A Simultaneous Choice Model of Departure Time and Travel Mode on One-Day Shopping Travel based on Disutility Minimizing Model Approach

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Abstract: This paper develops a simultaneous choice model of departure time and travel mode choices on one-day shopping travel based on minimizing disutility model approach. The model assumes that travelers decide both choices at the same time in order to minimize a numerous disutility types. The disutility types include shortage stay time disutility at a shopping place, parking charge disutility, inconvenience disutility due to travel time uncertainty, lateness home arrival time disutility, and disutility which consider a flexible daily time constraint such praying time-activity during noon until evening. The model was applied to the travelers who conduct one-day shopping travel based on home-shopping centre-home, H-SC-H, pattern, while available three travel mode choices i.e., car, motorcycle, and public transit. Regarding a goodness of fit test, the proposed model was acceptable. The results provide an expectation to develop a simultaneous choice model of departure time and the shopping place choice in further studies.

Key Words: Simultaneous choice model, departure time, travel mode, shopping travel, disutility minimizing model.

1 INTRODUCTION

Traveler's decisions on the departure time and travel mode are two determinant factors on travel demand analysis based on the activity behavior approach. In context of travel demand management (TDM), both choice problems are important to predict temporal demand for planning development and construction of new transportation infrastructure. The decisions also useful to test responses of demand related to improvement of operational strategies of traffic control or transportation measures. In addition, the usage of departure time and travel mode choice is to assess the effectiveness of implementation of travel demand management measures related to specific time (Bhat and Steed, 2002). In recent years, a departure time choice model with higher temporal resolution is also needed for modeling source emission and air quality (Popuri et al., 2008; Gadda et al., 2009).

During the past three decades, the departure time choice study has been conducted in many studies. Mostly the earlier researches used the discrete choice method which usually is based on the Random Utility Model (RUM) approach. The logit model and its' various development has dominated the studies using this approach. For instance, Abkowitz (1981),

McCafferty and Hall (1982), and Small (1982) developed the multinomial logit model (MNL) in order to model departure and arrival time choices of travelers, where their choices depended on demographic variables such us income, age, etc., and chosen mode. The MNL model was also used by Hendrickson and Plank (1984) in construction a simultaneous choice model of departure time and travel mode with 28 alternatives. The alternatives represented the combination among 4 modes (i.e., drive alone, auto, shared ride and transit) and 7 departure time intervals per 10 minutes. Mannering (1989) conducted investigation on the determinants of commuter flexibility in changing departure times and routes for the morning trip to work using Poisson regressions estimation method. Further, Chin (1990) proposed morning departure time choice model which used MNL and nested logit (NL) model in Singapore commuter case. In addition, Hunt and Patterson (1996) also adopted the logit model in examining the influence people in choosing a departure time for a hypothetical trip in Calgary, Canada. Formerly, McFadden (1978), and Ben Akiva & Lerman (1985) utilized the NL model to overcome violations of the independence of irrelevant alternatives (IIA) properties in the MNL model. Contrary, Jou (2001) proposed a joint model for departure time and route decisions with and without pre-trip information for commuters in Taiwan using a probit model.

The previous researches have been focused on the departure time choice models for commuting or work trips. However, a lot of earlier research was also focused on non-work trips such as shopping trips, recreation trips, etc. Bhat (1998a) developed a departure time and travel mode choice model simultaneously for urban shopping trips. He used a nested structure to construct the choice hierarchy, where the travel mode choices were the higher level and departure time choices were the lower level. The simultaneous choice model form adopted a MNL form for the travel mode choices, and an ordered generalized extreme value (OGEV) form for departure time alternatives. Bhat (1998b) also applied a mixed multinomial logit model to an analysis of travel mode and departure time choice for home-based, social-recreational trips for the San Francisco Bay Area. Furthermore, Steed and Bhat (2000) studied the departure time and trip purpose choices simultaneously for home-based social/recreational and shopping trips for the Dallas-Fort Worth region. They used the similar models approach as used in Bhat (1998a). This research focused on a non-work trip due to at least two reasons, i.e. non-work trips contribute to increasingly large proportion of urban trips recently, especially in peak periods, and non-work trips have a more temporal flexibility of individual than work trips (Bhat and Steed, 2002). In addition, the non-work trip provides more or less congestion and some environmental problems in the centre business district, CBD of city (Ramli et al., 2010a; 2010b).

Those previous studies of departure time choices for work and non work trips, are treating time as a discrete variable. The alternative of the departure time choices are represented by several discrete time periods, such as the time period in morning, the time period at noon, the time period in afternoon, the time period in evening, and the time period at night. There are four limitations in using this approach (Bhat and Steed, 2002). Firstly, the approach requires the rather ad hoc partitioning of time in a day into several time intervals, as a consequence differs of the partitioning time lead to different result of model. Secondly, a point of times is treated as part of an interval time nearing the boundary of the interval. Thirdly, the model provides departure time choices only in intervals of a time aggregate, resulting in the loss time in resolution, and lastly, the approach requires the same property of aggregate interval for forecasting utilization. Further, utilization of the logit model approach in this method leads to insufficiency of those models in the transform capability (Sumi et al., 1998). It is often difficult to clarify how each particular factor affects the observed result when

we are using the approach model comprehensively, particularly when we conform to the real world.

