people seek more flexible travel mode to fulfill that demand. Private vehicles offer maximum flexibility of travel, whereas public transit usually operates at a fixed route and with a fixed schedule, for which the accessibility and mobility services offered by public transit is usually less attractive than private vehicles (Hensher and Reyes, 2000; Currie and Delbosc, 2011). In order to make public transit ridership more attractive and consequently to reduce the use of private vehicles, it is imperative to identify the existing activity-travel patterns and tour formation of transit users. This understanding might help to find out the barriers that impede the use of public transit in making complex tours.

There are only a few prior studies that focused on trip chain behavior of transit users. Henser and Reyes (2000) identified the socio-demographic factors that influence people in Sydney, Australia, to choose trip chains of different complexity either by car or by public transit by using discrete mode choice models. They also provide insights about the extent to which trip complexity is a barrier to the propensity to use public transport. Another recent study conducted by Currie and Delbosc (2011) explored the trip chain behavior of public transit areas in Melbourne, Australia. Based on a univariate analysis, the authors represented that public transport chains for non work based travel were found to be more complex than those undertaken by car. However, the opposite were found for work based travel. None of the previous works focused on the daily activity-travel pattern (sequence of activity and travel) of transit users and their tour formation (simple and complex). Our research aims at filling this gap.

In order to narrow the focus, this research will study the dominant sequence of activity and travel of transit commuters within their work tour, how and what type of non-work activities are performed within complex work tours, and what are the factors that affect the choice of particular tour choice pattern. This study will provide better insights on complex movement patterns and tour formation of transit commuters, which will help to take necessary land use and transit related policies that can conveniently connect their non-work activity demands within their work tour. This will also help to predict the tour patterns of transit commuters with particular socio-demographic and economic background, which will eventually help to predict the number of stops within a tour and then to schedule a tour in an activity-based model.

Data and Sample

We use the National Household Travel Survey (NHTS) data for this study. NHTS is the source of information about travel by US residents in all 50 States and the District of Columbia. The data includes trips made by all modes of travel (private vehicle, public transportation, pedestrian, and

biking) and for all purposes (travel to work, school, recreation, and personal/family trips). The NHTS data contains four datasets or tables: households, persons, trips, and vehicles. Households table contains the information about the households that are surveyed and person table contains information about all individuals living in those households. Trips data table lists of all trips made the surveyed individual (one per household) and vehicles data table contains information about vehicles used by the corresponding households. For our analysis, we identified adult transit commuters, that is, those individuals who are at least 18 years old and have mentioned using transit as their work travel mode (as denoted by WRKTRANS variable on 'persons' data table). We treat a choice of trip mode as transit if it is any of the following: "public or commute bus", "paratransit/Dia-a-ride", "city-to-city bus (greyhound, Megabus, etc)", "Amtrak/commuter rail", and "subway/elevated/light rail/street car". We further filter this down and take only those who mentioned who worked on the survey data and took at least one transit trip on that day. This ultimately generates a sample of 2063 individuals.

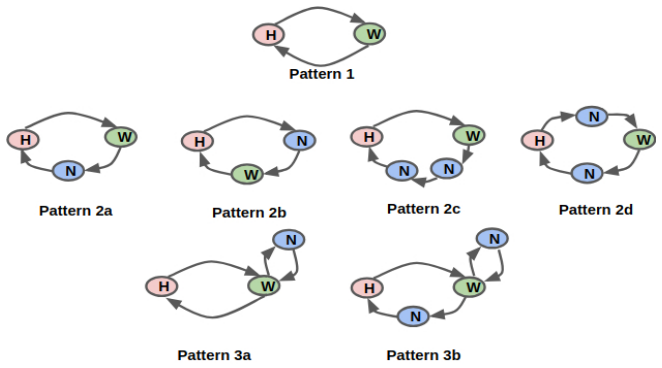

Figure 1 Seven dominant tour choice patterns for transit commuters: (1) home-based simple tour, (2a, 2b, 2c, 2d) home-based complex tours and (3a, 3b) home-based and work-based tour.

