Food Shopping Trip Characteristics Before and After the Light Rail

Jessica Y. Jew

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Committee:

Brian E. Saelens

Adam Drewnowski

Glen E. Duncan

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Abstract

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Jessica Y. Jew

Chair of the Supervisory Committee:
Brian E. Saelens, PhD
Department of Pediatrics and Psychiatry & Behavioral Sciences

Background: The Seattle Food Action Plan recommends improving healthy food access via non-auto transportation options, and light rail is a public transportation system recently introduced and currently being invested in and expanded. When studying food access, time is both an area-based measure of proximity and a component of travel cost to the individual, but proximity does not necessarily correspond with individual travel patterns. Studies of community food access or time use have not analyzed individual reported food shopping trip characteristics for relationships between time and transportation mode, route, and store type.

Objective: The overall aim of this study was to understand whether food shopping trips differ with respect to time and mode, and the effects on these travel factors of new light rail implementation as an environmental intervention on travel behaviors.

Methods: This study is a secondary analysis of the Travel Assessment and Community (TRAC) Study, a longitudinal study using the introduction of the light rail in Seattle as an environmental intervention. “Cases” were defined as adults living < 1 airline mile from the to-be-opened light rail stations, while the “controls” lived further away from the stations but in neighborhoods with initially similar built environment and census-based demographic characteristics. Food shopping trips from seven-day travel diaries in 2008-2009 (Phase 1) and then in 2010-2011 (Phase 2) after the light rail was running were identified for people with trips in both phases. The final analysis included food shopping trips from 187 cases and 200 controls totaling 1161 trips in Phase 1 and 1086 trips in Phase 2. Trips were characterized by mode, route, store, and time measures and analyzed descriptively only. Person-level outcomes were number of trips per week, classification by primary shopping mode, and average travel time by mode and per primary mode shopper.

Results: Non-auto modes were about 30% of all food trips, with 21.1% by walk/bike and 8.4% by transit. Median transit food trip travel time (43 min) was substantially higher than for other modes (20 min for auto and 17 min for walk/bike). Travel times were similar between routes (home-store-home vs other routes) and between store types (supermarket vs other store) within modes for trips overall, but route and store type percentage differed by mode. In Phase 2, only seven trips were associated with light rail, but these were all taken by cases. Mode distribution was similar between phases and case/control. Percentage of trips to supermarkets vs other stores was lower for cases. Transit travel time was lower in Phase 2 vs 1 (39 vs 50 min). Transit trip combinations were the most affected by phase or case. Person-level data indicated that people in Phase 2 vs 1 took fewer walk/bike trips per week on average (0.52 vs 0.67, P=0.0103). There was an increase in transit use by one scheme of classification as a primary transit shopper in Phase 2 (P=0.0125). The difference between cases and controls was smaller in Phase 2 vs 1 for average walk/bike trip travel time by 6 min.

Conclusions: Food shopping travel patterns were found to vary by transportation mode. Transit trip characteristics were impacted the most by phase or case/control, with lower transit travel times in Phase 2. Person-level data indicated changes in walk/bike and transit usage by phase and a differential effect on average walk/bike travel time for cases between phases. Understanding trip characteristics and travel behaviors and how they may be impacted by public transportation systems could have implications for transportation planning and inform strategies to promote food access by transit and walk/bike and reduce demand for automobile use.

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1. INTRODUCTION

Food shopping is an important activity in food access, which has been defined as "the ability of people to obtain the food items they need from the food outlets available in a given area, within the limits of their ability to get there and back, among other factors" (Gottlieb, 1996). Community-level food access focuses on food outlet availability for people living within an area, while a person's level of access may be indicated by individual resources, particularly motor vehicle access (USDA ERS, 2009).

Exploring non-auto food shopping is pertinent for people without access to a motor vehicle, but it is also Seattle's plan for environment and sustainability to lower the demand for motor vehicle trips and promote development and improvements so that walking, biking, and transit are viable modes for more people (City of Seattle Office of Planning and Development, 2015). This is reinforced by the first strategy discussed in Seattle's Food Action Plan to address barriers to healthy food access: "promote the location of healthy food access points that can be reached by walking, biking, or transit by all residents" (City of Seattle Office of Sustainability and Environment, 2012).

Light rail was newly introduced to Seattle in 2009, connecting Southeast Seattle with Downtown and the SeaTac airport. It is a mode currently being invested in and expanded, and Sound Transit 3 is expected to be introduced to voters for further transit expansion (Sound Transit). Light rail may provide faster and more frequent and reliable transit to neighborhoods as well as opportunities for growth and development (City of Seattle Office of Planning and Development, 2015). It is unknown how light rail influences food access, but it should be investigated how investing in a new transportation mode addresses the city's growth goals and promotes access to essential activities such as food shopping.

This study focuses on neighborhoods near and further away from eight Central Link light rail stations, from International District (Downtown) to Rainier Beach (Southeast Seattle). Of primary interest is how people are getting there and back, or the mode of transportation used for shopping, as well as the time it takes to do so. Time may be considered both a measure of proximity (Charreire, 2010) and affordability, which refers not only to the price of food but also to the travel and time costs involved (USDA ERS, 2009). Women surveyed in Southeast Seattle about healthy food access by Got Green reported that major barriers included cost (67%), location (23%), and time (10%) (Got Green, 2011). The overall goal of the study is to explore local food shopping trip patterns by transportation mode and use the background of the introduction of the light rail to investigate whether this environmental intervention had any impact on food shopping access.

2. BACKGROUND

This section summarizes data and findings related to food shopping travel and time and describes the scope of study approaches for food access. These areas of literature can be roughly divided into overlapping categories of food environment, behavior surveys, travel, and time use studies.

2.1 Conceptual frameworks

In addition to the time-related factors of proximity and affordability, food access has also been characterized by the dimensions of diversity (types of food outlets), availability (food supply at food outlets), and perception, which refers to how people perceive their own environments (Charreire, 2010). Missing from these dimensions is perhaps the notion of "accessibility" to refer to the ability to travel and time constraints on travel and food store access.

These factors are integrated into a framework by Glanz et al. for nutrition environments based on the ecological model. Proximity and diversity are represented by the community-level environmental variable of the distribution of food sources characterized by type and location, with the additional consideration of accessibility (i.e., hours of operation, drive-through) of those food outlets. Price and food availability are consumer nutrition environmental variables, and perception an individual variable. (Glanz, 2005) Food environment studies for community food access are based on the reasoning that environmental factors influence behavior, and therefore traditionally focus on proximity and diversity as community-level variables. It is unclear from the ecological-based model how the "general community" environment conforms to a community's travel patterns and capacity for travel. The USDA Food Security Assessment Toolkit also discusses availability and adequacy of public transportation systems as a community characteristic that supports access to stores (Cohen, 2002).

Rose et al. proposed another framework linking community food access to behavior based on an economic model. This model acknowledges travel cost as part of food cost, and that travel cost is related to food store placement. Car ownership may lower travel costs via travel time. Authors noted that time constraints influencing purchase decisions (such as the purchase of convenience or prepared foods) are not included in the model. (Rose, 2010)

This study more closely aligns with the Rose model by focusing on travel cost and the influence from transportation mode choice, since it is unknown whether car travel reduces the time spent traveling for food. Another aspect of the study is the introduction of a public transportation system as an environmental variable that could impact food access and differentially affect people living closer to the stations.

2.2 Food environment, behavior surveys, and travel

Community food access has commonly been measured spatially, assessing exposure using density measures or proximity measures of distance or time from home/residence (USDA ERS, 2009; Charreire, 2010). For example, 8-10 minutes from home to a supermarket by car was used as a proxy for access to a healthy diet in a methodological study that modeled travel time by mode (Burns & Inglis, 2007).

Many studies use home-based exposures as the point of analysis for spatial access, but this approach has some issues. How the neighborhood is defined changes the exposure to food outlets, and these may not correspond to individual travel patterns (Liu, 2015; Lyseen, 2015). People may not always be traveling directly from home to a grocery store, and the American Time Use Survey (ATUS) 2003-2007 found that about 64% of trips to grocery stores were from home to store and back, while 28% were clustered around other activities and travel to or from home, and 8% around work (USDA ERS, 2009). Also, the amount of time spent at home may be an important variable that affects the relationship between home-based exposure and behavior (Chum, 2015). Proximity is limited as a measure because people may not shop at the store that is closest to where they live. The National Household Food Acquisition and Purchase Survey (FoodAPS) 2012-2013 found that the usual store for grocery shopping is farther than the nearest SNAP-authorized supermarket or supercenter for the average household overall, households who do not drive their own vehicle, and for SNAP households (Ver Ploeg, 2015). Data from Seattle also suggests that the home food environment may not be directly correlated with behaviors or health outcomes. Researchers reported that the majority of people did not primarily shop at their nearest supermarket, and those shopping at low-cost supermarkets were more likely to travel further from home. Furthermore, fruit and vegetable consumption and obesity were both associated with the type of supermarket where the shopping occurred, rather than its physical distance from home. (Aggarwal, 2014; Drewnowski, 2014)

There has therefore been increased attention on environmental exposures beyond the home, such as along commuting journeys between home and work locations (Burgoine, 2013; Burgoine, 2014) or in "activity spaces" using GPS tracking or travel surveys that record a person's set of visited places (Kestens, 2010; Zenk, 2011; Christian, 2012; Kestens, 2012). These studies, which took place in cities from three different countries (Canada, US, UK), found that residential and activity-based food environments were different or weakly correlated. Findings were not consistent as to whether activity-based food environments vary by individual characteristics. They reported some associations between food environment exposure and food intake or obesity, but using different measures of store exposure and behavior. Studies differed on whether associations were modified by gender (Kestens, 2012; Burgoine, 2014). Activity-based food environments may better capture individual travel patterns, but these studies also face limitations of defining the environment, self-selection bias, and issues with level of exposure dependent on time constraints or mode of transportation. More advanced models of space-time access build in time constraints considering individual travel and time budgets (Widener, 2013; Horner & Wood, 2014) or store hours of operation (Chen & Clark, 2013).

While environment remains the focus of community food access studies, travel surveys are also useful for studying the food-related trips themselves. They have the advantage of recording individual-reported trips over modeled trips based on ecological measures, and also provide more detail into travel patterns than behavior surveys. This tool is utilized in the present study to analyze food shopping trips overall and average trip characteristics by person. Behavior surveys, however, may better capture person-level characteristics about "primary" shopping or the overall frequency of shopping.

Two recent travel diary studies about trip characteristics used distance to food store as the primary outcome. Kerr et al. used a two-day travel diary to analyze food shopping trips among 4800 adults in Atlanta and found an average distance traveled of 4.7 miles to the grocery store from previous recorded location. Distance traveled was related to type of store, route (home-work-food combinations, or "tour type"), day of week, and ethnicity. The distance was longer to superstores than grocery stores, on tours with differing origins and destinations, and on non-work days. Participants with the lowest income, non-Whites, and those without degrees traveled farther. (Kerr, 2012) In the present study, the relationship between time and store or route are also analyzed, though using a different typology. Day of the week and ethnicity are not, but it is recognized from the previous findings that these factors could be influential since time may be related to distance. The more neighborhood environment-focused study by Liu et al. used a seven-day travel diary and GPS tracking for 135 participants in five US cities. The average distance from home to grocery stores was 1.9 miles while the median distance was 0.4 miles. (Liu, 2015)

Neither travel diary study reported mode of transportation. Some data on mode is available from FoodAPS data, which reports that 68% of SNAP households use their own vehicle, 19% use someone else's, and 13% walk, bike, or take public transit or shuttle to their usual store. In contrast, 95% of higher income, nonparticipating households use their own vehicle. The distance to primary store was 3.8 miles for households overall, 4 miles for own vehicle, 3.4 for someone else's vehicle, and 0.92 for walk, bike, or transit. (Ver Ploeg, 2015) Analyses of transportation mode from ATUS 2003-2007 data showed that those who lived closest to grocery stores were more likely to walk or bike. USDA ERS defines low access as a distance greater than 1 mile for walking and 20 miles driving, medium access as a distance between 0.5 and 1 mile for walking and 10 to 20 miles driving, and high access as a distance less than 0.5 mile for walking and 10 miles driving. People with low access were most likely to drive (93.3%) compared to medium access (87.1%) and high access (65.3%). Only 0.3% of shoppers used public transportation. For low-income areas, percentage ranged from 0.1% in low access areas to 1.9% in high access areas. (USDA ERS, 2009)

In summary, the community food access literature to date has measured environmental exposures around homes and activity spaces, factoring in mode of transportation when it is considered by adjusting the exposure radius. It is recognized from behavior surveys that home environment does not necessarily correspond with travel. Travel diary studies analyzing trip characteristics as opposed to environment are not as common and have used distance to store as the measure of access. National surveys provide some data on the use of transportation mode for food shopping. The present study adds to the travel diary literature and to locally relevant data.

