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Grocery Shopping How Individuals and Built Environments Influence Choice of Travel Mode

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Abstract

This research investigated the influences of socioeconomic characteristics of individual travelers and of the environments where the travelers live and shop on choice of travel mode for grocery shopping. The data on travel for grocery shopping came from 2,001 respondents to the 2009 Seattle Obesity Study survey in King County, Washington. Eighty-eight percent of the respondents drove to their grocery stores, whereas 12% used transit or taxis, walked, biked, or carpooled. The addresses of 1,994 homes and 1,901 primary grocery stores used by respondents were geographically coded. The characteristics of built environments in the neighborhoods around homes and grocery stores and the distances between those homes and stores were measured in a geographic information system. Four binary logistic models estimated the impact of individual socioeconomic characteristics, distance, and built environments around homes and grocery stores on the travel mode used for grocery shopping. Fourteen variables were significantly related to mode choice. The strongest predictors of driving to the grocery store were more cars per adult household member, more adults per household, living in a single-family house, longer distances between homes and grocery stores (both the stores used and the nearest stores), and more at-ground parking around the grocery store used. Higher street density, more quick-service restaurants around homes, and more nonchain grocery stores near the primary grocery store used were related to not driving. Results suggested that reductions of distances between homes and grocery stores, clustering of grocery stores and other food establishments, and reductions in the amount of the parking around them could lead to less driving for grocery shopping.

Nonwork travel has grown to constitute a substantial part of people's travel time and contributes significantly to the number of trips that people take. According to the 2009 National Household Travel Survey, travel for shopping accounts for 19.6% of all trips in the United States, a share that is almost as large as that of work trips (1). This work focused on travel for primary grocery shopping to understand how this routine activity fits into daily travel patterns. Ninety-nine percent of households shop at grocery stores at least once a week (2), and in 2005, U.S. households made an average of 2.1 trips to a supermarket each week (3). In 1997, groceries and other foods sold for off-premises consumption made up

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about 15% of all retail sales (4). Although shopping for groceries contributes to habitual travel, little is known about such travel, how it may vary on the basis of individual and household characteristics, and how the characteristics of environments where people live may affect mode choice.

LITERATURE REVIEW

A limited number of studies on travel for grocery shopping exist. Some research was available from the fields of marketing, transportation and planning, and public health. Marketing research tended to focus on grocery destination choice (5, 6) and travel frequency (7–9). Transportation and planning research focused on the influence of built environments on shopping travel mode choice (10–14). Public health research concentrated on the relationship between access to food accessibility and health (15, 16) or on how economically challenged people accessed food sources (17–19). Overall, the research lacked generalizability because of the small number of people and locations studied and limited information on travel to grocery stores. The following review discusses what is known about the influence of individual socioeconomic characteristics and the attributes of built environments on mode choice for travel related to general shopping.

Individual Socioeconomic Characteristics

Handy compared mode choice for general shopping between genders and between women from different household types (20). She found that income and the presence and the ages of children had more significant effects on mode choice than gender. Bhat found that unemployed individuals were less likely to drive alone for general shopping than employed individuals (11). Chen et al. found that car availability and public transport fare played major roles in determining shopping mode choice (21). Guo et al. found that household size, being a female, and age (older than age 65 years) were positively related to the number of auto-based maintenance trips (including grocery shopping) (22). Household income, the number of cars per person, having a job, and being physically challenged were negatively related to the number of nonmotorized maintenance trips.

Car ownership has been an important determinant of shoppers' travel mode. Handy argued that for convenience and time-saving reasons, people who owned a car would use it for shopping purposes (20). Focusing on the food shopping behavior of low-income families in Austin, Texas, Clifton found driving to be their principal travel mode (14). For some, however, walking and taking transit were still important to access food. In a recent study in South Australia, Coveney and O'Dwyer investigated the grocery shopping travel mode of 16 households without cars and found walking to be the most common mode for those families (23). Overall, the literature showed that gender, employment status, income, the presence and the ages of children in a household, and vehicle ownership greatly influenced people's travel mode choice for shopping.

Built Environment Characteristics

Handy and Clifton found that shoppers in six neighborhoods in Austin, Texas, generally minimized their travel time to convenience goods (including groceries) (13). Similar findings were reported in Europe. For example, Holz-Rau studied shopping mode choice for households with access to a motorized vehicle in Berlin (24). He found that car usage increased rapidly when the distance from home to the closest grocery store exceeded 325 m. When the distance was longer than 670 m, the car became the major transportation mode for grocery shopping (25).

Neighborhood-level employment, population density, and land use mix were generally correlated with people's mode choice for shopping trips. Frank and Pivo found that employment density, population density, and land use mix were negatively correlated with single-occupancy vehicle usage for shopping trips but were positively related to transit and walking for shopping trips (26). Steiner showed that a significant number of people walked to their neighborhood shopping areas (27). Cervero argued that the intensity and the mix of land uses were significantly related to people's mode choices (e.g., driving alone, sharing a ride, or taking transit) (28). Moudon et al. found residential density to be significantly correlated with walking for transportation purposes (29). McCormack et al. found that proximity to and mix of destinations were strongly associated with walking for transport, suggesting that increasing the diversity of destinations might contribute to more transport related walking (30). Scheiner and Holz-Rau summarized such phenomena from two perspectives: first, a high density or land use mix provided more destinations and more access opportunities for residents who lived nearby; second, areas with higher development density or land use mix tended to have a good transit system (31).

