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Abstract

Logit destination choice models are developed in this study and the following hypotheses are examined: (1) time-of-day affects destination choice behavior; (2) the duration of stay at the destination affects destination choice, and (3) home location affects non-home-based destination choice. The statistical results offer strong evidence in support of the hypotheses.

1. INTRODUCTION

Numerous studies exist on the subject of spatial interaction in human behavior, e.g., trip distribution, migration, housing location, location of firms, or college choice. In the transportation planning field, destination choice models, which describe each traveler's choice of destination location in probabilistic terms, appear to be widely accepted as an alternative to trip distribution models. The former group of models are "disaggregate" in the sense that they are concerned with the choice behavior of each individual traveler, while the latter group of models are "aggregate" as they model the frequency of trips between a pair of origin and destination zones.

Aside from this aggregate vs. disaggregate distinction, there appear to be more similarities between the two groups of models than differences. In terms of functional forms, the logit model into which destination choice models are most frequently formulated, belongs to the gravity model family. In fact a production-constrained gravity model with an exponential deterrence function is identical, up to a constant multiplier, to a logit destination choice model with a "utility" function which includes a measure of spatial separation (e.g., travel time) as a linear additive term. The only difference is that disaggregate logit models of destination choice contain attributes of the individual or household, while aggregate trip distribution models contain zonal demographic and socio-economic measures.

There are many important similarities between the two. Firstly, the attributes of destination opportunities are represented in both groups of models by zonal figures such as the number of retail employees in the zone. The destination choice models are disaggregate when their treatment of decision makers is concerned; they are aggregate when the treatment of destination opportunities is concerned. It may not be practical to treat individual destination opportunities as destination alternatives in a discrete choice model because, unless there are only a limited number of opportunities as would be the case with, e.g., shopping malls in a metropolitan areas, it would mean a choice set with an excessive number of alternatives. Statistical modeling of spatial interaction on continuous geographical space may be an effective alternative.

More importantly from pragmatic viewpoints of improving the accuracy and policy sensitivity of destination choice models, they share with aggregate trip distribution models the following:

- they are trip-based,
- no effect of the time of day is assumed,
- no association is assumed between destination choice and the duration of activity at the destination,
- they are not mode specific when applied before modal split in the trip-interchange model, is largely due to the structure of the four-step procedure, in which destination choice models as well as trip distribution models tend to be applied. This problem is therefore not addressed in this study.

These characteristics of most destination choice models that have been inherited from trip distribution models imply rather restrictive assumptions that are unlikely to hold empirically. For example, the fact that disaggregate destination choice models have been applied to each trip while completely ignoring those trips that precede or follow it, may lead to a serious misrepresentation of destination choice for non-home-based trips. The implicit assumption in the conventional models that time of day does not affect destination choice behavior is not consistent with the notion that travel behavior is constrained by constraints stemming from time availability and speed of travel (*3*). And the assumption that destination choice is independent of the duration of activities at the destination does not agree with the viewpoint that the traveler allocates available time to activity and travel, which implies travel time and activity duration are negatively correlated.

One may argue that these restrictive assumptions have been adopted as simplifying assumptions to reduce computational requirements. This must have been critical at the time when the four step procedure was being developed because of the extremely restrictive computational and data handling capabilities available at that time. The environment of model development and application has changed quite dramatically due to fast and inexpensive computational power, abilities to store and access to large data bases, and efficient application software packages for data manipulation and statistical analysis that are now available. As a result, complex models which would have been considered impractical a decade ago are no longer impractical. This is especially the case with micro-simulation of the behavior of a household or an individual, which is drawing attention as a new approach to travel demand forecasting (*8*). In fact the models presented in this paper have been developed as part of the effort to develop a micro-simulation model system to generate synthetic travel patterns as reported in Kitamura et al. (*5*).

The purpose of this paper is to critically examine the above assumptions that have been either explicitly or implicitly incorporated in most models of trip distribution or destination choice.

