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Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Understanding travel behavior through changes in urban form, preference, and life events: A longitudinal study

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Abstract

This study uses residential relocation as a unique opportunity to capture changes in urban form before and after people move. Prior studies have used residential relocation as a way to isolate the causal effect urban form on travel behavior. Yet, longitudinal studies of changes in personal and household contexts through residential relocation are still very rare. Using a longitudinal sample of 223 participants (2012-2014), this study found significant positive impact of changes in neighborhood walkability ($\beta = 0.43$, $p < 0.05$) and regional accessibility ($\beta = 0.53$, $p < 0.05$) on walking. The results also indicate that preference for mixed-used neighborhoods is inversely related to auto trips ($\beta = -0.07$, $p < 0.05$), and preference for affordable housing has a negative impact on walking ($\beta = -0.19$, $p < 0.01$). A stronger preference for auto is negatively related to walking ($\beta = -0.39$, $p < 0.01$). For life events, reduced income is associated with higher walking trips ($\beta = 0.28$, $p < 0.05$), but change in marital status is related to lower transit trips ($\beta = -0.33$, $p < 0.05$). Findings highlight the importance of urban form in affecting travel behavior and call for the need to understand travel behavior through a more holistic framework that incorporates personal and household contexts to support more active travel in places where reducing auto trips is a top priority for regional and municipal strategic planning.

Keywords: Residential relocation, urban form, preference, life events, travel behavior

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1. Introduction

One of the challenges in land use and transportation research is to isolate the effect of urban form on travel behavior (Knuiman, et al. 2014, Frank, et al. 2007). Most preferred research design to understand the true effect of land use on travel behavior would be to conduct a random experiment in a controlled environment. However, it is not possible or even ethical to conduct an experiment by randomly assigning people to different locations and study how their behaviors change over time. Moving to Opportunity (MTO) study is perhaps the only randomized social experiment that aimed to examine the benefits of offering mobility opportunities to low-income families (Sanbonmatsu, et al. 2011). To our knowledge, only one study has used data from MTO to study travel behavior, focusing on the role of transportation in employment outcomes (Blumenberg and Pierce 2014).

As an alternative to a true randomized control study, researchers have often used two broad strategies to isolate the impact of urban form on travel behavior. The first strategy is to use a statistical control. This includes using econometric techniques, such as propensity matching and instrumental variables, to control for endogenous factors, e.g., residential self-selection (Cao, Mokhtarian and Handy 2008). A second strategy is to conduct a quasi-experimental study where researchers assess the impacts of specific policy interventions that provide opportunities to observe the effects of the policy intervention through natural experiments. Researchers have used a quasi-experimental design to assess before-and-after impacts of physical modifications to urban forms, such as the construction of a greenway (Fitzhugh, Bassett and Evans 2010) or a transit system (Hong, Boarnet and Houston 2016). Other approaches include assessing the impact of programming, such has a free bus pass program (Fujii and Kitamura 2003) or a congestion charging scheme (Eliasson, et al. 2009). Quasi-experimental studies are considered an improvement over cross-sectional studies because they allow comparison between a group that receives a treatment (experimental group), such as the construction of a new rail line or a new transport policy and a group that does not receive the treatment (control group) (Sallis, Story and Lou 2009, Boarnet 2011).

In transportation, a unique quasi-experimental research can be conducted by examining changes in people's travel behavior before and after they move to a new residence (Giles-Corti, et al. 2013, Scheiner and Holz-Rau 2013, Lin, Wang and Zhou 2018, Krizek 2003). These "residential relocation" studies allow researchers to directly compare differences in travel behavior between people who moved versus people who did not move. However, these studies are not without limitations. They may still suffer from self-selection bias where participant behaviors are affected by their motivations and preferences rather than policy interventions under study. For example, researchers have used residential relocation as a proxy to understand changes in the built environment on travel behavior (McCormack, et al. 2017). However, participants might have moved to a new neighborhood for reasons other than their travel needs (Vos, Derudder, Acker, & Witlox, 2012). People may not be fully aware of transport opportunities until after they move (Jones & Oglilvie, 2012). Furthermore, when people are moving, they may self-select into a neighborhood not only because of their preference but also because of the various factors like changes in lifestyle, life stage, employment, income, etc. (Sinniah, et al. 2016).

Building on the previous research on residential relocation, this study aims to examine whether changes in the built environment are associated with changes in travel behavior after people move to a new neighborhood. We hypothesize that the actual changes in the built environment are more predictive of people's travel behavior, rather than residential relocation itself. We also hypothesize that residential preference and travel preference have separate impacts on travel behavior, independent of changes in the built environment. Lastly, we posit that changes in lifestyle, such as marital status, income, household size, and work status, have a separate impact on travel behavior. By unpacking these individual factors related to residential relocation, this study provides a significant contribution to the body of knowledge on the causal effect of the built environment on travel behavior.

2. State of knowledge in travel behavior research

2.1. Land use and travel behavior research

Though urban planners and transportation researcher have long been interested in the interactions between land use and transportation, their interest in understanding the relation of neighborhood built environment and transportation is recent. Much of this interest was catalyzed by the movements like New Urbanism (Duany, et al. 1991, Calthorpe 1993) and Smart Growth (Danielsen, Lang and Fulton 1999, Burchell, Listokin and Galley 2000). Most of the earlier studies examining the land use and travel behavior relationship focused on the effect of aggregate land use features like density, and regional accessibility on automobile trips, more specifically on vehicle miles traveled (Handy 1992, Crane 2000, Boarnet and Crane 2001). Findings from these studies suggest that the built environment features are inversely associated with per capita vehicle miles traveled. Some of the studies that used aggregate land use data to examine that land use travel behavior relationship have found mixed results. However, the research that has focused the role of the neighborhood built environment on travel behavior have used more disaggregate data of the neighborhood built environment which include land use density, diversity, design, destination accessibility and distance to transit commonly called “5Ds”. Various studies have found that the 5Ds of the neighborhood built environment are associated with a reduction in driving and an increase in the use of other modes of transportation like walking, biking, and taking transit (Forsyth, et al. 2007, Næss 2012, Boer, et al. 2007, Lee and Moudon 2006, Saelens and Handy 2008, Southworth and Ben-Joseph 1995, Koohsari, Sugiyama and Mavoa, et al. 2016, Koohsari, Sugiyama and Lamb, et al. 2014).

2.2. Rising popularity of the “walkability” concept

Since the built environment features are often highly correlated with each other making it difficult to identify unique contribution of each feature (Cervero and Kockelman 1997), composite indices are popular among researchers examining the relation between neighborhood built environment and travel behavior (Frank, et al. 2010). Walkability index is one of the most popular composite indices used to predict walking behavior. Walkability index is usually created by combining features, such as residential density, land use mix, intersection density, and retail floor area into one score (Frank, et al. 2010). In addition, regional accessibility, commonly referred to as the ease of reaching major destinations (Handy and Niemeier 1997), is also considered an essential built environment feature. Research has found that people living in places with high regional accessibility by transit have low per capita vehicle miles and spend less time in the car (Ewing and Cervero 2001). Transport-related walking trips are also higher among people who live in an area with high regional accessibility (Cho and Rodriguez 2014 , Brown, et al. 2014, Frank, et al. 2010, Huang, Moudon and Zhou, et al. 2017).

There are a considerable number of studies from public health that have also evaluated the impact of neighborhood built environment on travel behavior and physical activity. These studies examine the effect of neighborhood built environment features that help improve opportunities for regular physical activity (Ramirez, et al. 2006, Sallis, Floyd, et al. 2012). With the aim of creating active communities, most of the studies from public health research examining built environment and travel behavior relationship examine how neighborhood built environment affects physical activity. Some studies have also examined the effect of neighborhood built environment on health outcomes related to the lack of physical activity such as obesity, diabetes, high blood pressure and various cardiovascular diseases (Sallis, Floyd, et al. 2012). There is substantial evidence suggesting that living in a highly walkable neighborhood is associated with higher levels of walking and engagement in physical activity, and lower incidence of various diseases like obesity, diabetes, high blood pressure, and various forms of heart diseases (Mobley, et al. 2006, Li, et al. 2009, Griffin, et al. 2014, Ewing, Meakins, et al. 2014). The evidence from these studies has consistently shown that the built environment plays significant role in explaining travel behavior. However, most of the studies that have examined the relation between neighborhood built environment and travel behavior are cross-sectional. Cross-sectional studies merely ascertain associational relationship and limit any causal inference. Therefore, there is an increasing number of longitudinal studies examining the effect of the neighborhood built environment on travel behavior.