Road density and connectivity were also found to be related to shopping travel behavior. For example, Guo et al. found that bikeway density and network connectivity were positively related to the frequency of nonmotorized maintenance trips (22).

Overall, distance between activities, development density, land use mix, and street network connectivity affected people's home-based shopping trips. People who lived in a neighborhood with higher density and land use mix were more likely to make nonauto shopping trips and possibly to substitute some auto trips with walking and biking. However, most research has focused on general-purpose shopping. A better understanding of how the built environment is related to travel mode choice for grocery shopping will help with evaluation of the potential effectiveness of different transportation and urban planning policies that aim to reduce car dependence and overall vehicle emissions.

OBJECTIVE

This research examined the determinants of travel mode choice for primary grocery shopping. Two sets of factors were hypothesized to influence travel decisions: the socioeconomic characteristics of the individual traveler and the characteristics of the built environments around people's homes and grocery stores, including those of the routes between these places.

METHODS

Research Design

The research used individual-level data to examine the likelihood that people would drive rather than use other transportation modes to travel to their primary grocery store.

By use of individual respondents' demographic and socioeconomic characteristics as the basic and dominant influence on travel mode choice (11, 12, 20), the analyses tested three levels of characteristics of the built environment that could further affect mode choice. The first level was the distance between the respondent's home and the grocery store that he or she reported using (20) and the grocery store that was closest to the respondent's home. The second and third levels were the characteristics of the built environment around the respondent's home (32) and those around the primary grocery store that the respondent reported using (27, 33), respectively. Characteristics of the built environment were construed to fit into three domains: the neighborhood environment, the presence and density of nearby food and physical activity facilities, and the characteristics of the street network and its traffic conditions.

Data

Individual Travel and Socioeconomic Data—Data on travel for grocery shopping and the travelers' socioeconomic characteristics came from the 2009 Seattle, Washington, Obesity Study (SOS) telephone survey, which included 2,001 respondents sampled from 97 zip codes within King County, Washington. The 20-min survey had 89 questions on diet quality, food shopping habits and expenditures, physical activity, food insecurity, perception of neighborhood and access, transport to work and school, health and body weight, and demographics. The survey protocol and instrument underwent human subjects review by the University of Washington.

Built Environment and Traffic Data—Objective data on the built environment came from the King County Assessor. Data on employment, parking, and food and fitness establishments were developed by the Urban Form Laboratory (UFL). The original food establishment data were provided by the Department of Public Health of Seattle and King County. The original data for fitness facilities came from InfoUSA.

Traffic condition data came from the Puget Sound Regional Council, which included estimated annual average daily traffic counts on major arterials; from the Washington State Department of Transportation, which included the number of pedestrian collisions within King County from 2001 to 2004; from the King County Geographic Information System Center, which provided King County road networks and trails data; and from King County Metro, which provided the number of bus stops within King County and the related bus ridership at each stop per day.

Measurements

Geographic Coding—The UFL geographically coded the home addresses of 1,994 of 2,001 SOS respondents. Of those, 1,985 reported their primary grocery store addresses, and

1,910 of them were successfully geographically coded (Figure 1). The initial data set from the Department of Public Health of Seattle and King County included 10,254 food permit records that were geographically coded to the King County parcel data on the basis of their addresses. The automatic geographic coding process left 1,500 food permits unmatched (match score, ≤60), and so these were manually geographically coded. A total of 10,215 of 10,254 (99.6%) food permit addresses were geographically coded. The UFL classified the permits into food establishments, which separated supermarkets from nonchain grocery stores. A total of 972 physical activity and fitness facilities were also geographically coded and classified by the UFL on the basis of the North American Industry Classification System.

Dependent Variables—The dependent variable was the respondents' reported travel mode to the primary grocery store. Of the 1,910 SOS respondents with geographically coded primary grocery stores, 25 of them did not report income or car ownership. The final models included 1,885 SOS respondents. Of those respondents, 1,659 (88%) drove to their primary grocery store and 226 (12%) walked (7.2%), took public transit (2.7%), biked (0.1%), or used other modes (2%), including carpooling, ordering online, and so on. Respondents who reported using a travel mode other than driving were grouped into one category to increase statistical power (22, 34).

Independent Variables—Variables characterizing the respondents' demographics and socioeconomic characteristics included age, gender, education level, household income, household size, house type, number of years that the respondent had lived in the current residence, and the number of children and cars within the household (13, 14). Distance variables included network distance from home to the reported primary grocery store (13) and distance to the closest supermarket and nonchain grocery stores, which served to measure exposure and access to a food source in an objective manner (35, 36).