Regarding the discrete choice method restrictions, the continuous method has been developed by some scholars. In this regard, the departure time is treated as a continuous scale. Mostly exploration of the continuous method used Cox's (1972) proportional hazard (PH) model approach. For example, Wang (1996) modeled the revealed preferences of the activity start times for the Canadians case by using a parametric-baseline, hazard-rate model of duration. The model examined how travelers maximize their total timing utility in order to determine their time choice. A hazard-based model was also used by Bhat (1996) to develop a shopping duration model that was grouped in a 7.5-minute interval-level. The model adopted a nonparametric baseline hazard distribution, while the covariate effect was controlled parametrically. Furthermore, Bhat and Steed (2002) proposed a continuous-time approach to develop a departure time choice model for shopping trips in the Dallas-Fort Worth case using a similar semi-parametric model. Their model was utilized to forecast temporal shift in urban shopping travel in the context of a congestion pricing evaluation. In addition, Lee and Timmermans (2007) developed an accelerated hazard model using a latent class specification, in order to grasp heterogeneity and tendency of accelerated or decelerated activity durations. Most recently, Komma and Srinivasan (2008) used the Gamma mixing distribution in non-parametric hazard model-to-model departure time choices, while Gadda et al. (2009) utilized the Bayesian estimation method in an accelerated hazard model. Lemp et al. (2010) introduced a continuous cross-nested logit (CCNL) model in order to propose the advantages of a random utility model (RUM) approach in a continuous choice setting. The model used Bayesian estimation technique to estimate a work-tour departure time model.

In the context utilizing the continuous method to relieve the discrete method constraint relating to the transform capability limitation, Sumi et al. (1990) began to introduce an approach model to reduce the transferability limitation issues. The model assumed that departure time decision of work travelers are affected only by the operational features of transit system. Basically, the proposed approach model used marginal utility or disutility of primary factors related to the points of time during one day from a commuting travel, such as departure time, arrival time, stay time, and travel time. Further, the approach model leads to utilization of the threshold time of disutility, which has to be avoided by individuals in order to choose their departure time or arrival time from origin or to destination place. In other words, the model used contrary assumptions with RUM approach, where a disutility minimizing model (DMM) approach was introduced in this study. In this regard, DMM approach assumes that travelers decided their choice based on minimization of sum types of disutility faced by individuals. In addition, a comprehensive choice model of departure time and a travel mode choice, simultaneously for commuting travel using DMM approach was developed by Li et al (2003).

In order to continue and to construct comprehensively the DMM approach, some previous researches using the approach were conducted. First of all, a model to consider the one day life cycle for non-work trips was proposed by Sumi et al., (1994). It was expanded to take account for more short time behavior (Sumi et al., 1995; Ramli et al., 2010b), and for the travel with a series of plural destinations (Ooeda et al., 2005). The model provided a basis for taking account of excess-day travel (Ooeda et al., 1997) and also for taking account of the frequency of a non-work trip (Chen et al., 2004, 2005). Focused on departure time and travel mode choice model simultaneously, Li et al. (2002) identified some types of determinant disutility for work commuting travel.

Furthermore, particularly to one-day shopping travels regarding situation in developing

countries, our previous researches have proposed some multi-dimensional choice model using disutility minimizing model approach. In this regard, we have proposed some choice models which consider the approach, such as leave time choice model (Ramli et al., 2010c), departure time choice model (Ramli et al., 2010b; 2011c; 2011d), and simultaneous choice model of departure time and travel pattern choice model (Ramli et al., 2011b), respectively. Those choice models consider praying time-activity as a flexible daily temporal constraint of travelers in Islamic society in the developing countries. However, lunch time-activity become significant factor that influenced travelers in deciding their departure time to shopping place in developed countries situation as provided in Ramli et al. (2010b).

In order to expand those choice models in term of step by step manner to complete the construction of the model approach comprehensively, the present paper attempts to develop a simultaneous choice model of departure time and travel mode choice for one-day shopping travel. In this regard, both choice problems are decided at a same time. As an expansion model, the model still considers the availability of praying time-activity as the flexible daily temporal constraint, a travel behavior on shopping traveler in most Islamic community in developing countries.

The remainder of this chapter is composed as follows. The next section presents the model structure development. Then, Section 3 demonstrates the application the model. Section 4 presents discussion that related to the result of the model implementation, and important findings. The final section, Section 5 provides summaries of this chapter

2 THE MODEL STRUCTURE DEVELOPMENT

The model structure development in this study utilize joint choice model approach, i.e. continuous choice model approach in analysis departure time choice as the first step, and discriminate choice model in analysis travel mode choice as the second step.

2.1 Disutility Types on One-Day Shopping Travel Considering Travel Mode

In the last two previous studies (Ramli et al., 2011d; and Ramli et al., 2011b), some types of disutility on one-day shopping travel have been introduced regarding to three main processes in accordance with the places where the decisions are made. The types of disutility are including two types of disutility, due to the earliness in morning and lateness at night. Both disutility types are assumed to express the variation of activity level which mainly dealt with in origin place processes (i.e. leave home process and return home process). The other types of the disutility are assumed in order to express the behavior to stay enough time at the shopping place, one is that due to the shortage of stay time for expressing the behavior to have enough stay time, and that due to the length of stay time to express the stay time is not extended if people feel it enough. Further, those chapters also introduced the effect of flexible daily time constraint, i.e. praying time during noon through evening, in order to response the availability of the constraint on one-day shopping travel behavior in most shopping travel in Islamic society.

As remainder, the functions of the all types of disutility and probability density of the constraint are presented again in following expressions:

$$D_1 = \begin{cases} -A(t_d - t_t).....(t_d < t_t) \\ 0.....(t_d \geq t_t) \end{cases} \quad (1)$$

$$D_2 = e^{-\alpha t_s} \quad (2)$$

$$D_3 = \beta t_s \quad (3)$$

$$D_4 = \begin{cases} B(t_h - t_b).....(t_h > t_b) \\ 0.....(t_h \leq t_b) \end{cases} \quad (4)$$

$$P_{t_{pf}}(t_{pf}) = \int_{-\infty}^{\infty} \phi_{ps}(\tau) \int_{t_{pf}-\tau}^{\infty} \phi_{pd}(s) ds d\tau \quad (5)$$

Where:
D_1: disutility of earliness home departure time on process of leave home;
D_2: disutility of stay time shortness at shopping place;
D_3: disutility of stay time lateness at shopping place;
D_4: disutility of lateness home arrival time on process of return home;
P_{tpf}: probability density of the praying time constraints;
t_d, t_h: departure time from home and arrival time at home respectively;
t_t : the threshold time when people become not to mind the earliness departure at home;
t_b: the threshold time when people become not to mind lateness arrive at home;
t_s : stay time at shopping centre;
t_{ps}, t_{pf} : start and end time of praying time-activity respectively;
A, B, α, and β: positive parameters.

