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Comparing Mode Shares for Non-residential Destinations in Urban and Suburban Environments

BY

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ABSTRACT

To ensure facility for multimodal transportation is one of the most important concerns in today's transportation sector, with initiatives being taken to make multimodal transportation popular. The built environment variables have a strong relationship with transportation mode choice, but whether that relationship holds true in urban and suburban neighborhoods in the same manner has not been considered. Using data for three non-residential land uses, this research explores whether the built environment variables in suburban areas influences mode share like it does in urban areas. We used survey data conducted at the establishments regarding respondents' travel characteristics from a previous study, as well as the built environment characteristics of the location around the establishments. Using mode choice and built environment data we ran multiple regression models with a dummy variable for suburban places. The results of our regression modeling showed the differing impacts of urban and suburban environments on the mode share. This could be an important consideration for future researchers in estimating travel behavior within different environments. Our study does not define the difference in the relationship but it shows that consideration regarding this matter should be taken into account. It would be vital for investigators to understand any unexpected travel behavior to an establishment in a suburban environment.

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1.0 INTRODUCTION

An increasing amount of research is being conducted to evaluate alternative modes of transportation other than private automobiles, such as walking, biking or taking transit (Dill, 2003; Handy, 2006; Litman, 2014; Bishop, 2015; Litman, 2015). These alternative transportation modes are also called active transportation or multimodal transportation. Making multimodal transportation more popular is beneficial in many ways. Natural resources are limited and automobile transportation is responsible for making then scarcer. Almost half of the oil used in the world is consumed by automobile transportation. Making alternative modes of travelling more available to people will result in less fuel consumption, and it will also help natural resource remain available. Another benefit of alternative transportation is when people reduce automobile trips, the amount of emitted gas is also reduced. Therefore this helps in reducing air pollution and contributes to environmental sustainability (Giles-Corti et al 2010). Shifting to multimodal transport also increases the amount of physical activity which can help to maintain good health by reducing obesity and other chronic diseases (Sallis et al 2004). Therefore, active transportation can benefit both people and the environment, by reducing the amount of automobile trips. Multimodal transportation is also important for the urban design. Automobile dependent transportation systems need a lot of land acquisition, which creates difficulty in maintaining an urban boundary. Multimodal transportation is capable of taking care of this issue, as it reduces the land consumption. Making alternative modes of transportation available to all the people also ensures cheap and equitable transportation for low-income people.

Understanding the multifaceted importance of active modes of transportation, researchers and policy makers are trying to make multimodal transportation available to the people. The choice of transportation mode depends on many factors and there is a strong relation with built environment variables. The definition of the built environment varied widely among the researchers, mostly “it is defined as the part of the physical environment which is constructed by human activity”, (Saelens & Handy, 2008). The built environment includes the Land Use, the Transportation System and the Urban Design. Land Use generally means the distribution of different kinds of activities, and their locations and densities across the space. Here, activities are grouped into different major categories, for example residential, commercial, and industrial and so on. The Transportation System refers to the infrastructures for transportation and also the transit facilities. The Urban Design is used to indicate the design of public spaces and the arrangement and alignment of the physical elements within it (Handy et al, 2002).

Many studies have been conducted regarding the relationship between built environment and travel behavior, and researchers have found a significant relationship between these two (Saelens et al, 2003; Cervero & Ewing, 2001; Sallis et al 2004). People’s choice of mode depends on different features of the neighborhood they live in such as population density, employment density, connectivity of the neighborhood and availability of transit. These kind of features vary across different neighborhoods from urban to suburban areas. Usually the urban neighborhoods have more residential density and connectivity and are expected to have more use of non-auto modes (Kitamura et al, 1997). Neighborhoods located in suburban areas often have less connectivity and the residents use more automobile modes.

As built environment has proven to impact people’s choice of transportation behavior, many initiatives have been taken to improve the built environment to enhance multimodal transportation. Based on different urban settings, variables may have different influences upon the travel behavior of the residents.

1.1 Background

The percentage of people living in suburban areas is growing at a very high rate – higher than the rate of urban growth. By 2000, half of the U.S. population lived in suburban areas (Hobbs & Stoops, 2002). The suburban residents usually are more dependent on automobile modes. A meta-analysis on the different studies regarding the impact of urban form on travel behavior (Leck, 2006) found that "Residents who live in more diverse urban environments are more likely to commute to work by transit or by slow modes". As suburban residents are becoming a major portion of the population, concerns have arisen to make them less dependent on the automobile mode to ensure a healthy and sustainable community.

From the continuing research about the relation between land use and travel behavior, it is known that residents' choice of travel mode is related to the characteristics of the neighborhood they live in. The different attributes of a neighborhood such as density, accessibility, connectivity and so forth, often determines the travel behavior of its residents. The earlier studies addressed this topic from a perspective of urban and suburban places (Handy, 1996b), where they compared travel patterns between the traditional urban neighborhoods and the more modern suburban neighborhood. Suburban neighborhoods showed more dependence on automobiles. Gradually, with the availability of more detailed information regarding the variables of the built environment around trip origin and destinations, many research has been conducted to analyze their interaction. Researchers have studied about different variables, which can be mainly categorized as density, diversity and design (Cervero & Kockelman, 1997) and their relation with different travel outcome such as amount of travel made by vehicle, choice of mode and so forth. The variables have a significant relation with different travel behavior in many cases, but that research has not addressed the issue of whether the variables are related differently in suburban areas. Rather, there exists the idea that built environment variables have same influence upon travel behavior everywhere. Our study was aimed at exploring whether this idea is true, or if there is any kind of difference between the influences in different areas, since the urban and suburban areas have many differences between the physical environments of the trip origins and destinations as well as the residents making the trip. These differences sometime lead to unexpected travel outcomes in suburban areas. So we came up with the idea to compare the multimodal trip generation in urban and suburban areas and explore the variation in the influences of built environment variables as well.

1.2 Objective

Many studies have analyzed the relation between built environment variables and travel behavior, but they considered the built environment variables have a common effect over different environments. The built environment variables vary to a large extent from urban to suburban environments. Also, they are oriented differently over different urban settings. So it would be interesting to see if the different built environment variables also have different influences on the travel behavior. Our study aims to explore the relation between built environment variables and mode choice for urban and suburban areas and to find whether that relationship is the same in different urban and suburban areas. The findings will facilitate future research about the differing impact of built environment variables in suburban mode share, and would also help researchers to understand unexpected travel behavior in suburban area.

1.3 Organization

The general outline of this research is described here. Section 2 contains the review of the existing literature regarding travel behavior and built environment variables. Section 3 describes the various data sources used in this research such as the survey data collected from another study and also the archived built environment data for regression analysis. Section 4 contains the analysis of this research, which is the regression model and result for the relation between different built environment variables and the non-auto mode share from the survey. Section 5 summarizes the results, recommendations and limitations of the study.