Though time is subject to reporting errors, one advantage of using time over distance is that the time is recorded from the actual trip while distance is calculated between two points, which does not account for discrepancies such as actual route taken or travel delays. Trips are analyzed as two-way, which provides more information to and from stores. This study is also unique in understanding travel through differences by transportation mode. It uses a seven-day travel diary to analyze food shopping trips from Seattle residents by mode, using travel time as the primary outcome. Type of store and route are also considered in combination with mode.

2.3 Time use

Modeled time can be a measure of proximity for food access in the food environment literature, but from an economic standpoint, time is a resource that must be spent and factors into travel and food costs. It should also be noted that there are other frameworks that play a role in time and food choice such as psychosocial and life course perspectives (Jabs & Devine, 2006). From an economic perspective that uses the theory of household production, individuals choose a mix of time and purchased goods (food products) to maximize well-being and minimize cost (Möser, 2010).

Analyses of time use studies for food shopping have separated shopping time from travel time. Based on data from ATUS, which records grocery shopping as an activity in a telephone survey of the previous day’s activities, the average hours spent purchasing groceries among people aged 15 or older (civilian, non-institutionalized) has been fairly constant (average 0.76 hours per day for those who engaged in the activity for 2008-2013). In 2013, the average was 0.75 hours, but it was 0.65 for men and 0.81 for women. The survey also found a difference in weekday (0.7) versus weekend/holiday (0.84). (Bureau of Labor Statistics) According to a study using four national time diary surveys from 1975 to 2006, grocery shopping time slightly increased (Zick & Stevens, 2009).

USDA ERS has also analyzed ATUS data for travel time. Using 2003-2007 data, the national average for one-way travel to a grocery store was about 15 minutes. People living in low-income areas with low access spent more time (19.5 minutes). Both people with and without low income in those areas spent about the same amount of time. However, people with low income in low-income areas with medium or high access took more time to get to the store than those who did not have low income. (USDA ERS, 2009) According to NHANES 2007-2010 data, 14% of SNAP participants and low-income non-SNAP participants reported that it took more than 30 minutes to get to a grocery store, compared to 8% of higher income shoppers (USDA ERS, 2014).

This study uses time measures of travel time, stay time, total time, and "travel time ratio" (relationship between travel and total time, which is actually a proportion). The stay time, or time spent in the store, is the most straightforward to get from travel diaries, while travel time is more difficult to assess. Dijst & Vidakovic posit travel time ratio as a measure of spatial reach, the set of activity spaces that a person can choose as a destination at an acceptable time cost. The ratio may be stable for similar types of activity places. Using a 1992 Dutch three-day travel diary study, they reported that 37% of time for grocery shopping was spent on traveling. (Dijst & Vidakovic, 2000) Other papers discussing the travel time ratio describe the notion that individuals may have a planned or desired value, and people may accept higher ratios when traveling by public transport compared to car (Mokhtarian & Chen, 2004; Lyons & Urry, 2005).

3. AIMS & HYPOTHESES

The first aim is to describe food shopping trips and compare characteristics by mode from both trip and person-level perspectives. The trip characteristics are time, route (defined by home and non-home locations before and after the store), and store type (supermarket or other). The primary outcome is travel time by transportation mode. Trips are additionally aggregated to the individual to study trip characteristics across individuals. Person-level variables are the number per week and percentage of trips taken by mode and categorization of individuals by primary shopping mode. Average travel time by mode is also compared. We hypothesize that most characteristics will vary by mode, but travel time may be about the same.

The second aim is to assess how the introduction of the light rail infrastructure influenced food shopping trip and person-level characteristics, comparing trips by individuals between phases and between cases and controls. The overall food environment in Seattle is unlikely to have changed before and after construction of the light rail for a variety of reasons, particularly the economic recession of December 2007-June 2009, but this public transportation infrastructure could have potentially changed overall mobility patterns and resulted in increased traffic to existing businesses near the stations. Consequently, food store exposure and accessibility for individuals could have changed. We hypothesize that there will be more trips associated with light rail for the cases (who live closer to stations) compared to the controls and that these may have a lower travel time than other transit trips because light rail may be faster and run more frequently and regularly. There may also be shifts in mode distribution and in trip characteristics by mode corresponding to altered mobility patterns.

The findings from this study may increase our understanding of food shopping behaviors in the region, specifically related to the time aspect of food access and differences by travel mode. The findings may also have implications for alterations to the built environment via access to light rail, and impacts on food shopping behaviors.

4. METHODS

4.1 THE TRAC STUDY

Data from food shopping trips were collected in the TRAC study. Methods are described in detail elsewhere (Kang, 2013; Hurvitz, 2014; Saelens, 2014). This is a longitudinal study with the primary aim to assess changes in walking behavior after the opening of the light rail system in July 2009. The current secondary analysis uses data collected in Phases 1 and 2. In Phase 1, 750 adults in the greater Seattle area were recruited from July 2008 to July 2009. Participants resided proximal (<1 airline mile, "cases") or distal (>1 airline mile, "controls") from future light rail stops, but they lived in areas with similar built environment characteristics (e.g., residential density, housing type, home values, bus transit access, and proximity to a neighborhood retail center defined by at least 1 grocery store, 1 restaurant, and 1 other retail store in close proximity to one another) and similar census-based demographic characteristics (household income and race/ethnicity). Eligibility criteria for individual participants were (1) at least 20 years of age, (2) able to complete travel log and survey in English, and (3) able to walk unassisted for at least 10 minutes. The study was approved by the Seattle Children's IRB.

Participants were provided with and instructed to wear a hip-mounted accelerometer, carry a GPS unit, and record their travel in a paper-based diary for seven consecutive days. For the travel diary, they were instructed to record places visited, activities, arrival and departure times, and travel modes for all daily destinations. Participants were asked to re-wear instruments and complete additional travel diaries up to two additional times until their data met data screening criteria (at least 5 days with any GPS data, 6 days with any data in travel diary, and 6 days with accelerometry data greater than 8 hours). Phase 2 took place from July 2010 to 2011 using the same methods. 706 participants completed Phase 1 and 595 participants completed Phase 2.

4.2 Food shopping trips

In Phase 1, there was an activity code in the travel diary that participants could select for shopping, but this was not specific to food shopping. In order to identify only those trips that were food shopping, food stores were identified by filtering for the activity code for shopping and then using the destination names and systematically determining whether the destination name was a food store. If the store was known to sell both food and non-food items (e.g., a drug store or warehouse club), it was classified as food shopping if in Phase 2 more than half of those stores were identified by a food shopping activity code as opposed to non-food. In Phase 2, participants were provided a food shopping activity code separate from other types of shopping in the travel diary. As with Phase 1, the trip was considered a food shopping trip only if store could be classified based on the recorded name. Trips were constructed using three locations: the previous destination, food store, and subsequent destination. Locations that participants assigned a transfer activity code (waiting or changing modes for transportation) were considered transfers and not destinations. Gas stations were considered a “transfer” for automobiles since this is a transportation-related stop and not a destination. For example, if the trip was home-gas station-store-home, it was considered a home-store-home trip. Trips with multiple food stores were divided into separate trips per store for analysis. Trips were eliminated from analysis if they were missing arrival or departure times or if mode was not reported or could not be ascertained. In Phase 1, 300 controls and 278 cases recorded food shopping trips. In Phase 2, there were 228 controls and 229 cases. Only people with food shopping trips in both phases were included, resulting in 200 controls and 187 cases in the final sample.

4.3 Travel time and transportation mode

There have been various ways of analyzing trips in the literature. Kerr et al, which analyzed distance, used the previous location as the origin (Kerr, 2012). USDA ERS analysis of ATUS had a more complicated methodology. Time was counted from previous location unless the respondent was subsequently traveling home. To deal with trip chaining (e.g., trips stringing together multiple activities; for example, a home-store-coffee shop-work-home trip), they added all legs of travel from home to the grocery store and from the grocery store to home, and chose the shorter total time. Mode of transportation was assigned based on the shorter travel side. (USDA ERS, 2009) The methodology by Dijst & Vidakovic was yet more complex. Four types of bases (home, work address, person's relatives, and person's friends) were determined. Travel time spent on the activity places was calculated by subtracting from the total time the travel time needed for a direct trip between the bases. Travel time was allocated proportional to the stay time in activity places. (Dijst & Vidakovic, 2000)

Although simplicity was a key factor in deciding on the methodology for the present study, transportation mode and the associated time for both legs (i.e., to and from food stores) of the trip were important. Travel time was calculated as the sum of the time from previous location to store and from store to subsequent location. Transfer time was included in the travel time. For trips in which there were multiple food stores visited consecutively, total travel time was divided evenly between stores and analyzed as multiple trips. For example, for a home-store 1-store 2-home trip, the total travel time from the three legs would be divided in half and assigned to two trips, home-store 1-home and home-store 2-home. 148 stores (12.7%) in Phase 1 and 141 stores (13%) in Phase 2 were in such multiple store trip chains. Dealing with trip chaining is controversial, but this method was adopted to avoid double counting the time and to use one store per trip as a standard.

Stay time was calculated from travel diaries as the time spent in the store, and total time (travel time plus stay time) and travel time ratio (travel time divided by total time) were derived from the travel and stay times. Trips with travel time greater than 3 hours were excluded from analysis based on boxplot visualization of the distribution (7 trips, though one of these trips dropped also resulted in the subject then being excluded). One trip with a stay time over 15 hours was also dropped (and the subject was then excluded as well).

Transportation mode was identified using the mode recorded in the travel diary. A trip was classified as walking or biking only if both legs of the trip were recorded as walking or biking. If either leg involved transit, the trip mode was classified as transit. The mode categories were therefore: Auto (auto/truck/van, car/vanpool, dial-a-ride/paratransit, taxi/shuttle bus/limousine, motorcycle), Transit (bus, monorail/trolley, light rail), Walking or biking only. Paratransit may be considered a specialized form of public transportation, but it was classified as Auto here because of its similarities to taxis and shuttles, limiting the Transit category to fixed route services. Transit trips where applicable were categorized as involving light rail. Ferry trips were excluded because it was assumed that the time involved in these trips would not be dominantly linked with food shopping, so the location before or after the store was counted as the ferry terminal.

4.4 Store and route type

Food stores were classified as supermarkets using names and classifications provided by Urban Form Lab. 2008 and 2012 food permits were used to correspond with the time of data collection for this study. Methodology behind this classification is described by Vernez Moudon, 2013. Supermarkets were defined as “nationally or regionally recognized chain establishments… primarily engaged in retailing a general line of food, such as canned and frozen foods; fresh fruits and vegetables; and fresh and prepared meats, fish, and poultry”. These were considered distinct from “grocery stores”, which were “independently owned stores selling a line of dry grocery, canned goods or nonfood items plus some perishable items”. Web searches were also used in making and verifying classifications. Discrepancies from the Urban Form Lab classifications were: stores that predominantly sell beverages were not included as food shopping here even if they were classified as a specialty food store; and Sam’s Club was considered a warehouse club, not a supermarket. Supermarket versus other store is used here as a dichotomous variable. Though supermarkets have limitations as a proxy for healthy foods (Ver Ploeg, 2012; Christian, 2012), they have been used in the literature as a marker for healthy food access because of the variety and price of foods offered (Burns & Inglis, 2007; Kestens, 2012).

Route type was based on four combinations of the previous and subsequent location classified as “home” or “other” (i.e., home-store-home, home-store-other, other-store-home, other-store-other). For trips with multiple food stores, the locations on either end of the chain of food stores were used to classify the route type for all the stores.