2.3. The recent focus on self-selection, preferences, and lifestyles

In travel behavior research, residential self-selection has been recognized as one of the most important confounders of the built environment and travel behavior relationship (Cao, Handy and Mokhtarian 2006, Conner and Sparks 2005, Handy, Cao and Mokhtarian 2005). Residential self-selection refers to the tendency of people choosing where to live based on their travel needs and preferences (Mokhtarian and Cao 2008). When quantifying the impact of built environment on travel behavior, ignoring the effect of residential self-selection can lead to overestimation of the true effect (Bhat and Guo 2007, Cao and Chatman 2016). However, researchers have also shown that the built environment has a significant effect on travel behavior independent of residential self-selection. In addition to self-selection, various studies have attempted to incorporate individual attitudes, values, and orientation, collectively called lifestyle choices (Van Acker, Wee and Witlox 2010), within travel behavior research (Salomon and Ben-Akiva 1983, Bagley and Mokhtarian 2002, Scheiner and Holz-Rau 2007, Kitamura 2009). Some of the studies have demonstrated that travel demand is heavily influenced by one's attitudes toward travel highlighting the fact that travel is not merely a means of reaching to a destination but has an intrinsic positive utility and is valued for its own sake (Mokhtarian, Salomon and Redmond 2001, Ory and Mokhtarian 2005, Cao, Mokhtarian and Handy 2009). Therefore, travel behavior is not only influenced by the objective features of the built environment or by the demographic characteristics, but it is also determined by cognitive and psychological factors related to individual preferences and attitudinal predisposition.

Recently, the concepts of mobility culture and mobility biography are gaining interest among travel behavior researchers. The concept of mobility culture contextualizes travel behavior as a manifestation of lifestyle orientations of a population within a region. Though initially used to study leisure travel behavior (Lanzendorf 2002) and more recently general travel behavior (Klinger and Lanzendorf 2016), studies examining the role of mobility culture have found that people from a car dominant culture are more likely to drive more compared to those who come of culture where walking, transit is more dominant. Since the development of lifestyle preferences, attitudes, motivation, and orientation happen over the course of life, some studies have used the concept of mobility biography to understand how travel behavior change over the life course, and how key events in life affect travel behavior (Lanzendorf 2003, Scheiner 2007). The core tenet of mobility biography is that travel behavior is stable and repetitive as long as the daily conditions are stable. However, any changes in the daily conditions due to new circumstances can lead to a change in travel behavior (Fatmi and Habib 2017). The new circumstances are generally results of the lifestyle choices. Such choices can lead to a change in family structure, employment status, or residential status which are found to be associated with travel behavior. Therefore, the findings from the studies that have used the concepts of mobility styles and mobility biography also highlight the importance preferences, attitudes and life events in the research examining built environment and travel behavior relationship.

3. Towards a new model of travel behavior research

3.1. Moving towards a longitudinal framework

In recent years, there has been a strong emphasis on using a longitudinal research design to strengthen causality in understanding the relationship between land use and travel behavior (Boarnet 2011, Frank, et al. 2007). A growing body of research has adopted a pre-post research design to examine the effect of a change in the built environment on travel behavior before and after a major urban infrastructure investment. For example, several studies have examined the impact of light rail (Brown and Werner 2008, MacDonald, et al. 2010, Hong, Boarnet and Houston 2016, Huang, Moudon and Zhouc, et al. 2017), while others have examined urban greenway corridors, bike trails, etc. (Panter, et al. 2016, Ngo, Frank and Bigazzi 2018). These studies have found that urban infrastructures like light rails and urban greenway corridor lead to a change in travel behavior, specifically an increase in active modes of transportation. Other studies have used residential relocation as a way to examine the effect of a change in the built environment on travel behavior (Krizek 2003, Giles-Corti, et al. 2013). Since residential relocation leads to a change in context, people are more likely to change their travel behavior after residential relocation (Bamberg 2006, Clark, Chatterjee and Melia 2014, Clark, Chatterjee and Melia 2016). Results from the residential relocation studies suggest that moving to a more walkable neighborhood leads to a decrease in auto use and an increase in active modes of transportation, such as walking, bicycling, and transit (Giles-Corti, et al. 2013, Scheiner and Holz-Rau 2013, Lin, Wang and Zhou 2018). These longitudinal studies are useful in explaining the causal relationship; however, they seldom incorporate several important confounders, such as a residential preference that may mediate or moderate the impact of the built environment on travel behavior.

3.2. Research gaps and the need for a holistic framework

Despite being a relatively new area of research, the research on the built environment and travel behavior is one of the heavily researched areas in urban planning. However, most of the studies have examined the relationship cross-sectionally which limit researchers from making causal claims that built environment affects travel behavior. Though there is an increasing number of studies that have examined the before and after effect of urban infrastructure projects to establish the causal relationship, most of them seldom account for important confounders, such as lifestyles, travel preferences, and attitudinal predisposition. Likewise, most of the residential relocation studies rely on retrospective surveys which often suffer from recall biases (Coughlin 1990). Furthermore, retrospective survey may not be an appropriate instrument to capture time-variant measures, such as preferences and lifestyles (Schwanen and Mokhtarian 2004). Studies that incorporate preferences and lifestyle factors often rely on retrospective design with only a handful of studies using a true longitudinal design (Clark, Chatterjee and Melia 2014, Clark, Chatterjee and Melia 2016).

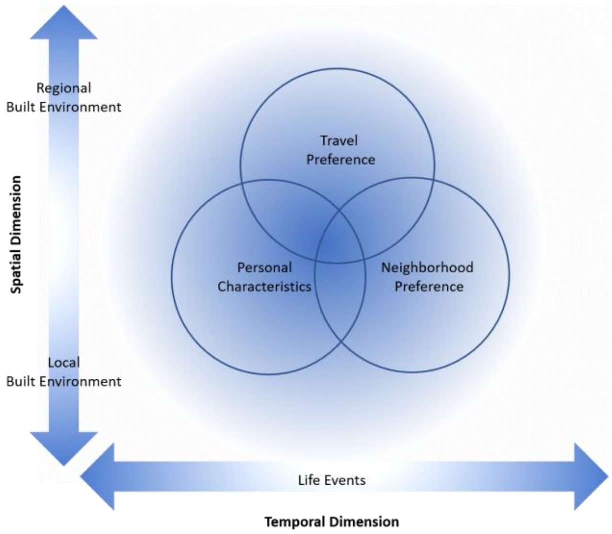

Figure 1. A holistic approach to travel behaviour research.

This study aims to examine whether changes in the built environment are associated with changes in travel behavior. By accounting for the changes in the built environment, life events as well as the changes in personal characteristics and preferences (Figure 1), this study makes two significant contributions to the existing body of knowledge. First, we use residential relocation as an opportunity to examine the effect of the changes in the built environment on travel behavior. Second, we account for the changes in residential preferences and travel preferences, which are considered key confounders in the literature. Lastly, this study incorporates changes in lifestyle factors, such as marital status, income, household size, and work status, to understand the effects of household contextual factors on personal mobility choices. By using a longitudinal study design with the careful inclusion of key confounders, this study not only makes a significant contribution to the growing body of literature on longitudinal evaluation but also helps advance the field by incorporating emerging theories from the mobility culture and biography research.

4. Method

4.1. Study context, design and data collection

The data for this study comes from a larger study called “CHANGE” – Changes in Health, Activity, and Nutrition across Geographic Environments which was initiated to document travel, activity and dietary behaviors of individuals and their generation of, and exposure to, air pollution before and after moving. The study was conducted in Metro Vancouver region. Metro Vancouver is a metropolitan area in western Canada, and it covers 22 municipalities, one electoral district, and one treaty First Nation (Figure 2). Being one of the fasted growing regions in Canada, Metro Vancouver is home to about 2.5 million people and projected to add 1 million more people and bring in more than 500,000 jobs coming to the region's current job market by 2040 (Metrovancouver 2011). Because of the region's growing economy, it attracts many immigrants coming from countries with diverse demographic, cultural and economic background. The member municipalities of Metro Vancouver are undergoing rapid urban transition and have a diverse range of built environment features that favor various modes of transportation. These variations in the built environment, economic, cultural and demographic composition provided a unique opportunity to examine how the change in urban form, preferences and life events affect travel behavior