Regarding to travel mode choice behavior, the present chapter also introduces two types of additional disutility that are faced by travelers as consequence of utilizing certain travel mode. Both disutility types are disutility of parking charge of travel mode particularly for utilizing private mode, and disutility of inconvenience due to uncertainty of travel time in case of using public mode. Those disutility types are expressed by following equations:

$$D_5 = \theta_i t_s \quad (6)$$

$$D_6 = \gamma_i t_n \quad (7)$$

Where:
D_5: disutility of parking charge of certain private mode such private car and motorcycle;
D_6: disutility of inconvenience due to uncertainty of travel time using a certain public transit mode;
t_s: stay time at shopping place;
t_n: travel time from origin to destination place or its opposite;
θ and γ: positive parameters.
i: type of certain mode

2.2 The Simultaneous Choice Model of Departure Time and Travel Mode

This sub section will show the model structure and its derivation of the departure time and travel mode choice simultaneously. The derivation of the model consist of two stage, i.e. derivation of departure time choice of each travel mode choice available, and then derivation of travel mode choice which consider the minimum value of the disutility total of each travel mode on the departure time choice process. In this regard, both choice problems, departure time and travel mode choices are assumed to be decided by travelers at a same time.

Furthermore, as commonly travel mode choice case in developing countries, travelers may face two mainly categories of their travel mode choices, i.e. travel mode categorized as private mode category such as private car or private motorcycle, and travel mode categorized as public mode category such as mini bus or para-transit, taxi, motor cycle for transit. We will derive the departure time choice model of the two categories respectively as follows.

2.2.1 Departure time choice model for private mode

In this case, travelers may face a numerous disutility types as shown in Figure 1. Those types of the disutility include disutility of earliness home departure time on home leaving process; disutility of shortness stay time at shopping place; disutility of lateness stay time at shopping place; disutility of lateness home arrival time on returning home process; disutility of flexible daily time constraint; and disutility of parking charge of certain mode. The derivation of the choice model in order to minimize those types of the disutility is similar to derivation of departure time choice model that provided in Ramli et al. (2011b; 2011c; 2011d). We will explain the derivation of the complexity of disutility types as below.

The departure time choice model of each travel mode regards that people choose their departure time to shopping place under consideration that the decision not only on leave time from the shopping place but also arrival time at home at a same time. This emphasizing leads to derivation of the model into two-step decision making case. The first step is condition where threshold time to get disutility of earliness home departure time, t_t is less than optimum departure time, t_{d0}, or threshold time to get disutility of lateness home arrival time, t_b, is less than arrival time at home, t_h. The second step is that t_t and t_b are equal or more than t_{d0} and t_h respectively. The model derivation of the departure time model as a two-step decision making is deduced in the next part as follows.

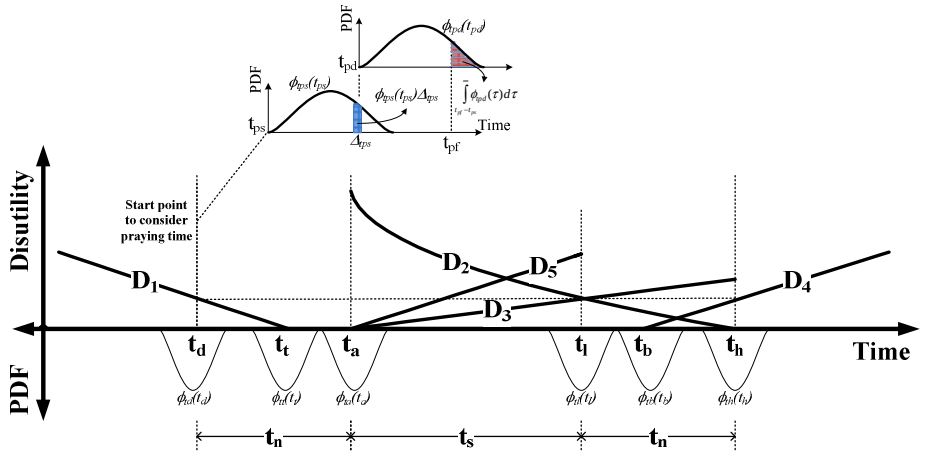


Figure 1 Hypothetical disutility on one-day shopping travel for private modes

The first step, regarding that individuals will consider their departure time to shopping place in order to minimize all of their disutility, and assuming all the types of utility are addible, the sum of disutility according to the places where decisions are made for the first case, D^{p}_{tot1}, is given as a function of stay time, t_s as follows.

$$D^{p}_{tot1}(t_s) = D_2(t_s) + D_3(t_s) + D_5(t_s) \tag{8}$$

Whereas the minimum of the sum disutility is given as an optimum point of stay time as below:

$$\left.\frac{D^{p}_{tot1}(t_s)}{dt_s}\right|_{t_{s0}} = 0 \tag{9}$$

Because that there are following relations among the variables related to time as below:

$$t_l = t_s + t_a \tag{10}$$

$$t_a = t_d + t_n \tag{11}$$

$$t_h = t_n + t_l \tag{12}$$

And assumption that total time consumption for the activity is less than the time interval from t_t and t_b, the person can choose the departure time from home and arrival time at home later than t_t and earlier than t_b, respectively. Hence, the distribution of departure time from home, $\emptyset_{td1}(t)$, can be stated as a unit distribution as follows.