2.0 LITERATURE REVIEW:

The study of the relationship of travel behavior and built environment variables has been conducted over time and researchers have interrogated many aspects of built environment variables and travel behavior (Ewing & Cervero, 2001; Frank & Engelke, 2001; Saelens et al, 2003; Cervero & Michael, 2003; Caoet al, 2006; Saelens & Handy, 2008; Rodriguez & Joo, 2009). The earlier studies focused on travel behavior among different neighborhoods, mainly referring to traditional urban or conventional suburban neighborhoods (Crane, 2000). The earlier studies mainly focused on the Vehicle Miles Traveled (VMT) and were based on surveys conducted from the households (Handy, 1996b). With improvements in measurements of the built environment variables, later studies researched the relationship of the variables with travel characteristics (Ewing & Cervero, 2001). These studies were conducted to investigate relations for a wider variation of travel outcomes such as VMT, travel mode choice and so on. Studies were conducted for different kinds of trips such as work trips and non-work trips, and different kinds of data were used. Most of the analyses used data from household surveys, however some collected data from establishments. In this section we cover the existing literature about travel behavior and different neighborhoods, then the literature about the relation of travel behavior with different built environment variables. We also cover studies about different kinds of data collection for the analysis of travel behavior at the end.

2.1 Travel Behavior in Different Neighborhoods:

With changes in urban patterns and the development of suburban areas, researchers were interested in studying the relation between land use pattern and travel characteristics. The structure of a community was categorized based on their accessibility within the community and to a regional center from the community (Handy, 1993). The neighborhoods were also classified to “Transit neighborhoods” and “Auto neighborhoods” in a study where the authored carried out match-pair analyses considering whether the neighborhood was laid out around a transit facility or not. (Cervero & Gorham, 1995). They also considered that whether the neighborhood was built before or after 1945 and whether they had a grid pattern or random pattern. They found influence of the neighborhood design onpeople’s mode choice and the transit neighborhoods had lower drive-alone mode shares than the automobile neighborhoods. Handy (1996c) had some significant finidngs that orientation of neighborhoods makes a difference in people’s choice of transportation. She studied four neighborhoods for non-work trips in order to find the relation with travel behavior, in two traditional downtown areas and two modern post World War II residential developments. She found that the percent of people walking to the shopping centre varied significantly between neighborhoods. While pedestrian oriented design initiates more walking, she also found people walking in adverse environments when the destination was close enogh to walk. However, people had a high tendency to walk to the downotwn area and trip frequency was also high. Another study by Handy (1996d) had modeled pedestrian walking to see the correlation between urban forms and pedestrian trips. With a proposed model for choice of pedestrian trips and the results of a study over six neighborhoods in Austin, they found that urban form has influence upon pedestrian trips with a destination, but for strolling trips they do not have any influence. There is a specific study about local shopping (Handy & Clifton, 2001). They found that the distance to the shopping center was not important in choice of residents mode share, it was the built environment that had more influence on mode choice.

The influence of type and mix of land use upon the use of transit and other non-automobile modes were studied using the American Housing survey for 1985, and they found residents of "traditional" neighborhoods were more likely to use nonautomotive modes for non-work trips than residents of "suburban" neighborhoods (Report 16 Transit and Urban Form, 1996).

A study (Cervero & Carolyn, 1995) investigated the influence of different kinds of neighborhoods on both non-work and commuting travel by comparing modal splits between two distinctly different neighborhoods in the San Francisco Bay Area. One area had compact neighborhoods with grid-like street patterns, mixed land uses, and pedestrian amenities and another was the nearby conventional suburban community. Both of the neighborhoods had similar income profiles, freeway and transit service levels, and geographical locations. After controlling for income and transit service levels, the residents of the more urban neighborhood had around 10 percent higher share of non-work trips by non-automobile modes than the residents of the suburban neighborhood on an average. The highest variation was found for trips made for shopping purposes under one mile. On average, non-work trips were more influenced by the neighborhood environment than the commuting trips.

The simple classification of urban and suburban areas is not solid enough to come to a final conclusion regarding people's travel choice. Handy (1996a) discussed several methods of exploring the link like simulation model, aggregate and disaggregate models, and indicated what it will take to make solid decisions about the link between urban form and travel behavior. From a review of the neighborhood design and travel characterisitcs (Crane, 2000), the author suggested that although some relationships between land use and travel outcomes seem simple, closer examination reveals interactions between many factors and suggested more research to draw better conclusions.

2.2 Travel Behavior and Built Environment:

There is a vast literature about the relation between the built environment and travel behavior. We are concentrating on mode choice in this review. Also, we are focusing on non-work trips rather than work trips. As the literature is spread over a wide area, we will be reviewing some meta-analyses. Built environment variables have a strong impact on people's mode choice. Built environments, are generally described as "D"s of development such as Density, Design, Diversity and Distance to Transit. The variables and related studies are described below:

Density:

Density is one of the most predominant variables in the built environment. It is usually measured as number of units per area. Employment, residential and intersection density are some variables that are measured per area. The travel patterns of the passengers change when density of the variables in the trip ends change. Density indicated the number of different origins and destinations within a certain area and with high density the number of accessible activities increase in the location. A large amount of activity within an area decreases the average length of the trip among the activities, and these shorter trips attract residents to use slower modes like walking or bicycling (Seskin et al, 1996). They also stated that in a dense compact area, transit services can perform better in low density with a lower number of vehicles resulting in lower operational costs.

But one study suggests that employment density at destination is more important than the population density in origin for the choice of modes (Cervero & Ewing, 2001). Frank et al (2008) studied census tracts for work and non-work trips and tested relationship of walking and transit mode share for population and employment densities at origin and destination areas. They found transit share of shopping trips to be greater at high population and employment densities. For walking share of shopping trips, they found significant positive relationship for higher population density at origin and higher employment density at destination. High density of employment and population at either trip end can have great impact on non-automobile trips. In a synthesis study in 2001, the researchers found the aggregate (linear) elasticity of density and vehicle trips to be -0.05, which means when density increases by 10%, the number of vehicle trips decreases by 5% , (Ewing & Cervero, 2001).

Diversity:

Diversity is usually estimated from the proportion of residential/commercial/retail land use or the employment-to-population balance indicator (Wang & Su, 2011). Cervero and Kockelman named some more variables indicating diversity such as dissimilarity index, entropy, vertical mixture, activity center mixture, commercial intensities and proximities to commercial retail uses (Cervero & Kockelman, 1997). They found that these factors lead to reduce single occupancy vehicle trip-making for non-work travel. Ewing and Cervero (Ewing & Cervero, 2001) conducted a synthesis study and calculated the aggregate (linear) elasticity of diversity or mix and vehicle trips to be -0.03 which means when diversity increases by 10%, the number of vehicle trips decreases by 3%. Zhang studied the relation for job housing balance and the walk/ bike mode choice of non-work trips for Boston using Household Travel Survey 1991 and the result showed positive elasticity (Zhang, 2004). From a study conducted on non-work trips indicated relationship between walking and mixed-use neighborhoods, indicating diversity of neighborhood can result to more non-auto trips (Rajamani et al, 2003). When different kind of destinations such as commercial and business places, are interrelated to a higher extent, people tend to walk more and drive less (Seskin et al, 1996).

Design:

Design is generally referred to as the pattern and characteristics of the street network of an area. Design can describe whether the street network is very dense urban interconnected roads or curvilinear residential roads. Typical measures are proportion of four-way intersections, freeway miles and numbers per developed acres, average street widths, and average block sizes which are site level measures. Street level measures are planting strips, street trees, overhead street lights, mid-block crossings, sidewalk length, slope, bicycle lanes and so forth. The site level measures are indications for accessibility for the pedestrians. On the other hand, street level measures describe the comfort level of walking/biking in an area. Many studies have been done upon the site level characteristics and found that walking trips have positive elasticity with intersection density (Frank, 2008) and street connectivity (Zhang, 2004). Zhang also tested the relationship of transit mode share and street connectivity and found positive relationship between them. The aggregate (linear) elasticity of street network density which is a design measure was found to be -0.05 with vehicle trips in the synthesis study (Ewing & Cervero, 2001). This elasticity suggests that if street network density increases by 10%, the number of vehicle trips decreases by 5%.