The neighborhood environment variables included residential and employment density, which have consistently been associated with mode choice (26, 37). Residential property value was included as an indicator of neighborhood wealth. Routine destinations, such as food stores and restaurants and physical activity and fitness facilities, were also considered. The latter were considered for possible trip chaining between shopping and recreation activities (38, 39). Transportation infrastructure was measured by the density of major streets, the density of minor streets and trails, the number of bus stops, and the number of at-ground parking stalls. Traffic condition variables included the estimated counts on major streets, the count of bus riders per bus stop, and the count of pedestrian–motor vehicle collisions (40).

Data Capture in Geographic Information System—Network distances between homes and the primary stores used were measured, as were those distances between home and the supermarket and the nonchain grocery store closest to the respondent's home. The ArcGIS network analyst program was used to measure the shortest time distance needed to travel between places on the basis of data from the StreetMap Premium North America NAVTEQ 2009 (Release 1) database of Environmental Systems Research Institute, Inc. The program considered, for example, one-way streets, speed limits, over- and underpasses, and transit-only lanes. Count and density measures of built environment variables around each respondent's home and around the primary grocery store used were averaged within a 0.5-mi (833 m) airline buffer [a round buffer defined by the half-mile (833-m) airline distance (as the crow flies), also known as Euclidean distance]. The size of the buffer corresponded to a 10-min walking distance, a catchment area used in other research (only two respondents reported biking to the grocery store) (22, 32, 33). Table 1 lists the built environment variables considered in this study.

ANALYSIS

Selection of Variables

Correlation analyses served to test the relationship between the independent variables selected in each of the five variable categories: neighborhood environment, food facilities, physical activity and fitness facilities, transportation infrastructure, and traffic conditions. If two variables were highly correlated with each other, only the variable with theoretical importance proved in previous research was kept. Bivariate analyses examined the relationship between the uncorrelated independent variables and the dependent variables (travel mode to primary grocery store). Statistical *t*-tests were used for continuous variables, and chi-square tests were used for categorical variables. Only variables that were significantly related to a respondent's travel mode to the primary grocery store were included in the final models.

Model Structure and Construction

Four binary logistic regression models were built. The modeling process borrowed from the traditional forward variable selection process, in which variables were sequentially added level by level and the significant variables identified in the previous models were controlled for. Model 1, the base model, included the socioeconomic characteristics of the respondents; Model 2, the distance model, added distance measures to the base model; Model 3 added the characteristics of the home neighborhood to the previous model; and Model 4 added the characteristics of the primary store neighborhood to the previous model. In Models 2 to 4, variables were added one at a time.

The goodness of fit of final models was tested by use of the Akaike information criterion and likelihood-ratio test. The Akaike criterion reflects the information loss when a proposed model is used to describe the reality and helps provide an understanding of the validity of the proposed models (41). The likelihood-ratio test compares the model fit between nested models.

RESULTS

Descriptive Analysis

Of the 1,885 SOS survey respondents included in the analysis, 62% were female and 38% male. The average age of the sample was 54.53 years. The average household income class ranged from $50,000 to $75,000. The average household size was 2.31, and the average number of children 0 to 12 years old within each household was 0.32. On average, 80.8% of the sample had at least 1 to 3 years of college education; they had lived in the current residence for 16.19 years and owned 1.75 cars per household. Seventy-seven percent of the respondents lived in a single-family house. The sample population was similar to that of King County (42), although it was older, more likely to be female, and living in a single-family house (Table 2).

The average network distance from home to the primary grocery store used was 3.12 mi (median, 2.04 mi). The network distances from home to the closest supermarket and nonchain grocery store were 1.22 mi (median, 1.02 mi) and 1.38 mi (median, 0.87 mi), respectively. The residential and employment density around home were 4.61 units per acre (median, 3.26 units per acre) and 11.84 jobs per acre (median, 1.86 jobs per acre), respectively. On average, there were 11 quick-service restaurants (median, three) within the 0.5-mi airline buffer around the respondent home, and the average street length was 19.07 mi (median, 19.14 mi). Table 3, Column D, summarizes the variables for the built environment around the respondent's home and primary grocery store used.

Bivariate Analysis

Bivariate analyses showed that drivers were, on average, 6 months younger than nondrivers. Drivers had a higher household income and were more likely to be female. Drivers tended to have a larger household with more children and cars. Drivers were more likely to be employed, to own and live in a single-family house, and to have lived longer in their current residence than the nondrivers. No significant differences in education level, marital status, and being Hispanic or white were detected between these two groups. Bivariate analyses also showed that distances between home and the primary grocery store used, the closest supermarket, and the closest nonchain grocery store were significantly shorter for nondrivers than for drivers.

Drivers and nondrivers lived in two different built environments at home. All the variables for the built environment in Table 1 were significantly different between these two groups, except for the number of swimming and skating facilities within the home neighborhood. Residential density, employment density, and average home value around nondrivers' homes were 9.93 units per acre, 49.64 jobs per acre, and $215,000 per unit, respectively, in contrast to the 3.85 units per acre, 6.38 jobs per acre, and $266,000 per unit, respectively, for drivers. Nondrivers had more food retail places, physical activity and fitness facilities, bus stops, and traffic signals within their neighborhoods. On average, nondrivers had 69 bus stops, 27,960 bus riders per day, and 6,338 at-ground parking stalls within the 0.5-mi buffer around their home locations; by contrast, the values for drivers were 26 bus stops, 3,574 bus riders per day, and 3,465 at-ground parking stalls.

