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Modeling of Shopping Participation and Duration of Workers in Calicut

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Abstract

Travel for shopping, one of the non-work activities, forms considerable portion of travel demand and significantly influences the traffic congestion in urban areas. An understanding of behaviour of urban dwellers with respect to participation, duration and timing of shopping activity will be of great help in formulating and assessing urban mobility improvement plans. This paper presents the efforts made to understand the shopping activity travel behavior of workers in Calicut city, one of the major urban centres in Kerala. Binary logit model is used for modelling the behavior of workers in taking up shopping activity. Activity duration, another component of activity participation behavior of individuals, greatly influences timing of travel and peak period congestion. Parametric and semi-parametric hazard based models are tried to model the duration of shopping activity. Parametric models based on Weibull distribution and without heterogeneity component are found to perform better. The modelling efforts helped in identifying the various variables that significantly influence the urban workers decision to participate in shopping. Duration of shopping activity is found to depend on household income, household structure, gender, age, travel mode, travel distance, travel cost, timing of activity and activity start time.

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Keywords: Urban commuters; activity participation; binary choice models; activity duration; hazard duration models

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1. Introduction

Polzin (2006) and Holt et al. (2005) made some of the contributions on non-work activities on travel demand, which include the significance of non-work discretionary travel. Purvis (1994) and Lockwood and Demetsky (1994) focused their studies to explore the effect of non-work trips on traffic congestion. These studies revealed the importance of the contributions made by non-work travel on traffic congestion. Gordon et al. (1998) investigated the role of non-work travel and its effect on travel demand.

Shopping is often considered to be an important element that affects the trip schedule of workers. Modelling of the commuters shopping activity helps to understand the related decision making process. These decisions include choice for travel mode, destination chosen, the time of day of activity participation and its duration. Understanding of activity-travel behaviour will help the planners and researchers to explore the effect of shopping on travel demand on and to devise measures to reduce the impact of such activities on travel demand. Hence, this study has concentrated on shopping activities of workers, taking into consideration the various attributes of household, personal, activity and travel. Given the importance of shopping activities, the focus of this paper is to model the shopping participation and duration of employed individuals, and to identify the most influencing variables.

2 Literature review

Some of the works pertaining to the various aspects of shopping are identified from literature. The study by Niemeier and Morita (1996) indicates that the modelling of non-work activity participation is complex. These complexities arise due to the flexibility, variability and the randomness in such behavior (Casto et al. 2010). Also, it was reported that increase in travel demand is largely due to the increase in non-work travel, (Hu and Young (1999) and Holt et al. (2005)). The variables identified from literature that pertains to non-work activity engagement are age, gender, household size, presence of children, number of workers and vehicle availability. Limanond et al. (2005) observed the influence of socio demographics on shopping frequency. Hamed and Easa (1998) found the influence of children on shopping activity.

Number of children, income, gender and trip-making characteristics emerged as the major factors affecting shopping duration. Time spent on shopping was influenced by type of post shopping activity, origin of shopping activity and time of day. Bhat and Steed (2002) developed a continuous time model of departure time choice for urban shopping trips using non- parametric base line hazard distribution, with unobserved heterogeneity. Age, gender, income, presence and age distribution of children, employment status emerged as the influencing factors.

3 Data

This work utilizes the activity and travel information collected from the households of various wards in the Calicut Corporation area using an activity-travel diary. The temporal classification used in the study is based on the categorisation proposed by Rajagopalan et al. (2010). Based on this study, a worker's day is divided into five broad periods; before work period, home-to-work commute period, work-based period, work-to-home commute period, and after work period. The preliminary analysis revealed that nearly 50% of the shopping activity participation is during work-to-home commute period. The shopping activity duration ranged from 15 minutes to 295 minutes with a mean duration of 89.9 minutes and standard deviation of 72.51 minutes. The distribution of non-work activities engaged by workers shows that the shopping activities constitute 36% of the non-work activities engaged by workers. The share of recreational and religious activities is 25% and 10% respectively.

