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Does urban form influence grocery shopping frequency?

A study from Seattle, Washington, USA

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University of Washington, Seattle, Washington, USA

Abstract

Purpose – The purpose of this paper is to ascertain how elements of the built environment may or may not influence the frequency of grocery shopping.

Design/methodology/approach – Using data from the 2009 Seattle Obesity Study, the research investigated the effect of the urban built environment on grocery shopping travel frequency in the Seattle-King County area. Binary and ordered logit models served to estimate the impact of individual characteristics and built environments on grocery shopping travel frequency.

Findings – The results showed that the respondents' attitude towards food, travel mode, and the network distance between homes and stores exerted the strongest influence on the travel frequency while urban form variables only had a modest influence. The study showed that frequent shoppers were more likely to use alternative transportation modes and shopped closer to their homes and infrequent shoppers tended to drive longer distances to their stores and spent more time and money per visit.

Practical implications – This research has implications for urban planners and policy makers as well as grocery retailers, as the seemingly disparate groups both have an interest in food shopping frequency.

Originality/value – Few studies in the planning or retail literature investigate the influence of the urban built environment and the insights from the planning field. This study uses GIS and a planning framework to provide information that is relevant for grocery retailers and those invested in food distribution.

Keywords Geographic information systems, Grocery shopping, Shopping frequency, Urban built environment

Paper type Research paper

Introduction

As the retail branch of the food system, grocery shopping habits link retail management and marketing, public health, and sustainability. Research concerning the frequency of grocery shopping has implications for understanding consumer behaviour and spending tendencies, fresh food intake, and food waste. While research regarding the effect of the urban environment on grocery shopping has tended towards discussions of obesity, policy, and health, studies investigating the consumer behavioural component of grocery shopping tend towards decisions made in the store and shopping demographics, but not the built environment. This study investigates

This research was supported by the Seattle Obesity Study funded by the National Institutes of Health. The paper has also greatly benefited from the comments of Professor Neil Towers and the two anonymous reviewers.
This study advances the literature on grocery shopping and the built environment through the exploration of grocery shopping travel frequency in the Seattle-King County area. Synthesising data from multiple King County sources, including the 2009 Seattle Obesity Study (SOS), this research uses binary and ordered logit models to estimate how, in addition to social and demographic factors, the form of the urban environment, including residential and job density, availability of at-ground parking, distance between home and store, property values, and restaurant proximity affects grocery shopping travel frequency. This research has implications for urban planners and policy makers as well as grocery retailers, as they seemingly both have an interest in food shopping frequency.

Background

Grocery shopping is an important economic activity. According to the Bureau of Labour Statistics, people living in the Seattle metropolitan area spent 12.8 per cent of their average annual expenditures on food in 2011-2012, which is close to the national average of 12.9 per cent. In comparison, Los Angeles averages 13.6 per cent and San Francisco, 11.5 per cent – all at the 95 per cent confidence level (BOL Statistics, 2014). Grocery shopping is also a very important non-work travel which constitutes a substantial part of people’s travel activities. According to the 2009 National Household Travel Survey, “Buy goods: groceries/clothing/hardware” was the second most common travel activity in the USA, which was ranked after “Go home” and before “Go to Work” and accounting for 12, 34, and 11 per cent of all reported US household trips, respectively. Grocery shopping was identified as the most frequent “Buy goods” activity for American households compared to clothing and hardware shopping (Krumm, 2012). Food Marketing Institute’s research reveals a national average of 1.6 trips per week to the supermarket with time and health concerns identified as barriers to shopping (Hartman Group, 2014).

Grocery shopping also has an impact on health outcomes. Researchers studied the 3,000 households’ grocery shopping behaviours in New Orleans, Louisiana and found that produce consumptions, which often associated with body mass index (BMI), were positively correlated with monthly grocery shopping frequency (Gustat et al., 2015). Researcher also found that people who frequently (at least once per week) shopped at food co-ops had a significantly better diet quality than those who did not. People who frequently (at least once per week) shopped at specialty shops or farmers’ markets had significantly lower BMI and waist circumference than those who did not. Food price, quality, proximity, and convenient hours affected people’s grocery shopping frequency and destination choice (Minaker et al., 2016).

Studies regarding grocery shopping largely fall into economic and public health arenas, with the built environment considered often as a subset of one or the other. Within the economic and retail arena, studies indicate that individuals’ attitudes towards food stores and established shopping behaviours influence shopping frequencies. Operational elements of shopping, such as travel mode (Jiao et al., 2011, Clifton et al., 2012) and average time and money spent (Ma et al., 2011) correlate with travel frequency. Socioeconomic and demographic factors also correlate with grocery shopping frequency. Household size, number of workers, income, and age are associated with more frequent trips (Bawa and Ghosh, 1999; Blaylock, 1989;
The effects of frequent grocery shopping have been explored as well, with frequent shoppers spending less money and time at the stores per visit (Bawa and Ghosh, 1999; Beatty, 2008) and increasing fruit and vegetable intake (Reedy et al., 2014).