4.5 Primary shopping mode

People were classified as primarily using a particular transportation mode for food shopping to analyze mix of mode usage at the person-level. Two schemes were considered. In the first, people were classified according to the highest percentage. If the percentage of walk/bike was tied with either auto or transit for the highest, the person was considered an auto or transit shopper assuming that at least one of the walk/bike trips would be closely associated with either auto or transit (ex. 20% auto, 40% walk/bike, 40% transit = transit shopper). If the percentage of auto and transit was equal, they were considered a mixed user. The second scheme was a majority only rule, with everyone whose mode percentages were all under 50% considered a mixed shopper.

4.6 Analyses

Demographic factors were compared between cases and controls using chi-square tests: age, gender, race, education, household size, vehicles in household, household income, and employment status.

The trip-level variables of interest were 1) Mode distribution, 2) Percentage of store type and route type by mode, 3) Time measures by mode, store type, and route type, and 4) Time measures further broken down by route type and store type within modes. Trip-level variables were analyzed descriptively for trips overall and between phases and by case/control. It is subjective what constitutes a substantial or meaningful difference in travel time for each mode, but to create a somewhat objective standard, 25% of the overall travel time per mode was used to indicate a difference in travel time between phases or by case/control (5 min for auto, 4.3 min for walk/bike, and 10.6 min for transit).

The person-level variables analyzed were 1) Number of food shopping trips per week and percentage of trips by mode, 2) Classification by primary shopping mode, 3) Average travel time by mode, and 4) Average travel time by primary shopper of a mode. Person-level variables were compared between phases and case/control, and also between cases and controls within each phase. The trips per week between phases were explored by paired t-test, and between case/control by t-test. For primary shopping mode, McNemar’s test was used between phases to gauge the change in categories. Chi-square test was used to compare the distribution of primary shopping mode for case/control. Paired t-test was used to compare average travel time by mode between phases, so people who did not use the same mode in both phases were excluded for the analysis of that mode. T-tests were used for case comparisons for both average travel time per person and per primary shopping mode. A Bonferroni correction (significance level of 0.05 divided by 3, P=0.0167) was used in comparing the three mode types to lessen the probability of Type I error from conducting multiple tests that contribute to one scientific question. All P-values were for two-sided tests. Descriptive analyses only were included for percentage of trips by mode and phase effect of average travel time for primary shopping mode because it was determined that statistical tests would not be appropriate. Comparing the proportion of trips by one mode ignores changes in proportions for other modes, and primary shopping mode could change between phases. Analyses were performed using Stata 12.

5. RESULTS

5.1 DEMOGRAPHICS

There were 387 people in the analyses, though 6 did not complete surveys providing demographic information [Table 1]. There were 200 controls and 187 cases. The mean age was 50 years. About two-thirds of the sample were female. The sample was over 80% White. Cases had a significantly lower proportion of Whites (79%) than did controls (87%) (P=0.02). There were higher proportions of African American or Black participants (6% vs 3%) and more than one race specified (5.5% vs 2.5%) for cases versus controls.

Most households were one-person households (41%), but about a third had one other person in the households and a quarter had more. About three-quarters (76%) did not have children. About 85% of the subjects owned one motor vehicle or more. Mean household incomes were distributed as follows: \$0-\$50,000 (36%); \$50,000-\$100,000 (43%) and >\$100,000 (21%). Three-quarters had completed college or more.

Answers regarding employment status were more frequently missing likely due to people leaving the question blank if not applicable, so percentages may be higher than actual. Considering only those who responded to the question about work, a little more than half of the subjects (54%) did paid work full time. About a third (30%) did paid work part time. Cases were slightly less likely to work part time (27% vs. 34%). About a quarter of the sample were retired, with a significantly higher proportion of cases (32%) than controls (21%) (P=0.03).

Compared to census data for Seattle, the sample had more females, was less racially diverse (70% White, 2010) and more educated (58% of persons age 25+ with Bachelor's degree or higher, 2010-2014). The median household income of the city is about $67,000 (2010-2014), and this sample appears to be about the same. However, the number of people per household in the city is 2.11 but for the sample is between 1 and 2, which translates to more income per household member in the sample. Household motor vehicle ownership for Seattle in 2014 was 83.7% overall, 95.8% for owner-occupied housing, and 73.3% for renter-occupied housing. The overall ownership percentage is similar to this sample. (Census Bureau)

Table 1. Demographics

	Total	**Controls**	**Cases**
		N (%)	
Subjects	387	200 (51.7)	187 (48.3)
Total surveys	**381 (98.5)**	**199 (99.5)**	**182 (97.3)**
Missing surveys	6 (1.6)	1 (0.5)	5 (2.7)
Age[1]			
≤ 50 years old	185 (48.7)	98 (49.3)	87 (48.1)
> 50 years old	195 (51.3)	101 (50.8)	94 (51.9)
Gender			
Male	124 (32.6)	62 (31.2)	62 (34.1)
Female	257 (67.5)	137 (68.8)	120 (65.9)
Race			
Caucasian or White	317 (83.2)	174 (87.4)	143 (78.6)
Other	64 (16.8)	25 (12.6)	39 (21.4)
Education			
Some college or vocational training or less (<16y)	96 (25.2)	50 (25.1)	46 (25.3)
Completed college/university (=16 y)	143 (37.5)	72 (36.2)	71 (39)
Completed graduate degree (>16 y)	142 (37.3)	77 (38.7)	65 (35.7)
Number in household			

1	156 (40.9)	85 (42.7)	71 (39)
2	127 (33.3)	65 (32.7)	62 (34.1)
3 or more	98 (25.7)	49 (24.6)	49 (26.9)
Number of children (under 18) in household[2]			
0	288 (76)	151 (76.3)	137 (75.7)
1 or more	91 (24)	47 (23.7)	44 (24.3)
Number of drivable motor vehicles in household			
0	57 (15)	28 (14.1)	29 (15.9)
1	165 (43.3)	88 (44.2)	77 (42.3)
2 or more	159 (41.7)	83 (41.7)	76 (41.8)
Approximate annual household income[3]			
$0-$50,000	133 (35.6)	72 (37.1)	61 (33.9)
$50,000-$100,000	161 (43)	82 (42.3)	79 (43.9)
>$100,000	80 (21.4)	40 (20.6)	40 (22.2)
You do paid work full time[4]			
Yes	185 (53.9)	98 (55.4)	87 (52.4)
No	158 (46)	79 (44.6)	79 (47.6)
You do paid work part time[5]			
Yes	102 (30.4)	59 (33.5)	43 (26.9)
No	234 (69.6)	117 (66.5)	117 (73.1)
You are retired[6]			
Yes	88 (26.4)	37 (21.4)	51 (31.9)
No	245 (73.6)	136 (78.6)	109 (68.1)

1. *N=380, 199 controls, 181 cases*
2. *N=379, 198 controls, 181 cases*
3. *N=374, 194 controls, 180 cases*
4. *N=343, 177 controls, 166 cases*
5. *N=336, 176 controls, 160 cases*
6. *N=333, 173 controls, 160 cases*

5.2 Trip-level data

5.2.1 *Trips overall*

There were a total of 2247 food shopping trips undertaken by 387 people across both phases [Table 2]. 1584 (70.5%) were taken by car. Walk/bike accounted for 474 trips (21.1%), whereas transit accounted for 189 trips (8.4%).

Table 2. Food shopping trip-level characteristics

		Travel		Stay		Total		Ratio	
	N (%)	**Med Mean (SD), minutes**							
Total	2247 (100)	20	25.8 (20.9)	17	22.4 (18.9)	40	48.2 (30.3)	0.54	0.54 (0.2)
Mode									
Auto	1584 (70.5)	20	24 (18.3)	20	24.7 (19.6)	41.4	48.7 (29.2)	0.5	0.51 (0.19)
Walk/bike	474 (21.1)	17	22.2 (20)	11	15.7 (14.9)	32	38 (26.8)	0.6	0.58 (0.21)
Transit	189 (8.4)	42.5	50.1 (27.2)	15	19.7 (18)	61	69.0 (34.8)	0.77	0.72 (0.17)
Route									
H-s-H	564 (25.1)	18	24 (21.4)	20	24.4 (20.5)	39	48.4 (31.7)	0.49	0.5 (0.21)
O-s-H	904 (40.2)	23	27.3 (19.9)	17	22.6 (18.9)	43	50 (29.2)	0.56	0.55 (0.19)
H-s-O	270 (12)	21	27.3 (21.3)	14	20.4 (20.1)	39.5	47.8 (33)	0.63	0.6 (0.2)
O-s-O	509 (22.7)	19	24.2 (21.7)	15	20.8 (16.3)	38	45 (28.8)	0.51	0.53 (0.21)
Store									
Supermarket	1552 (69.1)	20	25.3 (20.9)	17	22.4 (18)	40	47.7 (29.7)	0.53	0.53 (0.2)
Other	695 (30.9)	22	26.9 (20.9)	15	22.3 (20.9)	40.5	49.2 (31.5)	0.56	0.57 (0.21)
Mode & Route									
Auto & HH	332 (14.8)	16.8	21 (16.5)	24	27.9 (21.7)	40	49 (29.9)	0.42	0.45 (0.19)
Auto & Other	1252 (55.7)	20	24.8 (18.7)	20	23.8 (18.9)	42	48.6 (29)	0.51	0.52 (0.19)
Walk/bike & HH	194 (8.6)	17	23 (20.3)	15	18.3 (17.1)	35	41.4 (29.4)	0.57	0.54 (0.21)
Walk/bike & Other	280 (12.5)	17	21.7 (19.7)	10	13.9 (13)	30	35.6 (24.5)	0.63	0.6 (0.2)
Transit & HH	38 (1.7)	46.3	55.5 (35.9)	19	24 (18)	70	79.4 (39.3)	0.71	0.67 (0.2)
Transit & Other	151 (6.7)	42	48.9 (24.6)	13	18.7 (17.9)	60	67.4 (33.3)	0.78	0.73 (0.16)
Mode & Store									
Auto & SM	1125 (50.1)	20	23.4 (18)	20	24.2 (18.3)	41	47.6 (27.9)	0.5	0.5 (0.19)

Auto & Other	459 (20.4)	21	25.4 (19.1)	20	25.8 (22.5)	44	51.3 (32.2)	0.5	0.53 (0.2)
Walk/bike & SM	316 (14.1)	16.5	22.9 (21.7)	12	16.1 (15.1)	32	39 (28.3)	0.58	0.57 (0.21)
Walk/bike & Other	158 (7)	18	21 (15.6)	10	14.9 (14.5)	30	35.9 (23.3)	0.62	0.6 (0.21)
Transit & SM	111 (4.9)	43	51.8 (27.2)	16	22 (18.5)	65	73.8 (36.1)	0.73	0.7 (0.16)
Transit & Other	78 (3.5)	39	47.7 (27.2)	10.5	16.5 (16.8)	56	64.2 (32.3)	0.8	0.74 (0.18)

Absolute time measures were generally positively skewed, but time ratio was more evenly distributed [Figure 1]. Therefore, medians will be reported for time measures.