3.1 Model development

The present study used binary logit model for analyzing participation behavior in shopping activities and hazard duration models for modelling duration of shopping activities of workers. The variables used in the model development are shown in table 1.

Table 1. Variables used in model development

Variables	Definition
Household variables	
PINF	1 if infants are present in the household, 0 otherwise
WHENC	1 if individual and individual's spouse are employed and no children in the household, 0 otherwise
WHESGC	1 if individual and individual's spouse are employed and school going children in the household, 0 otherwise
NUNEMP	Number of unemployed adults in the household
HHINC	Monthly household income
Personal variables	
GEN	1 if male, 0 if female
PE	1 if the individual is a private employee, 0 otherwise
DE	1 if the individual is a daily waged worker, 0 otherwise
Activity-travel variables	
CAR	1 if mode used for shopping is car, 0 otherwise
TW	1 if mode used for shopping is two wheeler, 0 otherwise
BUS	1 if mode used for shopping is bus, 0 otherwise
TD	Travel distance to the shopping activity (in kilometres)
ACHHMEM	Number of household members accompanying the ride
WOR DUR	Time between arrival at work in the morning to departure from work in the evening (in minutes)
W-H	1 if individual does the shopping activity during work to home commute period, 0 otherwise
A-W	1 if individual does the shopping activity after work commute period, 0 otherwise
EP	1 if individual does the shopping activity in between 4 pm to 6pm
LEV	1 if individual does the shopping activity in between 6 pm to 8pm

3.2 Binary logit model

In the case of binary choice models, the choice set contains exactly two alternatives. For convenience the choice set is shown as $C_n = \{i, j\}$, where *i* represent the workers decision to participate in activity and *j* represents not to participate in activity. Therefore, the probability of a person '*n*' who decides to do shopping and the probability of not shopping are given in equation 2 and 3 respectively where u_{in} and u_{jn} are the utilities of alternatives i and j for the decision maker n.

$$P_n(i) = P(u_{in} > u_{jn}) \tag{1}$$

$$P_n(j) = 1 - P_n(i) \tag{2}$$

Equation 3 represents the general form of the binary logit model where the systematic components v_{ij} and v_{jn} are linear in parameters.

$$P_n(\mathrm{j}) = \frac{e^{v_{in}}}{(e^{v_{in}} + e^{v_{jn}})} \tag{3}$$

3.3. Hazard duration models

Hazard-based duration models are the main analytical tools used by researchers to investigate the duration of events (Schjerning, 2004) and especially activity episodes (Scott, 2000). The hazard function is defined as the probability that an event will happen at time t, given that it has not happened up to time t, or equivalently, the probability that a duration process will exit at time t given that it has been ongoing until that time. T is the random variable which denotes shopping duration in minutes. The mathematical definition for the hazard in terms of probabilities is given in equation 4.

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \le T < t + \Delta t / T \ge t)}{\Delta t} \tag{4}$$

For analyzing the duration of shopping activities semi-parametric and parametric models were used. The difference between these two models rests on the assumption for the baseline hazard. The semi-parametric (Cox) models assume proportionality. This assumption makes it easier to estimate the parameters of the covariates by partial likelihood estimation method. The parametric models assume a distribution for the baseline hazard and utilize full information maximum likelihood estimation method. For developing these models, different distributions namely Weibull, log-logistic and exponential distributions are used. The exponential model assumes a constant hazard and the Weibull model assumes a monotonic hazard. The hazard rate in this case allows for monotonically increasing or decreasing duration dependence. The log-logistic model assumes a non-monotonic hazard.

Another problem in specifying a hazard duration model is its unobserved heterogeneity. It occurs when unobserved factors influence duration. The failure to control for unobserved heterogeneity can produce severe bias in the nature of duration dependence and the estimates of the covariate effects (Heckman and Singer, 1984). The present study considered heterogeneity by specifying gamma distribution in a Weibull parametric model.