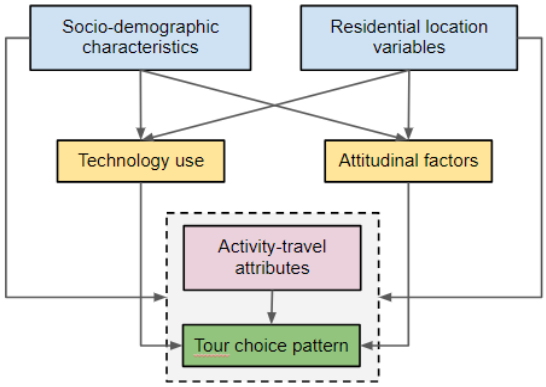

Figure 2 Structural equation model

Tour Formation of Transit Commuters

A tour is a sequence of trips that starts and ends at the same location. If the location in question is home that it is called home-based tour. Since our study involves working individuals, we are interested in tours where the non-home location is mainly workplace (tours should contains at least one workplace visit). A tour is called home-based only if the tour does not recur anywhere other than home. A home-based tour is called a simple home-based tour if it has exactly one non-home activity, that is, work. That means, a home-based simple tour is Home -Work-Home. On the other hand, home-based complex tours may contain non-home locations other than work (on they their way to work or on the way to home). Sometimes, tours can be made from within workplace: going somewhere from workplace and then return back to workplace. These tours are called work-based tours. When a home-based tour combined with a work-based tour, we refer to as "home- and work-based" tour. Simply put, home-based tours (simple or complex) have exactly one loop whereas home- and work-based tours have two or more loops. Figure 1 shows a couple of example cases of different tours.

Model Specification

Structural equation modeling (SEM) is widely used in travel behavior research, including trip chain generation (Golob, 2000), trips within work tours (Van Acker and Witlox, 2011), and commuter activity-travel patterns (Kuppam and Pendyala, 2001). We use SEM path model to investigate the structural relationships between different factors that affect the choice of particular tour pattern of transit commuters.

The exogenous and endogenous variables

The model's exogenous and endogenous variables and their summary statistics are shown in Table 2 and 3, respectively. The exogenous variables include household and personal socio-demographic characteristics and residential location variables. On the other hand, the endogenous variables shown in Table 3 are of four broad types: technology usage, attitudinal/perception factors, activity-travel attributes, and choice of tours. There are total three variables that represent the 'use of technology' by a person, such as count of using rideshare app in last 30 days, count of doing online shopping in last 30 days, and frequency of using internet. A person's attitude/perception towards travel is captured by four factors: does he perceive travel as burden?, does he think that price of gasoline may affect travel?, can transit reduce financial burden?, and can walk reduce financial burden? The perception of individuals towards these variables are represented in the scale of 5. Again, there are a total of six activity-travel time use and mode related variables that express activity-travel attributes. These are work duration, work travel time, non-work duration, non-work travel time, whether transit (transit and walk) is used in all trips of a tour, and whether multimodes (transit and other modes) are used in a tour. Finally, we have three tour choice pattern binary variables indicating whether an individual made at least one tour of a given type.

The structural equation path model

Let us denote measured exogenous variables as $\mathbf{X}$ and measured endogenous variables as $\mathbf{Y}$. The equation for the endogenous variables is given by: $\mathbf{Y = \Gamma X + BY + \zeta}$. For detail discussion on SEM path model, refer to Kline, 2016 and Rafiq and McNally, 2018.

The conceptual model

The conceptual structure of the proposed model is shown in Figure 2. An arrow indicates the direct effect from one variable to other. The rectangular boxes represent exogenous and endogenous variables (in fact a group of variables under the name). A variable is exogenous if it is not determined by the model (an arrow is directed from it) and it is endogenous if it is determined by the model (an arrow is directed to and/or from it). In our conceptual model, household and person level socio-demographic characteristics and residential location variables are exogenous variables. These variables will affect a person's technology usage, his/her attitudes/perceptions towards travel, activity-travel attributes, and choice of tour patterns. Again, the pattern of tour choice by an individual might be affected by his/her technology usage and attitudinal factors. Moreover, one of the important determinants of tour choice is various work and non-work activity demands (time use) and their associated travel needs (travel time and mode). The full list of variables under each group is listed in Table 2 and 3.

Estimation of the model

Based on our conceptual structure (Figure 2), we estimated a SEM path model using `lavaan` package in R. We took logarithms of all activity and travel durations and some location variables such as, worker density, residential density, distance from home to workplace to reduce skewness.

We used WLSMV (weighted least square mean and variance adjusted) estimator that works with categorical endogenous variables (we have three binary variables for tour choice patterns, which are regressed by a probit function in `laavan` (R documentation, 2018) and that accounts for non-normally distributed data (Muthen and Kaplan, 1992).

The main model fit statistic is χ^2 statistic that tests whether the observed covariance matrix and the model implied covariance matrix are equal. Smaller χ^2 value with high *p-value* (*p-value* > 0.05) indicates better model fit. However, χ^2 value tends to increase with sample size so models with larger sample sizes might show larger χ^2 value and subsequently may lead to rejection of an otherwise good model (Van Acker and Witlox, 2011). We report other model fit indices, such as χ^2/df, Root Mean Square Error Approximation (RMSEA), Comparative Fit Index (CFI), Tucker Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR).

Our conceptual structure resulted in a large χ^2 value with a lower *p-value* (74) = 148.5 (*p-value* = 0.000), which does not meet the cut off value (*p-value* > 0.05) Other model fit indices indicate satisfactory fit results (χ^2/df = 2, RMSEA= 0.023, CFI=0.99, TLI=0.97, SRMR=0.1) (for desired values of these indices, please see Van Acker and Witlox, 2011).