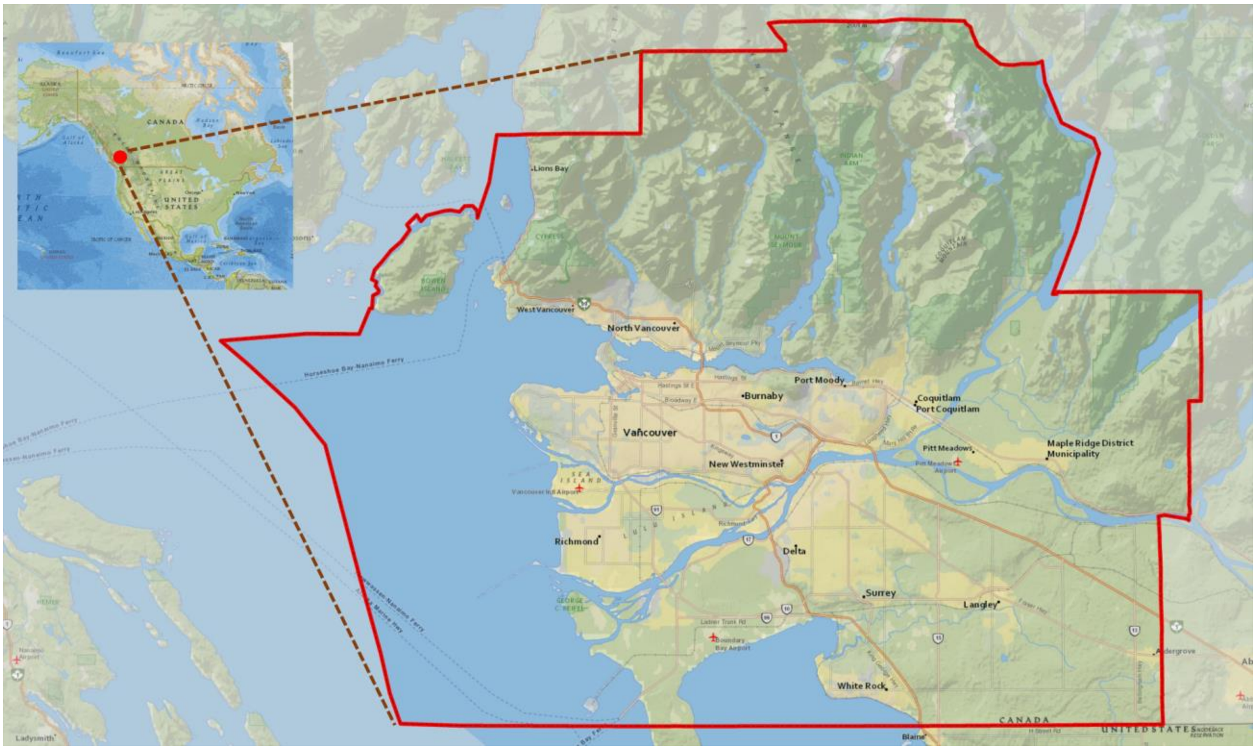

Figure 2. Study Area—Metro Vancouver regional boundary

Participants were recruited for the study between April 2012 and August of 2014. The study was advertised through a variety of channels, including print media, Facebook, Craigslist, emails to faculty and student listserves, fliers and mailouts to purchasers of condominium developments. Additionally, a survey research firm was also hired to recruit interested participants through their pre-existing panel of households. Interested individuals were directed to a website where they registered their personal information and were contacted by a member of the research staff.

Potential recruits were screened for their eligibility. Only one adult (18 or over) member per household could participate in the study. The participant had to be a resident of Metro Vancouver, must have lived in their current residence for at least six months, and planning to move within Metro Vancouver within six months, and no sooner than six weeks after initiating the study. To take part in the study, participants were required to complete a survey, and fill out detailed travel diaries for each trip taken outside of the home during the same four-day period. Six months after moving to their new residence, participants were asked to participate in a second, follow-up phase, during which they repeated the same study protocol.

A parallel sample of households who did not undergo a move, i.e., no change in the neighborhood built environment, was also recruited. Potential participants were preferentially recruited via a stratified recruitment strategy that sought to match controls to movers based on their socioeconomic and demographic criteria. Specifically, controls were recruited that matched existing movers on their gender, age category (ages 19-34, 35-64, 65 and over), personal income category (under $20,000/year, between $20,000 and $70,000/year, over $70,000 year) and the walkability index tertiles of their primary residence. The non-movers followed the same study protocol as movers, completing identical surveys, and filling out travel diaries during a specified four-day period. Six months after completing their first phase, non-movers were re-contacted to participate in an identical second phase.

4.2. Variables used

4.2.1. Travel behavior

The information from the travel survey was used to capture the travel behavior of the participants. The travel survey asked participants to record their travel information starting from their first trip in the morning and ending with the last trip each day for four days. The participants provided information on trip origin, destination, travel mode, arrival time, departure time, and activity done at the destination.

Average trips per day by three modes, which include auto, transit, and walking, were calculated using the data from the travel diary. For each of the three modes, the average trips per day were derived from total trips, and non-work trips. Change scores were calculated for each mode by subtracting average trips made in time one from the average trips made in time two resulting in six change scores.

4.2.2. Urban form

The urban form was measured using two indicators. The first indicator included neighborhood walkability index which measures the neighborhood conduciveness for walking. Frank, et al. (2010) developed the walkability index to measure neighborhood built environment. Walkability index is based on the data measured at parcel level which provide a high-resolution picture of neighborhood built environment. Walkability index is a function of net residential density, retail floor area ratio (FAR), land use mix and intersection density that captures whether a neighborhood has a physical environment that supports walking (Frank, et al. 2010).

The second indicator included regional accessibility which measures the travel time from a participant’s residence to major centers in Metro Vancouver by car and transit. The ten major locations identified by Metro Vancouver regional plan (Metrovancouver 2011) were used as the major destinations. Travel time was calculated by averaging the peak and off-peak travel time by car and transit.

Participant’s addresses were geocoded and linked to neighborhood walkability and regional accessibility in ArcGIS. Spatial join tool was used to link addresses with the two urban form indicators. Change scores for both neighborhood walkability and regional accessibility were created by subtracting time one indicator from time two indicators. The change scores were then dichotomized into two categories: i) decreased or unchanged, ii) increased. The same method was adopted to create two categories for the change in regional accessibility.

4.2.3. Preferences

For measuring neighborhood preference, the participants were asked about the type of neighborhood they like to live in if they were to move from their current neighborhood. They were given two options and asked to rank their preference for one type of neighborhood over other on a scale of 0 to 10. The scales were recoded so that high scores represented a higher preference for various characteristics of a walkable neighborhood. The two neighborhood characteristics included a preference for the walkable neighborhood and preference for neighborhood with mixed uses. In addition, the participants were also to rank whether affordability was the reason for their decision to live in their current neighborhood. The affordability preference was measured on a four-point scale. In addition to neighborhood preference, the participants were asked to rank modes of transportation, which include auto, transit, and walking, based on their preference. All travel preference indicators were measured using a four-point scale. Using the responses recorded in time one and time two, change scores were calculated.

4.2.4. Life events

The participants were asked “Over the past two years, have any of the following major events happened in your life?” to which they responded by selecting appropriate events that happened to them. The life events used for this study include a change in income, change in job or job location, change in marital status, and change in household size or household structure. All responses were binary variables. Responses reported in time two were used for analysis.

4.2.5. Covariates

Age, gender, ethnicity, education, and baseline travel behavior were used as covariates for study. Education was categorized into two categories: high school education, higher than a high school education. Likewise, ethnicity was recoded to create two categories which indicated whether participants were white or non-white. Baseline travel behavior included an average number of trips per day made by car, transit, and walking. In addition, a dummy variable was created to control for the effect of moving by categorizing the participants as movers and non-movers.

4.3. Analytic approach

R version 3.4.0 (R Core Team 2013) was used to analyze the data. Exploratory data analyses were done to examine the participant's socio-demographic characteristics, change in urban form, changes in neighborhood and changes in travel mode preferences, attitudes, and needs. T-tests for independence were done to examine differences in changes in travel modes between the two walkability change groups. Ordinary least square (OLS) regression analyses were done to examine the effect of a change in neighborhood walkability on travel behavior outcomes for each of the travel modes. OLS regression approach using change scores has been used by previous studies examining the effect of the change in built environment on travel behavior (Klinger and Lanzendorf 2016, Foster, et al. 2014). All the OLS models controlled for changes in regional accessibility, changes in neighborhood and travel preferences, life events, baseline travel behavior and other socio-demographic factors. The effect of "moving" on travel behavior was examined by the dummy variable created to identify residential movers from non-movers.

5. Results

5.1. Sample characteristics

Table 1 shows the demographic characteristics of the participants at baseline, changes in urban form, neighborhood preferences, and travel mode preferences. The average age of the participants was 35.68 with a standard deviation of 13.80. Females were over-represented in the study sample (Female = 66.67% vs. Male 33.33%). More than half of the total number of participants were of Caucasian origin (60.99%). An overwhelmingly high percentage of the total sample had at least a high school education (91.30%). More participants either had a decrease or no change in neighborhood walkability (69.51%) than those who had increased neighborhood walkability (30.49%). Almost an equal percentage of the total participants increased regional accessibility (34.08%). There was an overall decrease in neighborhood preference indicators (mean change for walkable neighborhood = -.42 and mean change for a neighborhood with mixed uses = -0.05). However, there was an increase in preference affordable housing (mean change = 0.01). The preferences for driving and taking public transit did not change at the two time-points, whereas there was a decrease in preference for walking (mean change = -0.10). 40.36 % of the total sample saw a change in their income over the past two years. Likewise, a similar proportion of the sample (43.50%) had a change in their work or work place location. 14.35% percent of the total participants had a change in marital status. Almost a quarter of the total sample (27.35%) had a change in household size or structure (for example, had children, children moved out of the house, or started caring for an elderly or sick relative). In addition, 60.09% of the total sample were movers and 39.91% non-movers.