Public health research focusing on obesity and food access often concerns grocery shopping. Research shows fruit and vegetable intake is influenced by personal opinions of an area’s food offerings (Reedy et al., 2014; Hollywood et al., 2013). In addition, fruit and vegetable intake increases with additional supermarkets in a given census tract (Morland and Evenson, 2009; Morland et al., 2002). The size of grocery stores may also influence public health, as obesity rates are lower in areas with supermarkets compared to those with a high prevalence of fast food and smaller food stores (Morland and Evenson, 2009). The food environment around homes such as the density of large grocery stores, convenience stores, and fast food restaurants within two and five miles of people’s homes were correlated with people’s fruit, vegetable, and fibre intake (Reitzel et al., 2016).

Urban form has a direct impact on people’s travel mode for both work and non-work travels (e.g. grocery shopping) (Rajamani et al., 2003). Different travel modes further influence people’s time and economic travel budget (Milakis et al., 2015b) and impose constraints on people’s ability to carry or move goods (e.g. groceries) (Lee and Moudon, 2006a; Handy, 1996). From the destination perspective, urban form characteristics include the spatial distribution of routine destinations, and specially food establishments within the cities (Black et al., 2011; Lamb et al., 2015). Researchers found that the average distance from homes to grocery stores played a significant role in determining people’s grocery shopping travel mode. Stores with more at-ground parking were more likely to attract car-based visits in the Seattle area (Jiao et al., 2011). This finding was confirmed in Sweden and Germany, where people rated that accessibility by car was the most important grocery store attribute (Anne Wiese et al., 2015). Thus that the built environment around people’s homes and grocery stores would affect their grocery shopping travel behaviour.

Methods

Theoretical framework

Using findings from previous research, this study classified factors influencing grocery shopping travel frequency into four categories: socioeconomic status (Bawa and Ghosh, 1999; Kim and Park, 1997; Blaylock, 1989; Frusti et al., 2002), attitudes towards food (Beatty, 2008; Wiig and Smith, 2009; Van Loo et al., 2010), general food shopping behaviour (Kahn and Schmittlein, 1989; Bawa and Ghosh, 1999; Wilde and Ranney, 2000; Handy and Clifton, 2001; Ma et al., 2011; Maxwell et al., 2010), and the characteristics of the urban built environment around an individual traveller’s home and grocery store (Agyemang-Duah et al., 1996; Boarnet and Crane, 2001; Ewing and Cervero, 2010; Boarnet, 2011). Socioeconomic status refers to demographic characteristics of the sample population, including age, race, and household income. Attitudes towards food included measures and perceptions of consumers’ expectations whether food should be inexpensive or food should be easy to cook. General food shopping behaviour pertains to consumers’ characteristics such as the average money and time spent in the store, as well as measures like travel distance and mode. Finally, factors comprising the urban built environment included items like the amount of at-ground parking and the density of food stores around the home.
Data sources
This analysis synthesised data from several sources within the King County area. The 2009 SOS telephone survey provided data on grocery shopping travel and the travellers’ socioeconomic characteristics. This effort sampled residents of the Seattle-King County area and included 2,001 respondents to a 20-minute survey which had 89 questions regarding diet quality, food shopping habits and expenditures, food insecurity, perception of home neighbourhood, and stores. The University of Washington Centre for Obesity Research (UWCOR) furnished data about individual store food costs. Objective data on the urban built environment came from the King County assessor and information regarding residential and employment density, property values, at-ground parking, and food and fitness establishments was supplied and developed by the Urban Form Lab at the University of Washington. The original food establishment data were provided by the Department of Public Health of Seattle and King County, while the original data for fitness facilities came from InfoUSA. The King County GIS Centre provided road network and other urban transportation infrastructure data. The study was approved by the University of Washington Institutional Review Board.

Measurements
Geocoding and store classification by food cost. Of the 2,001 SOS respondents’ home addresses, 1,994 were geocoded in GIS. While 1,985 respondents reported the address of their primary grocery store, the store address, and the related shopping frequency could only be verified for 1,862 respondents. Geocoding results showed that these respondents shopped at 207 grocery stores (Figure 1). UWCOR categorised the grocery stores based on the total cost of 100 commonly consumed food items from eight different supermarket chains (Mahmud et al., 2009). Of the 207 stores, 80 were classified as low-cost, 110 as medium-cost, and 17 as high-cost stores.