Street level characteristics have also been studied by in many analysis. The local topography and sidewalk availability attracts a large number of non-auto trips (Rodriguez & Joo, 2009). Kitamura et al (1997) conducted a study on data from San Francisco Bay area and found that frequency of walking and biking trips are higher when sidewalks are present in neighborhoods. The allocation of parking spots also is a measure of walkability as that make walking pleasurable and safe. Cervero & Kockelman (1997) conducted a study for non-private vehicle choice for non-working trips and proportion of front and side parking and found significant relationship between them.

Distance to Transit:

Distance to transit can be defined in many ways. Sometimes it is measured as the average distance of the street route from the place of interest (i.e. origin, destination) to nearest transit stop. It can be also represented by transit route density, distance between transit stops, or the number of station per unit area. In 2003, Bento et al conducted a study on National personal Transportation Survey and found that walk/bike mode choice has positive elasticity with distance to nearest transit stop. Mode share for transit trips have high correlation with transit access (Ewing & Cervero, 2010). A research was done on data collected from more than 1000 large employment sites in the San Francisco Bay Area to study the relation between transit use and transit mode choice and distance to the rail facility. This study found that the sites which have transit facility within one-quarter mile have significant relation with transit mode choice than the sites with distance between one-quarter and one-half mile (Dill, 2003). Another study (Lund et al, 2004) found that people who live near transit facilities are likely to commute by trnasit five more times as the average resident in the same city. This cmprehends the importance of distance to transit. They also found that the design and orientation of the elements of the neighborhood have minor influence upon transit mode share.

Some studies considered these built environment variables as a measure to define different neighborhoods. Sallis et al (2004) reviewed 11 studies which categorized neighborhoods based on different environmental characteristics related to walking. They considered area of higher population density, higher connectivity and greater mixed land use to be more walkable area and area with less density, low connectivity and mostly residential land use to be less walkable. From all the studies and all the trip purposes they found residents from high walkable area reported higher number of walking and biking trips per week. One of these 11 studies was about site design and pedestrian travel was made on 12 sites in the central Puget Sound region (Hess et al 1999). They chose neighborhoods based on similar in population densities, income and land use mix. Among the 12 neighborhoods, half had very extensive pedestrian facility but the other half had limited pedestrian facilities. After controlling for population densities, income and land use mix, they got three times higher walking in the urban sites than the sites having less pedestrian facilities. So the variables capturing the site design characteristics was important for pedestrian volume.

Self-selection is another significant feature to consider. Often residential preference becomes vital for the travel choice, especially pedestrian trips (Cao et al, 2006). In another study, Cao et al (2009) reviewd 38 studies addressing the issue of self selection and found srong relation between built environment and travel behavior even after controlling for self selection.

2.3 Different Sources of Data:

Many studies regarding travel behavior have been done on data collected from household surveys. Household surveys are a useful source of travel data as they ask people about the number of trips they make and also about the destination and mode choices. The trip data also contain information such as vehicle occupancy and time and day of travel. The household survey has some added benefits over the data used by ITE for trip generation purpose, which is the count of vehicle trips that enter and exit at the establishment level. The household travel survey contains people's multimodal travel behavior toward the establishment (Currans & Clifton, 2015).

In another study, Clifton et al (2013) have proposed that establishment level data collection from intercept travel survey is more useful than the count of vehicles by ITE. Apart from vehicle count, an intercept survey gathers better information about trip details and socio-demographic information of visitors. Sometimes trips are not made by a single mode only, often there are segment part of the trip, and information regarding the trip segments can be collected from the visitor. Demographic information from the visitors' survey helps to understand the purpose of trip behavior. Other information like vehicle occupancy and group size of the trip may be collected from observation by the surveyor though it is tricky to some extent. Questions can also be asked about the origin of trip and frequency of coming to the establishments. From this information important concepts regarding trip can be apprehended such as whether the trip is home based or not, whether it is a pass-by trip or internal capture trip.

The establishment level data collection also has some added advantages over the household travel survey in that it contains data about two steps of the basic four step travel demand modeling, trip generation and trip distribution, while the household survey can only provide data to estimate the trip generation. However, one benefit of household travel survey is that other information regarding the respondent characteristics are known from other sources like census data whereas the intercept survey researchers only learn about the characteristics asked of the respondents. Thus, from census data, the bias of the household travel survey data can be checked.

Using establishment level survey data also provides opportunity to observe the built environment variables around the establishment, and characteristics specified to an establishment can also be estimated. This would be helpful to both estimating trip generation and for creating new establishment.

Another study used data collected from intercept surveys (Schneider, 2015) in 20 San Francisco Bay Area shopping districts to find the association of local environment characteristics with walking and biking. The data came from a study conducted by the author to capture the pedestrian activity (Schneider, 2013) which surveyed stores from the same retail pharmacy chain. To estimate the transit use at the transit-oriented develoments in Portland area (Dill, 2008)

2.4 Summary:

Another study from San Francisco Bay Area data (Cervero & Michael, 2003) found diversity to be the strongest predictor for walking, but bicycle was equally influenced by all three types of variables- density, diversity and design. However they found the variables to be more influential on walking and biking around the origins rather than the destinations.

The literature review suggests about the strong relationship about built environment variables and travel behavior. Variables such as density, design, diversity have significant influence on travel mode choice. The knowledge from initial studies reveal the different kind of travel pattern between the urban and suburban environment, for example, change in transit mode share with density for different areas. The later studies researched the relation of more detailed built environment characteristics and travel outcomes. With a large body of research many studies found significant relation with the variables and travel behavior. The researches often classified the neighborhoods based on variables. But they considered one variable would have same impact on travel behavior on different environment. They did not consider that one variable may act in a different way when the variable is located in a completely different environment. Our study would like to analyze this gap and find whether the built environment variable have any different impact on mode share when they are in a suburban area.

3.0 METHODOLOGY:

This research is based on a previous trip generation study done in 2012 (Clifton et al) for three types of non-residential land use such as convenience stores, high turn-over restaurants, and drinking places. Altogether 78 establishments was surveyed to collect data from the visitors about their travel characteristics. The data were collected from different kinds of land uses across urban and suburban areas. People were asked about their mode of transportation for individual trip. They also gathered the value of the built environment variables around the establishment sites. The aim of the study was to develop multimodal trip generation methodology.

Using data from this 2012 study we aim to look more closely at the relationship between the built environment variables and travel outcomes. We also aim to find whether the built environment variables have any different relationships with travel mode choice between urban and suburban areas. Urban and suburban areas have different patterns of land use and characteristics of people, and we hypothesize that many variables will have different influence in suburban areas. First we classified the sites into urban and suburban area. To find the differences we ran different regression models for built environment variables with the mode choice of people for non-automobile modes. At first we run bivariate correlational analysis to understand how the built environment variables are correlated. Then we perform a stepwise regression for pooled, urban and suburban model separately to find the best variable predicting non-auto mode share. We performed multiple regression with the percent of non-auto mode share as dependent variable and some independent variables. These are the built environment variables, dummy for suburban areas, interaction variable between the built environment and the suburban dummy, dummy for convenience stores and interaction variables between dummy for suburban areas and convenience stores. The model showed the influence each built environment variable had upon the mode choice of people. The variable for suburban dummy and interaction variable showed the influence of that built environment variable in suburban areas. Therefore, from the direction and magnitude of the interaction variable we learned about how the variable affects the mode choice if the location is in a suburban area. Then we ran multiple regression analysis for pooled, urban and suburban models separately to see the relation of each built environment variable with each model. These analyses helped us to understand the difference between the relationships among the variables.