For environments around primary grocery stores, no significant differences in the numbers of supermarkets and golf and tennis, leisure sports, sports club, swim and skating facilities existed between the two groups. The difference in the average daily traffic volume on major streets within the 0.5-mi buffer was also not significant. All other built environment variables in Table 1 were significantly different. Residential density, employment density, and average home value around a nondriver's primary grocery store were 10.77 units per acre, 32.59 jobs per acre, and $237,000 per unit, respectively; in contrast, the values were

4.45 units per acre, 8.10 jobs per acre, and $223,000 per unit, respectively, for drivers. The neighborhoods around nondrivers' grocery stores contained more food places and fitness facilities, more bus stops, and higher street density. For nondrivers, the average number of bus stops, bus riders, and parking stalls around their primary grocery stores were 65.5, 22,057, and 6,624, respectively, in contrast to 35.26, 4,458, and 8,000, respectively, for drivers.

Table 3, Column G, summarizes the one-by-one test results for the different independent variables. Seven variables defining the respondents' socioeconomic characteristics remained in the base model. The other variables (age, employment status, and home ownership), which were significant in the bivariate test, were added one at a time to the base model, but none of them remained significant. For the distance variables, the one-by-one test showed that the network distances from home to the primary grocery store, to the closest supermarket, and to the closest nonchain grocery store were significantly different.

Employment density, the number of quick-service restaurants, the presence of a liquor store or tavern, and street density within the 0.5-mi airline buffer around home remained significant in the one-by-one test. Other variables such as residential density and the number of parking stalls in the home neighborhood became not significant.

For the neighborhood around the grocery store, employment density, five food establishment variables, the presence of an indoor fitness facility, the numbers of traffic signals and at-ground parking stalls, bus ridership, and the number of pedestrian or bike collisions remained significant in the test. These variables were included in Model 4.

Model Results

Model results are summarized in Table 4. Each model included 1,885 respondents: 1,659 (88%) of them drove to their primary grocery stores, and 226 (12%) used other transportation modes.

Model 1. Base Model—For Model 1, the −2 log likelihood was 878.749 and the Nagelkerke pseudo-$R2$ value was .453. The result showed that the number of adults, the number of children 0 to 12 years old, the number of cars per household adult, and the household living in a single-family house were positively related to the likelihood of driving. The respondent's gender, the average household income per adult member, and the number of years living in the current residence were not significant. Among all the socioeconomic variables, the number of cars per household adult, living in a single-family house, and the number of adults in the household were the top predictors for driving, with odds ratios (ORs) of 17.899, 2.808, and 2.174, respectively. Thus, when all the other variables are controlled for, adults living in households owning one more car per adult household member or having one more adult member had odds of 17.899 and 2.174, respectively, of being more likely to drive to their primary grocery store. Compared with the respondents living in multifamily houses, respondents living in single-family houses were almost two times more likely to drive to their grocery store.

Model 2. Distance Model—For Model 2, the −2 log likelihood was 759.023 and the pseudo-$R2$ value was .530. The results showed that all four variables in the base model remained significant. All three distance variables were also significant in the model. The distance to the primary grocery store used was the weakest predictor for driving [OR, 1.290; confidence interval (CI), 1.154 to 1.441], in contrast to the distance to the closest supermarket (OR, 2.073; CI, 1.487 to 2.891) and the distance to the closest nonchain grocery store (OR, 1.718, CI, 1.286 to 2.297). Thus, for a 1-mi increase from home to these destinations, the odds of driving would increase by factors of 1.290, 2.073, and 1.718, respectively.

Model 3. Home Neighborhood Model—Model 3 added four home neighborhood environment variables to Model 2. The −2 log likelihood value was 728.560, and the pseudo-$R2$ value was .555.

In this model, all base model variables retained significance. Income per household adult member was marginally significant. Time spent at the current residence and the respondent's gender were not significant. Network distance from home to the primary grocery store (OR, 1.292; CI, 1.154 to 1.447) and distance from home to the closest supermarket (OR, 1.525; CI, 1.066 to 2.181) remained significant, but the network distance from home to the closest nonchain grocery store was not significant.

Employment density within the 0.5-mi buffer around the home location had a weak but positive impact on driving, with an OR of 1.033. Other significant home neighborhood variables included the number of quick-service restaurants within the 0.5-mi buffer and street density (the total length of road networks with a maximum speed limit of 45 mph). The model showed that if one more quick-service store were added to the respondent's neighborhood, the probability of driving to the primary grocery store would decrease by a factor of 0.959. Similarly, for a 1-mi increase in the road network within the 0.5-mi buffer around home, the likelihood of driving would be reduced by a factor of 0.918. Having a liquor store or tavern in the neighborhood was not significant.

