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Specification of a tour-based neighborhood shopping model

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Abstract. This paper presents a state-of-the practice neighborhood shopping travel demand model. The model structure is designed to incorporate decisions across five dimensions of shopping travel, including decisions of: (1) household tour frequency; (2) participating party; (3) shopping tour type; (4) mode, and (5) destination choices using a tour-based nested-logit model. As a neighborhood model, we have also captured the interrelated effects of three main factors associated with shopping travel decisions both within and outside of the neighborhood, including the residential location within the neighborhood, the neighborhood regional setting and the household structure. The model was validated using the travel data collected in three neighborhoods located in the Puget Sound region, WA. Results show that household socio-demographics have significant effects on the decisions for household tour frequency, mode and destination choices, while the characteristics of the traveling party have considerable impacts on the decisions for tour type. The level of service and the zone attractions influence decisions about mode and destination choices. The day of week variable (weekday versus weekend) is statistically significant in all models, indicating that weekday shopping travel decisions differ from weekend, across all five dimensions of interest. The paper concludes with a discussion about how the model can be used to examine policy-related neighborhood issues (e.g. accessibility).

1. Introduction

A growing number of US metropolitan areas are turning to the concept of "smart growth" as a means of preserving neighborhood quality of life and addressing transportation and land use decisions (Song et al. 2002). Both the US Environmental Protection Agency (2002) and the American Planning Association (2002) have articulated principles that are designed to revitalize neighborhoods by creating a sense of community. Some of the techniques for accomplishing this include promoting mixed land use design, creating walkable neighborhoods, and providing a variety of transportation choices.

The concept of neighborhood design as a means of enhancing quality of life and mitigating the negative aspects of growth is not new. Many local and federal government agencies have identified neighborhood design as one alternative that can improve residential quality of life as well as help to reduce automobile travel in general (e.g. City of Portland, OR; City of San Diego, CA; Puget Sound Regional Council, WA), and non-work automobile trips in particular (Gordon & Peers 1991; Handy 1992). The reasoning is that a mixed-use core (MUC) would tend to induce a large proportion of non-work travel to stay within the neighborhood and that more walkable neighborhoods should, in turn, encourage non-motorized travel as replacement for vehicle trips for non-work (e.g. shopping) activities.

The main objective of this paper is to present the structure of a neighborhood travel demand model that would be suitable for exploring many of these hypotheses in greater detail. To formulate the model structure, we begin with a literature review that suggests that there are five important dimensions to shopping travel decision-making: (1) household tour frequency; (2) participating party; (3) shopping tour type; (4) mode, and (5) destination choice using a tour-based nested-logit model. We then propose a model to structure the interrelated effects of three main factors, separately found to be associated with shopping travel decisions: the residential location within the neighborhood, the neighborhood regional setting and the household structure.

2. Background

The literature suggests that there are five important decisions made by neighborhood residents when considering non-work travel. These include decisions about mode, destination, tour type, participating party, and trip frequency. With respect to mode choice, previous research indicates that mode choice decisions are affected by both the regional setting of the neighborhood (e.g. Handy 1992; Cervero & Gorham 1995; Cervero & Radisch 1996; Kockelman 1997) as well as the specific residential location within neighborhood (e.g. McCormack et al. 1995; Kitamura et al. 1997). Both Cervero and Radisch (1996) and Kockelman (1997) found that the impacts of locational factors on mode choice were profound, even after controlling for socio-economics.

The decision about shopping destination is usually implicitly investigated through the vehicle miles traveled parameter. Traveling fewer miles implies that travelers tend to visit activity sites in the vicinity of the residential location. Handy (1993) found that local accessibility and regional accessibility are correlated to vehicle miles of travel generated for shopping. Kockelman (1997) found that urban form variables, such as accessibility, have significant explanatory power in explaining travel mileage. These findings indicate that local and regional land use patterns can influence destination choice.

The type of shopping tour that a resident in a well-mixed neighborhood may elect to make (e.g. shopping-only tours, multi-purpose shopping tours) is clearly an important component in household shopping travel decisions. Ewing et al. (1994) analyzed Palm Beach countywide travel patterns and found that a high proportion (61%) of all trips were involved in multi-stop tours. Ewing et al. hypothesized that, due to the nature of the sprawl in Palm Beach County, residents tended to combine several trips into tours in order to reduce overall travel. Although the analysis is not specific for shopping travel, it is believed that shopping travel would be more likely to involve some sort of trip scheduling due to its flexible nature.

It is well-known that household structure and/or the allocation of domestic roles within the household affects both the number and distribution of trips (Town 1980; Lockwood & Demetsky 1994), the scheduling of non-work trips and evening activities (Kostyniuk & Kitamura 1982; Strathman et al. 1994), and daily activity behavior (Clarke et al. 1981; Pas 1984). Williams (1988) argues that "members of a household will generate both individual and common needs, and will collude in the organization of intraurban trips to the sites of their activities" (p. 535). Past studies examining shopping at the neighborhood level have also found that household structure and socio-economic variables are major determinants of non-work trip frequency (Ewing et al. 1996; Kockelman 1997).

The impact of land use on non-work trip frequency has been widely investigated, but the findings are inconclusive. Some studies have found that land use has no impact on non-work trip frequency (e.g. Handy 1993; Ewing et al. 1996), while others have suggested the impact is rather significant (e.g. Agyemang-Duah et al. 1996; Lee & Goulias 1997).

Many of the previous studies on neighborhood level travel have utilized cross tabulation (McCormack et al. 1995), regression analysis (Handy 1993; Kockelman 1997) and binary logit models (Cevero & Radisch 1996; Kockelman 1997). While these analyses provide important insights, the studies usually analyze only one dimension of travel activity at a time and thus, do not reveal much about the underlying decision processes. This paper provides a structure for considering these types of policy-related questions using a state of the practice tour-based nested logit model.

3. Empirical setting

We have chosen three neighborhoods to be analyzed in the study, including Upper Queen Anne Hill, Wallingford and Downtown Kirkland, all located in Puget Sound, Washington (see Figure 1). Their design characteristics (e.g. gridded streets, mixed use core, etc.) and regional setting make these neighborhoods useful for our study on the impacts of local and regional accessibility on travel decisions of neighborhood residents. In addition, the neighborhoods have been examined in a number of other studies (e.g. McCormack et al. 1995), which in turn provides a benchmarking for subsequent analysis efforts.

