STUDY ON TIME-BEHAVIORAL PROPERTY OF SHOPPING TRIP FOR SHORT TIME

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1. Introduction

Recently, research to non work trip in particular shopping trip found out more and more attention. At least there are some reasons for this condition, i.e. the shopping trips contribute increasingly large proportion to urban trips recently, especially on peak periods, the trips have more temporal flexibility of individual than work trips[1)], and also the trip provides more or less congestion and some kinds of environmental problem in the centre business district, CBD of city[6)].

For the reason, this paper attempts to describe time-behavioral properties of individuals who are conduct a short time shopping activity. In order to describe the phenomena, this research adopts and develops a disutility model approach. Many previous studies have given attention related to the non-work trips which use disutility model approach. Some of them proposed a model to consider the one day life cycle for non-work trips[7)] and it was expanded to take account for more short time behavior[8)], and for the travel with a series of plural destinations[5)]. In further, the model provided a basis for taking account of excess-day travel[4)] and also for taking account of the frequency of a non-work trip [2)-3)]. In the last of previous research, the authors of this paper have proposed choice model of departure time for trip to shopping place for certain purpose based on minimizing disutility[6)]. The model in particular, regard to daily shopping trip which consider lunch activity in around of the noon as constraint of travelers to decide their departure time.

There is differ situation when individuals conduct shopping activity that need very short time such us shopping for stationery equipments, etc. For trip of short time shopping activity trip, individuals usually treat the trip as jointly trip with another activity trip. In other words, the trip is conducted as sub-goal trip or secondary trip of a primary origin-destination trip. As consequently, stay time and or leave time at and from shopping place depend on arrival time at destination place of the primary trip. Another implication to shopping activity for short time only is that the trip is constrained by some constrains activities during the time period of primary trip is conducted by individuals, such as out-home breakfast activity, lunch activity, etc. The activities lead to availability of time constraint for the short shopping activity.

In order to describe the above phenomena, this research purposes to develop choice model of leave time from a place of shopping activity, in particular shopping trip activity that needed short time. The developing model based on minimization of some types of disutility that be faced by individuals during they stay at shopping place, and arrival at destination place. The model also considers influence of time constraint that available on time period during individuals departure from their origin place until arrive at destination place for their primary trip.

2. Development of Model Structure

The structure of model developing is derived from a set time-behavioral process of individuals in order to express their motivation during they conduct sub-goal or secondary trip and primary trip together. In this case, their times attributes consist of arrival time through leave time from shopping place as secondary trip, and arrival time at destination place of their primary trip. Generally, people that conducted shopping activity for short time will face two crucial times, i.e. leave time from shopping place as secondary place and arrival time at primary destination. By taking disutility model approach, we assume that each individual will effort to minimize to take all types of disutility that be appeared by the above crucial times. In this research, we consider two types of disutility that regarded to property of short time shopping activity. The first of two types of disutility is addressed to time duration that allocated by individuals to stay at shopping place, namely disutility of shortage stay time. The other disutility is related to lateness when individuals arrive at destination place, namely disutility of lateness arrival destination place. In order to represent influence of some activity constraint to the trip of short time shopping activity as mention in introduction chapter, the disutility of specific time constraint is introduced in this research. Those types of disutility are shown by Figure 1.

Furthermore, the proposed choice model of leave time from the shopping place will be deduced by taking probability model approach. For this reason, some parameters of the model related to time attributes during stay at shopping place and arrival time at the destination place will be defined as random variable. The next section will show derivation process of structure of proposed model based on availability of the above three types of disutility.

(1) Disutility on Short Time Shopping Activity

As explanation in the previous section that the model considers three types of disutility in order to be minimized by

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individuals during conduct their activity at shopping place until they arrive at primary destination place, the expression of those types of disutility will be explained as below.