Model 4. Primary Grocery Store

Neighborhood Model: Model 4 added 10 variables defining the neighborhood around the primary store used. The −2 log likelihood was 689.683, and the pseudo-$R2$ value was .583. The results showed that income per adult household member regained significance compared with the significance in Models 1 to 3 and the number of children within the household 0 to 12 years old became marginally significant. The number of adults within the household and the number of cars per household adult retained significance, with the number of cars per household adult remaining the strongest predictor (OR, 13.300; CI, 7.906 to 22.372) for driving. Significant network distance variables remained the same as in Model 3, as did the variables defining the neighborhood around homes. Employment density, the number of quick-service restaurant, and road density were positively, negatively, and negatively related to driving, respectively.

Of the 10 grocery store neighborhood environment variables, only two attained significance: the number of at-ground parking stalls around the primary grocery store (OR, 1.590; CI, 1.139 to 2.220) and whether a nonchain grocery store was near the primary grocery store (OR, 0.525; CI, 0.302 to 0.912).

The likelihood ratio tests showed that Model 4 was significantly better than all the previous models (Models 1 to 3) at the .0001 level. Akaike information criterion values for Models 1 to 4 were 892.749, 779.023, 756,560, and 739.683, respectively, also indicating that Model 4 fit the data the best.

DISCUSSION OF RESULTS

Model results were robust and consistent, showing that the likelihood of driving to the primary grocery store was determined primarily by individual socioeconomic characteristics, the environment around home, and the distance to the primary store used and to the closest supermarket. The environments around the grocery store had a modest influence on mode choice.

The number of cars per household adult, whether or not a person lived in a single-family house, and the number of adults within a household were significant in all models. The number of cars per adult household member was a consistently dominant predictor for driving. In Model 4, after all the other variables were controlled for, for each car added in a household, the odds of driving to the primary grocery store would increase by a factor of 13.300. This increase reflected similar findings in the literature (14, 20, 23). Model 4 also showed that when all other variables are controlled for, a respondent living in a single-family house would be two times more likely to drive to grocery stores than his or her counterpart who lived in a multifamily house. Furthermore, if the household had one more adult member, the odds of driving would increase by a factor of 2.097. Finally, income per adult was positively associated with driving to the grocery store. Further tests showed that income per adult was marginally correlated with car ownership.

The number of children within a household 0 to 12 years old was positively related to the likelihood of driving. That number of children was significant in Models 1 to 3 but only marginally so in Model 4. Similar findings about the influence of children on general shopping mode choice, together with the finding that individuals living in households with more adults were more likely to drive to their grocery store, were reported previously (20). This finding suggested that larger families might make larger grocery purchases that required a car (43). Model 4 showed that income per adult household member was weakly but positively related to the respondent’s probability of driving. Income was marginally significant in Model 3. Gender and the length of time living at the current residence were not significant in any of the models.

Network distances from home to the primary grocery store and from home to the closest supermarket were significant in Models 2 to 4, indicating that the longer that the distance between home and stores was, the more likely respondents were to drive to their primary store. In Model 4, for a 1-mi increase between home and the primary grocery store and between home and the closest supermarket, the probability of driving would increase by factors of 1.236 and 1.482, respectively. This increase suggested that to reduce people’s car dependence or promote local shopping (13), grocery stores should be located close to people's homes (29, 30). This proximity would be especially important for the population suffering from mobility constraints. Research in Atlanta, Georgia, found that small grocery stores tended to locate close to low-income neighborhoods, where they are most needed (43).

Three home neighborhood built environment variables were significant in Models 3 and 4. Employment density in the home neighborhood was positively but weakly related to driving (OR, 1.029), and the number of quick-service restaurants and street density were negatively related to the probability of driving (ORs, 0.970 and 0.915, respectively). Both of these variables were likely related to the respondents living in a more urban neighborhood (with more services and a denser street network) or a more suburban neighborhood (with fewer services and a less dense street network). This finding suggested that individuals in neighborhoods with destinations within short distances might have an increased probability of using nonmotorized travel modes for grocery shopping (33, 44).

For the built environment around the respondents' primary grocery store, the number of at-ground parking stalls within the 0.5-mi buffer around the store was the strongest predictor for driving (OR, 1.590). A higher street density (known to support nonmotorized travel modes) in the grocery store neighborhood was negatively related to driving. These two results confirmed that a car-dominated environment near stores is not likely to support alternative modes of travel. Limiting parking space around grocery stores might also encourage medium-sized grocery stores to locate in neighborhoods and thereby increase food accessibility in local communities (17, 18, 23, 35). Whether the primary grocery store was near a nonchain grocery store was also significant in the model (OR, 0.525). This finding suggested that groups of food stores would support nonmotorized travel, as shown in previous studies (30, 33).

As noted, model estimation was constrained by the highly skewed data set because the majority of respondents used the driving mode. A separate model including only nonmotorized shoppers might be needed in future research. Furthermore, the study's generalizability is limited because of the age and gender differences between the sample and the general population.

CONCLUSION

The number of cars per adult, living in a single-family house, and the number of adults in the household were the three strongest predictors of choosing to drive a car for grocery shopping. Distance variables were also highly correlated with people's travel mode choice. Network distances from home to the primary grocery store and to the closest supermarket were positively correlated with the likelihood of driving.