This section will describe the method of data collection, and the step by step process taken to perform the analysis:

3.1 Survey Data

The data was collected from 78 establishments including in three kind of land use such as convenience store, high turnover restaurants and drinking places. The establishments were chosen in a way so that those cover the Portland Metro area in both urban and suburban places giving us opportunity to analyze variables behavior along different neighborhoods (Table 1). Data was collected in the afternoon peak hour between 5 Pm to 7 Pm on weekdays to capture the peak travel characteristics. The respondents were asked about their travel and sociodemographic information. Two kinds of survey was conducted as short and long surveys. People who were not interested for long survey was asked four questions of short survey.

Table 1: Establishment Sites in urban and Suburban Areas

Land Use	Urban Area	Suburban Area	Total
Restaurant	28	11	39
Convenience Stores	15	11	26
Bars	13	0	13
Total	56	22	78

Apart from asking people about their trip characteristics and some personal information, the surveyors also collected the total counts of person entering and leaving the establishment. They also collected some site level information around the establishment such as the area of the building, parking capacity of the site.

3.2 Built Environment Variables:

Information related to the built environment of the establishment site was gathered both from onsite observation and archived data sources. Information related to parking and site amenities was collected from the site by the surveyors. Other built environment data such as transit information and different density was collected from different online sources such as Metro RLIS and Trimet. The activity density which is the value of Urban Living Infrastructure (ULI) was collected from the Metro context tool. The value of different built environment variables used in this study are listed below (Table 2) with the used units and data sources.

Table 2: Built Environment Variables and Their Sources

Built Environment Variable*	**Units**	**Data Source**
Number of Transit Corridors	Number of transit bus/rail lines within ½- mile	Light-rail and Bus Stop layer (RLIS, 2010)
People Density	Residents and employees per acre	ESRI Business Analyst (2010) and Multifamily/Household layers (RLIS, 2010)
Number of High- Frequency Transit Stops	Number of stops within ½-mile with headways under 15 Minutes	Bus Stop layer (RLIS, 2010) and TriMet schedules (2011)
Employment Density	Employees per acre	ESRI Business Analyst (2010)
Lot Coverage	Percent	Tax lot and Building Layers (RLIS, 2010)
Length of Bike Facilities	Miles	Bike Route layer (RLIS, 2010)
Access to Rail	Presence of rail station within ½-mile	Light-rail Stop layer (RLIS, 2010)
Intersection Density	Intersections per acre	Lines file (TIGER 2009)
Urban Living Infrastructure	Density index based on the number of retail & service establishments within ½ mile	Metro Context Tool, Portland Metro
Population Density	Residents per square mile	Population count based on Metro Data for residences. 2010.

Note: * Source: (Clifton et al, 2015)

3.3 Classification:

It was difficult to choose how to classify the areas into urban and suburban. Unfortunately, there was no straightforward guideline to differentiate areas into these two regions (Forsyth, 2012). Forsyth tried to define suburb by reviewing existing literature from different studies such as urban planning, history, sociology and urban geography. She found some key dimensions to define suburbs in her research which included the location, built environment characteristics, transportation facilities and type of the buildings based on the human activities conducted in the building. There are also some non-measurable dimensions such as the cultural environment, style of building design and planning. She found density to be one of the most used characteristics among the researchers to define suburb as it was both meaningful and easy to measure. She also found that many authors define suburban as primarily automobile based. But some studies also showed a form of collective transportation such as railways, buses and shared taxis providing access to and around suburbs.

Two studies were found to do the cluster analysis to determine different neighborhoods. (Nelson et al, 2006; De-min et al, 2004). The first study used nineteen variables including income level, age, education, intersection density, mobility, occupation status etc. The second study used seven variables for cluster analysis such as population density, ratio of public water consumption, road density, ratio of bottle gas consuming, ratio of renters, ratio of farm income and rent price. They tried to improve TIGER’s classification method by adding one more classification, named suburban, in addition to urban and rural.

The sites are spread over the different regions of Portland Metropolitan and those were chosen in a way to make sure they covered the range of all different kind of neighborhoods. K-means clustering analysis was done on built environment variables to classify the area types. The analysis was done by statistical package R and the variables included were intersection density, block size, percent of dwellings that are single family detached, percent of employment that is retail, and percent of parcel lot coverage by buildings. The intersection density and block size specify the connectivity and accessibility of an area. Percent of single family and retail employment show the type of land use in an area and also the number of different origins and destinations within a particular neighborhood. The percent of lot coverage indicate the available parking facility. So these variables have significant impact on travel behavior. Five unique classifications of area type resulted from the analysis from a very urban to suburban spectrum as follow (Clifton et al, 2012).

1. Central Business District (CBD) is the first cluster resulted from the analysis which had highest urbanization was found. By definition CBD is the commercial and business center of a city with high employment density. For our study it is the Downtown Portland area which serves as the region's center for finance, commerce, government, retail, tourism, arts and entertainment (2040 Growth Concept, 2014).

2. Urban Core neighborhoods are the next cluster in the spectrum. These are neighborhoods that are very close to the CBD and have great connectivity and transportation facility. (e.g., inner Northeast and Southeast Portland neighborhoods).

3. Neighborhood and Regional Centers are hubs of business and government services and usually have two-to-four story housing development which is served by high quality transit (2040 Growth Concept, 2014). These are the next cluster resulted from the analysis.

4. Suburban Town Centers and Corridors are typically areas farther from the Central Business District but more densely developed than suburban residential areas and these are in cluster 4 from the analysis.
5. Suburban Areas are the last cluster in the analysis and those are the least densely developed areas.

The following table (Table 3) shows the mean value of the variables entered into our analysis for different cluster resulted.

Table 3: Average Value of the Variables in Clusters

Cluster Number	Intersection Density (per acre)	Block Size (acres)	Single-Family (Percent)	Employment Retail (Percent)	Percent of Lot Coverage
1	0.37	1.5	4	10	46
2	0.27	1.8	59	13	27
3	0.21	3.2	61	13	27
4	0.03	14.4	60	19	16
5	0.04	16.2	47	15	16

Intersection density is high in an urban area and it shows the level of ease in movement between places. The density gradually decreases with cluster number indicating suburban area has less density. Block sizes are shorter in urban areas which also indicate the high intersection density. The percent of single families and retail employment increases with the cluster number except in cluster 5. The percent of lot coverage is the indication of how much of the area is covered by the establishment building. The value decreases with cluster number, which means the last clusters have more parking spaces. Clusters 1, 2 and 3 have high values of lot coverage, meaning less parking space which is a characteristic of urban neighborhoods. We also can see from the table that the first three clusters have similar values of the variables and the last two have similar values. Therefore, we are considering the sites located in the cluster 1, 2 and 3 as urban sites and 4 and 5 are suburban sites.

The location of different establishments considered in the study are shown in the map below with percentage of non-auto mode share (Figure 1).