4 Estimation results and discussion

The analysis focuses on the participation in shopping activities and duration of shopping activities, based on a set of explanatory variables. The model fit is studied using statistical measures, namely, t- statistic, log-likelihood value, chi-square value, pseudo R^2 value, adjusted R^2 value and predictability. The best model among the various duration models is selected based on pseudo R^2 value, AIC (Akaike Information Criteria) value and the graphical comparison of predicted versus observed survival distributions.

The shopping participation model is given in Table 2. Results indicate that presence of infants in the household is having a negative influence on the worker's decision to participate in shopping activity. Individuals in households with young children make less evening commute and post home-arrival stops, possibly because of the responsibility of taking care of young children at home. The dummy variable corresponding to wife and husband employed, presence of school going children is having a negative co-efficient. A possible reason for this is that working parents prefer to spend time at home with children after work. Workers from households with unemployed adults are less likely to participate in shopping. Greater the number of unemployed adults more is the opportunity to share the responsibility of household maintenance activities. Household income increases the propensity for workers to participate in shopping activity. With increasing income, there is likely more money available for participation in non-work, out-of-home activities. Age has a positive effect on the choice of shopping activity. Females are more likely to participate in shopping activity. It is also observed that private employees are more likely to participate in shopping activity and daily-wage workers are the least to participate in shopping.

Table 2. Shopping activity participation model

Variables	Coefficients	t- statistic
Constant	-2.881	-2.591
Household variables		
PINF	-2.118	-1.917
WHESGC	-0.895	-1.997
NUNEMP	-0.051	-2.551
HHTNC	0.031	1.817
Personal variables		
GEN	-0.578	-2.069
AGE	0.028	2.670
PE	0.852	1.943
DE	-0.382	-1.834
Activity-travel variables		
CAR	0.578	1.968
TW	0.535	1.894
SD	-0.460	-1.898
TD	-0.108	-1.894
WOR DUR	-0.039	-1.911
W-H	0.931	2.167
A-W	0.718	1.865
EP	1.198	4.048
LEV	0.806	2.294

Goodness of fit measures	-315.976
Log-likelihood for constant only model	-250.950
Log-likelihood at convergence	130.052
Chi-squared	0.206
McFadden Pseudo R-squared	0.149
Adjusted R-squared	78.52%
Percent correctly predicted	-315.976

Among the activity-travel variables, the effects of the travel mode variables are as expected. Commuting to work by private mode increases the participation of workers in shopping activity. It can also be observed that as commute distance increases, workers are less likely to participate in shopping. This reveals the importance of time constraints imposed by the longer commute. Individuals who work more, have less time available for non-work activities, and so engage less in such activities. Workers prefer work-home or after work period for participating in shopping activity. Among these, the most preferred period is work-home time period.

Results of shopping duration modelling efforts are shown in Table 3. Model results show that the semi-parametric model has the lowest pseudo R^2 value of 0.036. Among the models, the pseudo R^2 value is the highest and the AIC value is the lowest for Weibull parametric hazard model, which is, therefore selected. The results indicate that the Weibull distribution parameter P is highly significant and greater than one, implying an

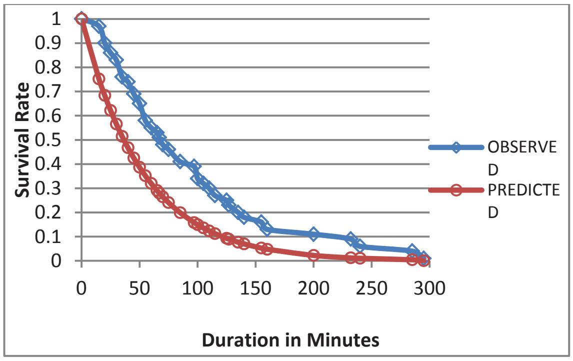
Table 3. Results of shopping activity duration modelling