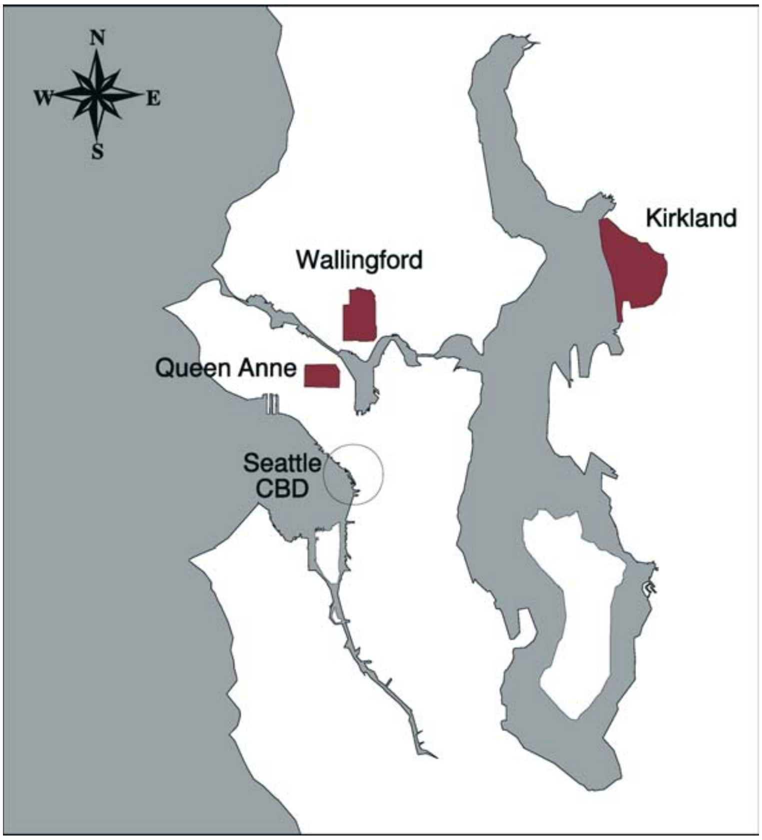

Figure 1. Regional settings of the study neighborhoods.

Upper Queen Anne Hill is the smallest study neighborhood of the three, roughly 0.5 miles wide by 0.7 miles long, and located just a few miles north of downtown Seattle. The neighborhood has a grid street pattern with an active shopping corridor along Queen Anne Avenue. The remainder of the neighborhood is primarily residential, ''with a few scattered retail and office facilities'' (McCormack et al. 1995, p. 9). Wallingford, approximately 0.75 miles wide by 1.25 miles long, is just a few miles west of the University of Washington, and a few miles north of Upper Queen Anne Hill. The neighborhood also has a gridded street network with shopping districts along two different streets. Located on the eastern shore of Lake Washington, Downtown Kirkland is the largest study neighborhood, approximately 1.25 miles long in the north–south direction with an additional 0.5 miles of residential area extending along Lake Washington to the south. Shopping and commercial facilities in Downtown Kirkland are more dispersed than in the other two neighborhoods, but still having a slightly greater concentration along one street.

Travel data were collected from the study neighborhoods by the Washington State Transportation Commission Innovations Unit during November and December of 1992. Detailed information about the data collection process can be found in Zemotel et al. (1993). Briefly, travel data were collected by first, randomly sampling households using the 'reverse directory' approach, and then recruited by telephone. Two-day travel diaries with assigned dates were distributed to households willing to participate in the project. All participating travelers were instructed to report, for all trips, the addresses of trip origins and destinations, the mode used, departure and arrival times, trip purposes, and names and relationships of any trip companions. The completed diaries were mailed back to the researchers for data extraction. The final data set contains travel information for approximately 300 households in each neighborhood.

From Table 1, it can be seen that the demographic characteristics of residents in Queen Anne Hill and Wallingford, the two neighborhoods located within the City of Seattle, are generally similar. In contrast Kirkland, the neighborhood located outside the City of Seattle, had the lowest average number of employees per household, the most vehicles available per household, the highest median age of adults (15 years old and older), and the fewest housing units per acre (Zemotel et al. 1993).

4. Theoretical model

This section begins with a few definitions, primarily that of 'shopping tour', followed by discussions of destination prioritizing scheme and the related assumptions, which are necessary for model development. Finally, the theoretical structure of the proposed shopping model and the choice set generation for each level are presented.

Table 1. Basic demographic characteristics of the surveyed households.

	Queen Anne	Wallingford	Kirkland
Average household size	2.2	2.1	2.0
Average number of employees/household	1.4	1.3	1.0
Average number of vehicles/household	1.7	1.6	1.9
Median age persons in households age 15 and over	39	37	47
Median household income[a]	\$45,000	\$38,100	\$41,200
Gross density (housing units/acre)	7.6	7.2	3.1

[a] Estimated from an income range, not from exact incomes.
Source: Zemotel et al. (1993).

4.1. *Defining shopping tours*

For the purposes of this study, a 'trip' is defined as a single leg of travel from one location to the next with each end identifying an 'origin' and 'destination', respectively. A 'shopping trip' refers to a trip in which a traveler intends to shop at the destination. A 'tour' is a chain of trips (or a single trip) that starts and ends at home. A tour 'stop' refers to a trip destination within a tour, excluding the 'origin' and the 'end'. A 'shopping tour' is a tour in which at least one stop in the tour is for the purpose of shopping.

For our study, shopping tours were classified into three main categories: shopping-only tours (OSH), multi-purpose shopping tours (MSH), and work-related shopping tours (WSH). A shopping-only tour is a shopping tour in which all stops within the chain are for the shopping purpose. Shopping-only tours are further categorized into one-stop shopping-only tours (OSH_1) and two-or-more-stop shopping-only tours (OSH_2+). A multi-purpose shopping tour is a shopping tour in which at least one stop is for a purpose other than shopping but none of the stops are for the work purpose. A work-related shopping tour is a shopping tour in which at least one stop is for the work purpose.

4.2. *Assumptions on travel behavior and stop prioritizing schemes*

Like others (e.g. Shiftan 1998), our assumption is that each tour is motivated by a single primary trip purpose. Travelers are assumed to choose the location of the primary tour stop based on the primary trip purpose only. The remaining stops in a tour (if any) are assumed to be motivated by convenience and travel efficiency, and the locational choices are determined based on the proximity to the route between home and the primary stop of the tour. This study also assumes that the locational choices for these secondary stops have no influence on selecting the primary or 'higher-prioritized' stops.

Shiftan (1998) suggested that one or more of three schemes can be used for prioritizing the tour destinations. The first possibility is a hierarchy of purposes. Trip purposes are prioritized based on constraints, with the highest priority given to the purpose having the most severe restrictions and the lowest priority assigned to the one having the most flexibility. The second possible prioritization scheme assumes that the destination farthest (timewise) from the origin is the primary destination. The third scheme assumes that the destination at which travelers spend the longest time is the primary destination.

In this study, a combination of the purpose hierarchy and longest-stay schemes was utilized. The purpose hierarchy scheme is used to prioritize destinations for tours of mixed purposes (e.g. MSH and WSH). The longest-stay scheme is used to prioritize shopping destinations for the tours having more than one shopping stop (e.g. OSH_2+, and possibly, MSH and WSH).

In the purpose hierarchy scheme, shopping is assigned the lowest priority assuming this type of trip has the greatest flexibility. Besides the large number of available shopping sites within a region (i.e. no fixed destination), when compared to other activity purposes, shopping travel is usually subjected to only minor time restrictions (i.e. could be undertaken any time the store is open) and minor individual restrictions (i.e. could conceivably be allocated to other household members). Furthermore, travelers can easily defer most shopping travel to alternative days. In contrast, work and work-related travel must be undertaken to fixed destinations (e.g. the offices), at certain times (e.g. working hours), and by specific persons. This prioritization is also consistent with Shiftan (1998), who ranks a shopping purpose as the lowest priority among purposes: work, school, visiting friends, entertainment and shopping.

The longest-stay scheme was used to prioritize stops in tours that consist of more than one shopping stop. That is, among multiple shopping destinations within a tour, the destination with the longest stay duration is assumed to be the primary or higher priority destination of the tour.