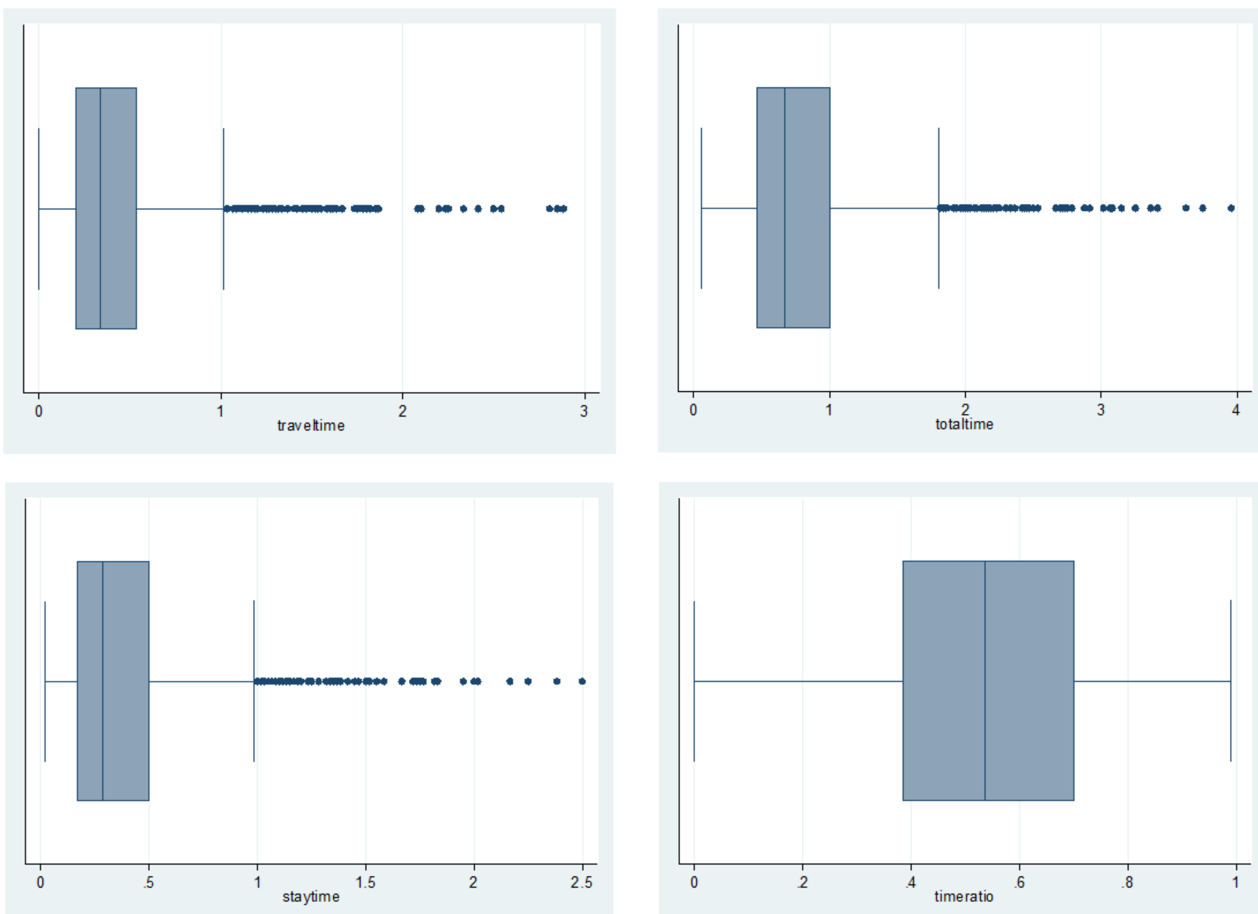

Figure 1. Distribution of time measures overall, in hours

Auto trips and walk/bike trips to food stores had shorter median travel times (20 vs 17 min) than did transit trips (43 min) [Figure 2]. Median stay (i.e., shopping) times ranged from 11 min (walk/bike) to 20 min (auto). Total times (travel and stay) were lowest for walk/bike (32 min), followed by auto (41 min), then transit (61 min). Time ratio (travel divided by total) was also higher for transit than for the other travel modes (0.77 vs 0.6 for walk/bike and 0.5 for auto).

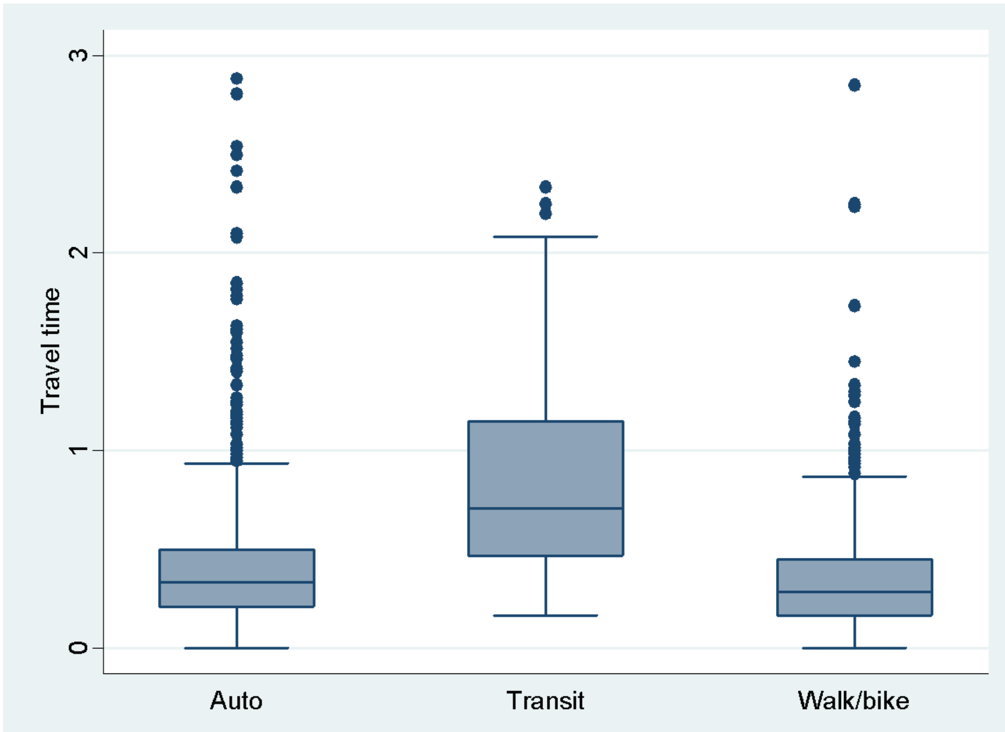

Figure 2. Travel time by mode

Most of the trips (69%) were taken to the supermarket and 31% to other food stores. Time measures were similar between store types. Home-home routes comprised 25% of all trips. For 65% of all trips, a trip to a food store was followed by going immediately home. In 23% of cases, a food store was between two non-home locations. People went from home to food store and then someplace else for 12% of trips.

Within modes, home-home routes were compared to all other types of routes. The division between routes was 20% home-home and 80% other routes for both auto and transit, but was 41% to 59% for walk/bike. Half of the travel time on a home-home route gives an estimate of how far (in time) the stores are located from home for those routes, which was about 9 min for auto or walk/bike, and 23 min for transit. Travel times were similar between route types for all modes, but stay times were slightly higher for home-home trips. Consequently, time ratios were somewhat lower for home-home trips across all modes and there were higher total times for walk/bike (35 vs 30 min) and transit home-home trips (70 vs 60 min).

Store type was also compared within modes. Supermarkets comprised 71% of auto trips, 67% of walk/bike trips, and 59% of transit trips. Travel times were again about the same between store types for each mode. For transit, total times were slightly higher for supermarkets (65 vs 56 min) and time ratio slightly lower (0.73 vs 0.8) than for other types of stores.

5.2.2 *Light rail*

Only eight food shopping trips were reported as involving light rail, though one of these took place in Phase 1 and is therefore disregarded as a light rail trip. All food shopping trips by light rail were by cases. None of the light rail food shopping trip routes were home-home; two were other-home and the rest were other-other. One was to a supermarket, and the rest were to other stores. The travel time for the seven trips was 34 min, stay time 11 min, total time 50 min, and time ratio 0.78. The number of trips is too few for robust comparisons, but these trips had lower median travel, stay, and total times than transit trips in Phase 1, but with a similar time ratio.

5.2.3 *Phase comparisons*

Out of 2247 total trips, 1161 (52%) were in Phase 1 while 1086 (48%) were in Phase 2 [Table 3a]. The distributions of trips by mode, store, and route type were generally similar between phases. There were slight shifts in walk/bike trip percentage (23% Phase 1, 19% Phase 2) and transit trip percentage (7% Phase 1, 10% Phase 2).

Within modes, more transit trips were in routes other than home-home in Phase 2 (86% vs 73%). In overall percentages, transit trips in other routes comprised 5% of total trips in Phase 1 versus 8% in Phase 2. More transit trips were to stores other than a supermarket in Phase 2 (48% vs 32%). In overall percentages, transit trips to other stores comprised 2% of total trips in Phase 1 versus 5% in Phase 2.

Median transit travel time for food shopping was lower in Phase 2 than Phase 1 (39 vs 50 min) [Table 3b, Figure 3a]. Figure 3a indicates that this trend in phase effect was similar for both controls and cases. Travel time was lower for transit home-home trips (33 vs 60 min) in Phase 2 versus Phase 1 while transit trips in other routes were similar between phases [Figure 3b]. Transit travel time was lower for other stores (37 vs 51 min) and also somewhat lower for supermarkets (40 vs 50 min) in Phase 2 versus Phase 1 [Figure 3c].

Table 3a. Phase and case comparisons for trip-level characteristics: Distribution

	Phase 1	Phase 2	Control	Case
	N (%)			
Total	1161 (52)	1086 (48.3)	1153 (51.3)	1094 (48.7)
Mode				
Auto	813 (70)	771 (71)	808 (70.1)	776 (70.9)
Walk/bike	265 (22.8)	209 (19.2)	242 (21)	232 (21.2)
Transit	83 (7.2)	106 (9.8)	103 (8.9)	86 (7.9)
Store				
Supermarket	808 (69.6)	744 (68.5)	863 (74.9)	689 (63)
Other store	353 (30.4)	342 (31.5)	290 (25.2)	405 (37)
Route				
H-s-H	296 (25.5)	268 (24.7)	282 (24.5)	282 (25.8)
O-s-H	466 (40.1)	438 (40.3)	484 (42)	420 (38.4)
H-s-O	124 (10.7)	146 (13.4)	138 (12)	132 (12.1)
O-s-O	275 (23.7)	234 (21.6)	249 (21.6)	260 (23.8)
Mode & Route				
Auto & HH	169 (14.6)	163 (15)	170 (14.7)	162 (14.8)
Auto & Other	644 (55.5)	608 (56)	638 (55.3)	614 (56.1)
Walk/bike & HH	105 (9)	89 (8.2)	98 (8.5)	96 (8.8)
Walk/bike & Other	160 (13.8)	120 (11.1)	144 (12.5)	136 (12.4)
Transit & HH	22 (1.9)	16 (1.5)	14 (1.2)	24 (2.2)
Transit & Other	61 (5.3)	90 (8.3)	89 (7.7)	62 (5.7)
Mode & Store				
Auto & SM	568 (48.9)	557 (51.3)	619 (53.7)	506 (46.3)
Auto & Other	245 (21.1)	214 (19.7)	189 (16.4)	270 (24.7)
Walk/bike & SM	184 (15.9)	132 (12.2)	178 (15.4)	138 (12.6)
Walk/bike & Other	81 (7)	77 (7.1)	64 (5.6)	94 (8.6)
Transit & SM	56 (4.8)	55 (5.1)	66 (5.7)	45 (4.1)
Transit & Other	27 (2.3)	51 (4.7)	37 (3.2)	41 (3.8)