$$\phi^{p}_{td1}(t) = \frac{1}{t_{d0} - t_t}, \quad (t_t < t_{d0}) \tag{13}$$

Where t_{d0} is a constant value given by the following equation:

$$t_{d0} = t_b - t_n - t_{s0} - t_n \tag{14}$$

The second step assumes that a person cannot choose their departure time within the range $[t_t, t_{d0}]$ or $t_t \geq t_{d0}$. It means that the individuals decide departure time also taking account of D_1 and D_4. As similar assumption with the first case, in particular that all the types of utility are addible, the total disutility in this case, D^{p}_{tot2}, is given as follows.

$$D^{p}_{tot2}(t) = D_1(t_d) + D_2(t_s) + D_3(t_s) + D_4(t_h) + D_5(t_s) \tag{15}$$

Regarding the relationships among the time variables in the Equations (8), (9), and (10), the Equation (13) can be restated as function of departure time, t_d as below:

$$D^{p}_{tot2}(t_d) = D_1(t_d) + D_2(t_d) + D_3(t_d) + D_4(t_d) + D_5(t_d) \tag{16}$$

Then, the optimum departure time of individual is given as following condition.

$$\left.\frac{D_{tot2}^{p}(t_d)}{dt_d}\right|_{t_d=t_{d2}} = 0, \qquad (t_t \geq t_{d0}) \tag{17}$$

Hereafter we shall regard every decision making is conditional on travel time and stay time in order to consider group of individuals and availability of travel time distribution.

In order to represent fact in the real world that human behavior always has dispersions, as consequence of individual and occasional differences, we have to define some parameters as random variables. In this case, we define t_t, t_b, and α as random variables to express the dispersions of departure time, leaving time, and stay time respectively. Their probability density functions (PDF) are denoted by $\emptyset_{tt}(t_t)$ and $\emptyset_{tb}(t_b)$ respectively and assumed their dispersions are independent to each other.

Regarding the above assumptions, Equation (11) and (15) are rewritten into the following expressions.

$$\phi_{td1}^{p}(t|t_n) = \int_{-\infty}^{t_{b0}^{*}}\int_{t_{d0}}^{\infty} \frac{1}{t_{d0}-s}\phi_{tb}(\tau)\phi_{tt}(s)d\tau ds, \qquad (t_t < t_{d0}) \tag{18}$$

The distribution of arrival time at destination for a given travel time, t_n, is given as follows.

$$\phi_{ta1}^{p}(t|t_n) = \phi_{td1}(t-t_n), \qquad (t_t < t_{d0}) \tag{19}$$

Considering the distribution of $\emptyset_{tt}(t_t)$, and $\emptyset_{tb}(t_b)$, the optimum departure time given by Equation (5.15) provides the distribution of departure time as follows.

$$\phi_{td2}^{p}(t|t_n) = \int \phi_{t_b}(t_b)\left|\frac{dt_b}{dt_{d2}}\right|\phi_{tt}(s)d\tau ds, \qquad (t_t \geq t_{d0}) \tag{20}$$

Then, the distribution of arrival time at the destination is again obtained as follows.

$$\phi_{ta2}^{p}(t|t_n) = \phi_{td2}(t-t_n) \quad (t_t \geq t_{d0}) \tag{21}$$

Because both distributions above have limitation from time constraint in the parentheses, they are not PDFs in normal sense. Then, the PDF of departure and arrival time are given by the sum of the Equation (16) and (18), and the Equation (17) and (19) respectively as follows.

$$\phi_{td}^{p}(t_d|t_n) = \begin{cases} \phi_{td1}^{p}(t|t_n) & .....(t_t < t_{d0}) \\ \phi_{td1}^{p}(t|t_n) & .....(t_t \geq t_{d0}) \end{cases} \tag{22}$$

$$\phi_{ta}^{p}(t_a|t_n) = \begin{cases} \phi_{ta1}^{p}(t|t_n) & .....(t_t < t_{d0}) \\ \phi_{ta2}^{p}(t|t_n) & .....(t_t \geq t_{d0}) \end{cases} \tag{23}$$

In order to take account of a human group with PDF of travel time distribution, $\emptyset_{tn}(t_n)$, Equation (20) and Equation (21) can be restated as follows:

$$\phi_{td}(t_d) = \int_0^\infty \phi_{td}(t|t_n)\phi_{tn}(t_n)dt_n \tag{24}$$

$$\phi_{ta}(t_a) = \int_0^\infty \phi_{ta}(t|t_n)\phi_{tn}(t_n)dt_n \tag{25}$$

The above argument leads to a complementary calculation that is possible to be done. In later, this paper will show comparison of departure time distribution derived from above equation to observed departure time distribution.

As purpose of this chapter to introduce time constraint related to the specific flexible daily time activity, i.e. praying time during noon through evening, now we will introduce the constraint into the departure time choice model. In order to show the constraint is taken account into the model, lets to denote start time and time duration of the noon-evening activity as t_{ds} and t_{dd}, and the distributions of these two as $\varphi_{ds}(t)$ and $\varphi_{dd}(t)$, respectively. Also the probability density function is denoted as $\varphi_{dn}(t)$. Then, the probability of that a given noon-evening activity time, t_{dn}, is included in the departure time, P_{pn}, is obtained by the multiplication of the probability that the activity has already started and the probability that the activity is still continuing.

$$P_{pn}(t_a) = \int_{}^{t_a} \phi_{ds}(\tau) \int_{t_a-\tau} \phi_{dd}(s)dsd\tau \tag{26}$$

If the arrival time or departure time is included in the flexible time constraint, the distribution of departure time and arrival time is corrected as follows.