The summary of changes in average daily total trips and average daily non-work trips by driving, transit, and walking are shown in table 2. The change in average daily trips (both total and non-work) by all three modes were negatives meaning that the there was an overall decrease in an average number of daily trips in the whole sample. A similar pattern was observed in participants whose walkability decreased or unchanged. There was a decrease in average daily total trips by auto (mean change = -0.31) and an increase in average daily total trips by transit (mean change = 0.03) and walking (mean change = 0.12) in the participants whose walkability increased. For the same group, average daily non-work trips by auto and transit decreased (mean change auto = -0.09, mean change transit = -0.03). However, there was an increase in an average daily non-work trips by walking for the participants with increased neighborhood walkability (mean change = 0.28). The two-sample t-test showed a significant difference (p-value =

0.007) in the change in average daily home-based non-work walking trips between the participants whose neighborhood walkability decreased or remained the same, and the participants whose neighborhood walkability increased.

Table 1 Summary of socio-demographic characteristics and key variables of interest

	N = 223 Mean (SD) or Count (%)
Socio-demographics (baseline)	
Age	35.68 (±13.80)
Gender	
Male	74 (33.33%)
Female	148 (66.67%)
Ethnicity	
Non-Caucasian	87 (39.01%)
Caucasian	136 (60.99%)
Education	
High school or lower	20 (8.97%)
Some college degree or higher	203 (91.03%)
Change in urban form	
Walkability Index	
Decreased or unchanged	155 (69.51%)
Increased	68 (30.49%)
Regional Accessibility	
Decreased or unchanged	147 (65.92%)
Increased	76 (34.08%)
Change in neighborhood preferences	
Preference for a walkable neighborhood	-0.42 (±3.05)
Preference for a neighborhood with mixed uses	-0.05 (±3.31)
Preference for affordable housing	0.01 (±0.84)
Change in travel mode preferences	
Preference for auto	0.00 (±0.87)
Preference for transit	0.00 (±0.89)
Preference for walking	-0.10 (±0.81)
Life Events	
Change in Income	
No change	133 (59.64%)
Change	90 (40.36%)
Change in work status/location	
No change	126 (56.50%)
Change	97 (43.50%)
Change in marital status	
No change	191 (85.65%)
Change	32 (14.35%)
Change in household size	
No change	162 (72.65%)
Change	61 (27.35%)
Residential relocation	
Moved to a new neighborhood	89 (39.91%)
Stayed in the same neighborhood	134 (60.09%)

Note: Because of missing data, the total count may not match the total sample size(N)

Table 2: Change in travel behavior by walkability groups (t-test results)

	Total Sample (N= 223)	Change in walkability		P-value
		Decreased or unchanged (N = 155)	Increased (N = 68)	
	Mean (SD)	Mean (SD)	Mean (SD)	
Total trips				
Δ Total auto trips	-0.17 (±1.35)	-0.11 (±1.33)	-0.31 (±1.40)	0.19
Δ Total transit trips	-0.02 (±0.85)	-0.04 (±0.88)	0.03 (±0.77)	0.74
Δ Total walk trips	-0.13 (±1.39)	-0.25 (±1.38)	0.12 (±1.38)	0.25
Non-work trips				
Δ Auto trips	-0.04 (±0.87)	-0.02 (±0.89)	-0.09 (±0.84)	0.46
Δ Transit trips	-0.03 (±0.51)	-0.03 (±0.52)	-0.03 (±0.49)	0.60
Δ Walk trips	-0.04 (±0.92)	-0.17 (±0.92)	0.28 (±0.85)	0.007***

*Note: Δ denotes the change measured in continuous scale: p<0.1; **p<0.05; ***p<0.01*

5.2. Total trip models result

Table 3 shows the results of the OLS regression model for changes in total average daily trips by walking, transit, and auto. The effect of an increase in neighborhood walkability on total average daily walk trips was significant (β = 0.43, SE= 0.22, p < 0.05,); increase in neighborhood walkability did not have a significant effect on transit use and driving. The change in regional accessibility had a significant positive effect on the change in total average daily walk trips (β = 0.53, SE = 0.22, p< 0.05) and a marginally significant effect on the change in total average daily transit trips (β = 0.27, SE = 0.14, p <0.1). Some of the neighborhood preference factors had a significant effect on mode usage, especially the change in preference for a neighborhood with mixed uses had a significant negative impact on the change in the total average daily auto trips (β = -0.07, SE = 0.03, p < 0.05). Likewise, there was a marginally significant negative effect of the change in preference for affordable housing on the change in average total daily walk trips (β = -0.19, SE = 0.11, p < 0.1). The change in auto preference had an inverse effect on the change in total average daily walk trips (β = -0.39, SE = 0.10, p < 0.01) whereas, the change in preference for walking had a positive impact on the change in total average daily walk trips (β = -0.23, SE = 0.11, p < 0.05). The relationship between change in preference for transit and change in transit use for the daily trips was marginally significant but in the expected direction (β = 0.11, SE = 0.06, p <0.1). Among the four life events factors included in the models, only the change in marital status had a significant negative effect on transit use (β = -0.33, SE = 0.15, p <0.05). Moving had a significant negative effect on total transit use (β = -0.34, SE = 0.15, p <0.05). Because of the missing variables, the number of observations in the three models was less than the total sample (n = 204 vs. N= 223). All models had a moderate model fit with adjusted R-square 0.30, 0.21, and 0.31 for walk trip, auto trip, and transit trip models respectively.

5.3. Non-work trip models result

The results of the OLS models for changes in average daily non-work trips by walking, transit, and auto are summarized in table 4. There was a significant positive effect of an increase in neighborhood walkability (β = 0.34, SE = 0.14, p <0.05) on the change in average daily non-work walk trips. The effect of an increase in regional accessibility the walk trips was marginally significant but in expected direction (β = 0.24, SE = 0.15, p <0.1). Like the total trip models, there was a significant negative effect of the change in preference for a neighborhood with mixed-use on the change in average daily auto trips (β = -0.05, SE = 0.02, p <0.01). The effect of the change in preference for affordable housing had a significant inverse effect on the change in average walk trips (β = -0.19, SE = 0.07, p < 0.01). The change in auto preference had a significant negative impact on the change in walk trips (β = -0.19, SE = 0.06, p < 0.01). Similarly, the change in preference for walking had a significant negative impact on the change in auto trips (β = -0.16, SE = 0.08, p < 0.05) and a marginally significant positive impact on the change in walk trips (β = -0.16, SE = 0.08, p < 0.05). Change in income had a significant positive impact on the change in walk trips (β =

0.28, SE = 0.14, p < 0.05) whereas the change in marital status had a significant negative effect on the change in transit trips (β = -0.24, SE = 0.10, p < 0.05). Change in work or work place location had a marginally positive effect on the change in transit trips (β = 0.12, SE = 0.07, p < 0.1). The effect of residential mobility was not significant for all the three modes of transportation. The regression models had a moderate model fit with adjusted R-square 0.36, 0.19, and 0.30 for walk trip, auto trip and transit trip models respectively. In addition, because of the missing variables, the numbers of observations were also different in the three models from the total sample (n = 199 vs. N = 223).

Table 3 -Effect of the changes in the built environment on travel behavior (total trips)

	Change in total trips		
	Δ Walk trips	*Δ Auto trips*	*Δ Transit trips*
	β (SE)	β (SE)	β (SE)
Constant	-0.02 (0.45)	-0.09 (0.46)	0.51* (0.28)
Change in urban form *(ref: decreased or unchanged)*			
Increase in neighborhood walkability	0.43** (0.22)	-0.14 (0.23)	0.09 (0.13)
Increase in regional accessibility	0.53** (0.22)	-0.10 (0.23)	0.27* (0.14)
Change in neighborhood preferences			
Δ preference for a walkable neighborhood	0.03 (0.03)	0.01 (0.03)	0.02 (0.02)
Δ preference for a neighborhood with mixed uses	-0.01 (0.03)	-0.07** (0.03)	0.01 (0.02)
Δ preference for affordable housing	-0.19* (0.11)	-0.01 (0.11)	0.002 (0.06)
Changes in travel mode preferences			
Δ preference for auto	-0.39*** (0.10)	0.09 (0.10)	-0.03 (0.06)
Δ preference for transit	-0.12 (0.10)	0.04 (0.11)	0.11* (0.06)
Δ preference for walking	0.23** (0.11)	-0.18 (0.11)	-0.05 (0.07)
Life events *(ref: no change)*			
Change in income	0.12 (0.22)	-0.14 (0.22)	0.04 (0.13)
Change in work status/location	0.02 (0.19)	0.03 (0.20)	0.18 (0.12)
Change in marital status	-0.06 (0.25)	0.23 (0.26)	-0.33** (0.15)
Change in household size or household structure	-0.02 (0.21)	-0.05 (0.22)	-0.002 (0.13)
Residential mobility *(ref: stayed in the same neighborhood)*			
Moved to a new neighborhood	-0.36 (0.24)	0.17 (0.25)	-0.34** (0.15)
Observations	204	204	204
R^2	0.36	0.28	0.37
Adjusted R^2	0.3	0.21	0.31
Residual Std. Error (df = 185)	1.18	1.23	0.73
F Statistic (df = 18; 185)	5.83***	3.95***	6.03***