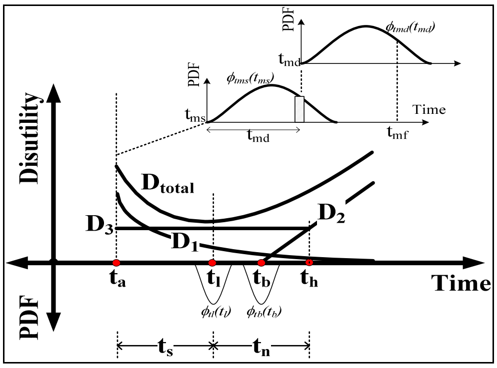


Figure 1: Hypothetical disutility of model

a) Disutility of shortage stay time at shopping place

According to duration that allocated by individual at shopping place, the individual will face disutility of shortage stay time, D_1. In this regard, we assume that individuals have enough time to stay at shopping place, so that they will effort to minimize the disutility. We assume that the values of the disutility decrease exponentially as shown by curve D_1 in Figure 1. Then, we formulate the disutility as below.

$$D_1 = e^{-\alpha t_s} \tag{1}$$

Where t_s is stay time at shopping place, while α is positive parameter.

b) Disutility of lateness arrival time at primary destination place

In this regard, we assume that individuals have designed a threshold time to arrive at a destination place as point time when they will suffer the disutility of lateness arrival at the place or not. Let to denote arrival time at destination place as t_h, and the threshold time as t_b. Then, the individuals will take a disutility when their arrival time at destination place later than the threshold time. The value of the disutility is assumed increase linearly as shown by curve D_2 in Figure 1. The expression of the disutility can be stated as follows:

$$D_2 = \begin{cases} B(t_h - t_b) ....(t_h > t_b) \\ 0 ....(t_h \le t_b) \end{cases} \tag{2}$$

where B is positive parameter.

c) Disutility of specific-time constraint

In the present paper, we introduce addition disutility regard to availability time constrain for trip that conduct secondary trip and primary trip together, i.e. disutility of specific-time for another activity during period time when origin-destination is conducted. As mentioned in the introduction section, there is different situation of many travelers whereas they consider not only lunch activity constrain, but also morning or afternoon activity constrain (for example, out-home breakfast activity, praying time activity, etc.) when they would like to decide their leave time from shopping place to primary destination place In this way, lets to define of start and end time of the constrain activity as t_{ms} and t_{mf} respectively. Hence, the disutility, D_3, as shown by curve D_3 in Figure 1, can be formulated as below:

$$D_3 = \frac{1}{t_{mf} - t_{ms}} \tag{3}$$

(2) Choice Model of Leave Time from Shopping Place

Based on assumption that individuals will decide or choose their leave time from shopping place, as secondary place, in order to minimize a numerous types of disutility that be faced, and assumption that the all types of disutility can be added each other, then the total disutility will be suffered by individuals can be derived step wise as below.

Let to denote D_{12} as the total disutility of D_1 and D_2, and we can write the disutility as follows:

$$D_{12}(t) = D_1(t_s) + D_2(t_h) \tag{4}$$

In the first step, we assume that individuals do not suffer disutility of lateness arrival time at destination place. So that, the Equation (4) can be rewritten as follow equation.

$$D_{12}(t_s) = D_1(t_s) \tag{5}$$

Where the minimum value of the disutility can be achieved under condition below:

$$\left.\frac{D_{12}(t_s)}{dt_s}\right|_{t_{so}^1} = 0, \qquad (t_b \ge t_h) \tag{6}$$

The second step that considered in this model is that individuals take disutility of lateness arrival time at destination place into account of the total disutility. Regard that there is relationship among variables related to time as follow:

$$t_h = t_l + t_n \tag{7}$$

$$t_l = t_a + t_s \tag{8}$$

Where t_a and t_n are arrival time at shopping place and travel time from shopping place to primary destination place respectively. So that, the Equation (4) can be rewritten as function of t_s as follow equation.

$$D_{12}(t_s) = D_1(t_s) + D_2(t_s) \tag{9}$$

The minimum value of the disutility can be achieved under condition below.

$$\left.\frac{D_{12}(t_s)}{dt_s}\right|_{t_{so}^2} = 0, \qquad (t_b < t_h) \tag{10}$$