More specifically, the following aspects of destination choice behavior are examined using an empirical data set:

- time-of-day dependence of destination choice,
- effect of the activity duration at destination on destination choice, and
- effect of home location on non-home-based destination choice.

It is hoped that this investigation will offer insights toward the development of a next generation of destination choice models. This paper is organized as follows. A review in literature is presented in Section 2. Given the objectives of this paper specified above, the review focuses upon time of day dependence, effect of activity duration and effect of home location in non-home-based destination choice models. During the study, a set of destination choice models were developed using SCAG (Southern California Association of Governments)'s 1991 household survey data. The model formulation is presented in Section 3. Following Section 3 is a description of the SCAG data set and this constitutes Section 4. Tests of time of day dependence, effect of activity duration and effect of home location are described in Sections 5, 6, and 7 respectively. Conclusion comes in Section 8.

2. LITERATURE REVIEW

Individuals' destination choice is complex behavior; it is a choice made to maximize preferences governed within constraints. The constraints are represented by a set of spatial, temporal and personal factors (*1*). Spatial and temporal factors refer to the time-space prism as identified by Hägerstrand (*3*). Personal factors refer to individuals' internal drives. Personal factors are associated with individuals' preferences, attitudes, household characteristics, and characteristics associated with destination alternatives. Given the specific objectives of this paper, the review hereby does not include effect of personal factors in destination choice models.

Typical variables used to represent the spatial separation between origin and destination are travel distance or travel time between the two. As explained in the gravity theory, the farther away a destination is the origin, the less attractive it is to the origin. In other words, individuals' utility decreases as spatial separation increases. Numerous studies have consistently proved this.

The spatial separation of a home-based trip differs from that of a non-home-based trip. This is especially the case when a trip chain instead of an isolated trip is considered. In non-home-based trips, not only the separation between origin and destination needs to be considered, but also the deviation of destination from home. Kitamura & Kermanshah (*6*) illustrated graphically that a destination closer to home is more attractive than one farther from home, given comparable distances between origin and the two destinations respectively. Their empirical model showed the destination-to-home distance is equally important as the origin-to-destination distance in non-home-based trips.

Temporal factors also affect destination choice (*3*). Temporal factors may be represented by store hours and time of day. The idea is quite simple. Take an example about shopping activity alone, shopping can not be done when the store is closed. Consequently in our modeling effort, the store location becomes unavailable to the decision maker when the store is closed. Store hours affect the size the choice set and thus the probabilities of available alternatives in the set.

Several studies have found store hours to be significant in destination choice (*6, 10, 4*). Time of day affects destination choice from a slightly different perspective from store hours. Our choice is governed not only by how fast we can travel but also how much time we have available (*7,5*). Time of day at least partially reflects the concept of time availability; situational effect also determines time pressure. Our own experiences suggest that ceteris paribus, we would be more willing to travel to faraway place in the morning than at night. The literature is limited in incorporating time availability in modeling destination choice. Landau (*7*) used the concept of deviation, which was initially defined by Damm (*2*). He defined that any location other than residential and work places is a deviation; deviation can be categorized by activity type. He then calculated the maximum amount of time that a person could spend at each shopping site. The calculated time directly affects the size of the choice set; positive value includes the site into the set and negative value excludes the site from the set.

Activity duration plays a role in our destination choice decision making. For example, we would be more willing to travel to a faraway place for a decent meal than for a hamburger. Alternatively, we may trade off between travel time and the time available at the destination; we might travel to a close place to obtain long duration at the destination or travel to a faraway place for a short stay at the destination. The literature is quite limited in identifying effect of activity duration in destination choice models. Stephanedes et al. (*9*) showed that the expected length of employment is the strongest determinant in their job search model.