*Note: All models controlled for ethnicity, gender, age, education, and travel behavior at baseline: p<0.1; **p<0.05; ***p<0.01: Δ denotes the change measured in continuous scale*

Table 4 -Effect of the changes in the built environment on travel behavior (non-work trips)

	Change in total non-work trips		
	Δ Walk trips	*Δ Auto trips*	*Δ Transit trips*
	β (SE)	β (SE)	β (SE)
Constant	-0.31 (0.29)	-0.09 (0.30)	0.30* (0.17)
Change in urban form *(ref: decreased or unchanged)*			
Increase in neighborhood walkability	0.34** (0.14)	-0.07 (0.15)	0.03 (0.08)
Increase in regional accessibility	0.24* (0.15)	-0.20 (0.16)	0.06 (0.09)
Change in neighborhood preference			
Δ preference for a walkable neighborhood	0.01 (0.02)	0.02 (0.02)	0.02 (0.01)
Δ preference for a neighborhood with mixed uses	0.001 (0.02)	-0.05*** (0.02)	-0.003 (0.01)
Δ preference for affordable housing	-0.19*** (0.07)	0.05 (0.07)	0.001 (0.04)
Changes in travel mode preferences			
Δ preference for auto	-0.19*** (0.06)	0.09 (0.07)	-0.03 (0.04)
Δ preference for transit	-0.01 (0.07)	0.05 (0.07)	0.05 (0.04)
Δ preference for walking	0.13* (0.07)	-0.16** (0.08)	0.005 (0.04)
Life events *(ref: no change)*			
Change in income	0.28** (0.14)	-0.11 (0.15)	0.05 (0.08)
Change in work status/location	-0.14 (0.13)	-0.05 (0.13)	0.12* (0.07)
Change in marital status	0.08 (0.16)	0.27 (0.17)	-0.24** (0.10)
Change in household size or household structure	-0.09 (0.13)	-0.06 (0.15)	-0.05 (0.08)
Residential mobility *(ref: stayed in the same neighborhood)*			
Moved to a new neighborhood	-0.05 (0.15)	0.22 (0.16)	-0.13 (0.09)
Observations	199	199	199
R^2	0.42	0.26	0.36
Adjusted R^2	0.36	0.19	0.3
Residual Std. Error (df = 180)	0.75	0.81	0.44
F Statistic (df = 18; 180)	7.18***	3.50***	5.62***

*Note: All models controlled for ethnicity, gender, age, education, and travel behavior at baseline: p<0.1; **p<0.05; ***p<0.01: Δ denotes the change measured in continuous scale*

6. Discussion

This study is one of the few studies that examine the effect of neighborhood built environment on travel behavior. Using residential relocation as an opportunity to explore the impact of the change in neighborhood built environment on travel behavior, this study shows that an increase in neighborhood walkability leads to an increase in walking trips independent of preferences and life events. This finding is consistent with the existing literature that has demonstrated a strong relationship between neighborhood built environment and walking (Frank, et al. 2007, King, et al. 2011, Carlson, et al. 2015). The significant positive effect of the change in neighborhood walkability on home-based non-work trips is also consistent with existing cross-sectional studies that have examined the relationship between the neighborhood built environment and home-based non work trips (Cao, Mokhtarian and Handy 2009, Manaug and El-Geneidy 2011, Frank, Bradley, et al. 2008). This study did not find a significant effect of the change in neighborhood walkability on the auto use and transit use. This could be because auto trips and transit trips are determined by factors like vehicle availability, distance to work, transit service quality, etc. The existing literature also suggests that neighborhood walkability has a limited impact on auto use (Stevens 2017). Likewise, higher neighborhood walkability may not necessarily mean high access to transit facilities (Southworth 1997) and therefore, an increase in neighborhood walkability alone may not be enough to increase transit usage.

The change in regional accessibility also had a significant impact on travel behavior. Increase in regional accessibility had a significant positive effect on total walk trips and a marginally positive effect on non-work walk trips. Other studies have also shown that having higher regional accessibility is associated with higher levels of walking (Cho and Rodriguez 2014 , Brown, et al. 2014, Frank, et al. 2010, Huang, Moudon and Zhou, et al. 2017). However, the marginally significant effect of regional accessibility on walking for non-work trips could be because of the nature of non-work trips by walking. Studies have found that non-work walk trips are short distance and therefore may not be affected by the macro-level built environment characteristics such as the change in regional accessibility (Saelens, Sallis and Frank 2003). This study also found a marginally significant effect of the change in regional accessibility on transit use for total trips. Though non-significant, the effect of the increase in regional accessibility on auto trips was in the expected direction. The highly walkable built environment and the efficient transit service at urban centers may coincide with the increase in total walking trips and transit usage (Hong, Boarnet and Houston 2016, Huang, Moudon and Zhou, et al. 2017).

This study also examined the effect of various factors related to neighborhood preferences and travel preferences on travel behavior; the results have important implication for planners and policymakers. Even though the effect of neighborhood preference for mixed uses on walking was not significant, there was a significant inverse effect of the change in preference for a neighborhood with mixed uses on auto trips. Therefore, policies geared towards changing preferences for a mixed-use neighborhood can also be useful in changing auto use. Another significant finding from this study is the inverse effect of preference for affordable housing on walk trips. The finding suggests that people who move to neighborhood based on affordability may walk less. One possible explanation for such a relationship could be the lower cost of housing in a neighborhood with minimal amenities that support walkability; the suburban areas which are mostly less walkable are often considered an option for affordable housing. Studies have shown that walkable neighborhoods tend to be less affordable (Talen 2010, Koschinsky and Talen 2015). Likewise, low supply of walkable neighborhood can lead to an increase in housing cost in the walkable neighborhood which can push people to move to less walkable but more affordable neighborhoods (Frank and Kavage 2009). Our results show that a higher preference for walking contributes to more walking but reduces driving for non-work trips. Likewise, a higher auto preference has an adverse effect on walk trips. These results show that preference has an additional impact on travel behavior in conjunction with the effect of urban form. These results are consistent with studies that have studied the effect of preference and attitudinal predisposition on travel behavior and argued that travel is not merely a derived demand with disutility but has a positive utility (Mokhtarian, Salomon and Redmond 2001, Ory and Mokhtarian 2005, Cao, Mokhtarian and Handy 2009).

Among the various life events examined in this study, there were some notable effects of life events on travel behavior. The change in income had a significant positive effect on the non-work walk trips. Studies have shown a significant association between walking and income level (Agrawal and Schimek 2007, Yang and Diez-Roux 2012). Since the models only use change in income, further analysis (t-test) was done to examine the nature of change in income (decrease vs. increase) and its effect on the walk trips (table 5 in appendix). The test showed that those whose income decreased or did not change in time two walked more for non-work trips that those whose income increased in time two. This finding is consistent with the cross-sectional studies that have shown a positive relation between lower income and walking level (Yang and Diez-Roux 2012). In addition to the effect on change in income, change in marital status had a significant negative effect on transit trips. Because the study did not ask the participants about the marital status, we were not able to further examine how the change in marital status (married vs. single) impacted transit usage. This study also found a marginally significant positive effect of the change in work or work location on transit use. Like marital status, we are not able to examine how the change in work affected transit use.

This study has several limitations. First, though this study examined the effect the change in built environment, neighborhood preference and travel preferences on travel behavior and found some significant effects, it could not adequately capture the effect of life events on travel behavior. Since the effect of life events on travel behavior take longer to appear, the research design used in this study may not have fully captured the effect. Other studies that have examined the effect of life events have used longer time frame to examine the effect of the life events on travel behavior. Second, though this study uses a robust study design, the small sample size can have a significant effect on the power of the study. The small sample size is a common problem in studies using longitudinal design because of the high attrition of participants. This was exacerbated by the challenge of following residential movers. Furthermore, limited funding was also a big reason that limited us from including more time points in our data. Third, the findings from this study might be specific to the geographic boundary and might be generalizable to another geographic and cultural context. Future studies can address the limitations of this study while examining the effect of the change in a neighborhood built environment and travel behavior using residential relocation approach.

7. Policy Implication

The findings from this study have four significant implications for planning and public policy. The first implication is related to the role of the built environment on travel behavior. The findings on the impact of the change in neighborhood walkability provide substantial evidence supporting the current efforts made by planners at the different levels of government to create walkable communities. The positive effect of regional accessibility on walking and transit trips shows that regional urban structure also has a significant impact on travel behavior. Studies have shown both local and regional built environment features affect travel behavior (Handy 1992, Cho and Rodriguez 2014). This highlights the need for regional governments to work toward increasing regional accessibility by investing in multimodal transportation infrastructure. Planners should therefore not only focus on making neighborhoods walkable at the local level but also work on making the neighborhood well connected to the regional urban centers.