$$\phi^c_{t_d}(t_d) = \left\{1 - P_{dn}(t_d)\right\}\phi_{t_d}(t_d) \Big/ \int \left\{1 - P_{dn}(\tau)\right\}d\tau \tag{27}$$

$$\phi^c_{t_a}(t_a) = \left\{1 - P_{dn}(t_a)\right\}\phi_{t_a}(t_a) \Big/ \int \left\{1 - P_{dn}(\tau)\right\}d\tau \tag{28}$$

2.2.2 Departure time choice model for public mode

In case travelers may choose public mode, the travelers will face similar types of disutility as in the former case, except disutility of parking charge. However, there is one additional type of disutility that may be faced by travelers, i.e. disutility of inconvenience due to uncertainty of travel time of the chosen public mode (D_6). The additional disutility is available on round trip of the shopping travel. Those types of disutility in this case are showed in Figure 2.

The total disutility of travelers that utilized public mode can be derived with the same way of the disutility of the travelers that choose private mode. Therefore, we can state the sum of the disutility of public mode utilization, D^{tm}_{tot}, for the two stage or conditions of the departure time choosing, $t_t < t_{d0}$ and $t_t \geq t_{d0}$, as below.

$$D^t_{tot1}(t_s) = D_2(t_s) + D_3(t_s), \qquad (t_t < t_{d0}) \tag{29}$$

$$D^t_{tot2}(t) = D_1(t_d) + D_2(t_s) + D_3(t_s) + D_4(t_h) + 2D_6(t_n), \qquad (t_t \geq t_{d0}) \tag{30}$$

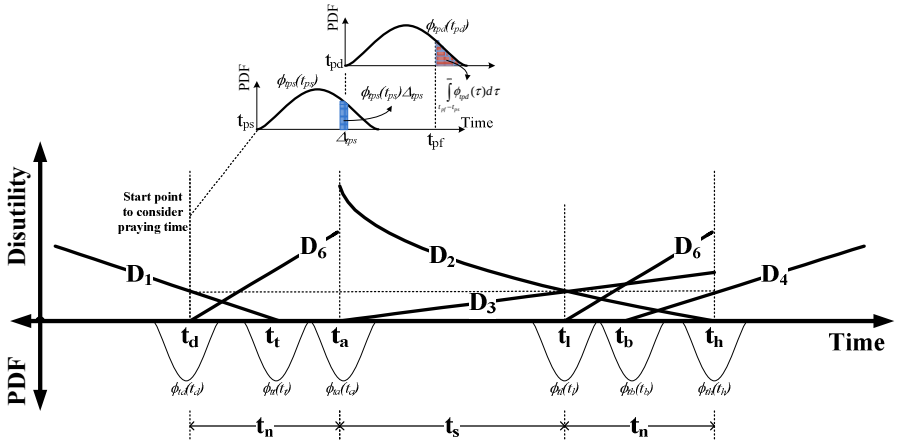


Figure 2 Hypothetical disutility on one-day shopping travel for public transit modes

Regarding the relationships among the time variables in the Equations (8), (9), and (10), the Equation (30) can be restated as also function of departure time, t_d as below:

$$D^t_{tot2}(t_d) = D_1(t_d) + D_2(t_d) + D_3(t_d) + D_4(t_d) + 2D_6(t_d), \qquad (t_t \geq t_{d0}) \tag{31}$$

Following the assumptions of the private mode as explained above, the distribution of departure time of travelers that utilize transit mode can be expressed as below.

$$\phi^t_{td1}(t|t_n) = \int_{-\infty}^{t^*_{b0}} \int_{-\infty}^{\infty} \frac{1}{t_{d0} - s} \phi_{tb}(\tau)\phi_{tt}(s)d\tau ds, \qquad (t_t < t_{d0}) \tag{32}$$

$$\phi^t_{td2}(t|t_n) = \int \phi_{t_b}(t_b) \left| \frac{dt_b}{dt_{d2}} \right| \phi_{tt}(s)d\tau ds, \qquad (t_t \geq t_{d0}) \tag{33}$$

Where t_{d0} is a constant value given by the following equation:

$$t_{d0} = t_b - t_n - t_s - t_n \tag{34}$$

Furthermore, the Equation (22) through the Equation (28) for private mode can be applied to public mode case in term that the Equation (29), the Equation (31), the Equation (32), and the Equation (33) are substituted into those equations.

2.3 Mode Choice Model on One-Day Shopping Travel

Based on the disutility minimizing model (DMM) approach, we apply discriminate

distributions of disutility to deduce mode choice model. In this case, given two kinds of mode as alternatives, we firstly denoted traveler's disutility choosing mode-*i*, TM_i, and mode-*j*, TM_j, as D_i and D_j respectively as shown by Figure 3.

According to assumption that traveler would choose the one with minimum disutility from the both available mode, we can state the probability of traveler to choose mode-*i*, P_i, as follows:

$$P_i = P\left(D_i < D_j\right) \tag{35}$$

The probability $\Delta_{qi}(D_i)$ that traveler judges $D_i=D$ in a little ΔD section would be calculated by:

$$\Delta qi\left(D_i\right) = \phi_{D_i}\left(D_i\right)\Delta D_i \tag{36}$$

In the same condition, if the traveler judges $D_j > D$ and then decides to choose mode-*j*, his choosing probability is given as follows:

$$\Delta P_i\left(D_i\right) = \phi_{D_i}\left(D_i\right)\Delta D_i \int_{D_j}^{\infty} \phi_{D_j}\left(D_j\right) dD_j \tag{37}$$