Dependent variables
The respondents’ travel frequency, or number of reported trips, to the reported primary grocery store was the dependent variable. As the survey interviewed primary shoppers, or those who completed the most grocery shopping trips in their households, travel frequency represented grocery shopping behaviour at the household level. Of the 1,862 respondent sample, 512 (27 per cent) respondents reported shopping no more than twice per month, 434 (23 per cent) respondents reported shopping once a week, 787 (42 per cent) respondents reported shopping two or three times per week, 92 (5 per cent) and 36 (2 per cent) reported shopping four to six times or more than six times per week. The 946 residents who reported shopping no more than once per week (50.8 per cent) were classified as infrequent shoppers. The remaining 916 respondents (49.2 per cent) of the three groups who reported grocery shopping at least two or three times per week were classified as frequent shoppers (Progressive Grocer, 2002). To understand the relationship between the urban built environment and grocery shopping frequency, the researchers built one binary model and one ordered logit model (Huntsinger et al., 2013; Nijland et al., 2013; Arentze et al., 2011). The binary logit model used the aggregated travel frequency (infrequent vs frequent shoppers) as the dependent variable. The ordered logit model used the five more detailed travel frequency categories as the dependent variable.

Independent variables
Independent variables were selected from the following four domains: socioeconomic status, attitude towards food, general food shopping behaviour, and the urban built environment.
Socioeconomic variables included respondents’ age, gender, education level, household income, household size, and the number of children and cars within the household (Hanson and Hanson, 1981; Blaylock, 1989; Benekohal et al., 1994; Bawa and Ghosh, 1999; Frusti et al., 2002; Yoo et al., 2006). Attitude variables included whether the respondents thought food should be inexpensive, easy to cook, and healthy (Beatty, 2008). Shopping behaviour variables included respondents’ travel mode and travel distance to store, primary grocery store type by cost of food in the store, and average money and time spent per visit in the store (Bawa and Ghosh, 1999; Wilde and Ranney, 2000; Yoo et al., 2006).

Urban built environment variables included four different sub-categories as follows (Table I): general neighbourhood environment, measured as residential and employment density, and residential property values to capture neighbourhood wealth (Cervero and Kockelman, 1997; Frank and Pivo, 1994; Chen et al., 2008); routine neighbourhood food-related destinations, measured as food stores and restaurants around the respondents’ homes and preferred grocery stores (Lee and Moudon, 2006b;
McCormack et al., 2008); transportation infrastructure, measured as the density of the road network, the count of signals and bus stops, the presence of trails, and the amount of parking at ground (Cervero and Radisch, 1996; Greenwald, 2003; Handy and Clifton, 2001; Lee and Moudon, 2006b; Steiner, 1998); and traffic conditions, measured as the estimated annual average daily traffic (AADT) on major streets, and the daily count of bus riders per bus stop (Moudon and Hess, 2000).

Data capture in GIS
ArcGIS Network Analyst and the ESRI StreetMap data were used to ascertain the network distances between homes and respondents’ primary grocery stores. Travel distance was measured in miles using the shortest driving time distance impedance of the ESRI StreetMap data, which considered one-way streets, speed limits, over- and under-passes, transit-only lanes, etc. Count and density measures of urban built environment variables around each respondent’s home and around the primary grocery store were derived from the King County parcel GIS data set and summed within a half-mile (833 m) buffer. The size of the buffer corresponded to a ten-minute walking distance, which is a catchment area convention used in other research (Cervero, 1996; Hess et al., 1999; Guo et al., 2007).

Analysis
Correlation analyses served to test the relationship between the independent variables selected in each of the four domains. If two variables were highly correlated with

<table>
<thead>
<tr>
<th>Domain</th>
<th>Sub domain</th>
<th>Variables</th>
<th>Measures (within a 0.5 mi airline buffer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built environment</td>
<td>Neighbourhood environment</td>
<td>Net residential density</td>
<td>Number of units per acre</td>
</tr>
<tr>
<td></td>
<td>variables</td>
<td>Net employment density</td>
<td>Estimates (jobs) per acre</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residential property value</td>
<td>Assessed property value per residential unit</td>
</tr>
<tr>
<td>Food stores</td>
<td>Supermarket</td>
<td></td>
<td>Count of places</td>
</tr>
<tr>
<td></td>
<td>Grocery store</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ethnic food store</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Convenience store</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restaurants</td>
<td>Traditional restaurant</td>
<td></td>
<td>Count of places</td>
</tr>
<tr>
<td></td>
<td>Ethnic dining</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fast food</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quick service</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coffee shop</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Taverns and pubs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>Major street density</td>
<td>Freeway and arterials in miles</td>
<td></td>
</tr>
<tr>
<td>infrastructure</td>
<td>Other street density</td>
<td>Streets with speed limit ≤45 mph in miles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Signallization</td>
<td>Count of traffic signs and signals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parking</td>
<td>Count of on ground parking stalls</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bus stops</td>
<td>Count of bus stops</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trail</td>
<td>Have trail or not</td>
<td></td>
</tr>
<tr>
<td>Traffic conditions</td>
<td>Bus ridership</td>
<td>Counts of bus riders per bus stop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Traffic volumes</td>
<td>Average estimated AADT on major street</td>
<td></td>
</tr>
</tbody>
</table>
each other, the variable with theoretical support and the strongest backing from previous research was kept. Bivariate analyses examined the relationship between the uncorrelated independent variables and the dependent variable. T-statistical tests were used for continuous variables and \( \chi^2 \) tests were used for categorical variables. Only significant variables were included in the final models.