Results and Discussion

In this section, we discuss unstandardized coefficients of *total* effects (Table 4) that are statistically significant. Due to limited space, we limit our discussion only on the effects of exogenous and endogenous variables on tour choices and tour modes. To show the variation among various tour patterns, we identify the most dominant seven tour patterns that constitute around 90 percent of the total tours. These tours are shown are in Figure 1 and the distribution of trip modes and nonwork activity purposes are tabulated in Table 1. We see that 56% tours are simple home-based tours. Irrespective of tour types, a good fraction of trips are made by public transit followed by cars and walks. Shopping and transporting someone are the dominant nonwork activities that are performed in work tours that contain nonwork activities. Work-based tours are mostly formed to go to eat (i.e., lunch) and are mostly made by walks.

Among the various socio-demographic characteristics, household size, income, presence of children, full time job status and flexibility of job significantly affect the tour choices. It is observed that with an increase of household size, the tendency to choose home-based simple tours increases and the tendency to make home- and work-based tours decreases. This means people from larger households tend to mix non-work activities within their work tours. This might be due to having other household members who might take care of essential non-work household activities (e.g., taking a child to school/daycare, grocery shopping). Both middle and high income make less home-based simple and more home- and work-based tours than low income people. As a dominant non-work activity within the home-based and work-based tour they take short walk trip and take lunch. Presence of child reduces home-based simple tours, perhaps because those individuals might take their child to daycare or complete shopping within a work tour and thus have fewer opportunities to make separate non-work tours. With the increase of the number of vehicles, the tendency to make 'home-based simple' tour increases. They might make separate non-work tour after returning home.

Men tend to make less non-work trips on their work commutes and make less home-based complex tours than women. Full time job holders tend to make less non-work trips on their way to work or way to home. As a result, they make less home-based complex tours and more home- and work-based tours. Higher residential density causes fewer home-based simple tours but more home-based complex tours. It might be easy for people in those areas to complete non-work activities on

their way to home near home location. As distance to work increases the chance to further travel from workplace to a non-work location declines hence tours from workplace reduces.

Technology usage impacts the choice of tours. For example, online shopping reduces less home-based simple tours and raises home-bound tours that has non-work activity on their way to work or way to home. This is because online shopping is usually done by higher income people and they have higher demand for non-work travel. Apparently, internet use is correlated with fewer home-based simple tours, and more mixing of non-work within work tours, particularly from going from workplace to non-work activity locations.

Attributes towards travel and transit influence people choice of tours. Those who think travel as a burden do not tend to mix non-work activity within their work tours, thus make less travel. Those who consider fuel price affecting travel prefer less to make tours from workplace, therefore make less home- and work-based tours. Individuals who treat transit as financial burden make tours from workplace and tend to make less home-based simple tours.

Finally, activity-travel time and trip modes also play role in choosing different tours. With the increase of work activity time, tendency of making all kind of work tours increases, particularly the tendency to make home-based simple tours is affected more. When people have to travel longer distance to work, they prefer less to make non-work on their way to home or way to work. If non-work activity demand increases, it causes non-work to be aligned with on the way to work or on the way home and also from workplace. That means, all but simple work tours increases. If longer travel time is required to reach non-work activity, it is preferred to make on the way to home, not from workplace. If one uses transit in all of its trip purposes in a tour, he/she has more tendency to do non-work activities starting from workplace (making work-based tours) and less so to do the same in home-bound tours. For multimodal tours, the relationship is reversed.

Conclusion

The complexity of travel behavior has significantly increased over the years as individuals respond to different activity demands and to the changing supply environment, measured by both congestion and cost, as well as emerging technologies. While personal vehicles arguably provide the most flexibility in terms of managing travel needs, the more sustainable mode of transport is public transit. Since public transit operates at a fixed route and with a fixed schedule, the accessibility and mobility services offered by it is usually less attractive than private vehicles (Hensher and Reyes, 2000; Currie and Delbosc, 2011). In order to make public transit ridership more attractive and consequently to reduce the use of private vehicles, our study aims to analyze the dominant sequence of activity and travel of transit commuters within their work tour, how and what type of non-work activities are performed within complex work tours, and what are the factors that affect the choice of particular tour choice pattern. We used 2017 National Household Travel Survey (NHTS) data to do necessary analysis and applied Structural Equation Modeling (SEM) to investigate the structural relationships among various socio-demographic, location, attitudinal, technology usage factors that might affect the choice of tour pattern of transit commuters. Results from the model shows that household income, full-time job status, residential density, online shopping, work and non-work activity time are the dominant factors that affect these choices. This study will provide insights on their tour formation patterns, which will help to take necessary land use and transit related policies that they can conveniently connect their non-work activity demands within their work tours. This will also help to predict the tour patterns of transit commuters with particular socio-demographic and economic background, which will eventually help to predict the number of stops within a tour and then to schedule a tour in an activity-based model.