Thus, the choice probability of travel mode-*i* in entire scope of *D* is determined by:

$$P_i\left(D_i\right) = \int_0^{\infty} \Delta P_i\left(D_i\right) dD_i = \int_0^{\infty} \phi_{D_i}\left(D_i\right) \int_{D_i}^{\infty} \phi_{D_j}\left(D_j\right) dD_j\, dD_i \tag{38}$$

Therefore, the choosing probability of travel mode-*j*, P_j, may be obtained simply by:

$$P_j = 1 - P_i \tag{39}$$

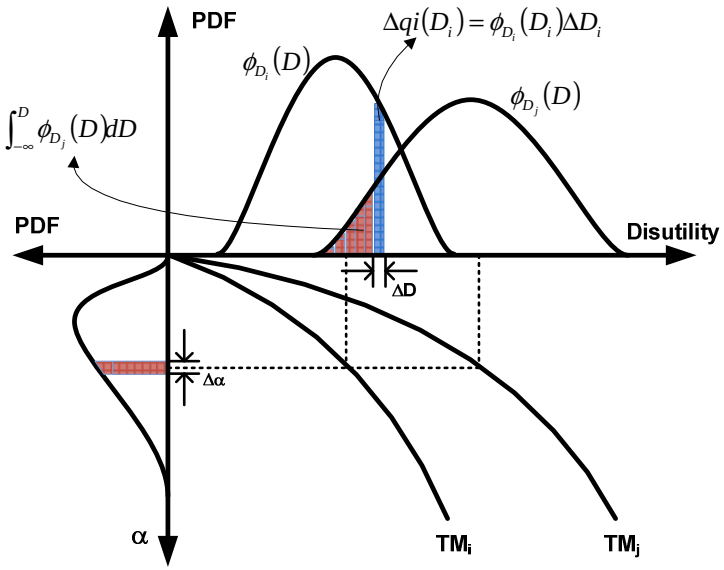


Figure 3 Diagram of disutility discriminate distribution on travel mode choice

Furthermore, in case more than two alternatives of travel mode are available to travelers, and the distribution of disutility total of each travel modes are known, the probability $P_k(D_k)$ choosing the k_{th} travel mode is calculated as below.

$$P_k(D_k) = \int_0^{\infty} \phi_{D_k}(D_k) \left[\prod_{m \neq k} \int_{D_k}^{\infty} \phi_{D_m}(D_m) dD_m \right] dD_k \tag{40}$$

Where $\phi_{D_k}(D_k)$ and $\phi_{D_m}(D_m)$ represent the *PDF*s of disutility derived from m_{th} and k_{th} travel mode separately, $\prod_{m \neq k}$ means that if $m=k$ then the multiplication is not needed.

3. THE MODEL APPLICATION

The above proposed model again can be applied to all travel behavior particularly on one-day shopping travel behavior of travelers in Islamic society, where travelers consider not only lunch time in around noon and dinner in evening, but also praying time constraint during in the noon through in the evening as flexible daily time constraints. Concerning the trip pattern of one-day shopping travel, H-SC-H, the duration or time length from departure from home to arrival at home is not so short since travelers have chance to do some activities in the shopping place as variation of tenants in the place such as mini-market to buy daily goods, book shop, a movie, cafeteria, restaurant, etc. In contrary, considering some outcome factors related to travel mode usage such as amount of parking charge, delay of travel time, the individuals will restrict the time length to stay at the shopping place. In addition, travelers is not necessary to leave their home earliness for most cases of H-SC-H travel pattern, because they have only one destination place in a day. Therefore, we can simplify the model to be applied to this behavior for each travel mode. In this regard, Equation (18) and Equation (34) do not need to be applied, so that travelers' behavior can be expressed enough by Equation (16), Equation (17), and Equation (33) with conditioning minus disutility of the length of stay time, and also by Equation (25) that is simplified to consider specific flexible daily time constraint during noon until evening. Thus, the parameters which used to represent the behavior of travelers are only t_b, α, t_{ps}, t_{pd}, β, θ, and γ. In the next sections, we will explain application of the model simplification.

3.1 Calculation Method to Estimate Parameters of the Model

The calculation method to estimate the model parameters that used in this model adapt the calculation method that developed in Ramli et al. (2011b) in term of simultaneous between departure time and travel mode choice. The following algorithm is applied for this purpose.

1) Define the four parameter, t_b, α, t_{ds}, and t_{dd} as random variable, and replace them with their average and standard deviation values, μ_{tb}, σ_{tb}, μ_{α}, σ_{α}, μ_{tps}, σ_{tps}, μ_{tpd}, and σ_{tpd} respectively. Then, give the initial value for the all parameters, including others parameters β, θ_c, θ_b, γ_t.
2) Generate a set of large numbers of random numerals using the average and standard deviation for each parameter.
3) Calculate the arrival time and its distribution for each travel modes by taking one of the numerals for each parameter that conditional to a certain value of travel time. Repeat the procedure until the set of random numbers are all taken into account.

4) Repeat the step (3) for the changing values of travel time according to the observed distribution until the full range of travel time is covered. In this regard, a certain time attribute when minimum value of disutility total is found, will be obtained as a magnitude time attribute of disutility objective function.
5) Weight the departure time distribution for each travel modes by sharing with travel time and arrival time distribution, and suppose them so that the departure time distribution is obtained for all members of the group.
6) Compare the calculated distribution of departure time with the observed one, and calculate the square difference between them.
7) Change the assumed values of the parameters in an iterative manner to reduce the square difference. In this matter a certain type of non-linear optimization programs is used to reduce square difference.
8) Stop the calculation when the variation of the parameters become small enough and regard the assumed values as the estimated values for the parameters.

3.2 The survey implementation

In order to apply the model, we use the result of survey activity in Makassar, Indonesia which explained in Ramli et al. (2011d). Travel demand of the citizens are served by mini bus and taxi as formal public transport that operated as para-transit, and some informal public transits such as tricycle and rent motorcycle. However, most of the people in the residential areas utilize private car, private motorcycle, and public transit such as para-transit, taxi, motorcycle taxi, and tricycle taxi, for their travels to shopping centre.