3. MODEL FORMULATION

The destination choice models developed in this study can be classified into two categories: home-based models and non-home-based models. The models in the first category are applicable to trips that originate from the home base, while the models in the latter group apply to non-home-based trips. The models of each group are further grouped into two: models for workers and models for non-workers. The worker is defined in this study as those who are either full-time or part-time employed/enrolled at schools.

The home-based destination choice models of this study are pre-modal split models and formulated using the network skim auto travel time. The model is time-of-day dependent, and the skim travel time for the time period in which the trip falls is used in both model estimation and prediction. The non-home-based models are also time-of-day dependent, but are formulated as post-modal split models. This reflects the consideration that the mode choice for non-home-based trips are heavily conditioned on the travel mode used for the trip that originated from the home base. Consequently it is more realistic to assume that the mode is predetermined, then a destination is selected for a non-home-based trip.

All models are formulated as multinomial logit models. The home-based models take on the following form:

$$P_i(j) = \frac{\exp(A_j - \lambda t_{ij})}{\sum_{k \in \Omega} \exp(A_k - \lambda t_{ik})}$$

where

$P_i(j)$ = probability that a trip starting from zone i will have zone j as its destination,

A_j = measure of the attraction of zone j,

λ = positive parameter representing the effect of travel time,

t_{ij} = travel time between zone i and zone j, and

Ω = set of all destination zones.

A_j and λ are composite variables which are specified in this study as functions of the characteristics
of the trip maker and his household, destination zone, and additional variables introduced in this study as described later.

The argument of the exponential function, often called "utility" function in the literature on discrete choice models, therefore take on the form,

$$A_j - \lambda t_{ij} = \sum_k \alpha_k^p D_{jk} + t_{ij} \sum_m \beta_m^p Z_{ijm}^n$$

where

α_k^p = coefficient of k-th destination attribute for trip purpose p,

D_{jk} = k-th attribute of destination j,

β_m^p = coefficient of m-th attribute for trip purpose p, and

Z_{ijm}^n = m-th attribute associated with zone i, zone j and trip maker n.

Parameter λ is replaced by $\sum_m \beta_m^p Z_{ijm}^n$ and the negative sign in front of λt_{ij} is now replaced by a positive sign. The Z_{ijm}^n include a variety of variables in this study, including person and household characteristics, time of day, and the duration of the activity at the destination. This formulation thus represents the consideration that the effect of spatial separation varies from person to person, by time of day or depending on the duration of stay at the destination.

The above expression is linear in the unknown parameters and the logit model can be estimated using standard procedures. No alternative specific constants (which are equivalent to the K-factors in the traditional gravity models) are adopted in the models.

The non-home-based models of this study take on the following general form:

$$P_i(j) = \frac{\exp(A_j - \lambda_d t_{ij} - \lambda_h t_{jh})}{\sum_{k\in\Omega} \exp(A_k - \lambda_d t_{ik} - \lambda_h t_{jh})}$$

where

λ_d = positive parameter representing the effect of the travel time between the origin and a potential destination,

λ_h = positive parameter representing the effect of the spatial separation between a potential destination and the home base, and

t_{jh} = travel time between zone j and the home base.

The critical difference here is the inclusion of the term, $\lambda_h t_{jh}$. This was proposed in Kitamura & Kermanshah (*6*) to represent the tendency in destination choice that, *ceteris paribus*, a trip maker traveling from a non-home location would prefer a destination that is closer to home.

As noted earlier, this study is an attempt to examine the time-of-day dependence of destination choice, the effect of the activity duration at destination on destination choice, and the effect of home location on non-home-based destination choice. To facilitate this investigation sets of variables that are not commonly used in trip distribution or destination choice models are introduced into the models of this study. They include:

- variables representing time of day, zone-to-zone travel time by time period,
- duration of the stay at the destination, and
- travel time from a potential destination zone to the home base.

As noted earlier in a footnote, the models developed here are intended for use in micro-simulation and attempt to capture all pertinent aspects of destination behavior, many of which would be impossible to represent in aggregate, trip based, or time-of-day independent approaches.