As for the influence of the built environment, employment density in the home neighborhood and parking availability around the primary grocery store were positively related to driving. The number of quick-service restaurants and the street density around home, as well as having another grocery store near the primary grocery, were negatively related to driving.

For the population with limited access to cars, living in a neighborhood with more grocery stores and less parking near grocery store locations will reduce their dependence on cars for grocery shopping.

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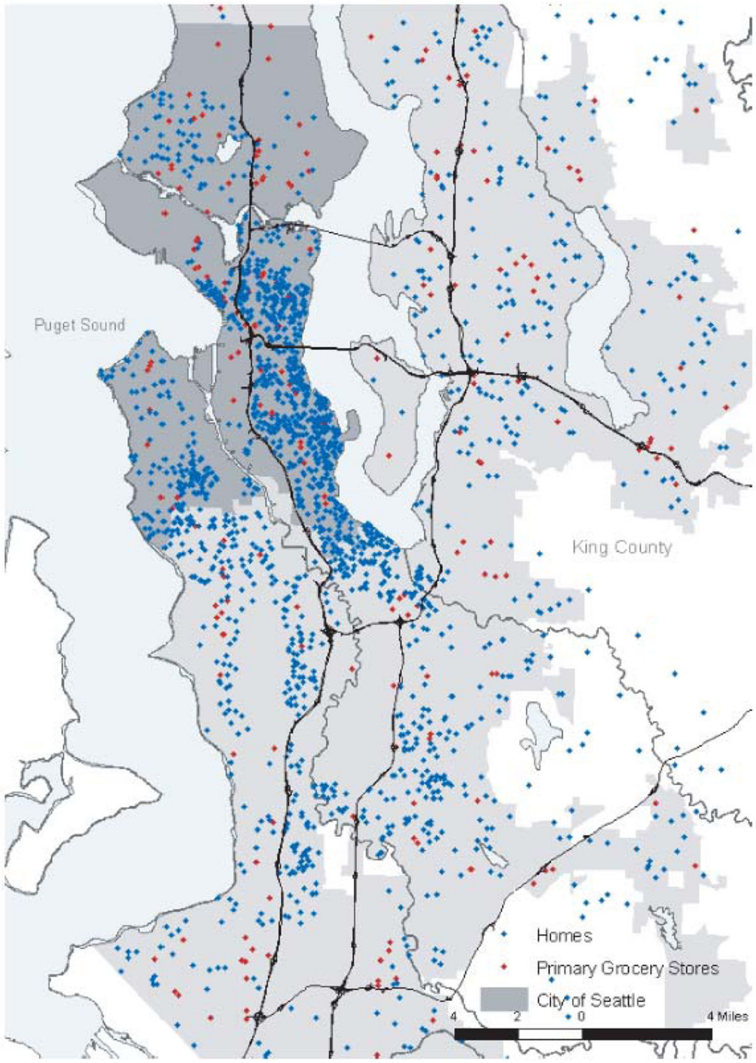

FIGURE 1.
Distribution of SOS respondents' homes and primary grocery stores

TABLE 1

Built Environment Variables Around Respondents' Home and Primary Grocery Store Used

Category	Variables	Measures (all measures taken within a 0.5-mi airline buffer)
Neighborhood environment	Net residential density	Number of units per acre
	Net employment density	Number of jobs per acre
	Residential property value	Assessed property value per residential unit
Food facilities	Supermarket	Count of places
	Grocery	
	Ethnic food store	
	Convenience store	
	Food/drugstore combo	
	Meat/fish	
	Produce	
	Traditional restaurant	
	Ethnic dining	
	Fast food	
	Quick service	
	Coffee shop	
	Liquor stores and taverns or pubs	
Physical activity and fitness facilities	Community center	Count of places
	Golf, tennis	
	Indoor fitness	
	Leisure sports	
	Outdoor sports	
	Swimming, skating	
	Sports clubs	
	Public facility	
	Private facility	
Transportation infrastructure	Major street density	Total centerline of freeway and arterials in miles
	Other street density	Total centerline of streets with speed limit ≤45 mph in miles
	Trail density	Total length of trails in miles
	Bus stop 2008	Count of bus stops
	Parking	Count of on-ground parking stalls
Traffic conditions	Traffic volumes	Average estimated AADT on major streets
	Bus ridership 2007	Counts of bus riders per bus stop
	Pedestrian collisions 2001–2004	Count of collisions

Note: AADT = annual average daily traffic.

TABLE 2

Socioeconomic Characteristics of Sample, Driver, and Nondriver Groups with King County's Population

Variable	All Sample	Driver	Nondriver	King County[a]
Age (years)	54.53	54.45	55.06	46.90[b]
Household income (thousands)	50–75	50–75	25–35	70[c]
Household size	2.31	2.41	1.57	2.37
Gender (male) (%)	38	37	45	50[d]
No. of children 0–12 years old	0.32	0.34	0.11	0.39[e]
No. of cars	1.75	1.89	0.69	1.67
Education (1–3 years of college education) (%)	80.8	81.4	77.1	73.5
Time (years) at current residence	16.19	16.78	11.86	12.85
Living in single-family house or not (%)	77	82	35	62

[a]Data in this column are from the Bureau of the Census (42).