Table 3b. Phase and case comparisons for trip-level characteristics: Travel time

	Phase 1		Phase 2		Control		Case	
	Med Mean (SD), minutes							
Total	20	25.6 (20.9)	20	26 (20.9)	20	25 (20.3)	20	26.7 (21.5)
Mode								
Auto	20	23.6 (17.9)	20	24.4 (18.8)	19.8	23.2 (18.3)	20	24.8 (18.3)
Walk/bike	18	23 (20.7)	16	21.2 (18.8)	16	19.9 (16.4)	19	24.6 (22.8)
Transit	50	54.4 (27.3)	39	46.8 (26.9)	47	50.7 (24.4)	39	49.4 (30.4)
Store								
Supermarket	20	25 (21.2)	20	25.7 (20.5)	19	24.2 (20.2)	20	26.6 (21.7)
Other store	22	27.1 (20.1)	21.3	26.7 (21.7)	22	27.2 (20.5)	21.5	26.7 (21.2)
Route								
H-s-H	18.3	24.5 (21.5)	17	23.5 (21.3)	16	21.3 (18.5)	20	26.7 (23.6)
O-s-H	23	27.2 (18.7)	22.8	27.5 (21)	23	27.4 (19.9)	23	27.3 (19.9)
H-s-O	20	25.7 (19.1)	22	28.8 (23)	20.5	27.1 (23.5)	21.5	27.6 (18.8)
O-s-O	18	24.2 (24.3)	20	24.3 (18.3)	18	23.2 (20.3)	20	25.2 (22.9)
Mode & Route								
Auto & HH	16	20 (14)	18	22.1 (18.7)	16	19.5 (15.8)	18	22.6 (17.1)
Auto & Other	20	24.4 (18.7)	20	25 (18.8)	20	24.2 (18.8)	20	25.3 (18.6)
Walk/bike & HH	19	23.1 (19.2)	15	23 (21.5)	15.5	20.8 (19.3)	20	25.3 (21)
Walk/bike & Other	18	23 (21.7)	17	19.9 (16.4)	16	19.4 (14.1)	18.5	24.1 (24)
Transit & HH	60.5	65.8 (33.5)	32.5	41.3 (35.1)	42.5	47.2 (25.1)	50	60.3 (40.6)
Transit & Other	44	50.2 (23.6)	40	47.8 (25.2)	48	51.3 (24.4)	39	45.2 (24.6)
Mode & Store								
Auto & SM	19	22.5 (17.9)	20	24.2 (18)	18	22.7 (18.7)	20	24.2 (17.1)
Auto & Other	22	25.9 (17.5)	20	24.9 (20.8)	22	25 (17.1)	21	25.7 (20.4)
Walk/bike & SM	18	23.7 (22.6)	15	21.7 (20.5)	15.5	20.2 (17.1)	19.5	26.3 (26.1)
Walk/bike & Other	19	21.5 (15.8)	17	20.4 (15.5)	17.5	19.4 (14.4)	19	22 (16.4)
Transit & SM	50	53.9 (26)	40	49.7 (28.5)	43.25	50 (23.1)	43	54.4 (32.4)
Transit & Other	51	55.2 (30.3)	37	43.7 (24.9)	52	51.9 (26.7)	34	43.9 (27.4)

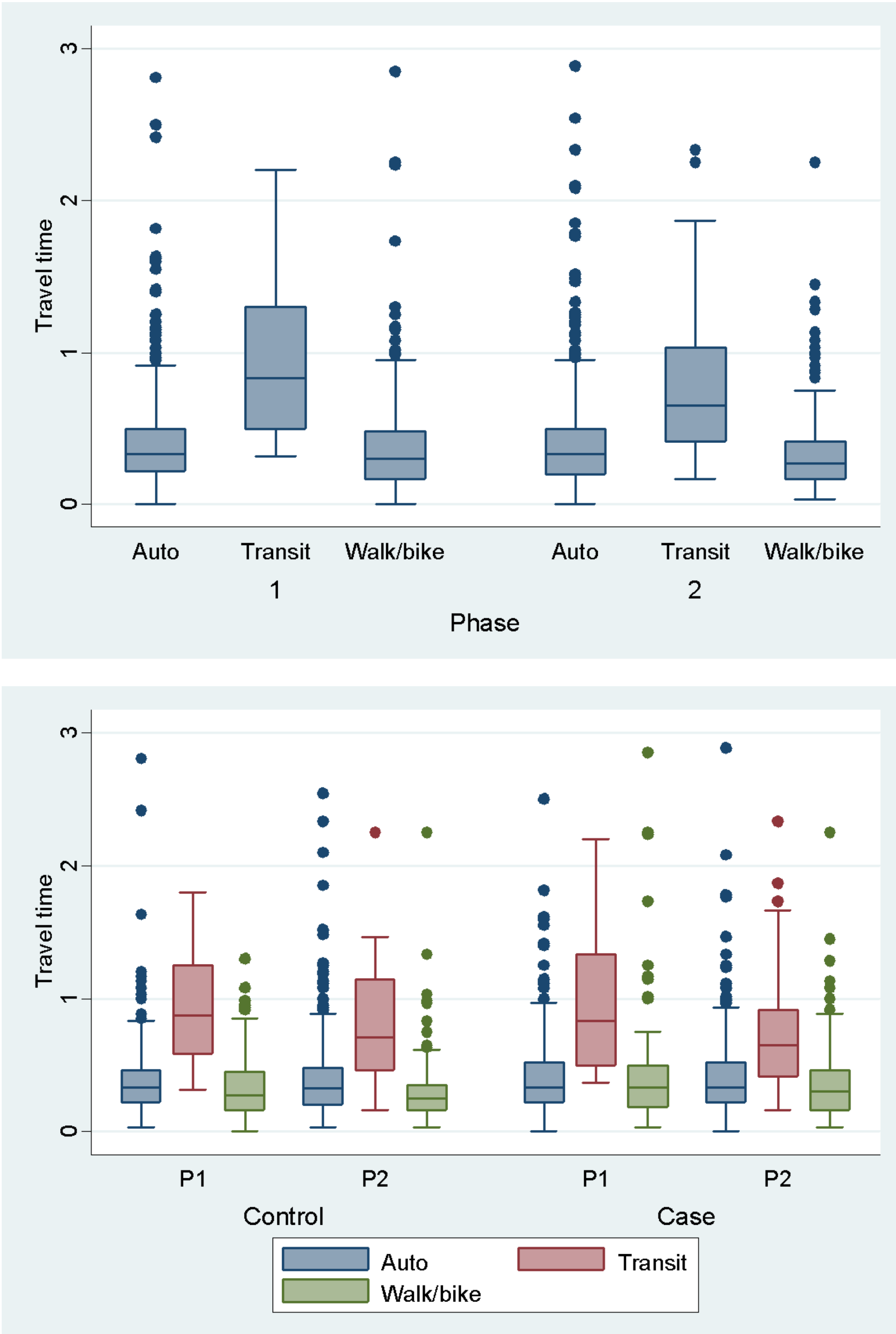

Figure 3a. Travel time by mode, Phase

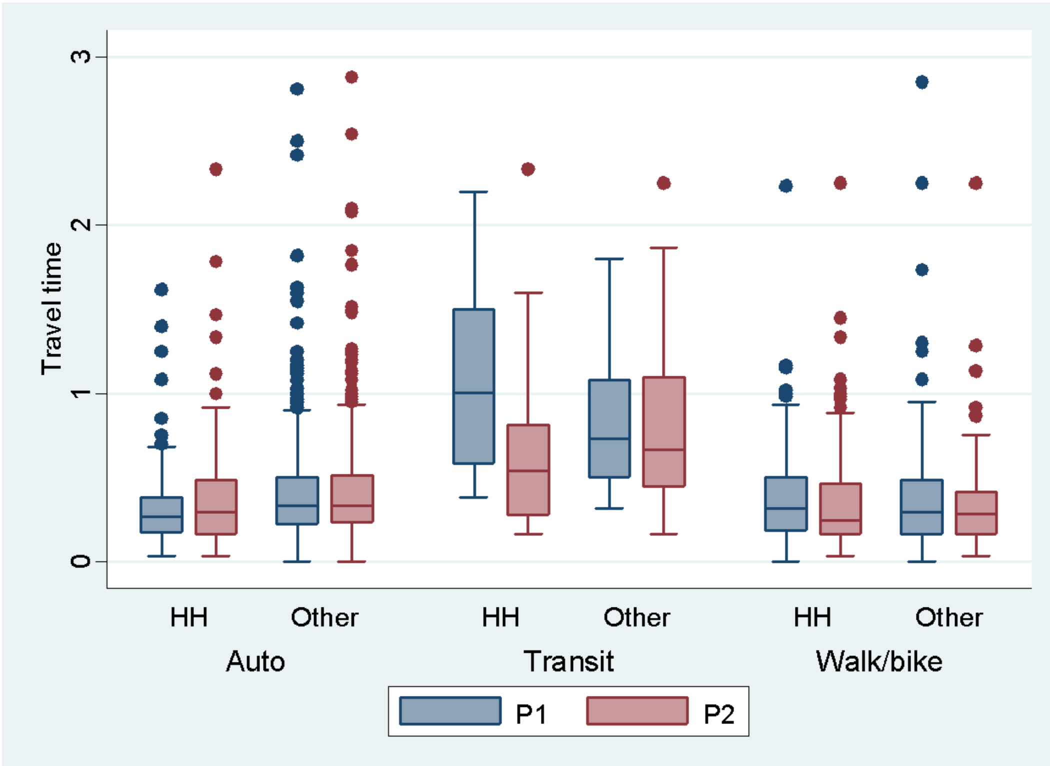

Figure 3b. Travel time by mode & route, Phase

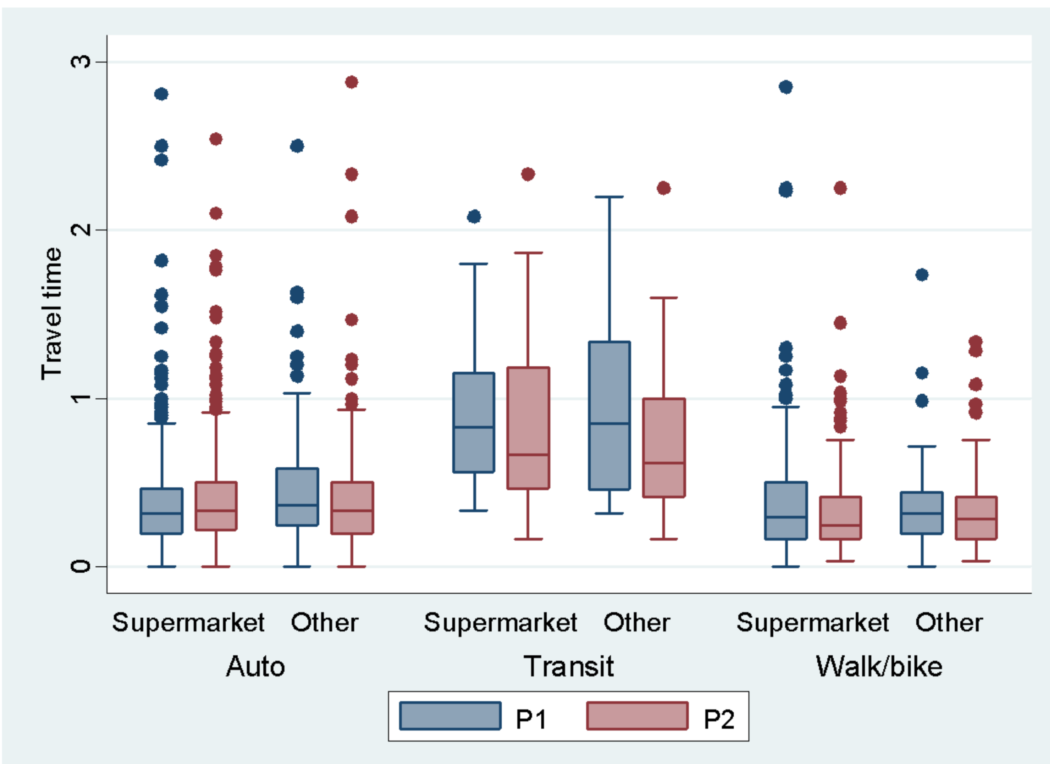

Figure 3c. Travel time by mode & store, Phase

Stay time (i.e., shopping time) was similar between phases. Transit total time was slightly lower in Phase 2 (57 vs 65 min). Total time was lower for transit home-home trips (61 vs 83 min). Transit time ratio for home-home trips was lower in Phase 2 (0.53 vs 0.74). Time ratios were the about the same for transit trips in other routes and for both store types.

5.2.4 *Case comparisons*

Out of 2247 total food shopping trips, 1094 (49%) were taken by cases and 1153 (51%) by controls [Table 3a]. Cases and controls were similar on most distribution measures, but fewer trips by cases were to supermarkets overall (63% vs 75%) and within each mode (65% vs. 77% Auto; 59% vs 74% Walk/bike; 48% vs 64% Transit. Overall percentages are less dramatic, but show that 25% of total case trips were auto trips to other stores, versus 16% of total control trips, and 9% of total case trips were transit trips to other stores, versus 6% of total control trips.

For routes, transit trips for cases were 73% on other routes, versus 86% for controls. In overall percentages, the trips on other routes were 6% for cases and 8% for controls.

For overall transit travel time, food shopping trip times for cases were slightly lower (39 vs 47 min). For trip combinations, walk/bike home-home trips had a higher time for cases (20 vs 15.5 min). Transit home-home trips had a slightly higher travel time for cases (50 vs 43 min), whereas trips on other routes had a slightly lower travel time for cases (39 vs 48 min). Transit trips to other stores had a lower travel time for cases (34 vs 52 min). [Table 3b, Figures 4 a-c] Figure 4a indicates that there was a trend toward slightly lower transit travel times and higher walk/bike travel times for cases in both phases.