Following the description of the data set and estimation procedure used in this study, theoretical discussions are first presented, then empirical results are given on each of the three subjects for investigation, namely, time-of-day dependence, the effect of the activity duration, and the effect of home location.

4. DATA AND ESTIMATION PROCEDURE

The results of the 1991 home interview travel survey conducted by the Southern California Association of Governments (SCAG) are used in the model development of this study along with accompanying land use and network data. Sub-samples of randomly selected individuals in the original survey sample with complete information, are used in this study.

The universe of the alternatives for destination choice can be defined as the set of 1,527 traffic analysis zones (TAZs) in SCAG's 1991 zone system. It has been shown that, if the multinomial logit model is the correct specification, then consistent estimates of its coefficients can be obtained by the standard maximum likelihood estimation by using a choice set that comprises the observed (chosen) alternative and additional alternatives randomly drawn from the universe. After comparing computational requirements and the precision in estimation based on the results of several test runs, it was decided to include a rather large number of 74 randomly drawn alternatives. For each observation in the data base, therefore, 74 TAZs are drawn randomly; these 74 alternatives and that TAZ actually chosen in the data set, comprise of the choice set for model estimation.

The original SCAG's trip purpose categories are grouped as follows in this study:

- work related,
- personal business,

- recreation and shopping,
- eat meal, and
- others.

Although models have been developed for work and school, they are not reported in this paper as they are less relevant to the purposes of this paper. The study period is from 3:00 A.M. of a day to 2:59 A.M. of the following day.

5. TEST OF TIME-OF-DAY DEPENDENCE

People allocate time to various activities, including traveling, and the amount of time available is limited. This forms the basis for suspecting time-of-day dependencies in destination choice behavior. For example, destinations choice in later parts of the day can be subjected to tighter time constraints, and therefore the choice set may contain only those alternatives that are located in the vicinity and are reachable. Likewise destination choice during a lunch break is severely constrained by the requirement that the trip maker must return to the work place by the end of the break.

The notion of "space-time prism" proposed by Hägerstrand is useful here (*3*). The speed of travel is finite and the time available for travel and activity is limited for a variety of reasons (e.g., commitment such as working, institutional constraints such as store hours, and physiological requirements). The individual's trajectory in time and space is consequently constrained. Hägerstrand's prism is the volume defined in the space-time dimension which contains all possible trajectories that can be taken by an individual, starting from a point (e.g., current location) and ending at a point where the individual must be (e.g., 9:00 A.M. at the office). The size of this prism varies depending on the time of day. To the extend destination choice is influenced by the prism, then, it is time of day dependent.

For example, Table 1 presents home-based destination choice models for recreation and shopping. The positive coefficient estimates of *Retail Employment* and *Population* indicate their positive contribution to the attractiveness of a zone as a destination for these purposes. The negative coefficient of *(Female)* $\times t_{ij}$ in the model for workers implies that the effect of spatial separation, or the impedance of travel, is greater with working women than with working men, and that working women's trips for recreation and shopping purposes tend to be shorter, *ceteris paribus*.

The model for workers contains three variables that represent time of day. Two of them, *D(4:00 - 6:00PM)* and *D(6:00 - 8:00PM)* are dummy variables which take on a value of 1 when the trip starting time falls in the interval indicated by the variable name. The negative coefficient estimates imply that recreation and shopping trips made in the respective periods tend to be shorter. The variable, *T*, simply represents time of day in hours continuously through the study period ($3.0 \leq T < 27.0$), except for the periods for which the dummy variables are defined, where it takes on a value of 0. The negative and significant coefficient implies that the impedance of travel increases toward the end of the day, consistent with the theoretical discussion above.