[b]Average age of population.

[c]Median household income.

[d]Population >18 years of age.

[e]Children 0–14 years of age.

TABLE 3

Important Independent Variables, Selection Process, and Descriptive Statistics

Domain (A)	Variables (B)	Measures (C)	Descriptive Statistics (D)	Selection Criterion (E)	Treated in the Models (F)	One-by-One Testing (G)
Individual and socioeconomic characteristics	Gender	Male/female	Male: 763, female: 1,235	Theory	Cat.	Base M
	Income per house-hold adult	Income categories	Min.: 0.2, max.:9, mean: 4.30, median: 4, SD: 1.81	Theory	Cont.	Base M
	Number of adults	Counts	Min.: 1, max.:9, mean: 1.78, median: 2, SD: 0.78	Theory	Cont.	Base M
	Number of 0–12 years old children	Counts	Min.: 0, max.:13, mean: 0.32, median: 0, SD: 0.79	Theory	Cont.	Base M
	Number of cars per household adult	Counts	Min.: 0, max.:4, mean: 1.01, median: 1, SD: 0.54	Theory	Cont.	Base M
	Time at current residence	Years	Min.: 1, max.:69, mean: 16.19, median: 12, SD: 13.46	Theory	Cont.	Base M
	Living in single-family house or not	Single/multifamily house	Single-family house: 1,459, multi-family house: 443	Theory	Cat.	Base M
Distance	Distance from home to primary grocery store	Net distance in miles	Min.: 0.02, max.:59.20, mean: 3.12, median: 2.04, SD: 4.40	Bivariate	Cont.	+
	Distance from home to closest super-market	Net distance in miles	Min.: 0.05, max.:8.56, mean: 1.22, median: 1.02, SD: 0.89	Bivariate	Cont.	+
	Distance from home to closets non-chain grocery store	Net distance in miles	Min.: 0.00, max.:10.45, mean: 1.38, median: 0.87, SD: 1.39	Bivariate	Cont.	+
Home built environment	Residential density	Number of residential units	Min.: 0, max.:28.84, mean: 4.61 median: 3.26, SD: 4.41	Bivariate	Cont.	
	Employment density	Number of jobs	Min.: 0, max.:273.67, mean: 11.84, median: 1.86, SD: 38.58	Bivariate	Cont.	+
	Quick service	Count of places	Min.: 0, max.:199, mean: 11.12 median: 3, SD: 28.83	Bivariate	Cont.	−
	Has liquor stores, taverns, pubs or not	Count of places	Has: 1,014, does not have: 978	Bivariate	Cat.	−
	Street density	Total length (mi) of streets with speed limit ≤45 mph	Min.: 3.31, max.:35.83, mean: 19.07 median: 19.14, SD: 5.46	Bivariate	Cont.	−
	Parking	Count of at-ground parking stalls (log transformed)	Original value (min.: 0, max.: 22,076, mean: 3,816, median: 2,769, SD: 3,581) log value (min.: 0, max.: 10, mean: 8.25, median: 7.93, SD: 8.18)	Bivariate	Cont.	

Domain (A)	Variables (B)	Measures (C)	Descriptive Statistics (D)	Selection Criterion (E)	Treated in the Models (F)	One-by-One Testing (G)
Primary store built environment	Residential density	Number of residential units	Min.: 0, max.: 26.51, mean: 5.20 median: 3.89, SD: 5.18	Bivariate	Cont.	
	Employment density	Number of jobs	Min.: 0, max.: 253, mean: 11.01, median: 4.65, SD: 24.65	Bivariate	Cont.	−
	Has nonchain grocery store	Count of places	Having: 1,055, not having: 843	Bivariate	Cat.	−
	Coffee shop	Count of places	Min.: 0, max.: 93, mean: 6.57 median: 3, SD: 10.22	Bivariate	Cont	−
	Quick service	Count of places	Min.: 0, max.: 199, mean: 14.37 median: 9, SD: 19.70	Bivariate	Cont.	−
	Traditional restaurant	Count of places	Min.: 0, max.: 119, mean: 6.4 median: 3, SD: 12.08	Bivariate	Cont.	−
	Liquor stores, taverns, pubs	Count of places	Min.: 0, max.: 46, mean: 4.74 median: 2, SD: 7.79	Bivariate	Cont.	−
	Has an indoor fitness facility	Count of places	Has: 1,392, does not have: 506	Bivariate	Cat.	−
	Traffic signal	Count of signals	Min.: 0, max.: 133, mean: 12.69 median: 8, SD: 16.41	Bivariate	Cont.	−
	Parking	Count of at-ground parking stalls (log transformed)	Original value (min.: 414, max.: 21,727, mean: 7,838 median: 6,382. SD: 4,844) Log value (min.: 6.02, max.: 9.99, mean: 8.97, median: 8.76, SD: 8.49)	Bivariate	Cont.	+
	Bus ridership. 2007	Counts of thousand riders per bus stop	Min.:0, max.: 161, mean: 6.31 median: 2.07, SD: 15.064	Bivariate	Cont.	−
	Pedestrian collisions, 2001–2004	Count of collisions	Min.: 0, max.: 404, mean: 36.55, median: 22.68, SD: 55.08	Bivariate	Cont.	−

Note: Base M = base model: − and +. negative and positive significance ($p < .05$) of test results, respectively; cat. = category variable; cant. = continuous variable; min. = minimum; max. = maximum; SD = standard deviation.