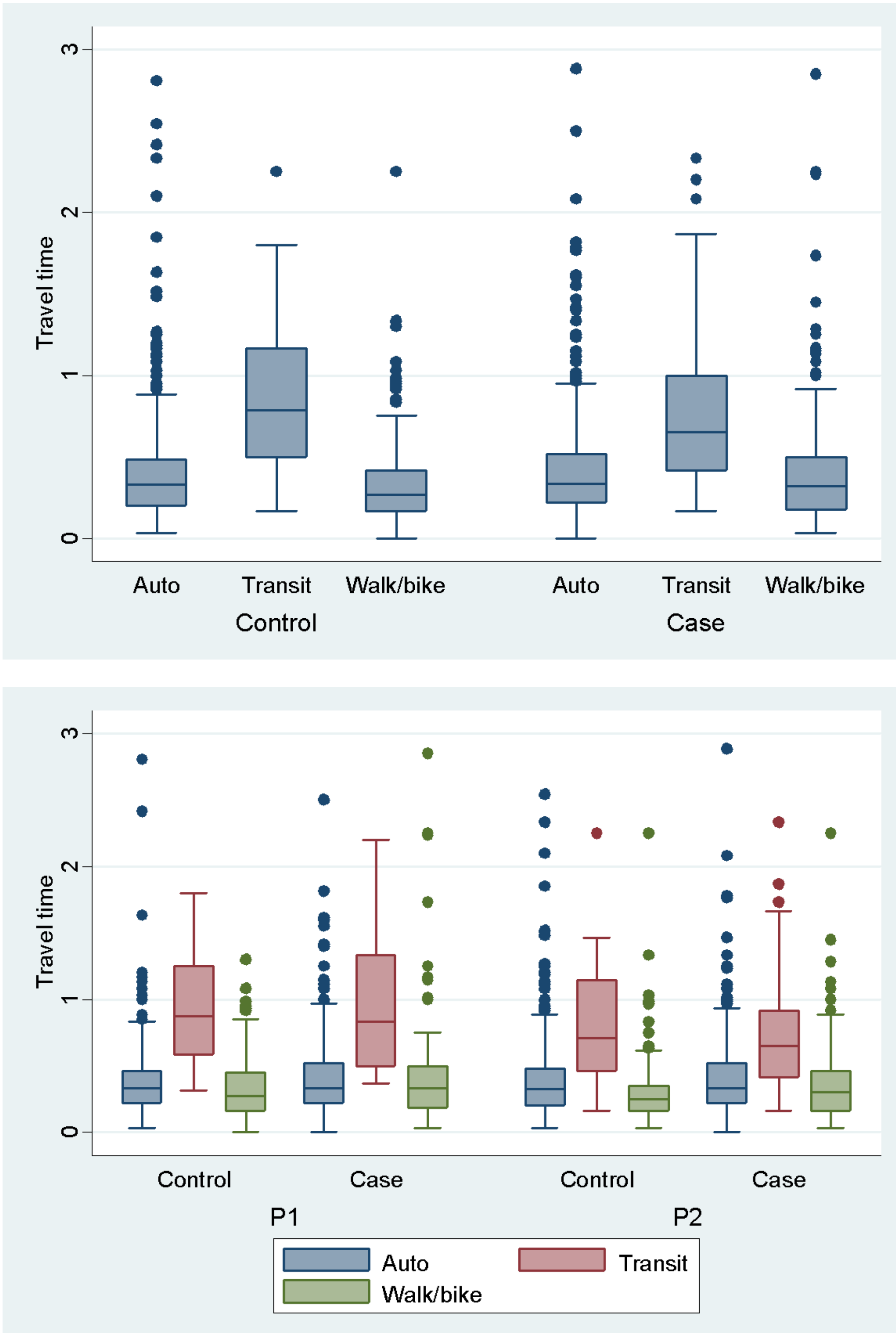

Figure 4a. Travel time by mode, Case

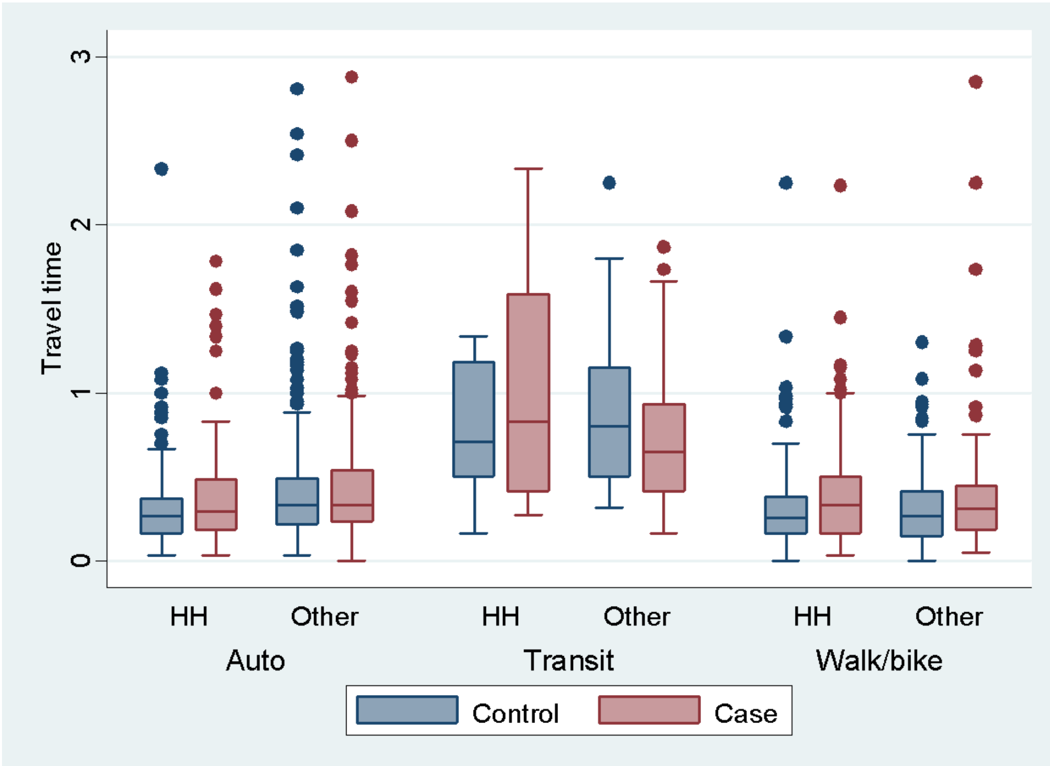

Figure 4b. Travel time by mode & route, Case

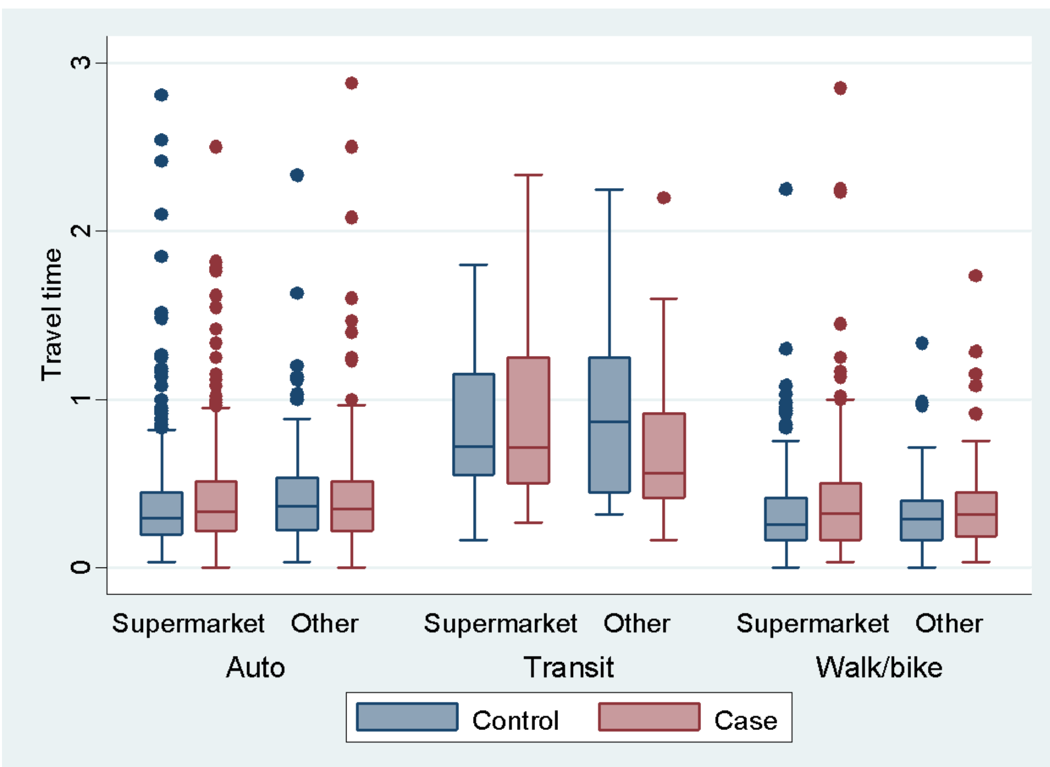

Figure 4c. Travel time by mode & store, Case

Stay times were lower for transit home-home trips for cases (16 vs 25 min), and higher for other routes for cases (18.5 vs 12 min). Total time was lower for cases for transit home-home trips (68 vs 83 min). The largest time ratio differences were for transit home-home trips, which was higher for cases (0.74 vs 0.58) and transit trips to other stores, which was lower for cases (0.69 vs 0.86).

5.3 Person-level data

The number of days of travel diary data had a median of 7 days and an average of approximately 7 days [Table 4], but the length of travel diary recording time varied among individuals. There was more range and variation of travel diary days in Phase 2, with a minimum of 2 days to a maximum of 16 days versus 5 to 9 days in Phase 1. The number of days did not appear to result in outliers for the number of food shopping trips, so all 387 participants were included for person-level analyses.

Table 4. Travel diary length in days

	Phase 1	**Phase 2**
Min	5	2
Max	9	16
Median	7	7
Mean	7.18	7.21
SD	0.57	1

5.3.1 *Number of trips per week and percentage of trips by mode*

People took an average of 2.93 food shopping trips per week in Phase 1 and 2.75 food shopping trips in Phase 2 [Table 5]. The number of trips per person could potentially be greater in Phase 1 because of the lack of a specific food shopping activity code, but no difference was found, which lends confidence to the validity of these comparisons. People in both phases took about 2 auto trips and 0.24 transit trips for food shopping on average. There were fewer walk/bike trips for food shopping on average in Phase 2 (0.52 vs 0.67, P=0.0103).

Table 5. Number of food shopping trips per week

	Overall	Phase 1	Phase 2	P-value	Control	Case	P-value
	Med Mean (SD), trips per week						
Trips	2.82 (1.35)	2.93 (1.78)	2.75 (1.69)	0.1174	2.8 (1.29)	2.85 (1.41)	0.7219
Auto	2 (1.41)	2.05 (1.75)	1.97 (1.64)	0.366	1.97 (1.36)	2.03 (1.46)	0.661
Walk/bike	0.59 (0.95)	0.67 (1.24)	0.52 (0.95)	0.0103	0.59 (0.95)	0.6 (0.96)	0.9303
Transit	0.23 (0.66)	0.21 (0.74)	0.26 (0.77)	0.1213	0.24 (0.68)	0.22 (0.64)	0.7372

The trends observed for the number of trips was similar when looking at the average percentage by mode of each person's trips [Table 6]. On average, the percentage of trips by mode were 72% auto, 20% walk/bike, and 8% transit. Walk/bike trips were a slightly lower percentage of trips in Phase 2 versus Phase 1 (19% vs 22%).

Table 6. Percentage of trips by mode

	Overall	Phase 1	Phase 2	Control	Case
	Mean (SD), percentage				
Auto	72.1 (35.7)	71.6 (39.5)	72.1 (39.6)	71.2 (36.1)	73 (35.4)
Walk/bike	20.1 (28.5)	21.6 (34.3)	18.7 (32.1)	20.5 (29)	19.6 (28.1)
Transit	7.9 (19.9)	6.8 (21.7)	9.3 (24.9)	8.3 (20.5)	7.4 (19.4)

Between cases and controls, no differences were found for number of food shopping trips or percentage of trips by mode. On average, both cases and controls took 3 trips total, 2 auto trips, 0.6 walk/bike trips, and 0.2 transit trips. No differences were found between cases and controls in either phase.