Binary and ordered logistic regressions were used to test the relationship between independent variables and the likelihood of respondents to be frequent or infrequent shoppers. First, four binary logistic regression models were created and tested. Model 1, the base model, only included the respondents’ socioeconomic characteristics. In model 2, respondents’ attitudes towards food and general shopping behaviour were added to the base model. Model 3 added the urban built environment variables of the home neighbourhood and model 4 was the final binary model, which added the urban built environment variables of the primary store neighbourhood. In models 2, 3, and 4, variables were added one at a time to the previous models.

Variables in the final binary model were kept in the ordered model to further test the relationship between the urban built environment and people’s travel frequency to grocery stores (Bhat and Guo, 2004; Habib and Miller, 2008; Srinivasan and Bhat, 2005).

Results
Descriptive analysis
Of the 1,862 SOS survey respondents included in the analysis, 62 per cent were female and 38 per cent were male. Survey respondents had an average age of 54.45 years and an average household income class of between $50,000 and $75,000. For modelling purposes, age was treated as a categorical variable and separated into three categories as young adult: 18-44 (26 per cent), middle-aged: 45-64 (50 per cent), and older adult: \( \geq 65 \) (24 per cent) (US Census Bureau, 2009). The average household size was 2.31 persons, with an average of 0.22 children between the age of 12 and 18. In total, 81 per cent of the sample had at least 1-3 years of college education. The average number of cars per household and per household adult was 1.74 and 1.01, respectively. The sample population was different from the King County population in that it was older, more educated, and more female (US Census Bureau, 2009) (Table II).

<table>
<thead>
<tr>
<th>Variable</th>
<th>All sample</th>
<th>Frequent shoppers</th>
<th>Infrequent shoppers</th>
<th>King County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age</td>
<td>54.53</td>
<td>54.48</td>
<td>54.63</td>
<td>37.00</td>
</tr>
<tr>
<td>Average household income</td>
<td>50k-75k</td>
<td>50k-75k</td>
<td>35k-50k</td>
<td>70k(^a)</td>
</tr>
<tr>
<td>Average household size</td>
<td>2.31</td>
<td>2.31</td>
<td>2.29</td>
<td>2.37</td>
</tr>
<tr>
<td>Average travel distance(mile)</td>
<td>3.12</td>
<td>2.25</td>
<td>3.99</td>
<td>NA</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>38%</td>
<td>41%</td>
<td>35%</td>
<td>50%</td>
</tr>
<tr>
<td>No. of children 12-18 yrs old</td>
<td>0.22</td>
<td>0.24</td>
<td>0.19</td>
<td>0.39(^b)</td>
</tr>
<tr>
<td>No. of cars per household</td>
<td>1.74</td>
<td>1.79</td>
<td>1.68</td>
<td>1.67</td>
</tr>
<tr>
<td>No. of cars per household adult(^c)</td>
<td>1.01</td>
<td>1.03</td>
<td>0.98</td>
<td>1.01</td>
</tr>
<tr>
<td>Education (1-3 years college education)</td>
<td>81%</td>
<td>83.1%</td>
<td>78.9%</td>
<td>73.5%</td>
</tr>
</tbody>
</table>

Notes: \(^a\)Median household income; \(^b\)0-14 years old children (US Census Bureau, 2009); \(^c\)adult over 18-years-old

Table II. Socioeconomic status of Seattle Obesity Study samples and King County’s population
In total, 88 per cent of the 1,862 respondents reported driving to their primary grocery store with 69 per cent shopping at low-cost grocery stores. In total, 12 per cent of the respondents reported using alternative transportation modes for grocery shopping. Among them, 156 respondents walked to the primary grocery store, 62 respondents took public transit, and four respondents rode bicycles.

Respondents' average grocery store trip length was 33.82 minutes with an average grocery bill of $68.71. The average travel distance from home to the primary grocery store was 3.12 miles. Average residential density around the homes was 4.75 units per acre and there were five food stores (including supermarkets, non-chain grocery stores, ethnic food stores, and convenience stores) and 3,816 at-ground parking stalls within the half-mile airline buffer around the homes. Job density and property values around the primary store averaged 11 jobs per acre and $225,000 per residential unit, respectively. On average, there were 43 different restaurants (which included traditional restaurants, ethnic dining, fast food and quick service restaurants, coffee shops, and tavern/pubs) within the half-mile airline buffer around the primary grocery stores (Table III).

Model results

Five independent variables were significant in the base model (age, gender, household income, car ownership, and the number of 12-18 year old children). In total, 12 variables were significant in the one-by-one stepwise test process, including the number of food stores, the amount of at-ground parking, the residential densities around the home, and the number of restaurants around stores. These variables were included in the final model (Table III).