The second implication of this study is the significant role of preference and attitudinal predisposition on travel behavior. Studies have already highlighted the need for soft policies targeted towards changing preferences and attitudes (Anable 2005, Hong, Boarnet and Houston 2016). Informational and educational measures like individualized marketing, public information campaign, and social media campaign are some of the approaches that can be used to influence preferences and attitudes (Garling and Fuji 2009). Studies have shown that such policies are affecting in influencing preference and leading to a change in travel behavior. The mass media campaign like TravelWise in the UK can be useful in changing public attitudes (Jones and Sloman 2003). In addition, more personalized approaches like Travel Feedback Program which are tailored towards influencing behavior at the individual level can also be effective in changing travel behavior (Fujii and Taniguchi 2006). Using such soft approaches in conjunction with policies targeted towards the objective built environment, planners can formulate plans and policies to manage travel demand effectively.

The third implication of this study is the need for increasing affordable housing in the walkable neighborhood. This study showed that preference for affordability has an adverse effect on walk trips. Cities should, therefore, be more aggressive in implementing policies to create a more walkable neighborhood to meet the demand for a walkable neighborhood. Amending the local development codes and zoning regulations that favor high density, mixed uses, and multimodal transportation network can have a significant effect in increasing the stock of walkable neighborhood to address high housing cost in a walkable neighborhood. Some of the examples include laneway housing or ancillary dwelling unit which can help increase rental housing stock in a walkable neighborhood. Likewise, inclusionary zoning can also be an effective legislative tool that municipalities can implement to increase affordable housing in a walkable neighborhood (Lerman 2006). Cities can also implement programs such as Living Smart Program initiated by the City of Portland Oregon (US Department of Housing and Urban Development 2018) for developing housing in smaller lots with small ground coverage to minimize the housing cost. Though these policies should be implemented after rigorous public input and engagement, these policies can provide a guiding framework to address housing affordability in a walkable neighborhood. The fourth implication of this study is the need to account for the effect of life events on travel behavior. Rather than using one size fits all approach in formulating land use and transport policies, planners and policymakers should also account the travel pattern and needs of the people in different stages of life (Zhang and Van-Acker 2017).

In addition to these policy implications, the geographic context of this study also has a significant policy implication for regional and municipal government in Metro Vancouver. Metro Vancouver, especially the city of Vancouver, have ambitious plans aiming to make a significant increase in non-motorized transportation, a significant decrease in per capita vehicle miles and creating communities that have diverse housing choices (Metrovancouver 2011, City of Vancouver 2012). Although the region is making good progress by investing in public transit, urban greenways, and walkable neighborhood, the findings from the study provide significant evidence regarding the need for policies geared towards addressing preferences, attitudes, affordability and the mobility needs of people at different life stages.

8. Conclusion

This study examined whether changes in the built environment are associated with changes in travel behavior. It used residential relocation as an opportunity to examine the effect of the changes in the built environment on travel behavior. It examined the effect of the change in neighborhood walkability in a change in travel behavior by simultaneously accounting for changes in neighborhood preferences, travel preferences, travel attitudes and lifestyle factors. The results of the study provide substantial evidence supporting the effect of a change in neighborhood built environment on travel behavior. Notably, the increase in neighborhood walkability can have a significant positive impact on walking trips. Since walking has numerous benefits related to physical, mental, social and environmental well-being, the findings from this study support the rationale for creating a more walkable neighborhood. The findings on the effect of changes in neighborhood preferences, travel preferences, travel attitudes and lifestyle factors indicate that policies targeted towards changing preferences and attitudes are equally important to change travel behavior. Likewise, the findings on the adverse effect of neighborhood affordability on walking behavior highlight the need for increasing housing affordability. Additionally, the findings of the study also suggest that the travel behavior is affected not only by the built environment, and preferences but also by life events.

Acknowledgements: The funding for this study was provided by the Heart and Stroke Foundation of Canada, Canadian Institutes of Health Research, Real Estate Foundation of BC, and the Bombardier Foundation for Sustainable Transportation. The authors would also like to acknowledge the support of the Pacific Institute for Climate Solutions (PICS).

Conflict of interest: Authors declare no conflict of interest.

References

Agrawal, Asha Weinstein, and Paul Schimek. 2007. “Extent and correlates of walking in the USA.” *Transportation Research Part D* 12: 548-563.

Anable, Jillian. 2005. “‘Complacent Car Addicts’ or ‘Aspiring Environmentalists’? Identifying travel behavior segments using attitude theory.” *Transport Policy* 12 (01): 65-78.

Bagley, Michael N., and Patricia L. Mokhtarian. 2002. “The impact of residential neighborhood type on travel behavior: A structural equations modeling approach.” *Annals of Regional Science* 36: 279-297.

Bamberg, Sebastian. 2006. “Is a Residential Relocation a Good Opportunity to Change People's Travel Behavior? Results From a Theory-Driven Intervention Study.” *Environment and Behavior* 38 (06): 820-840.

Bhat, Chandra R., and Jessica Y. Guo. 2007. “A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels.” *Transportation Research Part B: Methodological* 41 (05): 506-526.

Blumenberg, Evylen, and Gregory Pierce. 2014. “A Driving Factor in Mobility? Transportation's Role in Connecting Subsidized Housing and Employment Outcomes in the Moving to Opportunity (MTO) Program.” *Journal of the American Planning Association* 80 (01): 52-66.

Boarnet, Marlon. 2011. “A Broader Context for Land Use and Travel Behavior, and a Research Agenda.” *Journal of the American Planning Association* 77 (03): 197-213.

Boarnet, Marlon, and Randall Crane. 2001. “The influence of land use on travel behavior: specification and estimation strategies.” *Transportation Research Part A: Policy and Practice* 35 (09): 823-845.

Boer, Rob, Yuhui Zheng, Adrian Overton, Gregory K. Ridgeway, and Deborah A. Cohen. 2007. “Neighborhood

Design and Walking Trips in Ten U.S. Metropolitan Areas." *American Journal of Preventive Medicine* 32 (04): 298–304.

Brown, Barbara B., and Carol M. Werner. 2008. "Before and After a New Light Rail Stop: Resident Attitudes, Travel Behavior, and Obesity." *Journal of the American Planning Association* 75 (01): 05-12.

Brown, Scott C., Joanna Lombard, Matthew Toro, Shi Huang, Tatiana Perrino, Gianna Perez-Gomez, Elizabeth Plater-Zyberk, et al. 2014. "Walking and Proximity to the Urban Growth Boundary and Central Business District." *American Journal of Preventive Medicine* 47 (04): 481-486.

Burchell, Robert W., David Listokin, and Catherine C. Galley. 2000. "Smart Growth: More Than a Ghost of Urban Policy Past, Less Than a Bold New Horizon." *Housing Policy Debate* 11 (04): 821-879.

Calthorpe, Peter. 1993. *The Next American Metropolis: Ecology, Community, and the American Dream.* Princeton Architectural Press.

Cao, X.(J.), P.L. Mokhtarian, and S.L Handy. 2008. *Examining the Impacts of Residential Self-Selection On Travel Behavior: Methodologies and Empirical Findings.* University of Minnesota Center for Transportation Studies.

Cao, Xinyu(Jason), Patricia L. Mokhtarian, and Susan L. Handy. 2009. "The relationship between the built environment and nonwork travel: A case study of Northern California." *Transportation Research Part A: Policy and Practice* 43 (05): 548-559.

Cao, Xinyu, and Daniel Chatman. 2016. "How will smart growth land-use policies affect travel? A theoretical discussion on the importance of residential sorting." *Environment and Planning B: Urban Analytics and City Science* 43 (01): 58 - 73.

Cao, Xinyu, Patricia L. Mokhtarian, and Susan L. Handy. 2009. "No Particular Place to Go An Empirical Analysis of Travel for the Sake of Travel." *Environment and Behavior* 41 (02): 233 - 257.

Cao, Xinyu, Susan L. Handy, and Patricia L. Mokhtarian. 2006. "The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX." *Transportation* 33 (01): 1-20.

Carlson, Jordan A., Brian E. Saelens, Jacqueline Kerr, Jasper Schipperijn, Terry L. Conway, Lawrence D. Frank, Jim E. Chapman, Karen Glanz, Kelli L. Cain, and James F. Sallis. 2015. "Association between neighborhood walkability and GPS-measured walking, bicycling and vehicle time in adolescents." *Health & place* 32: 1-7.

Cervero, Robert, and Kara Kockelman. 1997. "Travel Demand and the 3Ds: Densitiy, Diversity, and Design." *Transportation Research-D* 02 (03): 199-219.