Variables	Cox **Coef.** **(t stat.)**	Exponential **Coef.** **(t stat.)**	Log-logistic **Coef.** **(t stat.)**	Weibull **Coef.** **(t stat.)**	Weibull-het **Coef.** **(t stat.)**
Constant	-	6.139 (6.150)	5.752 (10.205)	6.246 (10.967)	6.362 (10.442)
Household variables					
WHENC	0.547 (1.041)	-0.765 (-1.414)	-0.632 (-1.476)	-0.816 (-1.817)	-0.758 (-1.554)
WHESGC	0.049 (1.170)	-0.080 (-1.474)	-0.117 (-1.491)	-0.096 (-1.978)	-0.036 (-1.501)
NUNEMP	0.145 (1.417)	-0.138 (-1.108)	-0.142 (-1.774)	-0.134 (-1.669)	-0.132 (-1.647)
HHINC	-0.158 (-1.026)	0.581 (1.275)	0.522 (1.910)	0.575 (1.973)	0.564 (1.929)
Personal variables					
GEN	0.002 (1.061)	- 0.009 (-1.082)	-0.042 (-1.272)	-0.228 (-1.611)	-0.036 (-1.326)
AGE	0.015 (1.988)	-0.011 (-1.071)	-0.009 (-1.459)	-0.011 (-1.688)	-0.002 (-1.701)
Activity-travel variables					
CAR	-0.073 (-1.988)	0.029 (2.036)	0.075 (1.825)	0.049 (1.775)	0.017 (1.506)
BUS	0.357 (1.732)	-0.253 (-1.025)	-0.264 (-1.506)	-0.242 (-1.614)	-0.231 (-1.426)
ACHHMEM	-0.083 (-1.936)	0.098 (2.120)	0.207 (2.447)	0.215 (2.720)	0.120 (2.279)
TD	-0.027 (-1.111)	0.028 (1.454)	0.018 (1.407)	0.025 (1.676)	0.019 (1.555)
WORDUR	0.003 (-1.517)	-0.001 (-1.789)	-0.001 (-3.229)	-0.002 (-3.205)	-0.002 (-3.381)
W-H	-1.715 (-1.041)	0.814 (1.467)	0.647 (1.866)	1.046 (1.939)	1.027 (1.748)
A-W	0.315 (1.411)	-0.156 (-1.909)	-0.221 (-1.984)	-0.101 (-1.994)	-0.057 (-1.928)
EP	-0.881 (-1.716)	0.352 (1.959)	0.109 (2.010)	0.483 (2.888)	0.454 (2.045)
LEV	0.548 (1.655) -	-0.576 (-1.261)	-0.099 (-1.764)	-0.632 (-2.515)	-0.626 (-2.512)
Ancillary parameters					
Sigma	-	1.000	0.507 (7.236)	0.712 (9.223)	0.705 (8.390)
Lambda	-	0.013	0.018	0.012	0.011
P	-	1.000	1.917	1.405	2.031
Theta	-	-	-	-	0.002 (0.010)
Goodness of fit measures					
Log -likelihood value at convergence	-735.158	-237.172	-235.430	-222.970	-223.078
AIC	5.765	2.835	2.816	2.689	2.701
Mc-Fadden Pseudo R -squared	0.036	0.073	0.085	0.119	0.116
Adjusted R-squared	0.008	0.055	0.062	0.085	0.080