For the final binary logit model, income and the number of 12-18-year-old children within the household were positively correlated with the likelihood of being a frequent shopper with an odds ratio of 1.078 and 1.564, respectively. The respondents' age lost significance in the final model and respondents' gender, and the number of cars per adult member remained insignificant. Thinking food should be inexpensive (OR = 0.731), driving to the primary grocery store (OR = 0.525), average travel distance to the store (OR = 0.851), and average money and time spent in the store (OR = 0.985 and 0.981) were negatively related to the likelihood of being a frequent shopper. Compared to the respondents who shopped at high-cost grocery stores, respondents who shopped at low- or medium-cost stores were less likely to be frequent shoppers (OR = 0.436 and 0.478).

Three built environment variables around homes were included in the final binary model. Residential density and the number of food stores (grocery store and supermarket) around homes were not significant in the final binary model. Only the amount of at-ground parking around homes was negatively correlated with the grocery shopping travel frequency (OR = 0.860).

Three built environment variables around stores were included in the final binary model. They were job density, restaurant proximity, and average property value around the stores. Among them, only the average property value around stores was significant and negatively correlated with travel frequency (OR = 0.635). Both job density and restaurant proximity were insignificant in the final binary model.

For the ordered logit model, the household income and the number of 12-18-year-old children were positively correlated with grocery shopping travel frequency. This confirmed the results of the binary logit model. Being a female or a young adult (18-44 years old), which were not significant in the binary model, became positively correlated with the travel frequency in the ordered logit model.
<table>
<thead>
<tr>
<th>A: domain</th>
<th>B: variables</th>
<th>C: measures</th>
<th>D: descriptive statistics</th>
<th>E: treated in the models</th>
<th>F: one-by-one testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual and Socioeconomic Status</td>
<td>Age</td>
<td>Year</td>
<td>Young adult: 18-44 (26%), middle aged: 45-64 (50%), older adult: ≥65 (24%)</td>
<td>Cat.</td>
<td>Base model</td>
</tr>
<tr>
<td></td>
<td>Household income</td>
<td>Income categories</td>
<td>Min: 1, max: 15, mean: 2.31, median: 2, SD: 1.44</td>
<td>Cont.</td>
<td>Base model</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>Male/female</td>
<td>Male: 724, female: 1,179</td>
<td>Cat.</td>
<td>Base model</td>
</tr>
<tr>
<td></td>
<td>No. of cars per household adult</td>
<td>Count</td>
<td>Min: 0, max: 4, mean: 1.01, median: 1, SD: 0.54</td>
<td>Cont.</td>
<td>Base model</td>
</tr>
<tr>
<td></td>
<td>No. of 12-18 year old children</td>
<td>Count</td>
<td>Min: 0, max: 4, mean: 0.22, median: 0, SD: 0.55</td>
<td>Cont.</td>
<td>Base model</td>
</tr>
<tr>
<td>Attitude towards food</td>
<td>Thinking food should be inexpensive</td>
<td>Yes/no</td>
<td>Yes: 986, no: 603</td>
<td>Cat.</td>
<td>“−”</td>
</tr>
<tr>
<td>Food shopping behaviour</td>
<td>Driving to grocery store</td>
<td>Yes/no</td>
<td>Driving: 1,640, Non-driving: 222 (walking: 156, public transit: 62, biking: 4)</td>
<td>“−”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance from home to primary grocery store</td>
<td>Network distance in miles</td>
<td>Min: 0.02, max: 59.20, mean: 3.12, median: 2.04, SD: 4.40</td>
<td>“−”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Store type by cost</td>
<td>Low/medium/high cost</td>
<td>Low: 585, medium: 1,127, and high: 190</td>
<td>Cat.</td>
<td>“+”</td>
</tr>
<tr>
<td></td>
<td>Average money spent per visit</td>
<td>Dollar</td>
<td>Min: 1, max:350, mean: 70.73, median: 50, SD: 53.85</td>
<td>“−”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average time spent per visit</td>
<td>Minute</td>
<td>Min: 4, max:120, mean: 34.5, median: 30, SD: 18.05</td>
<td>“−”</td>
<td></td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>A: domain</th>
<th>B: variables</th>
<th>C: measures</th>
<th>D: descriptive statistics</th>
<th>E: treated in the models</th>
<th>F: one-by-one testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built environment around home and store</td>
<td>Residential density around home</td>
<td>Unit/acre</td>
<td>Min: 0, max: 30, mean: 4.75 median: 3.30, SD: 4.85</td>
<td>Cont.</td>
<td>“−”</td>
</tr>
<tr>
<td>No. of food stores around home</td>
<td>Count</td>
<td>Min: 0, max: 40, mean: 5.03 median: 3, SD: 7.02</td>
<td>Cont.</td>
<td>“−”</td>
<td></td>
</tr>
<tr>
<td>At-ground parking around home</td>
<td>Count of at ground parking (log transformed)</td>
<td>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)</td>
<td>Cont.</td>
<td>“−”</td>
<td></td>
</tr>
<tr>
<td>Job density around store</td>
<td>Job/acre</td>
<td>Min: 0, max: 253, mean: 11.03 median: 4.73, SD: 24.70</td>
<td>Cont.</td>
<td>“+”</td>
<td></td>
</tr>
<tr>
<td>Average property value around store</td>
<td>Dollar/unit</td>
<td>Original value (min: 82k, max: 1,015k, mean: 225k, median: 207k, SD: 80k) Log value (min: 11.32, max: 13.83, mean: 12.26, median: 12.24, SD: 0.35)</td>
<td>Cont.</td>
<td>“−”</td>
<td></td>
</tr>
<tr>
<td>No. of restaurants around store</td>
<td>Count</td>
<td>Min: 0, max: 518.96, mean: 42.56 median: 26.89, SD: 57.60</td>
<td>Cont.</td>
<td>“+”</td>
<td></td>
</tr>
</tbody>
</table>
Similar to the binary model, all six attitude and behaviour variables (thinking food should be inexpensive, driving to store, shopping at low- or medium-cost store, average network distance between homes and stores, and average time or money spent at stores) remained their significance and were negatively correlated with grocery shopping frequency in the final ordered model.