Therefore, we can formulate the distribution of leave time from shopping place for the both steps as follow equation.

$$\phi_{tl}^1(t) = \frac{1}{t_b - t_{l0}^1}, \qquad (t_b \geq t_h) \tag{11}$$

$$\phi_{tl}^2(t) = \frac{1}{t_b - t_{l0}^2}, \qquad (t_b < t_h) \tag{12}$$

Where t_{lo}^1 and t_{lo}^2 are a constant value that given by equation below.

$$t_{l0}^1 = t_b - t_a - t_{s0}^1 \tag{13}$$

$$t_{l0}^2 = t_h - t_b - t_a - t_{s0}^2 \tag{14}$$

To this end we regard that every individual decide their leave time from shopping place is conditional on stay time at the place as a constant value.

(3) Leave Time Choice Model which Consider Dispersion of Choice Behavior

In order to represent phenomena in the real word, whereas individuals inconsistent to their decision even they face the same condition and situation, as consequence of availability occasional different and various human characteristics, then we have to define some variables of those above models as random variables. Hereafter we shall regard that every decision making is conditional on stay time in order to consider group of individuals and availability of stay time distribution.

Therefore, in this research we define parameters t_b dan α as random variables in order to express dispersion of stay time at shopping place and arrival time at destination place respectively. Their probability density function (PDF) is denoted by $Ø_{tb}(t_b)$ and $Ø_{\alpha}(\alpha)$ respectively, and we assume that the distributions of the parameters is independent each other and conditional to given certain travel time, t_n.

Regarding the above assumptions, the Equations (11) and (12) are rewritten into the following expressions.

$$\phi_{tl}^1(t|t_n) = \int_{-\infty}^{\infty}\int_{t_{b0}^*}^{\infty} \frac{1}{t_b - t_{l0}^1}\phi_{tb}(\tau)\phi_{\alpha}(\alpha)d\tau d\alpha, \qquad (t_b \geq t_h) \tag{15}$$

$$\phi_{tl}^2(t|t_n) = \int_{-\infty}^{\infty}\int_{t_{b0}^*}^{\infty} \frac{1}{t_b - t_{l0}^2}\phi_{tb}(\tau)\phi_{\alpha}(\alpha)d\tau d\alpha, \qquad (t_b < t_h) \tag{16}$$

The distribution of arrival time at shopping place for a given travel time, t_n, and arrival time at destination place, t_h, are given as follows.

$$\phi_{ta1}(t|t_n) = \phi_{tl1}(t - t_n), \qquad (t_b \geq t_h) \tag{17}$$

$$\phi_{ta2}(t|t_n) = \phi_{tl2}(t - t_n), \qquad (t_b < t_h) \tag{18}$$

Because those above distributions have limitation from time constrain in the parentheses, they are not PDFs in normal sense. Then, the PDF of leave time and arrival time at shopping place are given by the sum of the equation (15) and (16), and the equation (17) and (18) respectively as follows.

$$\phi_{tl}(t_l|t_n) = \begin{cases} \phi_{tl1}(t|t_n) \text{.............} (t_b \geq t_h) \\ \phi_{tl2}(t|t_n) \text{.............} (t_b < t_h) \end{cases} \tag{19}$$

$$\phi_{ta}(t_a|t_n) = \begin{cases} \phi_{ta1}(t|t_n) \text{.............} (t_b \geq t_h) \\ \phi_{ta2}(t|t_n) \text{.............} (t_b < t_h) \end{cases} \tag{20}$$

In order to take account of a human group with PDF of travel time distribution, $Ø_{tn}(t_n)$, equation (19) and equation (20) can be restated as below:

$$\phi_{tl}(t_l) = \int_0^{\infty} \phi_{tl}(t|t_n)\phi_{tn}(t_n)dt_n \tag{21}$$

$$\phi_{ta}(t_a) = \int_0^{\infty} \phi_{ta}(t|t_n)\phi_{tn}(t_n)dt_n \tag{22}$$

The above argument lead to a complementary calculation is possible to be done. In later, this paper will show comparing leave time distribution derived from above equation to observed leave time distribution.