The time of day effects as captured by the home-based models are summarized in Table 2. The *T* variable, when included in the model, is always negative, suggesting that time constraints tightens and trip makers' destination choice is made in a more contracted space in later parts of the day. The *D* variables capture the characteristics of time-of-day dependence that are unique to each trip purpose. Non-workers' home-based destination choice is evidently not time-of-day dependent.

6. EFFECT OF ACTIVITY DURATION AT DESTINATION

From the same reason that the total amount of time available for activity and travel is limited, it follows that there are tradeoffs between the amount of time that is allocated to activities at destinations and the amount of time spent for traveling. Individuals maker may choose ~~to~~ travel farther to reach an opportunity of higher quality, but spend less time on activity, or settle for a lower quality, but closer opportunity and spend more time there.

On the other hand, it can be argued that individuals are unlikely to travel a long distance to spend a small amount of time at the destination. One may organize activities over a long span of time and plan to engage in many activities when he visits a distant destination. In order to examine which hypothesis better represents destination choice behavior, the observed duration of stay at the destination as one of the explanatory variables. Estimation results are summarized in Table 3 for both home-based and non-home-based models.

The coefficient estimates are all positive and significant. It can be concluded that destination choice is associated with the time spent at the destination for most types of activities. It can be further argued that individuals who are spending larger amounts of time at the destination tend to have destinations farther away. The variable was not significant and not included in the non-home-based models for recreation/shopping and others. There is no evidence that destination choice for these purposes is associated with the duration of stay at the destination.

7. EFFECT OF HOME LOCATION ON NON-HOME-BASED DESTINATION CHOICE

The hypothesis here is that destination locations in a trip chain, where more than one destination is visited, are chosen while considering the home location. The reason for this is obvious. If the trip maker plans to return home at all, then attempts to minimize travel cost would lead to the selection of destinations that are closer to home than away from home. This hypothesis has been tested and confirmed in Kitamura & Kermanshah (*6*). A more rigorous test is performed in this study by adopting more comprehensive destination choice models. The results are summarized in Table 4.

In is evident from Table 4 that coefficient estimates of t_{ij} and t_{jh} are very close to each other for most of the trip purpose categories used in the study. This is in particular the case for workers' models for personal business, recreation/shopping, and non-workers' personal business. The differences between the two coefficients are 3% or less for these three models. The models for other purposes also show similar coefficients. Also note they have similar t-statistic values.

Two trip purposes, work related and eat meal, exhibit the tendency that the origin-to-destination travel time affects destination choice more than does the destination-to-home travel time. Yet, the coefficients of t_{jh} are significant in these models.

The results have offered strong evidence that the home location is important in non-home-based destination choice. For personal business and recreation/shopping, the destination-to-home travel time is as important as the origin-to-destination travel tiem.

8. CONCLUSION

Logit destination choice models are developed in this study and the following hypotheses are examined:

- time-of-day affects destination choice behavior,
- the duration of stay at the destination affects destination choice, and
- home location affects non-home-based destination choice.

The statistical results offer strong evidence in support of the hypotheses. The study results point to ways destination choice models can be improved in non-trip-based applications along clock time, such as micro-simulation of daily travel patterns.

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List of Tables:

Table 1 Home-Based Destination Choice Models: Recreation/Shopping

Variable	Workers Estimates	Workers t-ratio	Non-workers Estimates	Non-workers t-ratio
(Retail Employment)/1000	0.47	21.74	0.53	16.92
(Non-retail Employment)/1000	-0.0078	-2.03	-0.016	-2.79
(Population)/1000	0.041	13.69	0.046	10.62
t_{ij} [1]	-7.89	-20.87	-10.52	-48.41
(Activity Duration) × t_{ij} [1]	0.66	20.37	0.47	6.99
$T^2 \times t_{ij}$ [1]	-0.20	-7.24		
D(4:00 - 6:00 PM) × t_{ij} [1]	-1.84	-4.66		
D(6:00 - 8:00 PM) × t_{ij} [1]	-2.81	-6.95		
(Female) × t_{ij} [1]	-0.40	-1.96		
(Single Female) × t_{ij} [1]			-1.05	-1.56
N	5210		2618	
L(0)	-22494.1		-11303.2	
$L(\hat{\beta})$	-8153.7		-3846.1	

[1] travel time between i and j. [2] T = 0 for 6:00 to 8:00 PM.