Regarding the built environment variables around the homes, the residential density around homes was weekly correlated with grocery shopping travel frequency. The number of at-ground parking around homes was still negatively correlated with grocery shopping frequency. For variables regarding the built environment around the grocery store, the average property value around stores was negatively correlated with travel frequency. Both job density and having a restaurant around stores were not significant in the final ordered logit model (Table IV).

Discussion of results
Both the binary and ordered logit model showed that the travel frequency to the primary grocery store was associated with individual socioeconomic characteristics, attitudes towards food, general shopping behaviour, and the urban built environment around the home and primary grocery store. With at least two variables significant in the final regression models, the respondents’ socioeconomic variables clearly affected travel frequency. Variables in the attitude and general shopping behaviour category exerted a very strong influence on travel frequency. All six variables in this category were significant in both models. The built environment variable had a direct, but modest influence on travel behaviour, which confirmed findings in previous studies (Ewing and Cervero, 2010; Bhat and Guo, 2007; Cao et al., 2009; Milakis et al., 2015a).

Demographic and socioeconomic characteristics
Household income and the number of teenage (12-18) children within the household were significant in both binary and ordered logit models. Compared to infrequent shoppers, those that shopped frequently lived in higher income households with more teenage children. The findings about teenage children on grocery shopping travel is new to the literature and suggests when planning for new grocery stores, both private (grocery store operator) and public sectors (urban planner/government officials) should well consider the increasing demand generated by the teenage population. Similar results about household income on trip frequency were reported by previous studies (Yoo et al., 2006; Blaylock, 1989; Bawa and Ghosh, 1999; Mortimer and Clarke, 2011; Frusti et al., 2002). Being a young adult (18-44) or a female was significantly correlated with more grocery shopping travel in the ordered logit models. Compared to males, females were 19.7 per cent more likely to shop at the grocery stores one or more times per week, supporting findings in previous literature (Feng et al., 2013; Gentina and Bonsu, 2012; Luceri and Latusi, 2012; Frank et al., 2009). The number of cars per adult was significant in the base model. It lost its significance in both final models after including other car related variables such as: driving to the grocery store or not, and the network distance between homes and primary grocery stores. It’s expected that the variance explained by car ownership could be explained by these two variables.

Attitude and behaviour
The attitude and behaviour variables showed a very strong influence on grocery shopping frequencies in both final models. Compared to infrequent shoppers,
| Individual demographics and socioeconomic | | \(n=1,862\) | | Individual demographics and socioeconomic | | \(n=1,862\) |
|---|---|---|---|---|---|---|---|
| **Age (18-44)** | 0.285 | 0.086 | 1.330 | 0.961 | 1.840 | 0.376 | 0.007 | 0.104 | 0.648 |
| **Age (45-64)** | 0.099 | 0.485 | 1.104 | 0.837 | 1.455 | 0.232 | 0.053 | | |
| **Age (≥65)** | 0.000 | 0.000 | | | | | |
| **Gender (female)** | 0.133 | 0.245 | 0.875 | 0.699 | 1.096 | 0.197 | 0.040 | 0.009 | 0.385 |
| **Household income** | 0.075 | 0.000 | 1.078 | 1.035 | 1.122 | 0.089 | 0.000 | 0.055 | 0.124 |
| **No. of 12-18 yrs. old children** | 0.447 | 0.000 | 1.564 | 1.255 | 1.948 | 0.446 | 0.000 | 0.271 | 0.622 |
| **No. of cars per adult** | 0.174 | 0.132 | 1.190 | 0.949 | 1.483 | 0.152 | 0.107 | −0.033 | 0.337 |