When effect of time of activity constraint is considered on leave time decision, the model becomes much complicated. Let to denote start time and time duration of activity constrain as t_{ms} and t_{md}, and the distribution of the both as $Ø_{tms}(t_{ms})$ and $Ø_{tmd}(t_{md})$ respectively. Then, the probability of that a given arrival time is included in the activity constrain time, P_M, is obtained by the multiplication of the probability that the activity has already started and the probability of the activity is still continuing. The probability can be stated as follows.

$$P_M(t_a) = \int^{t_a} \phi_{ms}(\tau) \int_{t_a-\tau} \phi_{md}(s) ds d\tau \quad (23)$$

If the arrival time or leave time is included in time of the activity constrain, we assume and simply that the trip is restrained. The distribution of leave time and arrival time is corrected as follows.

$$\phi^c_{t_l}(t_l) = \{1 - P_M(t_l)\}\phi_{t_l}(t_l) \Big/ \int \{1 - P_M(\tau)\} d\tau \quad (24)$$

$$\phi^c_{t_a}(t_a) = \{1 - P_M(t_a)\}\phi_{t_a}(t_a) \Big/ \int \{1 - P_M(\tau)\} d\tau \quad (25)$$

3. Application of Model

The above proposed model can be applied to travel behavior especially for trip to shopping place that need short time for the shopping activity. Concerning with the short time shopping activity, travelers is not necessary to late for arrival time at destination place for most cases of shopping activity as secondary trip from a primary origin-destination trip pattern. In other word, individuals usually avoid to take disutility of lateness arrival time at destination place. Therefore, we can simply the model to apply to this behavior. In this regarding, Equation (16) and Equation (18) does not need to be applied, so that travelers' behavior can be expressed enough by Equation (15) and Equation (17). Thus, the parameters which used to represents the behavior of travelers are only t_b, α, t_{ms}, and t_{md}. In the next sections, we will explain application of the above model simplification. In order to apply the model, a calculation method was developed as well as a survey to a case on shopping trip at a stationery shop in Makassar city, Indonesia, was done. This chapter will explain the process and the result of the both activities.

(1) Calculation Method to Estimate Parameters Values of the Model

The calculation method to estimate parameters values of the model that used in this research is procedure to find a set of numerals possibly regarded as the parameters, and the calculated values surely depend on the set of assumed initial values. The following method was applied for this purpose.

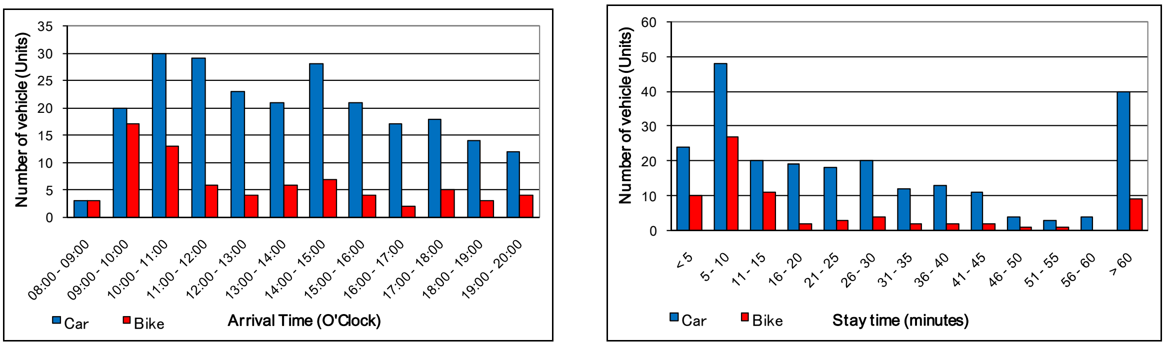
1) Replace the four parameters, t_b, α, t_{ms}, and t_{md} that defined as random variable, with their average and standard deviation values, μ_{tb}, σ_{tb}, μ_α, σ_α, μ_{tms}, σ_{tms}, μ_{tmd}, and σ_{tmd}, respectively. Then, give initial value for the parameters.
2) Generate a set of large numbers of random numerals using the average and standard deviation of the parameters.
3) Calculate the arrival time and leave time and their distribution by using taking one of the numerals for each parameter that conditional to a certain value of travel time. Repeat the procedure for the all of random numbers.
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.
5) Weight the leave time distribution by sharing with travel time distribution, and suppose them so that the leave time distribution is obtained for all members of the group.
6) Compare the calculated distribution of leave time with the observed, and calculate the square difference of them.
7) Change the assumed values of the parameters in an iterative manner to reduce the square difference. In that 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 enough small and regard the assumed values as the estimated values for the parameters.