Cho, Gi-Hyoug, and Daniel Rodriguez. 2014 . "Location or design? Associations between neighbourhood location, built environment and walking." *Urban Studies* 52 (08): 1434-1453.

City of Vancouver. 2012. *Greenest City 2020: Action plan.* Vancouver: City of Vancouver.

Clark, Ben, Kiron Chatterjee, and Steve Melia. 2016. "Changes to commute mode: The role of life events, spatial context and environmental attitude." *Transportation Research Part A: Policy and Practice* 89: 89-105.

Clark, Ben, Kiron Chatterjee, and Steve Melia. 2014. "Life events and travel behaviour: Exploring the interrelationship using UK Household Longitudinal Study data." *Transportation Research Record* 2413: 54-64.

Conner, Mark, and Paul Sparks. 2005. "Theory of Planned Behavior and Health Behavior." In *Predicting Health Behavior: Research and Practice with Social Cogntive Models*, edited by Mark Conner and Paul Norman, 223-275. Open Unviersity Press.

Coughlin, Steven S. 1990. "Recall bias in epidemiologic studies." *Journal of clinical epidemiology* 43 (01): 87-91.

Crane, Randall. 2000. "The influence of urban form on travel: an interpretive review." *Journal of Planning Literature* 15 (01): 03-23.

Danielsen, Karen A., Robert E. Lang, and William Fulton. 1999. "Retracting Suburbia: Smart Growth and the Future of Housing." *Housing Policy Debate* 10 (03): 513-540.

Duany, Andrés, Elizabeth Plater-Zyberk, Alex Krieger, and William R. Lennertz. 1991. *Towns and Town Making Principles.* Harvard Graduate School of Design.

Eliasson, Jonas, Lars Hultkrantz, Lena Nerhagen, and Lena Smidfelt Rosqvist. 2009. "The Stockholm congestion – charging trial 2006: Overview of effects." *Transportation Research Part A: Policy and Practice* 43 (03): 240-250.

Ewing, Reid, and Robert Cervero. 2001. "Travel and the Built Environment A Synthesis." *Transportation Research Record* 1780: 87-114.

Ewing, Reid, Gail Meakins, Shima Hamidi, and Arthur C. Nelson. 2014. "Relationship between urban sprawl and physical activity, obesity, and morbidity – Update and refinement." *Health & Place* 26: 118-126.

Fatmi, Mahmudur Rahman, and Muhammad Ahsanul Habib. 2017. "Modelling mode switch associated with the change of residential location." *Travel Behavior and Society* 09: 21-28.

Fitzhugh, Eugene C., David R. Bassett, and Mary F. Evans. 2010. "Urban trails and physical activity: a natural experiment." *American journal of preventive medicine* 39 (03): 259-262.

Forsyth, Ann, J. Michael Oakes, Kathryn H. Schmitz, and Mary Hearst. 2007. "Does Residential Density Increase Walking and Other Physical Activity?" *Urban Studies* 44 (04): 679-697.

Foster, Sarah, Matthew Knuiman, Paula Hooper, Hayley Christian, and Billie Giles-Corti. 2014. "Do changes in residents' fear of crime impact their walking? Longitudinal results from RESIDE." *Preventive medicine* 62: 161-166.

Frank, Lawrence D, James F Sallis, Brian E Saelens, Lauren Leary, Kelli Cain, Terry L Conway, and Paul M Hess. 2010. "The Development of a Walkability Index: Application To the Neighborhood Quality of Life Study." *Behavioral Journal of Sports Medicine* 44 (13): 924-933.

Frank, Lawrence D., Michael J. Greenwald, Steve Winkelman, James Chapman, and Sarah Kavage. 2010. "Carbonless footprints: Promoting health and climate stabilization through active transportation." *Preventive Medicine* 50: S99–S105.

Frank, Lawrence Douglas, Brian E. Saelens, Ken E. Powell, and James E. Chapman. 2007. "Stepping towards causation: Do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity?" *Social Science & Medicine* 65 (09): 1898-1914.

Frank, Lawrence, and Sarah Kavage. 2009. "A National Plan for Physical Activity: The Enabling Role of the Built Environment." *Journal of Physical Activity and Health* 06 (02): S186–S195.

Frank, Lawrence, Mark Bradley, Sarah Kavage, James Chapman, and T. Keith Lawton. 2008. "Urban form, travel time, and cost relationships with tour complexity and mode choice." *Transportation* 35 (01): 37-54.

Fujii, Satoshi, and Ayako Taniguchi. 2006. "Determinants of the effectiveness of travel feedback programs—a review of communicative mobility management measures for changing travel behaviour in Japan." *Transport Policy* 13: 339-348.

Fujii, Satoshi, and Ryuichi Kitamura. 2003. "What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change." *Transportation* 30 (01): 81-95.

Garling, Tommy, and Satoshi Fuji. 2009. *Expanding Sphere of Travel Behaviour Research: Selected Papers from the 11th International Conference on Travel Behaviour Research.* Edited by Ryuichi Kitamura, Toshio Yoshii and Toshiyuki Yamamoto. Emerald Group Publishing.

Giles-Corti, Billie, Fiona Bull, Matthew Knuiman, Gavin McCormack, Kimberly Van Niel, Hayley Christian Anna Timperio d, l Sarah Foster, Mark Divitini, Nick Middleton, and Bryan Boruff. 2013. "The influence of urban design on neighbourhood walking following residential relocation: Longitudinal results from the RESIDE study." *Social Science & Medicine* 77: 20-30.

Griffin, Beth Ann, Christine Eibner, Chloe E. Bird, Adria Jewell, Karen Margolis, Regina Shih, Mary Ellen Slaughter, Eric A. Whitsel, Matthew Allison, and Jose J. Escarce. 2014. "The Relationship between Urban Sprawl and Coronary Heart Disease in Women." *Health Place* 20: 51-61.

Handy, S L, and D A Niemeier. 1997. "Measuring accessibility: an exploration of issues and alternatives." *Environment and Planning A* 29: 1175-1194.

Handy, Susan L. 1992. "Regional Versus Local Accessibility: Neo-Traditional Development and Its Implications for Non-work Travel." *Built Environment* 18 (04): 253-267.

Handy, Susan, Xinyu Cao, and Patricia Mokhtarian. 2005. "Correlation or causality between the built environment and travel behavior? Evidence from Northern California." *Transportation Research Part D* 10: 427-444.

Hong, Andy, Marlon G. Boarnet, and Douglas Houston. 2016. "New light rail transit and active travel: A longitudinal study." *Transportation Research Part A: Policy and Practice* 92: 131-144.

Huang, Ruizhu, Anne V. Moudon, Chuan Zhou, Orion T. Stewart, and Brian E. Saelens. 2017. "Light rail leads to more walking around station areas." *Journal of Transport & Health* 06: 201-208.

Huang, Ruizhu, Anne V. Moudon, Chuan Zhouc, Orion T. Stewart, and Brian E. Saelens. 2017. "Light rail leads to more walking around station areas." *Journal of transport & health* 06: 201-208.

Jones, Peter, and Lynn Sloman. 2003. "Encouraging behavioural change through marketing and management: what can be achieved." 1*0th international conference on travel behaviour research.* Lucerne, Switzerland. 10-15.

King, Abby C., James F. Sallis, Lawrence D. Frank, Brian E. Saelens, Kelli Cain, Terry L. Conway, James E. Chapman, David K. Ahn, and Jacqueline Kerr. 2011. "Aging in neighborhoods differing in walkability and income: associations with physical activity and obesity in older adults." *Social science & medicine* 73 (10): 1525-1533.

Kitamura, Ryuichi. 2009. "Life-style and travel demand." *Transportation* 36 (06): 679-710.

Klinger, Thomas, and Martin Lanzendorf. 2016. "Moving between mobility cultures: what affects the travel behavior of new residents?" *Transportation* 43 (02): 243-271.

Knuiman, Matthew W., Hayley E. Christian, Mark L. Divitini, Sarah A. Foster, Fiona C. Bull, Hannah M. Badland, and Billie Giles-Corti. 2014. "A Longitudinal Analysis of the Influence of the Neighborhood Built Environment on Walking for Transportation: The RESIDE Study." *American Journal of Epidemiology* 180 (05): 453-461.

Koohsari, Mohammad Javad, Takemi Sugiyama, Karen Elaine Lamb, Karen Villanueva, and Neville Owen. 2014. "Street connectivity and walking for transport: Role of neighborhood destinations ." *Preventive Medicine* 66: 118–122.

Koohsari, Mohammad Javad, Takemi Sugiyama, Suzanne Mavoa, Karen Villanueva, Hannah Badland, Billie Giles-Corti, and Neville Owen. 2016. "Street network measures and adults' walking for transport: Application of space syntax." *Health & Place* 38: 89-95.

Koschinsky, Julia, and Emily Talen. 2015. "Affordable Housing and Walkable Neighborhoods A National Urban Analysis." *Cityscape* 17 (02): 13-56.