| Attitude and behaviour | | | | Attitude and behaviour | | |
|---|---|---|---|---|---|---|---|
| **Thinking food should be inexpensive** | −0.313 | 0.005 | 0.731 | 0.586 | 0.912 | −0.272 | 0.004 | −0.457 | −0.086 |
| **Driving to Store** | −0.644 | 0.003 | 0.525 | 0.344 | 0.802 | −0.609 | 0.001 | −0.953 | −0.265 |
| **Store type (low)** | −0.831 | 0.000 | 0.436 | 0.274 | 0.693 | −0.803 | 0.000 | −1.174 | −0.431 |
| **Store type (medium)** | −0.739 | 0.000 | 0.478 | 0.316 | 0.722 | −0.700 | 0.000 | −1.027 | −0.373 |
| **Store type (high)** | | | | | | | |
| **Network distance home – store (mile)** | −0.162 | 0.000 | 0.851 | 0.810 | 0.893 | −0.133 | 0.000 | −0.166 | −0.099 |
| **Average money spent at store ($)** | −0.015 | 0.000 | 0.985 | 0.982 | 0.988 | −0.016 | 0.000 | −0.018 | −0.014 |
| **Average time spent at store (min)** | −0.020 | 0.000 | 0.981 | 0.973 | 0.988 | −0.016 | 0.000 | −0.022 | −0.010 |

| Home Urban Built Environment | | | | Home Urban Built Environment | | |
|---|---|---|---|---|---|---|---|
| **Residential density around home** | −0.023 | 0.139 | 0.978 | 0.949 | 1.007 | −0.026 | 0.043 | −0.050 | −0.001 |
| **No. of food stores around home** | 0.090 | 0.236 | 1.094 | 0.943 | 1.269 | 0.097 | 0.120 | −0.025 | 0.219 |
| **No. of at ground parking around home (LN)** | −0.151 | 0.000 | 0.860 | 0.807 | 0.916 | −0.118 | 0.000 | −0.169 | −0.067 |

| Store urban built environment | | | | Store urban built environment | | |
|---|---|---|---|---|---|---|---|
| **Job density around store** | 0.000 | 0.888 | 0.888 | 0.995 | 1.005 | 0.001 | 0.522 | −0.003 | 0.006 |
| **Average property value around store (LN)** | −0.422 | 0.014 | 0.655 | 0.467 | 0.919 | −0.393 | 0.007 | −0.677 | −0.109 |
| **Have a restaurant around store** | 0.087 | 0.603 | 1.091 | 0.786 | 1.513 | 0.069 | 0.618 | −0.202 | 0.304 |

**Constant** | 9.061 | 0.000 | | | | | |

**Notes:** Bold, significant at 0.05 level, italic, categorical variable, and LN, natural log transform
frequent shoppers were less likely to agree that food should be inexpensive and more likely to shop at the high-cost grocery stores. This suggested they are less economically constrained than infrequent grocery shoppers, who might limit their grocery store visits due to financial reasons (Clifton, 2004; Darko et al., 2012). Frequent shoppers were less likely to drive and travelled significantly shorter distances to grocery stores (Table II: 2.55 vs 3.99 miles), which suggested they lived closer to grocery stores and thus might have more choice of foods in their neighbourhood. Further, frequent shoppers spent significantly less money and time per store visit than infrequent grocery shoppers. This suggested that frequent shoppers were more concerned with the freshness of the groceries and thus may have better health statuses than infrequent shoppers (Minaker et al., 2016).

As expected, the network distance between homes and stores was negatively correlated with travel frequency. Previous studies using the same dataset found that drivers travelled significantly farther to the store than non-drivers (3.33 vs 1.52 miles) (Jiao et al., 2011; Hillier et al., 2011). This indicated that shorter distances between homes and stores might increase grocery shopping frequency by modes other than driving (Handy and Clifton, 2001; Whelan et al., 2002). This finding is interesting for both policy makers and grocery retailers as they could increase people’s healthy food exposures by building more urban grocery stores and still potentially reducing related car traffics. The increasing popularity of small urban grocery stores (e.g. Whole Foods, Trader Joe’s) and the shrinking of big box grocery stores (e.g. Walmart, Target) seem to support this finding (Tuttle, 2014).

**Urban form around the homes and stores**

Urban form factors had a modest influence on grocery shopping frequency. The number of at-ground parking around homes was negatively correlated with grocery shopping frequency in both final models. Further tests showed that the variable was negatively associated with the average distance between homes and stores. This indicated that respondents living in suburban neighbourhoods with lots of at-ground parking stalls were more likely to make fewer but longer distance grocery shopping trips. Residents living in urban neighbourhoods with fewer at-ground parking stalls were more likely to make more but shorter trips. Similar findings about land use mix on general shopping behaviour were reported in previous studies (Agyemang-Duah et al., 1996; Duncan et al., 2010; Boarnet et al., 2011), in which shopping activities were more likely to be chained with other activities (i.e. dining out and entertainment activities) (Dawson and Lord, 2012; Boarnet, 2011). The average property value around stores was negatively correlated with grocery shopping frequency in both models. This may point to big box grocery stores mostly locating in low-cost suburbs. Consumers usually do not visit these stores often, but when they do, they likely spend more time and money in the store to justify the high-travel cost (Darko et al., 2012; Hillier et al., 2011).