5. Shopping model structure

Our model was structured based on the shopping tour model component of the Stockholm Model System (SMS) model (Algers et al. 1995). The SMS shopping model has a structure that captures the interactions among household members, and the land use effects on decisions across five dimensions of shopping travel in an integrated form. Each decision is conditioned by higher level choices, and is influenced by the choices at the lower level via the expected utility (i.e. the logsum). Bowman and Ben-Akiva (1997) noted that the SMS was probably the most advanced tour-based application of travel forecasting, and it has been utilized in several European cities. A few modifications were made to generalize the model for a greater variety of household structures, and to ensure the model captures the effects of both neighborhood and regional accessibility; nevertheless, the model largely retains the generic characteristics of the SMS model.

Figure 2 shows the proposed structure of our shopping model. The choice set for each of the five dimensions is described in Table 2. The decisions about how many shopping tours to undertake in a day are made in the top level of the structure. The decision unit at this level is household. Each household has five available alternatives, ranging from making no tours up to making four tours (a number empirically set by our data).

The model level 2 predicts the household member(s) who actually make the shopping tour, again with the household as the decision unit. The model simulates shopping travel behavior for households with up to two adult members and an unlimited number of children. Ten possible party alternatives are available (see Table 2), allowing households to assign shopping activity to either individuals or the groups of household members. As can be seen in Table 2, four of the ten alternatives represent parties of one adult of different sex and employment status combinations. The other three alternatives repre-

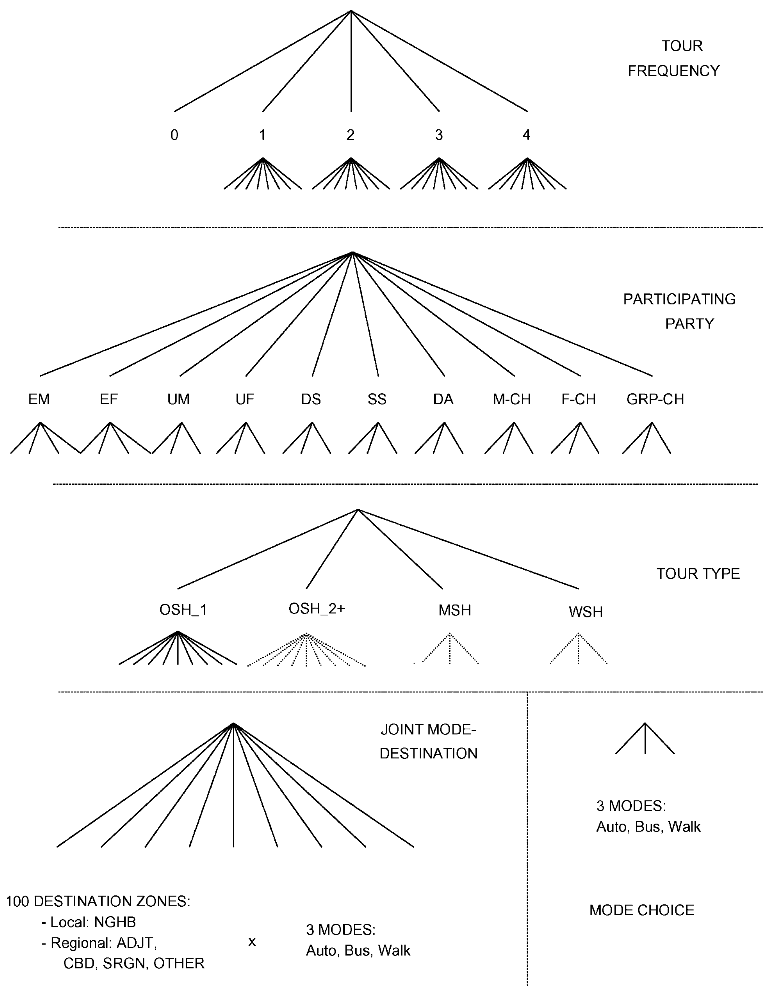

Figure 2. Modified SMS shopping model structure.

Table 2. Descriptions of the model choice sets.

Alternative	Description
Household tour frequency – number of shopping tours a household will generate in a day:	
0	Making no shopping tour
1	Making one shopping tour
2	Making two shopping tours
3	Making three shopping tours
4	Making four shopping tours
Party choice – party of household's members that actually make the shopping tour:	
EM	Group of one employed male
EF	Group of one employed female
UM	Group of one unemployed male
UF	Group of one unemployed female
DS	Group of two adults with different sexes and an age difference of less than 15 years, e.g. husband–wife, roommates, or siblings[1]
SS	Group of two adults with same sex and an age difference of less than 15 years, e.g. roommates, friends, or siblings[1]
DA	Group of two adults with different ages (an age difference of more than 15 years), e.g. a parent and his/her adult son/daughter, or siblings[1]
M–CH	Group of one adult male and children
F–CH	Group of one adult female and children
GRP–CH	Group of two adults (either DS, SS or DA) and children
Tour type choice – type of shopping tour that the group will make:	
OSH_1	One-stop shopping-only tour
OSH_2+	Two-or-more-stop shopping-only tour
MSH	Multi-purpose shopping tour
WSH	Work-related shopping tour
Mode choice – type of mode that the group will use:	
BUS	Bus
WALK	Walking
CAR	Passenger car
Destination choice – location choices for the primary shopping stop in the tour:	
NGHB	Zones within the residence neighborhood
ADJT	Zones adjacent to the residence neighborhood
SRGN	Zones with more than 2000 retail employees
CBD	Zones representing Downtown Seattle
OTHER	Other zones that potentially are shopping destination choices

[1] An age difference of 15 years is an arbitrary definition informed by prior research. The survey data we are using do not provide this information.

sent party formations among adult members, including the party of two adults with similar ages but of different sex (DS), two adults with similar ages and same sex (SS), and two adults with an age difference of more than 15 years (DA). The last three alternatives represent group formations among adult member(s) and children: a party of one adult male and children (M–CH), a party of one adult female and children (F–CH), and a party of two adults with any combination of sex or age (DS, SS, DA) and children (GRP–CH).

The choice set for a household depends mainly on the structure of the household. For example, a single-mom family in which the female adult is employed, has a total of two party alternatives: EF and F–CH, while a traditional family with two children will have a total of six party alternatives: EM, UF, DS, M–CH, F–CH and GRP–CH.

In the travel data, about 12% of all reported shopping tours were undertaken with persons who belong to another household. These tours were excluded from the model development process since the group formations with non-household members are outside the scope of this study.

The logsum at this level can be interpreted as the household accessibility to shopping over all possible choices of parties, tour types, modes and destinations (Algers et al. 1995). The logsum variable also acts as a proxy for the number of adult members in the household and if the household has children. That is because households with more adult members and children will have more available party choices, which in turn, results in a larger logsum value.

Decisions about the type of shopping tour to undertake are made in level 3. The decision unit here is traveling party, since a household has already assigned the shopping activity to a traveling party in the level above. The choice set comprises four shopping tour types: OSH_1, OSH_2+, MSH, and WSH. The work-related shopping tour alternative is allowed only for the parties of one employed person (i.e. EM and EF). The events that a group of two or more members (e.g. DS, SS, DA, F–CH, M–CH and GRP–CH) undertook a work-related shopping tour are rare; therefore, the corresponding alternatives were not included in the choice set.