Krizek, Kevin J. 2003. "Residential relocation and changes in urban travel: Does neighborhood-scale urban form matter?" *Journal of the American Planning Association* 69 (03): 265-281.

Lanzendorf, Martin. 2003. "Mobility biographies. A new perspective for understanding travel behavior." *10th International Conference on Travel Behaviour Research.* Lucerne. 10-15.

Lanzendorf, Martin. 2002. "Mobility styles and travel behavior: Application of a lifestyle approach to leisure travel." *Transportation Research Record: Journal of the Transportation Research Board* 1807: 163-173.

Lee, Chanam, and Anne Vernez Moudon. 2006. "Correlates of Walking for Transportation or Recreation Purposes."

Journal of Physical Activity and Health 03: S77-S98.

Lerman, Brian R. 2006. “MANDATORY INCLUSIONARY ZONING-THE ANSWER TO THE AFFORDABLE HOUSING PROBLEM.” *Boston College Environmental Affairs Law Review* 33 (02): 383-416.

Li, Fuzhong, Peter Harmer, Bradley J. Cardinal, and Naruepon Vongjaturapat. 2009. “Built environment and changes in blood pressure in middle aged and older adults.” *Preventive Medicine* 48 (03): 237–241.

Lin, Tao, Donggen Wang, and Meng Zhou. 2018. “Residential relocation and changes in travel behavior: what is the role of social context change?” *Transportation Research Part A: Policy and Practice* 111: 360-374.

MacDonald, John M., Robert J. Stokes, Deborah A. Cohen, Aaron Kofner, and Greg K. Ridgeway. 2010. “The effect of light rail transit on body mass index and physical activity.” *American journal of preventive medicine* 39 (02): 105-112.

Manaug, Kevin, and Ahmed El-Geneidy. 2011. “Validating walkability indices: How do different households respond to the walkability of their neighborhood?” *Transportation Research Part D: Transport and Environment* 16 (04): 309-315.

McCormack, Gavin R., Lindsay McLaren, Grazia Salvo, and Anita Blackstaffe. 2017. “Changes in objectively-determined walkability and physical activity in adults: a quasi-longitudinal residential relocation study.” *International journal of environmental research and public health* 14 (05): 551.

Metrovancouver. 2011. *Metro Vancouver 2040 Shaping Our Future: Adopted by the Greater Vancouver Regional District Board on July 29, 2011 Updated to July 28, 2017.* Regional Growth Strategy Bylaw No.1136, 2010, Vancouver: Metrovancouver.

Mobley, Lee R., Elisabeth D. Root, Eric A. Finkelstein, Olga Khavjou, Rosanne P. Farris, and Julie C. Will. 2006. “Environment, Obesity, and Cardiovascular Disease Risk in Low-Income Women.” *American Journal of Preventive Medicine* 30 (04): 327–332.e1.

Mokhtarian, Patricia L., Ilan Salomon, and Lothlorien S. Redmond. 2001. “Understanding the Demand for Travel: It's Not Purely 'Derived'.” *Innovation: The European Journal of Social Science Research* 14 (04): 355-380.

Næss, Petter. 2012. “Urban form and travel behavior: Experience from a Nordic context.” *The Journal of Transport and Land Use* 05 (02): 21–45.

Ngo, Victor Douglas, D. Lawrence Frank, and Alexander Y. Bigazzi. 2018. “Effects of new urban greenways on transportation energy use and greenhouse gas emissions: A longitudinal study from Vancouver, Canada.” *Transportation Research Part D: Transport and Environment* 62: 715-725.

Ory, T David, and L Patricia Mokhtarian. 2005. “When is getting there half the fun? Modeling the liking for travel.” *Transportation Research Part A: Policy and Practice* 39 (2-3): 97-123.

Panter, Jenna, Eva Heinen, Roger Mackett, and David Ogilvie. 2016. “Impact of new transport infrastructure on walking, cycling, and physical activity.” *American journal of preventive medicine* 50 (02): e45-e53.

R Core Team. 2013. “R: A language and environment.” Vienna: R Foundation for Statistical Computing.

Ramirez, Laura K. Brennan, Christine M. Hoehner, Ross C. Brownson, Rebeka Cook, C. Tracy Orleans, Marla Hollander, Dianne C. Barker, et al. 2006. “Indicators of Activity-Friendly Communities An Evidence-Based Consensus Process.” *American journal of preventive medicine* (31(6), 515-524.) 31 (06): 515-524.

Saelens, Brian E., and Susan L. Handy. 2008. “Built Environment Correlates of Walking: A Review.” *Med Sci Sports Exerc* 40 (07): S550–S566.

Saelens, Brian E., James F. Sallis, and Lawrence D. Frank. 2003. “Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literatures.” *Annals of behavioral medicine* 25 (02): 80-91.

Sallis, James F., Mary Story, and Deborah Lou. 2009. “Study Designs and Analytic Strategies for Environmental and

Policy Research on Obesity, Physical Activity, and Diet: Recommendations from a Meeting of Experts." *Am J Prev Med* 36 (02): S72–S77.

Sallis, James F., Myron F. Floyd, Daniel A. Rodrıguez, and Brian E. Saelens. 2012. "Role of Built Environments in Physical Activity, Obesity, and Cardiovascular Disease." *Circulation* 125 (05): 729-737.

Salomon, I, and M Ben-Akiva. 1983. "The use of life-style concept in travel demand models." *Environment and Planning A* 15: 623-638.

Sanbonmatsu, Lisa, Lawrence F. Katz, Jens Ludwig, Lisa A. Gennetian, Greg J. Duncan, Ronald C. Kessler, Emma K. Adam, Thomas McDade, and Stacy T. Lindau. 2011. "Moving to opportunity for fair housing demonstration program: Final impacts evaluation." U.S. Department of Housing and Urban Development .

Scheiner, Joachim. 2007. "Mobility biographies: Elements of a biographical theory of travel demand." *Erdkunde* 61 (02): 161-173.

Scheiner, Joachim, and Christian Holz-Rau. 2013. "Changes in travel mode use after residential relocation: a contribution to mobility biographies." *Transportation* 40 (02): 431-458.

Scheiner, Joachim, and Christian Holz-Rau. 2007. "Travel mode choice: affected by objective or subjective determinants?" *Transportation* 34: 487-511.

Schwanen, Tim, and Patricia L. Mokhtarian. 2004. "The extent and determinants of dissonance between actual and preferred residential neighborhood type." *Environment and Planning B: Planning and Design* 31 (05): 759-784.

Sinniah, Gobi Krishna, Muhammad Zaly Shah, Geoff Vigar, and Paulus Teguh Aditjandra. 2016. "Residential Location Preferences: New Perspective." *Transportation Research Procedia* 17: 369-383.

Southworth, Michael. 1997. "Walkable Suburbs?: An Evaluation of Neotraditional Communities at the Urban Edge." *Journal of the American Planning Association* 63 (01): 28-44.

Southworth, Michael, and Eran Ben-Joseph. 1995. "Street Standards and the Shaping of Suburbia." *Journal of the American Planning Association* 61 (01): 65-81.

Stevens, Mark R. 2017. "Does Compact Development Make People Drive Less?" *Journal of American Planning Association* 83 (01): 07-18.

Talen, Emily. 2010. "Affordability in New Urbanist Development: Principle, Practice, and Strategy." *Journal of urban affairs* 32: 489-510.

US Department of Housing and Urban Development. 2018. *Portland, Oregon: Living Smart Program.* Office of Policy Development and Research (PD&R). Accessed 07 19, 2018. https://www.huduser.gov/portal/casestudies/study_101711_1.html.

Van Acker, Veronique, Bert Van Wee, and Frank Witlox. 2010. "When transport geography meets social psychology: toward a conceptual model of travel behaviour." *Transport Reviews* 30 (02): 219-240.

Yang, Yong, and Ana V. Diez-Roux. 2012. "Walking Distance by Trip Purpose and Population Subgroups." *American Journal of Preventive Medicine* 43 (01): 11-19.

Zhang, Junyi, and Veronique Van-Acker. 2017. "Life-oriented travel behavior research: An overview." *Transportation Research Part A: Policy and Practice* 104: 167-178.

Appendix

Table 5: Change in travel behavior by the change in income (t-test)

	Change in income		P-value
	Decreased or unchanged N = 159	Increased N = 62	
Total trips			
Δ Total auto trips	-0.26 (±1.44)	0.06 (±1.09)	0.12
Δ Total transit trips	0.03 (±0.89)	-0.12 (±0.73)	0.22
Δ Total walk trips	0.03 (±1.29)	-0.53 (±1.55)	0.007***
Non-work trips			
Δ Auto trips	-0.09 (±0.88)	0.10 (±0.85)	0.16
Δ Transit trips	0.01 (±0.55)	-0.15 (±0.39)	0.040**
Δ Walk trips	0.11 (±0.86)	-0.38 (±0.97)	0.0004***

*Note: Δ denotes the change measured in continuous scale: p<0.1; **p<0.05; ***p<0.01*