The authors also tested the interaction terms between income, gender, and age with built environment variables around homes and stores. The results showed that income was correlated with both the residential density around homes and the at-ground parking around homes. However, when introducing the interaction terms of income and density, as well as income and at-ground parking space around homes, to the two final models, none of them were significant. Age and gender were not correlated with any home or store built environment variables and the corresponding interaction terms were not significant in either final model.
Summary

Overall, ten variables were significant in both binary and ordered logit models. Summarizing these findings, we found that frequent grocery shoppers were more likely to be female or young adults. They usually had higher household incomes and more teenage children in the family. They often shopped at high-cost grocery stores and were less concerned about food cost. Compared to infrequent shoppers, frequent shoppers usually lived in higher density neighbourhoods with fewer at-ground parking and closer distances to grocery stores. These urban form characteristics affected the plausible transportation modes available to them and their grocery shopping travel budgets (measured by time and money). Because of the shorter distance from homes to stores, they were able to visit these stores more often with non-motorised transportation modes and also benefited from stronger healthy food exposures than infrequent shoppers.

Compared to frequent shoppers, the infrequent shoppers were more likely to be male or older adults. They usually had lower household incomes and fewer teenage children in the household. They tended to shop at low- or medium-cost grocery stores and think food should be inexpensive, which could potentially reduce their healthy food exposures. In terms of urban form characteristics, they usually lived in low-density neighbourhoods with more at-ground parking spots around homes and further away from their primary grocery stores. These factors again influenced the plausible travel modes available to them and affected their grocery shopping time and cost budgets. Due to economic (lower household income) and urban form (longer distance) constraints, they usually made fewer grocery shopping trips. But when they did, they would drive further away to stores and spend more time and money per visit perhaps as a way to justify the travel cost (Chung and Myers, 1999; Hubley, 2011; Michimi and Wimberly, 2010).

The findings inform both public health and transportation planning policies. By allocating smaller grocery stores to lower income neighbourhoods (e.g. food deserts) (Jiao et al., 2012), urban planners and policy makers could reduce the average travel distances between homes and stores, which in turn would increase local residents’ grocery shopping frequency and their healthy food exposures (Minaker et al., 2016). Similar movements have been observed in New York City, Philadelphia, Pittsburgh, Baltimore, and the State of Maryland, where some big box grocery stores have been replaced by smaller urban neighbourhood grocery stores (NSOPP Center, 2016).

Meanwhile, by introducing more neighbourhood grocery stores and reducing the number of at-ground parking around homes, planners and policy makers could increase residents’ probability of using nonmotorized travel modes for grocery shopping (Van and Senior, 2000; Schwanen et al., 2004; Zhang, 2004) and potentially replace grocery shopping trips with local shopping activities (Ewing et al., 1996; Handy and Clifton, 2001). Lastly, by introducing neighbourhood grocery stores, planners, and policy makers could also potentially reduce people’s auto dependence for grocery shopping (Handy and Clifton, 2001) and remove potential transportation barriers for the underserved populations (Jiao and Dillivan, 2013).

Limitations

The generalisability of the findings was limited by the following facts. The samples were older and included more women than the aggregate King County population, which might not be representative of the food shopper population in the area. Grocery stores were not evenly distributed in the study area, with more grocery stores located in...
the north Seattle area increasing the risk of spatial autocorrelation. Data on the respondents’ grocery shopping travel frequencies and travel times were self-reported and collected at the individual level rather than from the household level. Furthermore, statistical models were affected by the multicollinearity. A structural equation model would provide a better understanding about the causal relationships between variables (Cao et al., 2009; Golob, 2003). Also, no information about possible trip chaining was collected in the survey, which limited the possibility to explore detailed travel behaviour. Lastly, characteristics of the urban built environment and urban form in the Seattle-King County area might differ from those of other metropolitan areas. Similar studies in other regions would help to better understand the relationship between the built environment and people’s grocery shopping travel behaviour.

Conclusion
The study showed that individual travellers’ socioeconomic status, attitude, and general food shopping behaviour (e.g. thinking food should be inexpensive, shopping at high-cost stores, driving to grocery stores, or money and time spent per store visit), as well as the urban form surrounding both their homes and their primary grocery stores, were correlated with travel frequency to their primary grocery stores. Among them, people’s attitude and general food shopping behaviour had the strongest influence on grocery shopping frequency. Driving to stores, thinking food should be inexpensive, and the network distance between homes and stores had a major negative impact on grocery shopping travel frequency, while the urban built environment factors had a modest influence on travel frequency.

Urban form factors affected the spatial distribution of grocery stores and the related travel modes available for grocery shopping, which together influenced the monetary and temporal costs of travel for grocery shopping. Specifically the number of at-ground parking stalls around homes and the average property value around the stores were negatively associated with grocery shopping travel frequency. Frequent shoppers were more likely to shop at nearby medium- or high-cost grocery stores and use non-motorised transportation modes. However, infrequent shoppers were more likely to drive significantly longer distances to low-cost grocery stores located in remote areas.

References


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