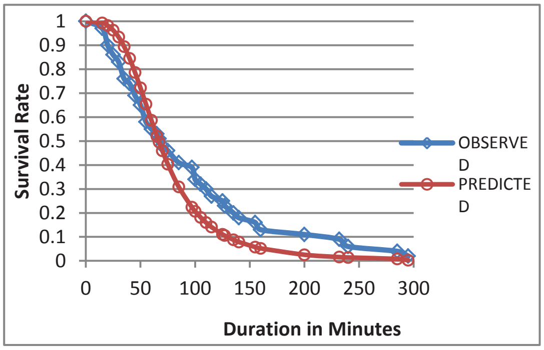
increasing hazard function. That is, the longer a commuter stays in a shopping activity, the more likely he/she will end it. The results also show that the heterogeneity factor (θ) is not significant. The reason for this may be accommodation of heterogeneity by the distributional assumption in the hazard model. This confirms the assumption that the vector of independent variables captures all the variability in shopping duration. To understand the model's prediction capability, graphical comparisons of predicted and observed survival distributions of the various parametric models are shown in Fig 1a, Fig 1b and Fig 1c. The comparisons indicate that the Weibull-Parametric hazard model fits the observed duration data better than the other models. This is reflected in the corresponding pseudo R^2 value as well.

The effect of household socio-demographics on the selected model indicates that employed couples are likely to engage in shopping activity for shorter periods. This is perhaps an indication of the time constraints faced by them. The presence of unemployed adults in the household results in shorter duration for shopping. Household income has a profound impact on shopping duration. Commuters with high income are likely to have longer durations than those with low income. Among the personal variables, the effect of gender on shopping duration is significant. Males pursuing shopping activities are likely to have shorter duration than females. The results also indicate that aged commuters are likely to have shorter shopping duration. This result is expected since aged commuters are likely to have more family responsibilities that place binding constraints on shopping duration.

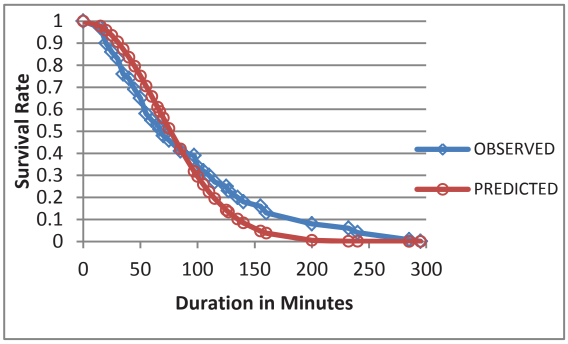
The effect of activity-travel variables indicates that the travel mode significantly influences the time spent on shopping. The car users spend more time on shopping than bus users. The private vehicles are likely to unwind the time constraints connected with bus schedules and routes. Commuters travelling longer distance to shopping locations are likely to spend more time on shopping. In addition, if there are more people in vehicle, then the time spent on shopping increases. This is because more people in the group generate greater needs to be satisfied. The dummy variable corresponding to work duration is negative and highly significant. This indicates that the workers having longer working hours are likely to spend less time on shopping. This is an indication of the less time available for non-work activities to them. Commuters pursuing shopping activities during work-to-home time period have longer duration compared to post-home arrival time period. The time of day variables indicate that workers pursuing shopping activities during evening peak are likely to spend more time on shopping, while those who engage in shopping during late evening are likely to spend less time on shopping.



(a) Exponential Parametric Model



(b) Log-Logistic Parametric Model



(c) Weibull Parametric Hazard Model

Fig. 1 Survival Distribution

5. Conclusion

This study focused on the development of a binary choice model for estimating the chances of participating in shopping activity and hazard duration model for activity duration of workers. This study revealed that the age of the person and household income positively influence the participation in shopping activity, while travel distance and number of non- working adults in household negatively influence shopping. Workers prefer to participate in shopping during the travel from work to home. Females spend more time on shopping than males. Travel mode significantly influences the duration of shopping. Employed couples, males and older commuters and persons commuting to work by bus spent less time on shopping. Household income, travel distance and group size have positive effect on duration of shopping, while age and work duration have negative effect. Majority of the shopping activities are performed during evening and hence shopping activity participation has greater influence on peak period congestion. The activity participation and duration models can be used to assess the shift in travel demand due to the change in work duration. These models along with time of day models will be useful in scheduling and sequencing of activities and thus arrive at better forecast of travel demand

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