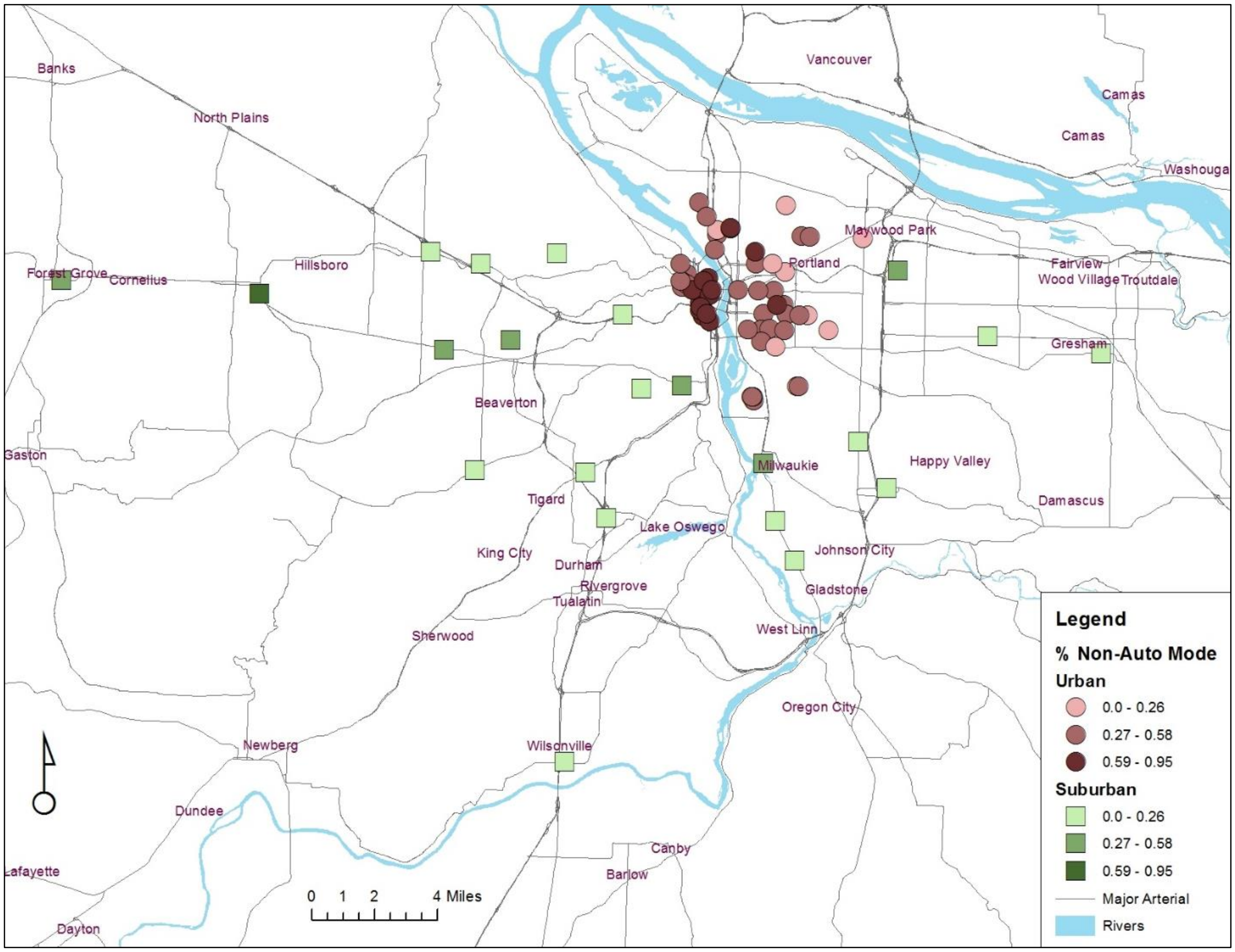

Figure 1: Location of the Establishments

From the map, it can be seen that the urban establishments are located at the center of the city, also have higher percentage of non-auto mode share for most of the establishments. On the other hand, the suburban establishments are located on the outer circle of the city and most of the establishments have low percentage of non-auto mode share. Expectedly, the urban sites have greater share for non-auto modes. The split of the mode share for urban and suburban establishments are shown here (Figure 2) from the survey data of the previous study (Clifton et al, 2012):

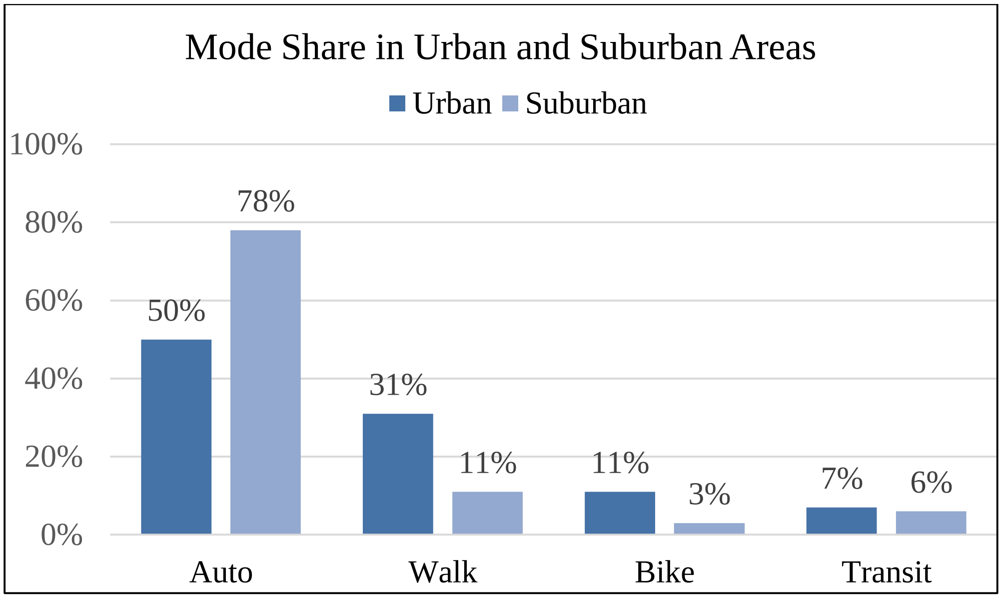

Figure 2: Mode Share for Urban and Suburban Areas

This chart shows the percentage of individual mode for different urban environments. The urban establishments have lower auto mode share than the suburban sites. The walking and biking mode share is greater in urban area, the percentage of transit mode share is almost equal for the two areas. This shows the differential travel behavior of the visitors to the non-residential destinations for two urban settings.

3.4 Summary:

The sources of data for the study have been outlined in this section. We have used the data from a previous study done by Clifton et al in 2012 which included three types of non-residential destinations. The travel information was collected from a survey and the built environment variables were collected from archived sources.

The proposed methodology have also been discussed here. To analyze the sites for different urban environments, the data was required to classify to urban and suburban categories. The classification was done based on the clusters resulted from the study done by Clifton et al (2012). After classification, we compared the built environment variables and mode share for the two environments and there was much variation in the data for two areas.

To understand whether the different built environment variables have different impacts upon the mode share, we conducted some analyses which are included in the next section.

4.0 ANALYSIS

To understand the relation of the built environment variables over different neighborhoods, we first ran bivariate correctional analyses for three different data sets: the pooled data, urban data and suburban data. The results of the correlational analyses are listed in the Appendix A. While almost all variables were significantly and highly correlated for pooled and urban datasets, there was a much less level of correlation for the suburban dataset. These results indicate the different levels of correlation for the urban and suburban areas and reveal that the orientation of the built environments are also different in different environments. As the built environment variables are highly correlated for the pooled model, we decided to run regression models with one built environment variable at a time.