(2) Implementation of Survey

Application of model was done to a short shopping trip at a stationery shop in Makassar City, Indonesia. By consideration the large number of data for the trip, we choose Agung Stationery shop, one of the most crowded of stationery shop that available in Makassar City. Due to condition of the shop location and also limitation to observe customer of the shop directly in term of individually, then a parking survey to the shop's customers who are using car or bike was implemented. In this matter, we assume and simply that the number of customers in term of person is substituted by number of customers in term of number of vehicles. The parking survey was done by using record to plat number of vehicle method, whereas surveyor recorded arrival time and departure time of each vehicle at and from parking area of the stationery shop. A survey was conducted during 08:00 am until 08:00 pm. There are 236 units of car and 74 units of bike that recorded during the one day survey. In order to observe travel time, a survey using questionnaire based on interview method was done to individuals who live at ten residences area in the city that have already traveled to shopping place for short time activity.

(3) Results of Survey

The result of survey related to primary time attributes (i.e. arrival time and stay time) of individuals at the stationery shop in Makassar city is described in the Figure 2a and Figure 2b of each the attribute respectively.



a. Arrival time b. Stay time

Figure 2: Attribute of individuals at stationery shop

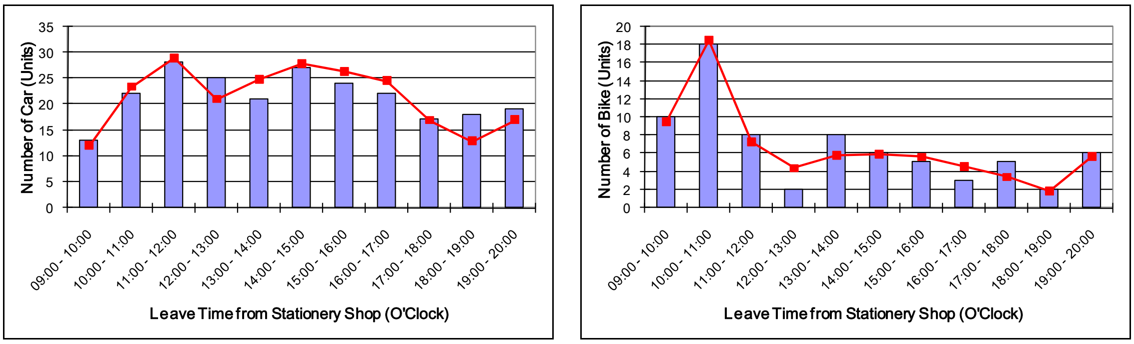
Figure 2a shows distribution of arrival time attribute for the both categories of the shop's customers, i.e. individuals utilize car and individuals utilize bike. The figure shows that arrival time of individuals for the first category has distribution be spread evenly from morning until evening, while arrival time of customers in the second category has distribution that concentrated in the morning. Figure 2b describes distribution of stay time attribute at the stationery shop of individuals that used car and bike. The Figure shows that there is similarity of distribution pattern of stay time attribute for the both categories of customers, i.e. they have short stay time (time duration 5 until 45 minutes) to conduct stationery shopping activity at the place. However, there are individuals in large number that have stay time more than one hour. This exception represents the customers that bought stationery goods in large portion, so that they need more and more stay time to process their business

(4) Results of Calculation

The estimated parameters values of the model for the both categories of stationery shop's customers by using the calculation method that was developed in the previous section are shown in Table 3. The table also shows a numerous the statistics parameters i.e., the minimized square difference values, R_{Min}, and fitness of the calculated and observed leave time distributions, χ^2, KS, and degree of freedom.