Table 2 Coefficients and t-Statistics of Time-of-Day Variables in Home-Based Models

Workers			Non-Workers		
Variables	Estimates	t-ratio	Variables	Estimates	t-ratio
Work Related					
Time of day	-0.22	-5.89			
D(7:00 - 9:00 AM)	-0.20	-2.17			
Personal Business					
Time of day	-0.26	-7.86	Time of day	-0.34	-7.69
D(7:00 - 11:00 AM)	-1.94	-4.11	D(9:00 - 11:00 AM)	-4.86	-8.01
D(5:00 - 7:00 PM)	-2.76	-4.96			
Recreation/Sopping					
Time of day	-0.20	-7.24			
D(4:00 - 6:00 PM)	-1.84	-4.66			
D(6:00 - 8:00 PM)	-2.81	-6.95			
Eat Meal					
Time of day	-0.19	-6.30	Time of day	-0.37	-3.83
D(11:30 - 1:00 PM)	-9.12	-6.46	D(11:00 - 12:00 PM)	-2.62	-1.91
D(5:30 - 7:30 PM)	-3.82	-7.82	D(5:00 - 7:00 PM)	-3.82	-7.82
Others					
Time of day	-0.21	-7.71	D(8:00 - 9:00 AM)	-1.36	-2.45
D(7:00 - 9:00 AM)	-3.35	-8.77	D(2:00 - 3:00PM)	-3.57	-3.62
D(2:00 - 4:00 PM)	-4.61	-7.99			

Table 3 Coefficients and t-Statistics of Activity Duration in Home-Based and Non-Home-Based Models

Home-Based Models (for auto trips only)				
	Workers		Non-Workers	
Trip Purpose	Estimates	t-ratio	Estimates	t-ratio
Work Related	0.21	4.37		
Personal Business	0.66	13.03	0.39	5.23
Recreation/Sopping	0.66	20.37	0.47	6.99
Eat Meal	1.48	13.22	2.02	4.22
Others	0.49	8.76	0.35	1.58
Non-Home Based Models				
	Workers		Non-Workers	
Trip Purpose	Estimates	t-ratio	Estimates	t-ratio
Work Related	0.25	7.81		
Personal Business	0.22	5.45	0.53	5.08
Recreation/Sopping	0.35	15.57		
Eat Meal	1.48	13.22	0.94	2.70
Others	0.49	8.76		

Table 4 Coefficients and t-Statistics of Origin-to-Destination Travel Time and Destination-to-Home Travel Time in Non-Home-Based Models

	Workers		Non-Workers	
Work Related	Estimates	t-ratio	Estimates	t-ratio
t_{ij}	-5.20	-11.6		
t_{jh}	-2.39	-5.3		
Personal Business	Estimates	t-ratio	Estimates	t-ratio
t_{ij}	-5.56	-26.1	-7.93	-10.4
t_{jh}	-5.73	-27.7	-7.74	-10.1
Recreation/Sopping	Estimates	t-ratio	Estimates	t-ratio
t_{ij}	-6.41	-53.0	-7.50	-29.5
t_{jh}	-6.60	-55.2	-6.37	-25.2
Eat Meal	Estimates	t-ratio	Estimates	t-ratio
t_{ij}	-14.15	-16.1	-11.73	-13.4
t_{jh}	-10.99	-12.5	-9.49	-11.1
Others	Estimates	t-ratio	Estimates	t-ratio
t_{ij}	-6.55	-20.9	-9.30	-8.8
t_{jh}	-7.99	-25.3	-9.82	-9.1