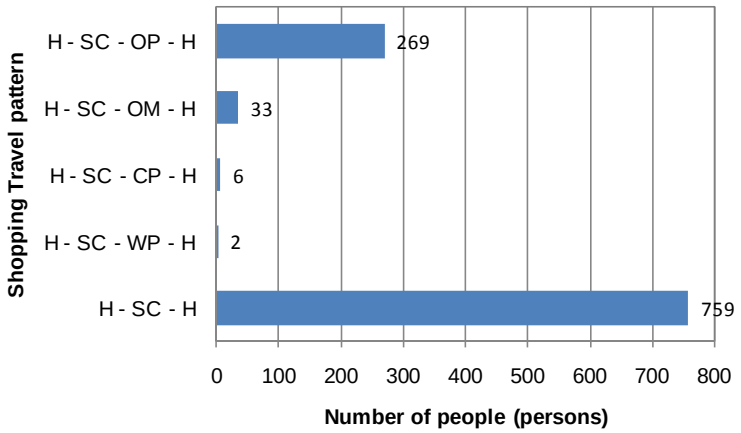


Figure 4 Distribution of travel pattern on shopping travel

Figure 4 and Figure 5 show the execution of the survey address to travel pattern and travel mode utilization respectively. The Figure 4 shows that most travelers have conducted their shopping travel with home-shopping centre-home (H–SC–H) travel pattern. However, the number of travelers with home-shopping centre-other place-home (H–SC–OP–H) travel pattern is also significant. Meanwhile, others travel patterns, i.e. home-shopping centre-other shopping centre-home (H–SC–OM–H), home-shopping centre-campus-home (H–SC–CP–H), and home-shopping centre-work place-home (H–SC–WP–H) are conducted by minority of travelers.

Furthermore, Figure 5 shows distribution of travel mode usage for one-day shopping

travel by travelers in the city, particularly travel mode of travelers with H–SC–H travel pattern. The Figure shows that the private car and motorcycle are majority of utilized travel modes in all age categories by travelers on one day shopping travel activity. In other side, mini bus as para-transit became more eligible than taxi, tricycle, and rent motorcycle.

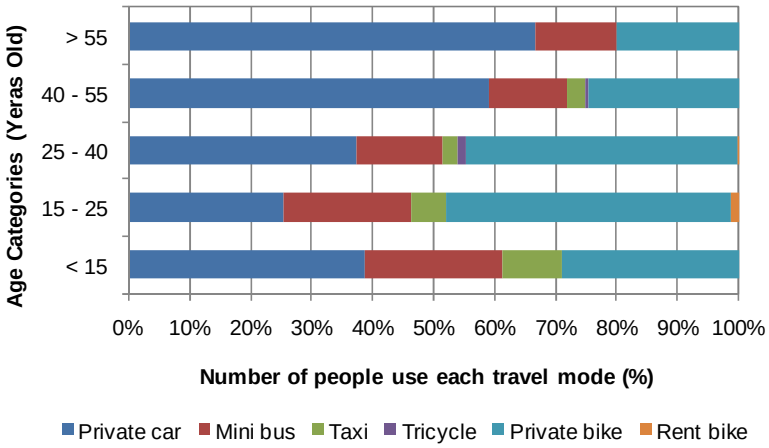


Figure 5 Distribution of travel mode for shopping travel based on age categories

According to the above travel shopping condition, the present chapter is focused on travelers with home-shopping centre-home (H–SC–H) travel pattern in order to test the simultaneous model of departure time and travel mode choice that proposed in the previous section. In this regard, number of travel mode is divided into three alternatives, i.e., private car, private motorcycle, and public transit representing all type of available mode. The number of data to estimate parameters model of the three alternative modes is 292, 290, and 168 respectively.

3.3 The calculation results

The estimated parameters of the model are shown in Table 1 along with the statistics showing the minimized square difference values, R^2_{min}, and fitness of the calculated and observed departure time distributions to all types of travel mode by using *Kolmogorov-Smirnov* (*K-S*) test. The departure time distributions of each chosen travel mode that obtained from the calculation are shown in Figures 6.

It was revealed that the calculation reproduced the observed distributions well though the significant levels of goodness of fit by *Kolmogorov-Smirnov* (*K-S*) test reached 20% for the three departure time distributions of private car, private motorcycle, and public transit mode.

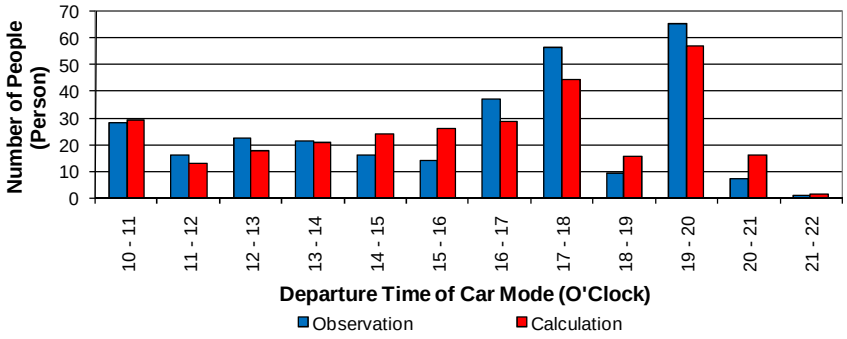
4 DISCUSSIONS

According to the calculation result shown in Table 1, we can discuss some important findings as below.