In the lower levels, the choice decisions were modeled separately for different tour types. For OSH_1 and OSH_2+, the decisions of mode and primary destination choice are modeled conjointly; the decision unit is the traveling party assigned to a shopping activity. The logsum of the mode-destination model can be interpreted as the home-based accessibility for shopping over all possible choices of modes and destinations (Algers et al. 1995). Thus, the model structure allows us to investigate how home-based accessibility for shopping influences the choices of making OSH_1 and OSH_2+ shopping activities.

The destination choice set for a particular residential location comprises 100 zones. Zones were carefully designed such that the model can capture both the effects of intra-neighborhood location and regional settings on mode-destination decisions. The alternative zones were classified into five groups: neighborhood zones, adjacent zones, super regional zones, downtown Seattle zones and other potential zones.

Neighborhood zones are used to represent the proximity of the residential location to the neighborhood mixed-use core and to other shopping stores within the neighborhood. Each household location has a unique set of seven annular neighborhood zones. They are defined by a series of seven 0.2-mile network-distance rings, centered at a household of interest. For example, Figure 3 plots the seven neighborhood zones for household ID 1149 in Kirkland. Note that the definition of these neighborhood zones was limited to be within the neighborhood study area only and are not overlapped with the "adjacent zones".

Adjacent zones are those travel analysis zones (TAZs) defined by the Puget Sound Regional Council (PSRC) as adjacent to the neighborhood. Households residing in the same neighborhood will have the same set of adjacent zones, but will have a different set from households residing in another neighborhood. Super-regional zones were defined as those PSRC TAZs with retail employment greater than 2000 employees within the zone. There are nine super-regional zones located in the Puget Sound area and included in the choice set. Downtown Seattle zones are those zones representing downtown Seattle. Since the TAZs covering the downtown area are generally very small, they were aggregated into three larger zones for our analysis. Finally, "other potential" zones were defined as those travel analysis zones that were primary shopping destination choices in the travel data but not belonging to the four classes described above.

The mode choice set includes three alternatives, auto, bus, and walking. Biking and other transit modes, such as ferry, were excluded from the analysis since they were extremely rare in the travel data. Note that all 100 destination alternatives are available for auto travel. The bus mode is allowed for all zones, except for the adjacent zones due to the lack of the event in travel data. Walking applies to only the seven neighborhood zones and five adjacent zones in close proximity to the residence. This is because traveling to a distant zone by walking is unlikely to be a choice for most travelers. Bonnard (1987) noted that including improbable alternatives in the choice set can potentially cause biased parameter estimates.

For MSH and WSH, only the decisions of mode choice are modeled. Recall that according to our travel behavior assumptions, shopping destinations in the MSH and WSH tours are the secondary destination of the tours, and the locational choices are made based on the proximity to the route from home and the primary destination of the tour. To model shopping destination choices for these tour types would require substantial information regarding the

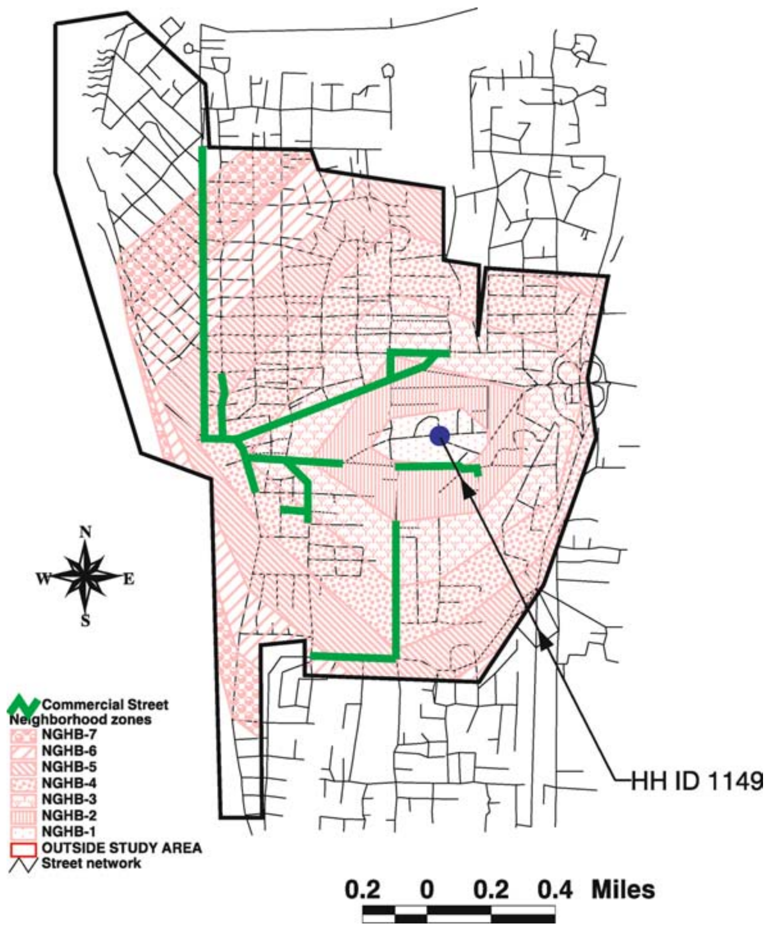

Figure 3. Neighborhood zones for HH ID 1149 in Kirkland.

primary destination of the tour, therefore, the secondary destination decisions were excluded from the model. The mode choice set includes the same three alternatives, auto, bus, and walking.

The explanatory variables investigated in the study can be categorized into five groups: level-of-service, zone attractions, characteristics of the participating party, household socio-demographics and days of week variables. Table 3 lists the explanatory variables (and their abbreviations) investigated for the shopping model specification.

The level of service variables, which represent the connections between residential locations and activity sites, were primarily used in the destination choice model. The travel time and travel cost variables were used to indicate the impedance of visiting destination choices for auto and bus travel, while the walking distance variables were used for walking travel. These variables were estimated using information contained in the PSRC regional travel demand model and the TIGER network file. (Detailed discussions of the scheme for estimating these variables are provided in Appendix 1).

Table 3. Definitions and abbreviations of the explanatory variables.

Abbreviation	Definition
Level of Service	
TTIME_WKD	Travel time for weekday tour (in minutes)
TTIME_WKE	Travel time for weekend tour (in minutes)
TCOST	Travel cost ($)
WDIST_WKD	Walking distance for weekday tour (in miles)
WDIST_WKE	Walking distance for weekend tour (in miles)
Characteristics of Destination Zones	
LOGRET	Number of retail employment in a logarithm form
NGHB_KL	1 if the destination choice is a neighborhood zone for Kirkland residents
Characteristics of the Participating Party	
GROUP2+	1 if the party is composed of two or more persons
GRP_CH	1 if the party is composed of at least one child
GRP_>65	1 if the party is composed of at least one person whose age is older than 65 years old
FEMALE	1 if the party is composed of one female
EMPLOY	1 if the party is composed of one employed adult
Household Socio-demographics	
HHSIZE	Number of members in household
HHINC	Household income (in $1,000)
VEH_AVAL	Number of vehicles available to household
NUM_CHLD	Number of children in household
HH_2EM	1 if the household has two employed male members
HH_2EF	1 if the household has two employed female members
HH_2UM	1 if the household has two unemployed male members
HH_2UF	1 if the household has two unemployed female members
Day of Week	
WKETOUR	1 if the tour is made on weekend
WEEKEND	1 if the day is weekend
FRIDAY	1 if the day is Friday
SATURDAY	1 if the day is Saturday
SUNDAY	1 if the day is Sunday

* Number of retail employment was extracted from the (incomplete sentence).