At first we ran stepwise regression model for the pooled, urban and suburban dataset which is referred as Model 1. Then we ran regression models with interaction variables to explore how the built environment variables act differently in a suburban area which is referred as Model 2. We ran the same regression model for different built environment variables individually. We added a dummy variable indicating whether the site is in an urban area or suburban area to find how individual built environment variables act differently and a have dummy variable for convenience stores to see how trips to and from convenience stores can affect the multimodal activity. We also used a land use suburban interaction coefficient to estimate the mode share for a convenience store located in a suburban area. The variables used in the study are listed in Table 4 with the range and mean value for different neighborhoods:

Table 4: Value of the Variables used in Regression Models

Built Environment Variable	Urban					Suburban				
	Mean	SD	Range			Mean	SD	Range		
Number of Transit Corridors	29	34	2	to	112	9	8	0	to	25
Number of High-Frequency Transit Stops	62	54	14	to	244	8	10	0	to	35
Access to Rail	0.48	0.5	0	to	1	0.36	0.5	0	to	1
Length of Bike Facilities	7.6	2.8	3.4	to	13.8	4.4	1.4	0.2	to	6.8
Intersection Density	0.29	2.84	0.11	to	0.56	0.04	0.03	0.01	to	0.11
Lot Coverage	33	12	19	to	67	16	3	9	to	21
Retail and Service Employment Index	2.27	0.74	1.00	to	4.20	1.46	0.26	1.00	to	2.09
Employment Density	27	35	1	to	141	5	4	0	to	15
Person and Employment Density	43	38	9	to	164	13	4	6	to	23
Population Density	8	3	1	to	14	4	2	1	to	7

Therefore, the differences in the variables for the two areas are explicit from the table. Whereas the range of the variables for the urban area is very wide, the range of the variables is not that wide for the suburban variables. The mean of the variables are also very diverse from urban to suburban areas.

After analyses of Model 2, we found some variables having different impacts for suburban establishments. We ran regression model with those variables for pooled, urban and suburban dataset separately which is referred here as Model 3.

4.1 Stepwise Regression: Model 1:

We ran stepwise regression models to find the best variable among the ten selected built environment variables to predict the non-auto mode share. Regression was run for urban, suburban and the pooled dataset to see whether the best variable is same for all the model. The dependent variable was the percentage of non-auto mode share and the independent variables was the ten built environment variables and the stepwise method was chosen to find the variable with highest adjusted R2. Different variables came out as best variable to predict non-auto mode share for different models. The results from the stepwise regression is as follow (Table 5):

Table 5: Results from Model 1:

Model	Built Environment Variables	Coefficient	Adjusted R^2
Pooled Model	(Constant)	0.16***	0.62
	Number of High-Frequency Transit Stops	0.43***	
	Intersection Density	0.41***	
Urban Model	Constant	0.32***	0.52
	Person and Employment Density	0.72***	
Suburban Model	Constant	0.09	0.22
	Intersection Density	0.51**	
Note	***p-value ≤ 0.01, **p-value ≤ 0.05, *p-value ≤ 0.10		

From the stepwise regression, we found a model with two variables performed well for the pooled data. The variables are the number of high frequency transit stops and intersection density. For the urban model the best predictor variable is the person and employment density, whereas for the suburban model it is the intersection density. Therefore, for the urban model where the density of population and employment is high, people also use multimodal transportation. However, for suburban areas the best variable for predicting non-auto mode share is the intersection density. This indicates that in suburban areas people tend to walk more when they have more connectivity and accessibility to the destinations. We also found from the correlation analysis that the employment density has a negative relation with population density, transit facility and intersection density. We could not achieve a high level of significance with our small data sample, but it suggested that employment density has a negative effect.

4.2 Multiple Regression: Model 2:

Then we ran multiple regression models for the pooled dataset with one built environment variable at a time and some other independent variables to understand the effect of each built environment variable. Different variables used in the multiple regression model is as below:

Dependent Variable: Percentage of Non-auto Mode Share

Independent Variables:

1. Built Environment (BE) Variable (one variable at a time)
2. Dummy for Suburban Establishment
3. Interaction Variable Between BE and Dummy for Suburban
4. Dummy for Convenience Stores

5. Interaction Variable Between Dummy for Convenience and Dummy for Suburban

We ran ten different models for ten different built environment variables keeping all the other variables same.

Therefore, the equation for non-auto mode share is as follow:

$$\%_{non-auto\ mode\ share} = \beta_0 + \beta_1 * BE\ Variable + \beta_2 * (BE\ Variable * Dummy_{Suburban}) + \beta_3 * Dummy_{Suburban} + \beta_4 * (Dummy_{Convenience} * Dummy_{Suburban}) + \beta_5 * Dummy_{Convenience}$$

Here,

$$\%_{non-auto\ mode\ share} = \%_{walk\ mode\ share} + \%_{bike\ mode\ share} + \%_{transit\ mode\ share}$$

$$BE\ Variable = Built\ Environment\ Variables\ listed\ in\ the\ chart$$

$$BE\ Variable * Dummy_{Suburban} = Built\ Environment\ Interaction\ Variable\ for\ Suburban\ Area$$

$$Dummy_{Suburban} = \begin{cases} 1 & for\ suburban\ area \\ 0 & for\ urban\ area \end{cases}$$

$$Dummy_{Convenience} = \begin{cases} 1 & for\ convenience\ store \\ 0 & for\ restaurants\ and\ bars \end{cases}$$

We ran the regression model for each variable individually and found coefficients for each variable at different significant level. The built environment variables, their coefficient with level of significance and Adjusted R^2 value for respective model are listed in Table 6.

Table 6: Results from Model 2:

Built Environment variable	Constant β_0	Dummy suburban β_1	Built Environment Variable β_2	Built Environment Variable * Dummy Suburban β_3	Dummy convenienc β_4	Dummy Suburban * Dummy Convenience β_5	Adjusted R^2
Number of Transit Corridors	0.364***	-0.284***	0.005***	0.002	-0.019	0.139*	0.587
Number of High-Frequency Transit Stops	0.314***	-0.201***	0.003***	0.001	-0.008	0.116	0.594
Access to Rail	0.423***	-0.294***	0.167***	-0.155	-0.042	0.17	0.36
Length of Bike Facilities	0.078	0.063	0.054***	-0.055**	0.029	0.101	0.55
Intersection Density	0.081	-0.019	1.429***	0.904	0.004	0.080	0.539
Lot Coverage	0.101	-0.001	0.012***	-0.010	0.016	0.113	0.534
Retail and Service Employment Index	0.015	0.189	0.209***	-0.261*	0.019	0.122	0.574
Employment Density	0.37***	-0.178**	0.004***	-0.018*	0.006	0.141*	0.583
Person and Employment Density	0.312***	-0.337***	0.004***	0.009	0.013	0.076	0.604
Population Density	0.215**	-0.222	0.003***	0.005	-0.002	0.103	0.401
Note	***p-value ≤ 0.01, ** p-value ≤ 0.05, *p-value ≤ 0.10						

The value of the coefficient in the chart shows the type of influence the variable has on non-auto mode share. The sign of the coefficient shows whether the influence is positive or negative and the magnitude of the coefficient shows how strongly it affects the mode share. The p-value indicates whether the relationship is significant or not. The Adjusted R^2 shows to what extend the model can describe the variation of the dependent variable.