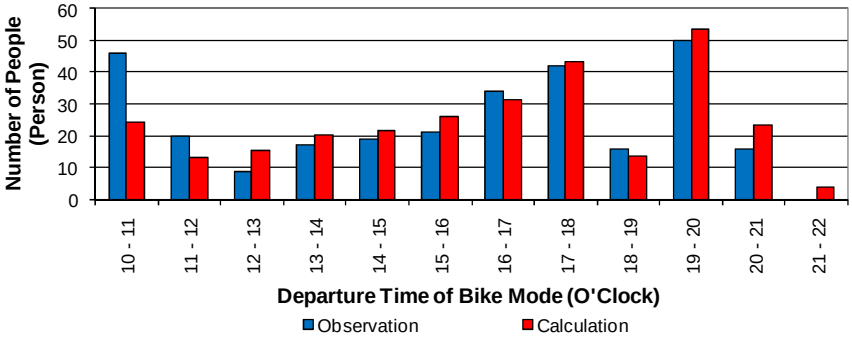
The parameters values of threshold time of home arrival time indicate that travelers of the three types of travel mode have high tolerance to the time when they leave shopping place

to return home. The values of average and standard deviation of the threshold time respectively are 20.07 p.m. and 3.91 hours. These values mean that travel behavior of the people on one-day shopping travel is most of travelers chose the earliest and the latest their home arrival time in the afternoon and the midnight respectively.

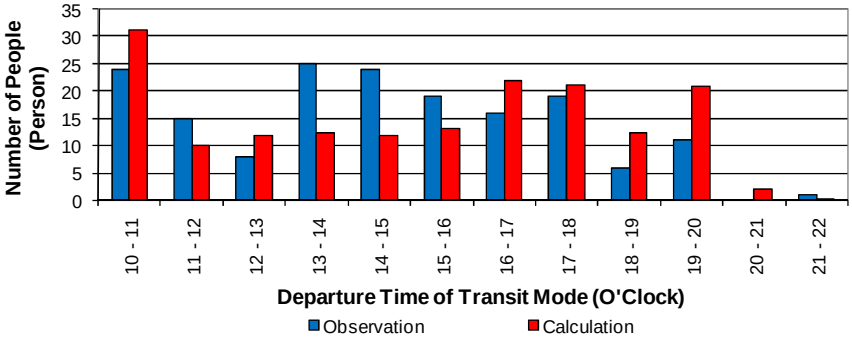
In particular to the parameters values of the flexible daily time constraints, i.e., praying time activity during in the noon until in the evening, the people gave priority to conduct the two types of praying time-activity, "*ashar*" praying time and "*maghrib*" praying time, in the period time of the latest afternoon through the latest evening. The phenomenon was indicated by the average value of start time and duration time of the praying time, where the values respectively are 17.34 p.m. and 2.08 hours. These mean that travelers are inclined to choose their home departure time after and before critical time of the constraint.



a. Departure time distribution of travelers choosing auto car mode



b. Departure time distribution of travelers choosing private motorcycle mode



c. Departure time distribution of travelers choosing transit mode

Figure 6 Calculated distribution of the simultaneous choice model

Table 1 Calculation result of parameters

Parameters of model	Values of parameters
μ_{α}	0.1332
σ_{α}	0.1800
β	0.1387
μ_{tb}	20.0686
σ_{tb}	3.9105
μ_{tps}	17.3362
σ_{tps}	0.2079
μ_{tpd}	2.0835
σ_{tpd}	0.1967
θ_{c}	0.0458
θ_{b}	0.0519
γ_{t}	7.0798
Number of data	750
Square error minimum (R^2_{min})	1945.761
Degree of freedom (df)	19
α of KS test (%)	20

According to the above results, we can state that the model can represent the factual phenomena regarding to availability of the flexible daily time constraint during noon through evening as a constraint that considered by individuals to decide their departure time and travel mode to shopping centre simultaneously. In other words, the flexible time constraint should become one of primary consideration to choose travel mode and departure time of travelers at a same time. However, we expect that the proposed model can be tested to other situations and also use the constraint phenomenon as one of major factors that influenced individuals to choose their travel mode and departure time.

5 CONCLUSSION

The present study has proposed a simultaneous choice model to describe travelers decisions to choose departure time and travel mode at the same time based in consideration existence of flexible daily time constraints on one-day shopping travel. The model is derived from three processes of one day shopping travel, in particular home-shopping centre-home (H–SC–H) travel pattern. The three consist of process to departure from home, process to stay at shopping place, and process to return to home. These processes lead to four types of disutility, i.e., disutility of earliness home departure time, disutility of shortage of stay time at shopping place, disutility of length of the stay at the place, and disutility of lateness home arrival time. In addition, in regard to consider the distinguishing of implication of each travel mode utilization, disutility of parking charge for private travel mode and disutility of inconvenience due to uncertainty of travel time for public transit mode are accommodated into the model. Particularly, the model also proposes to accommodate a specific time constraints of travelers, i.e. praying time-activity during in the noon through in the evening as a flexible daily temporal constraint that considered by individuals to decide their departure time and travel mode to shopping place. However, the model was simplified to apply the properties of one-day shopping travel behavior, i.e., length duration of stay time and necessity to leave home earliness.

The proposed model was applied to survey data of the one-day shopping travel of individuals in Makassar, Indonesia, the country in Asian developing countries that explained in Ramli et al. (2010b). In this regard, there are three travel mode choices as alternatives of the travelers, i.e. private car, private motorcycle, and public transit representing all types transit available, such as mini bus, taxi, tricycle, and motorcycle taxi to serve their shopping travel. It was revealed that the model and estimated parameters provided acceptable productivity of departure time and travel mode choices at the same time. Concerning the flexible time constraint, the model can be observed in the three alternatives of travel modes.

As conclusion, the model with estimated parameters is to be tested further by applying to others situations, and we can expect that the model can be applied in a straight-forward in forecasting departure time and travel mode simultaneously on one day shopping travel.

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