The measures of attraction were also primarily used in the destination choice models. These variables were estimated from the 1990 TAZ retail employment data supplied by PSRC. The data were applied directly for adjacent, downtown Seattle, super-regional and other regional zones. For neighborhood zones, the TAZ retail employment was allocated to each zone using information about the size[1] and location[2] of all stores in the study neighborhoods.

The characteristics of traveling party variables were tested in the tour type, the mode and the destination choice models, since the party is the decision unit for these three travel dimensions. Household socio-demographic variables were primarily used in the tour frequency, the participating party, the mode and the destination choice models. The day of week variables were investigated in all models of the entire structure. These three variable groups were extracted directly from the travel data.

6. Final model specification

The entire structure of our shopping model was estimated using the software package Limdep 7.0 for Windows. Due to the large number of alternatives at all five levels of the proposed model, limited-information (LI) maximum-likelihood techniques were employed to estimate the model. With this method, the coefficients of the model are estimated sequentially from the 'bottom up'. That is, the coefficients of the bottom level are first estimated conditionally on the higher level, then the coefficients of the higher level are estimated using the logsum variables from the lower level (Bhat 1998). The steps are repeated until the coefficients for all levels have been estimated. The LI approach yields consistent, but not asymptotically efficient estimates (Ben-Akiva & Lerman 1985).

Amemiya (1978) has demonstrated that using the LI approach yields an incorrect (too small) variance–covariance matrix of the coefficient estimates at the higher levels of the model structure (Ben-Akiva & Lerman 1985). This results in *t*-statistics that are too large, which in turn, increases the likelihood of falsely rejecting the null hypothesis. Amemiya (1978) and McFadden (1981) proposed methods to correct the estimated variance–covariance matrix, however, these approaches are not commonly used due to the computational burden of their implementation (Ben-Akiva & Lerman 1985, p. 289). One logical way to handle this is to use stricter confidence levels, for example, 0.02 instead of 0.05, for the models at higher levels. The present study imposed confidence levels of 0.050, 0.045, 0.040 and 0.035 for the mode-destination, the tour type choice, the participating party and the tour frequency substructures, respectively.

Initially, a nested structure was specified for the mode and destination choice models for shopping-only tours (both the nested structures of mode choice then destination choice and of destination choice then mode choice); however, these model structures yielded logsum parameters slightly greater than, and statistically insignificantly different from, one. Therefore, the final mode-destination choice model takes a joint logit form. Given the variety of shopping activities that are available within walking distance, it is believed that TN residents are not more likely to change mode than change destination, or vice versa. The joint mode-destination decisions for home-based shopping is highly plausible.

6.1. *Mode-destination joint model for shopping-only tours*

The mode-destination choice set for shopping-only tours contains 207 choices: 100 zones by auto, 95 zones by bus and 12 zones by walking. The study employed a simple sampling strategy to draw a random sample of 75 alternatives for each observation to estimate the model. The 75 alternatives include the chosen alternative plus other 74 alternatives randomly selected from the 206 non-chosen alternatives. Ben-Akiva and Lerman (1985) note that the resulting estimators, using the sampled alternatives, are consistent. Table 4 presents the variables entering the final model and their estimated parameters.

The first variable, the logarithm of the amount of retail employment within the zone, represents the zone's attraction. From Table 4, its parameter estimate has, as expected, a positive sign. That is, the probability of selecting a particular shopping destination increases as the amount of retail employment in the zone increases. A dummy variable representing Kirkland neighborhood zones was also introduced to the model due to our concerns about the resolution of the retail employment data. For instance, a large proportion of retail employment in Kirkland is for tourist shopping, rather than for household maintenance (Rutherford 2000). Thus, despite high retail employment, the Kirkland zones would probably not draw as many shopping activities directly from their residents. The dummy variable was found to be statistically significant to the model, and its coefficient estimate has a negative sign, which implies a weaker attraction power of Kirkland neighborhood shops, consistent with our concerns.

The parameters for travel time, travel cost and walking distance all have negative signs, implying that, all else equal, closer zones have a higher probability of being selected as a shopping destination. The result is intuitively reasonable and consistent with most previous studies (e.g. Ben-Akiva & Lerman 1985; Innes et al. 1990; Algers et al. 1995). The model also allows

Table 4. Specification of the mode-destination joint logit model for shopping-only tours.

Explanatory variable	Estimated coefficient	Standard error	*p*-value
Retail employment (in logarithm) – for all zones	0.68	0.04	0.000
Alternative specific dummy – neighborhood zones for Kirkland residents*	−1.43	0.20	0.000
Travel time for weekday travel – auto and bus travel to all applicable zones	−0.16	0.01	0.000
Travel time for weekend travel – auto and bus travel to all applicable zones	−0.14	0.01	0.000
Travel cost divided by household income – auto and bus travel to all applicable zones	−12.37	2.70	0.000
Walking distance for weekday travel – walk travel to all applicable zones	−5.06	0.50	0.000
Walking distance for weekend travel – walk travel to all applicable zones	−3.89	0.43	0.000
Alternative specific constant – auto travel to neighborhood zones	−1.64	0.18	0.000
Alternative specific constant – auto travel to adjacent zones	−3.25	0.23	0.000
Alternative specific constant – auto travel to downtown Seattle zones	−3.58	0.34	0.000
Alternative specific constant – auto travel to super regional zones	−2.96	0.25	0.000
Alternative specific constant – auto travel to other regional zones	−2.86	0.17	0.000
Alternative specific constant – bus travel to neighborhood zones	−2.89	0.47	0.000
Alternative specific constant – bus travel to downtown Seattle zones	−0.33	0.38	0.385
Alternative specific constant – bus travel to super regional zones	−0.68	0.47	0.148
Alternative specific constant – walk travel to adjacent zones	−1.41	0.40	0.000
Number of Observations		655	
Log-likelihood for the equally likelihood model		−2827.95	
Log-likelihood for the market share model		−2626.76	
Log-likelihood at convergence		−1729.80	
Likelihood ratio index versus Zero		0.388	
Likelihood ratio index versus market share		0.341	

* 1 if the destination choice is a neighborhood zone for Kirkland residents.

different parameters for travel time and walking distance distinguishing between weekdays and weekends. The log-likelihood ratio test confirmed the significant difference between weekday and weekend parameters at a 5% level of significance (or a *p*-value of 0.05). The sign and magnitude of the estimated parameters reveals that travelers are willing to go farther to shop on weekends, which is also intuitively plausible since travelers tend to have fewer time restrictions on weekends. The ratio of the estimated parameters showed that travelers are willing to spend 1.18 times that of weekday travel time for shopping on weekends, and are willing to walk 1.30 times that of weekday walking distance for walk travel to shopping on weekends. The remaining parameters are the alternative specific constants (ASCs) for different combinations of the mode-destination categories. These parameters represent the effect of all unmeasured attributes of each category.