5.3.2 *Classification by primary shopping mode*

As described in the methods, there were two classification schemes used, the first assuming that some walk trips would be associated with transit or auto, and the second a simpler majority only. Using the first scheme, for trips overall, the breakdown was 78% auto, 14% walk/bike, 7% transit, and 1% mixed. With the second majority only scheme, the corresponding breakdown was 78%, 14%, 6%, and 2%. [Table 7a]

Table 7a. Primary shopping mode

	Overall	Phase 1	Phase 2	P-value[a]	Control	Case	P-value[b]
	N (%)						
	Scheme 1						
Auto	302 (78)	295 (76.2)	294 (76)	1	152 (76)	150 (80.2)	0.442
Walk/bike	54 (14)	65 (16.8)	52 (13.4)	0.1112	31 (15.5)	23 (12.3)	
Transit	27 (7)	23 (5.9)	37 (9.6)	0.0125	16 (8)	11 (5.9)	
	Scheme 2						
Auto	300 (77.5)	294 (76)	294 (76)	1	151 (75.5)	149 (79.7)	0.772
Walk/bike	54 (14)	65 (16.8)	52 (13.4)	0.1112	31 (15.5)	23 (12.3)	
Transit	25 (6.5)	23 (5.9)	35 (9)	0.029	14 (7)	11 (5.9)	

a. Exact McNemar's significance probability
b. *Chi-square test probability*

Table 7b. Primary shopping mode by phase

	Both phases	Neither phase	Phase 1 only	Phase 2 only
	N			
	Scheme 1			
Auto	266	64	29	28
Walk/bike	30	300	35	22
Transit	16	343	7	21
	Scheme 2			
Auto	266	65	28	28
Walk/bike	30	300	35	22
Transit	16	345	7	19

Between phases, there was a significant change in primary transit shopping for the first scheme (P=0.0125), but for the second scheme the difference was not significant (P=0.029). There were 21 new transit shoppers under the first scheme but 19 for the second scheme, and 7 former transit shoppers in both schemes [Table 7b]. In other words, the first scheme indicates that the percentage of walk/bike and transit trips became equally high for two more people. Transit shoppers made up 6% of the sample in Phase 1 and 10% or 9% in Phase 2 for schemes 1 and 2 respectively. The distribution of classification by primary shopping mode did not change between case/control overall or in either phase.

5.3.3 *Travel time*

For trips overall, the average travel time per person for a food shopping trip was 26 min. By mode, average travel times were 24 min auto, 23 min walk/bike, and 50 min transit [Table 8a]. For travel time by primary shopping mode, the average travel time per person was 25 min for auto, 26 min for walk/bike, and 42 min for transit [Table 9a].

Table 8a. Average travel time for all trips

	N	Mean (SD), minutes
Trips	387	26.3 (13.2)
Auto	343	24.4 (12.5)
Walk/bike	173	23.4 (17)
Transit	78	49.7 (23.3)

Between phases, there were no significant differences in the mean of the average travel times for each mode per person for those who had taken the mode in both phases [Table 8b]. Average travel time for walk/bike trips was lower in Phase 2 (21 vs 26 min).

Table 8b. Average travel time, Phase

	Obs	Phase 1	Phase 2	P-value
		Mean (SD)		
Trips	387	26.5 (17.2)	26.9 (17.8)	0.6926
Auto	290	24.5 (13.5)	25.3 (15.9)	0.453
Walk/bike	83	25.6 (25.3)	20.5 (16)	0.0276
Transit	26	52.3 (23.6)	51.6 (24.5)	0.918

Between cases and controls, there were no differences in the mean of the average travel time per person [Table 8c]. Average case walk/bike travel time was higher (26 vs 21 min). There were also no significant differences between cases and controls in either phase, though the difference for cases-controls in Phase 2 (2.1 min) was less than Phase 1 (7.7 min).

Table 8c. Average travel time, Case and Case x Phase

	Control Obs	Case Obs	Control	Case	Case-Control	P-value
			Mean (SD)			
All						
Trips	200	187	25.4 (12.1)	27.3 (14.3)	1.89	0.1603
Auto	178	165	23.9 (13.6)	25 (11.2)	1.08	0.4256
Walk/bike	88	85	21 (13.3)	25.8 (20)	4.73	0.0678
Transit	42	36	51.7 (22.3)	47.4 (24.5)	-4.29	0.4217
Phase 1						
Trips	200	187	24.8 (13)	28.3 (20.7)	3.57	0.0414
Auto	165	151	22.7 (11.1)	26.1 (15.1)	3.35	0.0242
Walk/bike	74	60	21.1 (14.4)	28.9 (28.7)	7.73	0.0449
Transit	24	20	54.9 (23.8)	55.3 (32.7)	0.43	0.9601
Phase 2						
Trips	200	187	26.7 (19.6)	27.1 (15.8)	0.357	0.8443
Auto	160	157	25.2 (19.2)	25.3 (14.1)	0.113	0.9524
Walk/bike	57	65	20.6 (13.4)	22.7 (17.5)	2.15	0.4529
Transit	31	29	48.8 (22)	45.4 (22.7)	-3.39	0.5594

When people were classified by primary shopping mode, the results were similar. Average time (23 vs 28 min) was lower in Phase 2 for walk/bike shoppers [Table 9a]. There were no significant differences between cases and controls, though the average time for walk/bike shoppers (30 vs 23 min) was higher for cases. There were also no significant differences between cases and controls in either phase. Average travel time for walk/bike shoppers had a slightly smaller difference for cases-controls in Phase 2 (8.3 min) vs Phase 1 (12.5 min). Average travel time for transit shoppers had a slightly greater difference for cases-controls in Phase 2 (-8.8 min) vs Phase 1 (0.3 min) [Table 9b].

Table 9a. Average travel time by primary shopping mode

	Overall	Phase 1	Phase 2	Control	Case	P-value
	Mean (SD)					
	Scheme 1					
Auto	25.1 (10.6)	24.2 (12.1)	25.7 (17)	24.3 (10.4)	25.9 (10.9)	0.2005
Walk/bike	26 (19.1)	28.4 (27.2)	22.8 (19.8)	23.2 (12.5)	29.9 (25.3)	0.2058
Transit	41.6 (16)	47.9 (22.7)	42.4 (19.8)	40.3 (16.7)	43.4 (15.4)	0.6304
	Scheme 2					
Auto	25 (10.6)	24.2 (12.1)	25.7 (17)	24.2 (10.4)	25.8 (10.8)	0.207
Walk/bike	26 (19.1)	28.4 (27.2)	22.8 (16.3)	23.2 (12.5)	29.9 (25.3)	0.2058
Transit	43.3 (15.3)	47.9 (22.7)	42.7 (20.1)	43.3 (15.7)	43.4 (15.4)	0.9858

Table 9b. Average travel time by primary shopping mode, Case x Phase (Scheme 1)

	Control	Case	Case-Control	P-value
	Mean (SD)			
Phase 1				
Auto	23.2 (10.8)	25.2 (13.2)	2.02	0.1507
Walk/bike	23 (13)	35.5 (37.8)	12.5	0.0656
Transit	47.8 (17.9)	48.1 (27.9)	0.31	0.9748
Phase 2				
Auto	25.6 (19.4)	25.8 (14.1)	0.17	0.9317
Walk/bike	19.5 (11)	27.8 (21.3)	8.28	0.0712
Transit	46.7 (20.8)	37.9 (18.2)	-8.8	0.1812

6. DISCUSSION

This study used travel diaries from Seattle residents near and further away from the Central Link light rail stations to analyze food shopping trips on time measures by mode of transportation. The findings here are new to the literature on community food access in multiple aspects. First, there is no data investigating food shopping trips specifically in relation to light rail. Second, transportation mode does not appear to have been considered on the trip-level from travel diaries. Third, travel and stay time along with their relationship through total time and time ratio has rarely been reported together from travel diaries, and especially not from a seven-day travel diary. Lastly, these data are analyzed from both trip and person-level perspectives.

Overall, results show that there were some unique characteristics in food shopping travel patterns by mode. Travel times were similar between route or store type within modes while other time measures varied more. Transit trips appeared to be most affected by phase and case, even though few trips involved light rail. Person-level data indicated that walk/bike and transit use for food shopping were affected by phase but not by case/control. Walk/bike travel time was differentially affected for cases and controls by phase.

6.1 Trip characteristics by mode

Overall distribution of modes showed that auto trips were the majority of food shopping trips, but almost a third of trips did not involve a car. Most non-auto trips for food shopping were walk/bike. The average percentages of trips by mode among people were the about the same as the trip-level distribution of modes. When people were classified by primary shopping mode, the percentage of auto shoppers was higher and the percentage of walk/bike shoppers lower than the total trip percentages. The percentage of people who used transit for at least half of their trips (6.5%) was much higher than the national average of shoppers using public transportation of 0.3% or the 1.9% of shoppers in low-income high access areas (USDA ERS, 2009), as might be expected from an urban setting. Route type for trips overall was also very different from national ATUS data, in which 64% of trips were home-home (USDA ERS, 2009) as opposed to 25% in this sample.

The travel time both for all trips and by person had an average of 26 min, which is similar to the national average for one-way travel to a grocery store of 15 min (USDA ERS, 2009). The home-home route data here by mode found that the median auto travel time one-way was about 9 min, which is in line with the finding that almost all of the most vulnerable populations in Seattle lived within a 10-minute drive or bus ride to a low- or medium-cost supermarket (Jiao, 2012). However, the hypothesis that travel time would be somewhat similar between modes was not supported. Auto and walk/bike were very similar, but the travel time for transit was more than double the time for other modes. The estimated bus route time may be much shorter because it does not factor in individual preferences for which stores to visit by transit or the time associated with walking, waiting, and making stops along the route. The average travel times by mode from trip-level data were nearly identical to person-level data.

In examining whether other trip characteristics differed by transportation mode, it was observed that walk/bike trips differed from auto on the factors of stay time (and therefore total time and time ratio) and home-home route percentage. The walk/bike travel time was similar to auto, but because walk/bike had lower stay times, the time ratio was still lower for auto. A greater percentage of walk/bike trips than for other modes were home-home, so walk/bike trips may be most affected by the home environment. Still, the majority of walk/bike trips in this sample were not home-home.

For transit, the percentages for home-home versus other routes were similar to the ones for auto, which suggests that transit was useful for accessing stores often when en route to or from another destination not in walking distance. The percentage of transit trips to supermarkets was lower than other modes, suggesting that transit might be used to access a more diverse range of store types. Transit travel times for route and store combinations were similar, but total times were slightly lower for other routes compared to home-home and other stores compared to supermarkets. However, time ratio was higher for these combinations, which was largely true as well for other modes. Since transit travel times and total times were higher for than for other modes, the time cost for transit may be one factor for why most of the time, people preferred to either drive or walk/bike to stores. People may also need to be willing to accept a higher travel time ratio with transit trips, in agreement with findings from time ratio literature (Lyons & Urry, 2005).

6.2 Light rail

Light rail was rarely utilized in association with food shopping in this sample, but the few of these trips that were taken were by those who lived closer to the stations, as hypothesized. It is possible that the light rail stations are not near the food stores that other non-rail transit (i.e., bus) routes reach, that the stations are not as accessible as bus stops, or that the light rail is more expensive. Other reasons for low utilization may include social norms, inconvenience, or not enough time passed since the opening of the light rail system to change behavior. Rail and bus lines in some communities have been planned around commuter routes, with rail especially for long distance. There is a potential equity issue around unequal funding, since rail may be used by more affluent transit users for longer commute trips. (Gottlieb, 1996) Although light rail differs from commuter rail, the women surveyed in Southeast Seattle expressed that the light rail was costly and inconveniently did not have transfers, unlike the bus system. An interviewee perceived Sound Transit, the agency operating the light rail system, as “elitist”. (Got Green, 2011) Adult fares for the light rail are based on distance. Reduced fares for one price one-way are available for youth, people age 65 or older, and people with disabilities. A low-income fare via the ORCA LIFT card was recently implemented March 2016 and therefore unavailable during the time of this study. (Sound Transit)

Time measures from the seven trips associated with light rail did indicate that they took less time than the same types of transit trips from Phase 1. Light rail may be faster than other forms of transit because of increased frequency and schedule regularity in addition to better right-of-way than most bus routes. Avoiding the problem of congestion could also potentially make light rail trips faster than driving. One could imagine that someone would be taking the light rail to or from another destination and then visit a store en route to home or somewhere else on foot/bike or by car, and indeed all light rail food shopping trips in Phase 2 were associated with other destinations.