The coefficients in the table show that the suburban dummy coefficient β_1 is negative and significant in many cases, which indicates the expected low non-auto mode share for suburban area. People are less likely to travel to the establishments by non-auto mode when they are in a suburban area. On the other hand, the convenience dummy coefficient β_4 is not significant and the magnitude is also very low (slightly below and above zero) demonstrating that whether they are going to a convenience store does not influence people's choice of travel mode. The coefficient for interaction between land use and suburban area β_5 is slightly positive but not significant for different built environment variables. This interaction variable represents whether the establishment is both a convenience store and in a suburban area and not related to the built environment. Thus, there are almost similar values for all the variables. This indicates that people walk to a convenience store slightly more when they are in suburban area.

From the coefficients for the built environment variables β_2 , it is clear that all the built environment variables have significant coefficients for each model. All the coefficients are positive, which means that percentage of non-auto mode share will increase with an increase in these variables. As expected, almost all the variables have a high value which indicates the importance of these variables on non-auto modes.

We were mainly interested to see how the built environment variables have different influences in the suburban areas. It is better to use the standardized coefficients when comparing the effects of variables in suburban areas. Standard coefficients of built environment variables and their interaction with dummy variables are shown in the following figure (Figure 3):

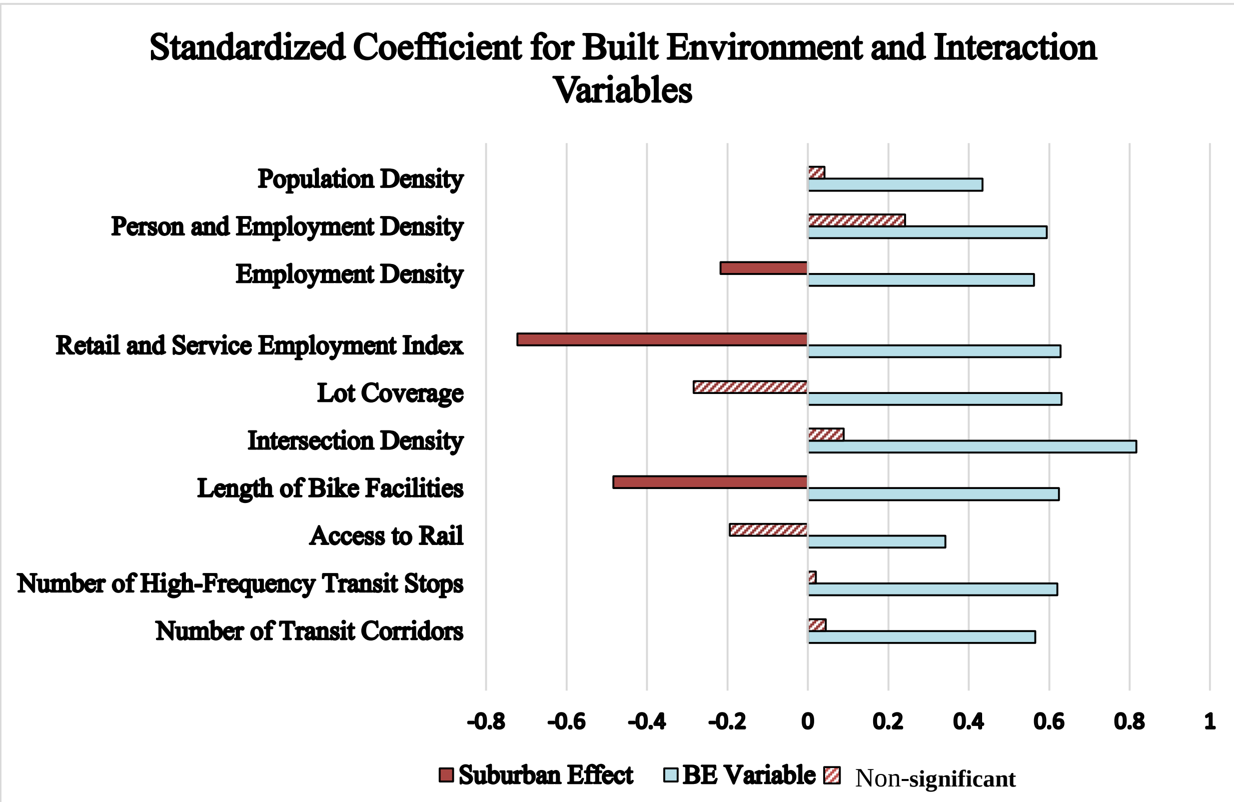

Figure 3: Standard Coefficient for Built Environment and Interaction Variables

The coefficient β_3 for the interaction variable is the additional variable for the built environment variables when the site is in a suburban area. It is a measure of how the built environments have different impacts on non-auto modes in a suburban area. Only the employment density, length of bike facilities and retail and service employment index have significant coefficients. These coefficients also have different direction of value for the suburban area than the pooled model. This leads to some interesting finding regarding these variables in a suburban area.

First, the employment density represents about the number of jobs available per acre in the half mile buffer around an establishment. With increase in employment density, the number of destinations per unit area also increases. The significant coefficient for employment density 0.562 indicates an increase in non-auto mode shares with employment density. However, for the suburban area (when suburban dummy=1), the coefficient is negative, which means that non-auto mode share decreases with an increase in employment density in suburban areas. This indicates the different influence of employment density in suburban areas. Although the number of destinations rises with employment density that does not have positive impact on non-auto mode share for suburban places.

Retail and service employment index shows a similar trend of coefficients for the suburban areas. The index is the average Urban Living Infrastructure (ULI) score from the Metro Context Tool within a half-mile buffer around establishments. It represents the density of retail and service employments which serve the daily needs. The coefficient is highly positively correlated with the pooled model and negatively correlated with the suburban model. Therefore, the influence of retail and service employment index is different in suburban area. The relation is similar to the employment density coefficient, but as here the retail businesses are considered, the difference between urban and rural area is also more robust.

Another important observation was the effect of the length of bike facilities. Increase in bike length generally should result in more biking, and we found that influence for the pooled model. The bike length facility had a dissimilar relation when the establishment was in suburban area, it had negative coefficient meaning non-auto mode share goes down with bike length facility in suburban areas.

Therefore, we found three of the built environment variables to have different impact for non-auto mode share in suburban area. To explore the differences more, we ran regression models for urban, suburban and pooled dataset separately for the significant built environment variables.