TABLE 4

Final Results for Models 1 to 4

			95% CI exp(B)				95% CI exp(B)				95% CI exp(B)				95% CI exp(B)	
Variable	**Sign**	**OR**	**Lower**	**Upper**	**Sign**	**OR**	**Lower**	**Upper**	**Sign**	**OR**	**Lower**	**Upper**	**Sign**	**OR**	**Lower**	**Upper**
Individual and Socioeconomic Characteristics																
1 Gender (male)	0.067	0.715	0.499	1.024	0.078	0.707	0.480	1.040	0.223	0.781	0.525	1.162	0.123	0.722	0.477	1.092
2 Income per adult	0.578	1.023	0.943	1.110	0.117	1.071	0.983	1.167	0.052	1.092	0.999	1.194	**0.022**	**1.113**	**1.015**	**1.220**
3 Number of adults	**0.000**	**2.174**	**1.564**	**3.020**	**0.000**	**2.084**	**1.465**	**2.965**	**0.000**	**1.975**	**1.382**	**2.823**	**0.000**	**2.097**	**1.445**	**3.043**
4 Number of children 0–12 years old	**0.035**	**1.519**	**1.030**	**2.241**	**0.025**	**1.606**	**1.061**	**2.431**	**0.029**	**1.580**	**1.047**	**2.385**	0.053	1.491	0.995	2.235
5 Number of cars per adult	**0.000**	**17.899**	**11.525**	**27.796**	**0.000**	**15.190**	**9.285**	**24.853**	**0.000**	**13.100**	**7.934**	**21.629**	**0.000**	**13.300**	**7.906**	**22.372**
6 Time at current residence	0.079	1.014	0.998	1.031	0.118	1.014	0.997	1.031	0.261	1.010	0.993	1.027	0.492	1.006	0.989	1.024
7 Live in single-family house	**0.000**	**2.808**	**1.860**	**4.239**	**0.000**	**2.324**	**1.499**	**3.602**	**0.014**	**1.861**	**1.135**	**3.050**	**0.003**	**2.199**	**1.297**	**3.729**
Distance Variables																
8 Network distance from home to primary grocery store					**0.000**	**1.290**	**1.154**	**1.441**	**0.000**	**1.292**	**1.154**	**1.447**	**0.000**	**1.236**	**1.099**	**1.390**
9 Network distance from home to closest supermarket					**0.000**	**2.073**	**1.487**	**2.891**	**0.021**	**1.525**	**1.066**	**2.181**	**0.036**	**1.482**	**1.026**	**2.142**
10 Network distance from home to closest nonchain grocery store					**0.000**	**1.718**	**1.286**	**2.297**	0.250	1.194	0.383	1.615	0.750	1.054	0.762	1.459
Home Built Environments																
11 Employment density									**0.000**	**1.033**	**1.014**	**1.052**	**0.006**	**1.029**	**1.008**	**1.050**
12 Quick service									**0.002**	**0.959**	**0.934**	**0.984**	**0.043**	**0.970**	**0.941**	**0.999**
13 Has a liquor store or tavern									0.074	0.638	0.389	1.045	0.054	0.599	0.356	1.009
14 Street density									**0.003**	**0.918**	**0.868**	**0.971**	**0.005**	**0.915**	**0.860**	**0.974**
Primary Grocery Store Built Environments																
15 Employment density													0.148	0.975	0.942	1.009
16 Has a nonchain grocery store													**0.022**	**0.525**	**0.302**	**0.912**
17 Coffee													0.358	1.038	0.958	1.125
18 Quick service													0.854	1.004	0.963	1.046
19 Traditional restaurant													0.130	0.944	0.877	1.017

			95% CI exp(B)				95% CI exp(B)				95% CI exp(B)				95% CI exp(B)	
Variable	**Sign**	**OR**	**Lower**	**Upper**	**Sign**	**OR**	**Lower**	**Upper**	**Sign**	**OR**	**Lower**	**Upper**	**Sign**	**OR**	**Lower**	**Upper**
20 Bus ridership, 2007 (per thousand riders)													0.687	1.011	0.960	1.064
21 Liquor store or tavern													0.960	0.998	0.929	1.072
22 Has an indoor fitness facility													0.114	0.628	0.353	1.117
23 Traffic signals													0.523	1.013	0.975	1.052
24 Number of at-ground parking stalls (In)													**0.006**	**1.590**	**1.139**	**2.220**
25 Pedestrian collisions, 2001–2004													0.687	1.003	0.990	1.015

Note: In = natural log transform. Boldface indicates significance ($p < .05$) of the test results. Data for 1,885 respondents were used for each model.