A series of indicator variables were also analyzed to evaluate the significance of the party characteristics on mode-destination choice. For example, it would be interesting to examine whether or not a party that includes at least one retired person or a party that includes at least one child would influence the choice of auto for shopping travel. Neither of these indicator variables was found significant to the model. The finding suggests that travel with the elderly or children does not significantly increase or decrease the probability of choosing to drive for shopping-only tours among TN residents. It should be noted that, however, parties including at least one child represented and/or at least one retired person approximately 17% and 9% of all observations used to calibrate the model and thus, the finding should be considered suggestive rather than conclusive.

6.2. *Mode choice for MSH*

The final model specification for MSH is shown in Table 5. Among several socio-economic and traveling party variables investigated, only the number of vehicles available to the household was found significant in the model. The negative sign of the coefficient estimate, consistent with our *a priori* expectation, indicates that as the number of household vehicles increases, the less likely the traveling party is to ride a bus.

The ASCs represent the average effects from all unmeasured variables for the utility of choices, compared to the base alternative, which is walking here (i.e. the ASC for base alternative was designated to be zero). The ASC estimates reveal that with respect to the effects of all unobserved attributes, auto is the most preferred mode choice, while bus is the least preferred choice for multi-purpose shopping tours among the three available alternatives.

Table 5. Specification of the mode choice model for multi-purpose shopping tours.

Explanatory variable	Estimated coefficient	Standard error	*p*-value
Number of vehicles available to household – bus	−0.97	0.39	0.014
Alternative specific constant – car	2.22	0.14	0.000
Alternative specific constant – bus	−0.48	0.50	0.335
Number of observations		582	
Log-likelihood for the equally likelihood model		−639.39	
Log-likelihood for the market share model		−228.91	
Log-likelihood at convergence		−225.16	
Likelihood ratio index versus zero		0.648	
Likelihood ratio index versus market share		0.016	

6.3. *Mode choice for WSH*

Table 6 shows the final model specification for WSH. Again, only the number of vehicles available to the household was found to be significant in the model. Not unexpectedly, as this variable increases, the utility of choice of auto increases.

Similar to the mode choice for MSH, the ASC estimates reveal that with respect to the effects of all unobserved attributes, auto is the most preferred mode choice, while bus is the least preferred choice for multi-purpose shopping tours among all three available alternatives.

6.4. *Party and shopping tour type sub-structure*

The shopping tour type and the participating party models were estimated simultaneously, and their final specifications are shown in Tables 7 and 8,

Table 6. Specification of the mode choice model for work-related shopping tours.

Explanatory variable	Estimated coefficient	Standard error	*p*-value
Number of vehicles available to household – car	0.85	0.28	0.002
Alternative specific constant – car	0.22	0.48	0.647
Alternative specific constant – bus	−0.81	0.35	0.019
Number of Observations		178	
Log-likelihood for the equally likelihood model		−195.55	
Log-likelihood for the market share model		−114.58	
Log-likelihood at convergence		−108.61	
Likelihood ratio index versus zero		0.445	
Likelihood ratio index versus market share		0.052	

respectively. For the tour type model (Table 7), the estimated parameters of all explanatory variables have a logical sign. The first two variables represent indicators for the party of two or more persons making OSH_2+ and MSH shopping activities. The positive coefficient indicates an increasing probability of making these two shopping tour types in travel groups consisting of two or more persons. The finding suggests that when traveling with another adult and/ or with children the group is more likely to make additional shopping trips (OSH_2+) and more likely to combine shopping trips with trips of other purposes (MSH), than when traveling alone.

The next two variables represent indicators for the party of one female adult specific to OSH_2+ and MSH tour types, respectively. The coefficient signs suggest that the probability of making these tour types increase when the shopping party consists of one adult female. One possible explanation is that women generally bear more household maintenance activities than men (Turner & Niemeier 1997; Mauch & Taylor 1997; Van Beek et al. 1997), and would be more likely to potentially combine trips of different purposes into multi-stop tours (OSH_2+ or MSH), rather than making several one-stop tours.

Table 7. Specification of the tour type choice model.

Explanatory variable	Estimated coefficient	Standard error	p-value
Indicator for a party of two or more members – OSH_2+	1.27	0.29	0.000
Indicator for a party of two or more members – MSH	0.85	0.21	0.000
Indicator for a party of one female member – OSH_2+	0.72	0.27	0.008
Indicator for a party of one female member – MSH	0.53	0.16	0.001
Indicator for a party of one employed member – MSH	−0.52	0.16	0.002
Indicator for weekend travel – OSH_2+	0.58	0.21	0.005
Indicator for weekend travel – WSH	−2.01	0.26	0.000
LOGSUM (from the mode-destination joint choice) – OSH_1	0.31	0.12	0.000*
Alternative specific constant – OSH_2+	−0.88	0.55	0.109
Alternative specific constant – MSH	1.20	0.50	0.017
Alternative specific constant – WSH	1.73	0.52	0.001
Number of observations		1095	
Log-likelihood for the equally likelihood model		−1517.99	
Log-likelihood for the market share model		−1230.70	
Log-likelihood at convergence		−1148.62	
Likelihood ratio index versus zero		0.243	
Likelihood ratio index versus market share		0.067	

* Note that the p-value for the logsum variable is for testing H_0: $\beta = 1$.

Table 8. Specification of the party choice model.

Explanatory variable	Estimated coefficient	Standard error	p-value
Indicator for weekend travel – DS	0.49	0.24	0.039
Indicator for weekend travel – F–CH	−0.70	0.33	0.032
Indicator for households with two employed female members – EF	2.41	1.07	0.024
LOGSUM (from the tour type choice model) – all alternatives	0.66	0.45	0.448*
Alternative specific constant – EM	−0.23	0.21	0.269
Alternative specific constant – EF	−0.13	0.27	0.620
Alternative specific constant – UF	−0.23	0.21	0.276
Alternative specific constant – DS	−1.16	0.28	0.000
Alternative specific constant – SS	−0.74	0.50	0.137
Alternative specific constant – DA	−1.13	0.51	0.028
Alternative specific constant – M–CH	−2.24	0.45	0.000
Alternative specific constant – F–CH	−0.10	0.30	0.974
Alternative specific constant – GRP–CH	−1.22	0.37	0.001
Number of Observations		1095	
Log-likelihood for the equally likelihood model		−2521.33	
Log-likelihood for the market share model		−999.81	
Log-likelihood at convergence		−985.60	
Likelihood ratio index versus zero		0.609	
Likelihood ratio index versus market share		0.014	

* Note that the p-value for the logsum variable is for testing H_0: $\beta = 1$.

The indicator for the party of one employed person was found to affect choice of shopping tours by decreasing the utility of making MSH shopping activities. The finding suggests that the party of one employed member is less likely to make a multi-purpose shopping tour. Perhaps as a result of their time constraints, employed persons may tend to make shopping trips on their commute to/from work, which in turn, reduces the need for making multi-purpose shopping tours. Jou and Mahmassani (1997) analyzed activities on work commute tours of residents in Dallas and Austin, TX, and found that 3% of all morning commute tours and 19% of evening commute tours involved shopping activities.