6.3 Phase and Case Comparisons

Transit trips appeared to be most affected by phase or case, though this may be because there were fewer transit trips to compare than for other modes. Transit trips comprised less than 10% of all trips, and when broken down into trip combinations were 1-8% of all trips by phase or case/control status. Person-level data showed that there may have been some shifts in travel behavior for transit and walk/bike use for food shopping between phases as well as a differential effect on walk/bike travel time per person for cases between phases.

For phase effect, transit trips took less time in Phase 2 while auto and walk/bike stayed the same. However, average transit trip travel time for people who took transit in both phases was not lower in Phase 2. The transit trips could have belonged to a different group of people in Phase 2, which influenced the trip characteristics. Transit home-home and other store trips decreased the most in travel time, with a smaller decrease also observed for supermarket trips. It could be that people were more frequently linking stores to other destinations in their transit trips, and the home-home trips became more efficient in terms of travel time, total time, and time ratio. They may also more often had taken transit to get to stores other than a supermarket, and those trips also had a lower travel time.

Person-level data between phases showed that people took fewer walk/bike trips per week on average, although there was no difference in the classification of people as primary walk/bike shoppers. The average walk/bike travel time per person was somewhat lower in Phase 2, which was also reflected by the average travel time for walk/bike shoppers. Meanwhile, there was a difference in primary transit shopping, with more new transit shoppers than former. Whether the difference was statistically significant depended on the classification scheme used. The trends for walk/bike or transit use were not observed for case/control, so it may be that other effects such as aging of the sample can account for these differences in behavior between phases.

For case effect, case and control trips differed by frequency to supermarket versus other stores. Case transit trip travel times were slightly lower. Various time differences were seen for all transit trip combinations. It appears that case transit trips were more frequently home-home and to other stores versus supermarkets in comparison with controls. For case transit home-home trips, total time was lower but time ratio was higher. For case transit trips to other stores, travel time and time ratio were lower. Cases had a higher travel time for walk/bike home-home trips and higher average travel time both for walk/bike trips per person overall and in Phase 1 (but not Phase 2) and for primary walk/bike shoppers in both phases, though these differences were not significant. Other analyses for person-level data between cases and controls showed that there were no differences overall or in either phase.

Considering case/control and phase together for potential effects of light rail, median transit trip travel time was lower in Phase 2 vs Phase 1 by 11 minutes and for cases vs controls by 8 minutes. Boxplots showing both phase and case [Figures 3a, 4a] indicated that the case effect was much slighter than the phase effect on transit travel time, and that the case effect did not affect phases differently nor did the phase effect affect cases or controls differently. For transit trip combinations, the direction of phase and case effects on percentage of transit trips and travel time were opposite for home-home but the same for other stores. Person-level data showed no significant differences between cases and controls in each phase, but a few observations were noted. The difference between case and control average walk/bike travel time per person in Phase 2 vs Phase 1 was smaller by 6 min, where case time was higher than control in Phase 1 but only slightly higher in Phase 2. Similarly, for walk/bike shoppers, the difference in average travel time in Phase 2 vs Phase 1 was smaller by 4 min. For average primary transit shopper travel time, the difference in Phase 2 was greater by 9 min, where case time was about the same as control in Phase 1 but lower in Phase 2. Both lower transit and walk/bike travel times may contribute to the observed difference.

6.4 STRENGTHS & LIMITATIONS

The approximately seven-day travel diary represents food shopping behavior likely more accurately than travel diaries of shorter duration or survey questions asking for recall of time spent or primary food store. It is possible that the accuracy of participant recording of times and destinations on the travel diary was improved with GPS tracking since they know the data can be linked. This study uniquely analyzes time use for food shopping in detail, considering both trips to and from the store as well as time spent shopping. We also consider how this time can vary depending on travel mode, route, and store type. However, trip-level data was analyzed descriptively only, so these observations apply to the study sample and cannot be used to draw conclusions about the population. Trip data were also analyzed on the person-level to add more perspective about shopping behaviors and travel time by mode by person.

Seven days is likely still not long enough to capture all food shopping routines, which is where behavior surveys could have an advantage. Travel diaries are not strong in reliability or validity because they are self-reported. Additionally, the travel log instrument was changed for Phase 2. Food shopping trips were inconsistently retrieved from Phase 1 and 2 because of the change in activity code, and misclassification errors are greater in Phase 1 since store names had to be relied upon. Light rail code was included in Phase 1, and this code may have been confused with other modes such as monorail and streetcar because there was at least one food trip reported as light rail in Phase 1.

Another feature of the study was that effects from phase, case/control, and case/control by phase were explored. Although we do not expect the distribution and availability of stores to have changed significantly between time points, there are inevitably changes in businesses and in grocery offerings that may affect food shopping trips. This study also did not consider online shopping or grocery delivery services, which may have changed in popularity over time. While the fairly short time frame does make this less of a limitation, it also means that there might not be enough time elapsed for behaviors to change and that we cannot assess longer term food shopping behavior changes that could be associated with light rail infrastructure, such as the impacts of likely future transit oriented development around light rail stations. That light rail was under construction during Phase 1 could also have affected travel patterns, especially for the cases. There could also have been differences within cases between those who lived closer to and further away from the stations.

It is unknown how people operationalize the time they spend food shopping or traveling and where the division is between travel time for food or for other destinations. Travel time related to food stores may be underestimated because of stops like ATMs, post offices, or coffee shops that people might not consider as destinations. It could also be overestimated if the travel time is more closely associated with another activity. There are more complex schemes for calculating travel time that may be preferred to use. The handling of trips with multiple stores here also may introduce bias in time measures by route type. Lastly, because trips are structured as before-food-after, actual trips associated with light rail or other modes may be higher.

6.5 Implications and future directions

Auto and walk/bike were comparable on many trip characteristics for trips overall and were mostly unaffected by phase or case/control status in the present study, though the difference in average walk/bike travel time per person between case/control was smaller in Phase 2 vs 1. More walking trips were home-home than for other modes, which suggests that improving walking access to stores near where people live or developing housing and food stores in close proximity may be a good strategy for better food access. In Seattle, up to 34% of low-income populations were within a 10-minute walk to a medium-cost supermarket and only 3% to a low-cost supermarket (Jiao, 2012).

Meanwhile, transit can be costly for food shopping, both in terms of the fare required for public transit and the higher travel time involved relative to other modes. Transit trips, like auto trips, were often not home-home, so strategies to improve transportation access should look beyond the residential neighborhood. Transit trips to food stores in the present study also frequently involved trips to stores other than supermarkets, and time measures appeared somewhat variable by route and store type and by phase and case. Changes to public transportation systems may impact transit food shopping trip characteristics, walk/bike travel times, and potentially, decisions to take transit or walk/bike on the person-level. Even though many of the observed trends could be due to other effects over time, such as aging of the sample, the aging of the US population may also point to a need for more transportation access to food as the most active forms of transportation become less feasible. If light rail were used for food shopping instead of bus, there may be savings in time cost. National data indicates that lower income populations use auto for shopping less often (Ver Ploeg, 2015) and are more likely to experience high travel times (USDA ERS, 2014), so improving walking and public transit access may help to decrease barriers for food access. A case study in which the Flint Farmers' Market moved to a downtown location near the main bus terminal reported a greater proportion of shoppers who took transit or walked/biked to the market and an increase in shoppers from high socioeconomic distress neighborhoods (Sadler, 2016).

To improve transportation access to food, solutions proposed have included providing transportation subsidies and modifying fares, altering existing public transit routes, and creating circulator routes, which are buses or shuttles designed for non-commuter trips. Supermarkets could also be encouraged to set up their own shuttle services, which could possibly be made more feasible by reducing parking lot size requirements or via subsidies. Developing new stores or other venues selling healthy foods such as farmers' markets in areas with low access would be another approach. (USDA ERS, 2009; Gottlieb, 1996) Such food outlets could be developed with attention to site accessibility by walk/bike and transit. Programs like Local Food, Local Places encourage local food access through siting farmers' markets, grocery co-ops, business incubators, and community gardens in walking or transit-accessible areas or improving access to existing sites (EPA Smart Growth).

As the Seattle Food Action Plan describes, food access can be incorporated into planning and in evaluation criteria for transportation projects (City of Seattle Office of Sustainability and Environment, 2012). The most current draft of the City of Seattle Comprehensive Plan mentions food access under Growth Strategy ("support convenient access") and Community Well-being ("encourage coordinated service delivery", "support efforts to provide access", "encourage public and private efforts that support culturally appropriate food opportunities"), but nothing is explicitly transportation-related. It does call for focusing growth in areas within a ten-minute walk of light rail stations and in nearby urban villages to leverage this transportation investment. (City of Seattle Department of Planning and Development, 2015)

Transit oriented development near light rail stations could be an opportunity to increase both walk/bike and transit access to food, for example building shops or locating a farmers' market near the transit access locations. In Seattle, the Rainier Beach Food Innovation District is currently being planned around the light rail station to include a food bank and food hub functions such as aggregation and processing (City of Seattle, 2014). It would also be important to ensure walkability, bike access, and transit connections around the light rail stations.

Seattle could assess consumer transportation needs and existing bus service and use the information to plan for transportation system improvements. One assessment tool could be a survey of shoppers regarding walk/bike access, reasons for using or not using the light rail or bus to stores, and preferences for travel time. It has been suggested that travel time can be used productively, so the cost of travel time could be reduced to the individual as it is converted to activity time (Lyons & Urry, 2005)--meaning that people may be willing to travel for longer instead of seeking to minimize the time. Also, the results from this travel diary study could be compared with future iterations of the same study or other data from Seattle and new light rail expansion for a more comprehensive picture of food shopping trip characteristics for city residents. Food store availability near the stations and frequency of shopping trips to those stores could be included to further study the impact of the stations and transit oriented development.

Distance in relation to travel time was not studied here, but it may be that because light rail can cover more distance in less time, it allows people to access more food stores even if travel time does not decrease so long as food stores are within walking distance from light rail access points. Overall shopping frequency was not considered and may not be accurately reflected by a seven-day diary, but frequency would factor into an individual's total time spent shopping. The travel cost associated with transit fares and automobile gasoline use could also be analyzed in addition to time cost by mode. Demographics were also not considered, and there would likely be differences in travel patterns by vehicle ownership, socioeconomic status, gender, and possibly other factors. Consumption data would be another interesting area of study, since transportation modes could potentially affect purchase decisions.

Future research in food access should incorporate transportation mode, either by area-based measures of transportation access or individual-reported travel patterns. Studies on community food access may continue to find proximity from home to be a useful spatial measure especially for walk/bike access. Another area-based perspective would be to study food store location relative to high transit and walk/bike accessible areas, such as transit hubs and main streets, or to other frequently accessed services and businesses. Identifying barriers to food access for individuals could involve surveying shoppers at stores about their travel and reasons for visiting the store, as well as asking targeted populations or areas of interest about barriers and travel behaviors. Travel diaries can be used to provide an overview of a sample's travel behavior and food shopping trips.

7. CONCLUSIONS

Travel diaries recording food shopping trips in the region showed unique trip characteristics by mode. Light rail was infrequently associated with food shopping trips, but were more common for people living closer to stations. It was noted that the introduction of light rail did not seem to affect most measures, but there were some phase and case effects in transit trip characteristics and phase effect on transit and walk/bike use on the person-level as well as a differential effect on average walk/bike travel time per person for cases between phases. As Seattle seeks to offer more transportation options and lower demand for automobile use, understanding the trip characteristics of an essential activity such as food shopping and how they may be impacted by public transportation systems can inform efforts to improve access.

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