Table 3: Result calculation of parameter

Parameters of model	**Category of Customer**	
	Car	Bike
μ_{α}	-0.1403	-0.1988
σ_{α}	0.0797	0.1334
μ_{tb}	11.7391	11.4707
σ_{tb}	0.4365	0.4948
μ_{tms}	9.7857	10.3678
σ_{tms}	0.2735	0.2531
μ_{tmd}	4.9691	4.6164
σ_{tmd}	3.1106	2.9357
Number of Data	236	73
Square Error$_{min}$	77.3398	17.0286
α of χ^2 test (%)	5	5
α of KS test (%)	20	20
Degree of freedom	3	3



a. Customers use car b. Customers use bike

Figure 3: Leave time of calculation and observation

The distributions of leave time from the stationery shop that resulted from the calculation are shown in Figures 3. It was stated that the calculation reproduced the observed distributions well though the Chi- square tests gave small values of goodness of fit (i.e. 5%) for all categories. On the other side, the significant levels of goodness of fit by *Kolmogorov-Smirnov* (*K-S*) test reached 20% for the both categories.

4. Discussion and Conclusions

(1) Discussion

According to comparing the parameters values of the model to each category in the Table 3, we can find that there are slightly different of time-behavior properties between category of individuals that used car and category of individual that used bike. The different properties of travel behavior attributes include standard deviation of parameter α, and average of start time of constrain activity. However, almost parameters values have similar values for the both categories. The difference of parameter α show that individuals category that used car have behavioral property of stay time at shopping place longer than individuals category of bike user. In contrary, the bike user category has start time for constrain activity later than car user category. As consequence of the different, the both categories also have different to distribution of leave time from the shop. Figure 3 shows that leave time distribution of individuals that utilized car category is smoother than individuals that utilized bike category. However, the both categories have similarity phenomena in the morning and in the lateness evening.

In generally, we may state that the slightly different is caused of availability of the human property variation related to time-behavioral in order to response stay time at shopping activity and start time of constrain activity, such as variation of characteristic individuals to asses enough time at shopping place, dispersion to obtain when to begin a constrain activity, variation of travel time, etc.

(2) Conclusions

This paper has proposed a choice model of leave time from shopping place for short time shopping activity. The model is developed in order to describe time-behavioral properties of the shopping activity, whereas the activity is sub-goal or secondary trip from a set primary origin-destination trip. The model considers some types of disutility that available during travelers stay at shopping place and arrive at destination place. In this regard, there are three types of disutility taking account into the model, i.e., disutility of shortage stay time at shopping place, disutility of lateness arrival time at primary destination place, and disutility for time of an activity constrain during period time the set primary origin-destination trip. The model assumed that leave time choice from shopping place is decided by travelers or shop customers according to minimum value of sum those disutility.

In order to apply the model, travel-activity behavior of customer on a stationary shop that can be categorized as short time shopping activity, was surveyed as case study. This research conducted survey at Agung Stationery Shop, the most crowded stationery shop in Makassar City, Indonesia. Due to limitation to observe individual directly, the survey applied parking survey based on record of plat number of vehicle for two categories of customer, i.e. customer which utilized car and bike respectively. The parking survey involved one day survey from 8:00 a.m. until 8:00 p.m. In other side, a survey by using questionnaire based on interview method was done to individuals who are live at ten residences area in Makassar City in order to observed travel time of travelers.

The calculated result by using a try-and-error process method based on simulation approach showed that the proposed model can produce a goodness of fit to observed data. In further, there is slightly different behavioral property of stay time dispersion between individuals or shop customers which utilized private car mode and individuals which used motor-bike, as well as average of start time for the constraint activity of the both individual categories. In summary, the model can be tested further by applying to other situations, and we can expect that it provides a basis to find more advanced and expended models, such as trip pattern and or destination choice models, and so on.

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