Our model also indicates that day of week has an effect on the type of shopping tour taken. The indicator variables for weekend tours have a positive coefficient for making a OSH_2+ tour and a negative coefficient for making a WSH tour. This finding suggests that tripmakers are more likely to make OSH_2+ (multi-stop) shopping tours on the weekend than on a weekday. Yet the likelihood of making a WSH shopping tour was found to decrease on weekends. This is also sensible since there is a natural reduction in the number of WSH.

The logsum from the mode-destination joint model is significant to the utility of making OSH_1 tours. The coefficient estimate is positive and consistent with global utility maximization (less than one). However, the logsum was found insignificant in explaining the utility of making OSH_2+ activities, and with its negative coefficient was theoretically unsatisfactory. As a result, the mode-destination joint model was detached from the choice of making OSH_2+ tours. Recall that the logsum can be interpreted as home-based shopping accessibility. Therefore, the finding indicates that better home-based accessibility for shopping increases the probability of making OSH_1, but does not significantly increase the probability of making OSH_2+.

For the logsum variables of the mode choice models for MSH and WSH, it was found that both are insignificant in explaining the utility of making MSH and WSH, with a p-value of more than 0.50. It suggests that the decisions for mode choices and the decisions to undertake a MSH or a WSH are independent. With the extremely low likelihood, both of the models were also removed from the model structure.

The estimated ASC for the choice of OSH_2+ tour types was negative, while those for the choices of MSH and WSH shopping activities are positive. These ASCs were estimated using the choice of OSH_1 as a base alternative. The estimates suggest that with respect to all unobserved attributes, a traveling party is more likely to make a multi-purpose tour and a work-related tour and less likely to make multi stop shopping tours, than to make one-stop shopping tours.

Table 8 shows the final specification of the participating party model.[3] It is expected that household decisions about who shops may vary between weekday and weekend. To capture this effect, the study used a series of the weekend travel indicators to investigate the day of week difference across all party alternatives. In the final model specification, the weekend indicator was found to be significant in explaining the utilities of two alternatives: a party of two household adults with similar ages but DS, and a party of an F–CH. The indicator for DS has a positive sign, which suggests that the probability that two adults from a household with similar ages but of different sexes will make a shopping tour increases on the weekend. However, the estimated indicator for F–CH is negative, which indicates that the likelihood that an adult female with child(ren) will undertake a shopping activity on a weekend decreases compared to a weekday, regardless of the actual number of tours generated.

The next group of explanatory variables, the household structure indicator variables were tested for all four party alternatives of one adult, EM, EF, UM and UF. Our final model indicates that the indicator for households with two employed female members is statistically significant to the model, and has a positive coefficient as expected. That is, the likelihood that a group of one employed female engage in shopping increases in a household with two employed female. The other three household structure indicators were found insignificant to the model, possibly due to the undersampling of the households with two members of the same demographics. It was found that households with two employed male members, with two unemployed male members and with two unemployed female members, each represent less than one percent in the travel data. These three indicators are excluded from the final model.

The logsum coefficient estimate from the tour type choice model is positive and less than one. The coefficient's p-value (0.45), however, reveals that the nested structure of the participating party and the tour type choices model is not statistically significant better than the multinomial logit structure. Nevertheless, the researchers elected to keep the nested structure for conceptual reasons and since past studies found some evidence that the decision for who participates in a shopping activity is conditioned on the type of shopping activity to be undertaken (see Algers et al. 1995 for example).

The ASC estimates for each party alternative are also shown in Table 8. Recall that the variables reflect the average effects of all attributes unmeasured in the model. Among them, the ASC estimate for a party of one female adult and child(ren) has the highest value, while the ASC estimate for the party of one male and child(ren), on the other hand, has the lowest value.

6.5. *Tour frequency sub-structure*

The final specification of the shopping tour generation model is shown in Table 9. As before, it is expected that household decisions on the number of shopping tours undertaken would vary between weekday and weekend. From Table 9, the weekend indicator was found to be significant for making three tours in a day. The positive sign of the parameter estimate suggests that the utility of making three tours increases on weekends relative to weekdays.

The coefficient for the number of household vehicles available was found to be significant in explaining the utility of making two tours. This indicates that the more vehicles available to the households, the greater the probability of making two shopping tours per day. Past studies have also found that greater numbers of household vehicles increase the likelihood of making more shopping activities (e.g. Agyemang-Duah et al. 1996).

The logsum variable from the household allocation model was found significant to the model.[4] Its coefficient estimate is positive and significantly less than one, supporting the nested structure logic. As discussed earlier, the logsum variable here is a proxy for the number of adult members in the household and if the household has children. The positive sign of the coefficient implies that households with more adult members and with children have a higher likelihood of making one or more shopping tours in a day. This is consistent with past activity-based travel studies finding that "household structure,

Table 9. Specification of the tour frequency model.

Explanatory variable	Estimated coefficient	Standard error	p-value
Indicator for weekend – three tours	1.09	0.33	0.001
Number of vehicles available to household – two tours	0.24	0.09	0.004
LOGSUM (from the participating party choice model) – all alternatives, except 0 tour	0.36	0.09	0.000*
Alternative specific constant – one tour	−0.79	0.19	0.000
Alternative specific constant – two tour	−2.44	0.24	0.000
Alternative specific constant – three tours	−3.97	0.31	0.000
Alternative specific constant – four tours	−5.55	0.48	0.000
Number of observations		1420	
Log-likelihood for the equally likelihood model		−2285.40	
Log-likelihood for the market share model		−1564.20	
Log-likelihood at convergence		−1545.10	
Likelihood ratio index versus zero		0.324	
Likelihood ratio index versus market share		0.012	

* Note that the p-value for the logsum variable is for testing H_0: $\beta = 1$.

especially the presence of children, fundamentally influences household members' activity and travel patterns" (Kitamura 1988).

From Table 9, the ASC estimates for each alternative are plausible. That is, with respect to all unmeasured variables, there is increasingly less chance of making higher tour frequencies as the number of tours increase. Finally, we found a strong correlation between household income and the number of vehicles available to the households. To avoid multicollinearity problems, we decided to keep the number of vehicles available because it yielded better explanatory power. The logsum variable from the participating party model was also strongly correlated with variables of household size, the number of adult household members and the number of children household members; therefore all these socio-demographics were automatically excluded from the model.

6.6. *Elasticities*

Aggregate elasticities were also estimated for the tour type choice model, the party choice model and the shopping tour generation model as presented in Tables 10–12, respectively. These measures represent the overall elasticity of choice probabilities to uniform changes in independent variables for all applicable samples in the data set. The elasticity measures of the mode-destination joint logit model are not presented here due to the large number of the possible alternatives (207 mode-destination choice combination).

Table 10. Tour type elasticities.

Independent variables	Choice			
	OSH_1	OSH_2	MSH	WSH
Party of two or more persons	−0.163	0.146	0.045	−0.163
Weekend travel	0.005	0.253	0.005	−0.451
Party of one or more female member	−0.121	0.185	0.105	−0.121
Party of one or more employed members	0.063	0.063	−0.183	0.063

Table 10 indicates that the variable of a party of two or more persons appears to have the strongest (negative) effect on the choice of OSH_1. The weekend travel appears to have strongest influence in selecting OSH_2+, but the greatest negative effect in choosing work-based shopping tours. For the party choice model (see Table 11), the indicator variable of weekend travel appears to have a greater impact on choice of a tour party than the indictor variable for a household with two employed female members. In Table 12, weekend travel indicator variable suggests that weekend travel increases the probability of two shopping tours per day, while the number of available vehicles enhances the likelihood of three shopping tours per day.

Table 11. Party choice elasticities.

Independent variables	Choice									
	EM	EF	UM	UF	DS	SS	DA	M–CH	F–CH	GRP–CH
Weekend travel**	−0.080	−0.032	−0.080	−0.080	0.053	−0.080	−0.080	−0.080	−0.080	−0.080
HH: two employed females	*	0.013	*	*	*	0.013	0.013	*	−0.057	0.013

* These alternatives are not in the choice set for a household with two employed females.
** Given the limitations of the sequential estimation, the effects of weekend travel from the lower structure cannot be estimated.

Table 12. Tour generation elasticities.

Independent variables	Choice				
	No tour	1 tour	2 tours	3 tours	4 tours
Weekend travel	−0.055	−0.055	0.345	−0.055	−0.055
Number of vehicles available to household	−0.017	−0.017	−0.017	0.328	−0.017

7. Discussion and conclusion

This paper investigates the decisions made by residents living in neighborhoods across five dimensions of shopping travel: household tour frequency, participating party, shopping tour type, mode and destination choices. The unique challenge of this study was to develop a theoretically sound shopping model that could capture the effects of the influencing factors indicated in past literature, including residential location within the neighborhood, regional setting and household structure. Our shopping model structure was developed from the SMS shopping model (Algers et al. 1995). Modifications were made to extend the SMS shopping model to capture the effects of residential location within neighborhood (modification on the choice set in the destination-mode choice model) and to generalize the alternative choice set to be more applicable to a wider variety of household structures (modifications on the household allocation choice level). The model was calibrated using the travel data collected from the three sample neighborhoods located in the Puget Sound region, WA.

The LI maximum likelihood technique was used to estimate the model. The independent variables significant to the model include household socio-demographics, characteristics of the participating party, level of service variables, the destination zone attractions and day of week variables. The parameter estimates for all explanatory variables had logical signs.

The study found that household socio-demographics have significant effects on decisions of how many shopping tours to make and how and where to go (mode and destination), while the characteristics of those household members making the tour impacted the decision about tour type. The level of service and the zone attractions influence decisions about mode and destination. The day of week variable (weekday versus weekend) is statistically significant to all models, indicating that weekday shopping travel decisions are fundamentally different from weekend, across all five dimensions of interest. For example, the likelihood that a household decides to make three shopping tours in a day increases on weekends, while the likelihood that a traveling party elects to undertake a work-related shopping tour decreases on weekends.

The logsum from the mode-destination choice model, which can be interpreted as home-based accessibility for shopping, was found significant in explaining the utility of the choice of making a OSH_1, while not statistically significant to the utility of OSH_2+. The result suggests that the mode and destination choice decisions appear to associate with the decisions of engaging in a OSH_1, while seeming to be independent from the decisions of engaging in a OSH_2+. Future studies using travel data collected from other geographic regions are needed to confirm this finding.

There are some limitations to this study. The travel data used for the study were collected from residents who live in traditional neighborhoods only. Some researchers have argued that traditional neighborhood residents probably have different attitudes from suburban neighborhood (SN) residents (Kitamura et al. 1997), leading to different revealed travel behavior. Kitamura et al. (1997) found that traveler attitudes affect travel behaviors, and the effects are even stronger than those associated with location and socio-economics. Hence, the results of the analysis as well as information revealed from the estimated coefficients may hold only for those traditional neighborhood residents, and may not represent characteristics of the entire population as a whole. Using travel data collected from traditional neighborhood residents also potentially yields less precise coefficient estimates of specific variables (as opposed to using travel data from all market segments). An obvious example is that traditional neighborhood residents tend to have superior accessibility to local shopping stores.

With respect to the model estimation, due to the large number of alternatives, the study used LI maximum likelihood techniques to estimate the model coefficients through a partitioning scheme. This approach yields consistent, but not asymptotically efficient coefficient estimates (Ben-Akiva & Lerman 1985). Coefficient validation at the top three sub-models of the proposed model cannot be performed conclusively. Information revealed from these sub-models should be considered suggestive. The study also assume the travel data that were collected on two consecutive days (for each household) are completely independent from each other. This may lead to too-small estimated standard errors, and underestimation of the standard error from using the LI techniques.

Finally, shopping travel decisions are based on complex behaviors; they comprise several dimensions, and all are conceivably interrelated with one another. It is difficult, with present knowledge and technology, to incorporate all travel decision dimensions into a single model and estimate the model coefficients with high accuracy. The model used here considers only five dimensions of shopping travel behavior, excluding all other dimensions. Should another dimension be entered in the proposed model, the model might obtain different values of the coefficient estimates or even different model structures.

Appendix 1: Estimation of travel time and travel cost variables

The PSRC regional travel demand model yields information on travel distances between all pairs of TAZs. McCormack (1999) argued that the model TAZ-to-TAZ travel distance was estimated by considering the network characteristics (e.g. speed limits and level of congestion on each link) and limited by certain assumptions. In particular, these distances may not truly represent the actual distances for short trips. Therefore, the present study followed the methodology employed by McCormack (1999) to estimate our travel distances. Travel was categorized into two types: short trips and long trips. Short trips are defined as intra-neighborhood travel and travel to the adjacent TAZs; all other trips are considered long. For short trips, the network distance from the residential location to the destination zone centroids was used. All network distances were estimated from the TIGER network file on GIS. For long trips, the modeled TAZ-to-TAZ travel distances provided by PSRC were used.

Similarly, travel times were also estimated separately. The TAZ-to-TAZ off-peak travel times provided by PSRC were used directly for long trips. Travel time for short trips was derived from the network distance by regressing the PSRC travel time on the PSRC travel distance for all pairs of the study neighborhood TAZs and their adjacent TAZs. The coefficients of determination for the regression equations are 0.896 and 0.830, respectively. The equations are,

$$\text{Travel time for auto} = 0.523 + 2.646 * \textbf{distance}$$
$$\text{Travel time for bus} = 7.632 + 15.000 * \textbf{distance}$$

Auto travel costs were estimated by multiplying the travel distance with the operating and maintenance cost[5] plus the parking cost (if any) at the destination zones[6]. Bus travel costs were the product of bus fares[7] and the number of people in the travel parties (with a maximum of three persons).

Notes

1. The sizes of the neighborhood stores were extracted from the neighborhood parcel map and field verified during a site visit.
2. The locations of the neighborhood stores were provided by the Washington State Transportation Commission Innovations Unit in the form of an ArcView theme.
3. The model was estimated using the travel data of households consisting of no more than two adult members only.
4. The logsum was used as an explanatory variable for all tour generation alternatives, except generating no tour.
5. The operating and maintenance cost for auto ($0.15/mile) was estimated by PSRC (Niemeier 1994).
6. The average parking cost for each TAZ was provided by PSRC.
7. Bus fares were assumed to be off-peak adult fares. In 1992, one-zone and two-zone bus fares were $0.85 and $1.10 per person, respectively (personal communication with an administrator of Metro, the bus service in King County).

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