4.3 Multiple Regression: Model 3:

To understand the different behavior of the variables in different urban context, we ran the following univariate regression for urban, suburban and the pooled model only considering the three significant built environment variables from previous model. The different variables considered in this model are as below:

Dependent Variable: Percentage of Non-auto Mode Share

Independent Variables:

1. Built Environment (BE) Variable
    a. Employment Density
    b. Length of Bike Facility
    c. Retail and Service Employment Index
2. Dummy for Convenience Stores

So the equation for non-auto mode share is as follow:

$$\%_{non-auto\ mode\ share} = \beta_0 + \beta_1 * BE\ Variable + \beta_2 * Dummy_{Convenience}$$

We ran the regression model for three different model and got the following results:

Table 7: Results from Model 3

Built Environment variable	Coefficient	Pooled Model (78)	Urban Model (56)	Suburban Model (22)
Employment Density	Constant	0.295***	.370***	.192***
	Dummy convenience	0.017	0.013	.443**
	B.E.	**0.674*** **	**.703*** **	**-0.288**
	Adjusted R^2	0.438	0.474	0.154
Length of Bike Facilities	Constant	-0.014		
	Dummy convenience	0.088	0.059	0.392
	B.E.	**0.709*** **	**.682*** **	**-0.015**
	Adjusted R^2	0.471	0.438	0.066
Retail and Service Employment Index	Constant	0.059	.167***	0.083
	Dummy convenience	0.062	0.062	.379*
	B.E.	**0.717*** **	**.705*** **	**0.062**
	Adjusted R^2	0.489	0.47	0.069
Note	***p-value ≤ 0.01, ** p-value ≤ 0.05, *p-value ≤ 0.10			

The result from different models indicate the same trend of coefficients obtained from our previous models with interaction coefficients for pooled models. The model with employment density and bike length has negative coefficients for suburban model, whereas the urban model and pooled model have positive coefficients. This indicates that these two variables have different impacts on non-auto modes in suburban areas. Though the retail and service employment index has a positive value for the suburban model, the magnitude is very low compared with other urban and pooled models. This indicates that retail and service employment do not help to increase non-auto mode share in a suburban area as it may help in an urban area. The coefficients are not significant in suburban areas and one reason may be the low sample size for suburban area than the urban area. Also, the range of built environment variables are lower than urban area which might cause a non-significant relationship. The Adjusted $R^2$is lower for the pooled model here than the regression model with interaction variables indicating the model performs well when the interaction between variables is considered.

As the coefficient for the suburban model is not significant, it is difficult to draw a solid conclusion from it, although the results indicate that there are differences in the influence of the variables for suburban areas. It would be worthy to conduct more research to find the differences with more confidence. There might be one reason for the different influences in suburban area, which is a lowest value of a built environment variable, required to impact the mode share of the respondents. As the built environment variables have a low range of values for suburban area, that threshold values might not be achieved and the variables was not able to influence travel mode share. Also, the built environment variables are highly correlated which limited us from using many independent variables in the model. We had considered only one built environment variable at a time for regression, but there might be some synergy between the variables. Perhaps considering this synergy would help to find better conclusion regarding the mode share.

4.4 Summary:

The analyses carried out to understand the relation between non-auto mode share and the built environment variables are described in this chapter. We found the impact of built environment variables is different over the urban and suburban area.

From correlational analysis, it was found that the variables are highly correlated in the pooled model. The regression analyses carried out for individual built environment variable showed the impact of that variable on non-auto mode share. The interaction variable in Model 2 showed the impact of the built environment variable for an establishment in suburban area. From regression analyses of Model 2 and Model 3 we found employment density, length of bike facility, and retail and service employment index had negative impact for suburban area while it had positive impact for pooled model. In Model 3, the level of significance for suburban data was not significant. Therefore, coming to a solid conclusion is challenging, but the results directs to the differential impact of these variables for suburban area. The built environment variables may impact travel behavior in a different way in suburban area. There might be some synergy between the variables which defines the influence on non-auto mode share. Our result also indicate that only the measure of the built environment variables is not enough to understand the relation with travel behavior, how the built environment variables are oriented should also be considered.

5.0 CONCLUSIONS

One of the most growing concerns about policy making today is the provision of making the environment supportive for active transportation. The different variables of the built environment are being considered as important as those which have some proven influence upon active transportation. Generally urban neighborhoods are supposed to have more development in active transportation than the suburban places, and the built environment variables in suburban areas are assumed to be similarly related to multimodal transportation of urban areas. In our study we analyzed whether there is any difference between the influence of the built environment variables between different neighborhoods located in urban and suburban areas. We found differences in the correlation for the built environment variables for urban and suburban data set, indicating differences in the orientation of variables in two areas. We developed regression models for different built environment variables and used dummy variable to indicate area type. For some of the variables we found coefficients of different direction indicating different nature of influence. Thus, from our analysis, we found an indication about the difference in relation of built environment variables in suburban areas and the urban areas. One built environment variable may be one of the reasons to increase non-auto mode share in urban area, but it may also decrease non-auto mode share in suburban area. Therefore, the relation may not be always considered as a constant over the areas, rather possible variation should be brought to consideration. The variation may happen due to the orientation of the built environment variables, how the built environment variables are located is very important. There also might be some synergies between the built environment variables, which defines the influence on the travel behavior. We had small range of data and observation, but our finding indicates scope for future research on this area. Policy makers can consider the threshold values for the variables which can define which value of the variables would have impact on mode share. The possibility of synergy between the built environment variables would be also worthy to consider. Planners, policy makers and business owners often want to predict the number of probable visitor for a new establishment. Special consideration should be taken when the establishment is in a suburban area and also for improving suburban neighborhoods' suitability for multimodal transport.

5.1 Limitation:

We conducted the study as a little effort to find if there is any difference in the relationship of multimodal transportation and the built environment variables in the suburban area, and the result indicated difference for some variables. Although there was some limitation in our study which can be taken care to get better conclusion about this field. The first limitation is that we did not consider the bias of self-selection. Many people choose their mode not for the reason they find it comfortable but due to their inclination of that mode. People even choose to where they live based on the type of transportation they want to take. So their choice of mode is self-selected rather than it is because of the built environment in the neighborhood. The consideration of self-selection often has significant impact on the result. But we do not have data regarding that in our survey. It would be interesting to address the issue of self-selection in future analysis to see how that affect the result.

Another limitation was the limited sample size for the establishments within suburban area. Our study examined 78 establishments and only 22 of them was in suburban area. There was also less variability in the value of the variables we regressed in the model for the suburban area. A large sample size probably could have given more variation in data and also the model would have more significant relationship.

We only did the analysis for three land use types such as convenience stores, restaurants and bars. Including more land uses into our research could have brought change in the result. Also, we used a secondary data for the research, therefore did not have the flexibility to ask required question. A dedicated survey would provide with necessary information.

5.2 Recommendations:

Landscape of the cities are changing and suburban areas are growing at a fast rate. Much emphasis are given to the suburban area to decrease the auto dependency of the residents. From our analysis we found that some built environment variables can have different relationship with non-auto modes in suburban area, and the performance of the built environment measures are related to the urban context of the area. While our study does not define the exact magnitude of difference for the two areas, it reveals about the presence of the difference. This would be important for future researchers to carry research for suburban area and also to explain any unexpected travel behavior. When analyzing built environment variables, individual attention should be made to the suburban area, and the orientation of the variables should also be observed. The significance of a built environment variables largely depend on the context of the variable. The built environment variable may not influence travel behavior because of the orientation of the variable. The relation of the built environment variable with other variables in also vital. The measurement of one variable may not contain the information about the setting of the variable which plays a significant role for choice of travel mode. Understanding these facts would be beneficial for the planners, policy makers and the establishment owners to estimate expected travel behavior of the visitors for an establishment.

6.0 REFERENCES

2040 Growth Concept. (2014, December 19). Retrieved from Oregonmetro: http://www.oregonmetro.gov/2040-growth-concept

Bishop, Z. (2015). *Multi Modal Transportation Benefits: and Studies.* Virginia Ball Center for Creative Inquiry.

Cao, X., Handy, S. L., & Mokhtarian, P. (2006). The influences of the built environment and residential self-selection on pedestrian behavior: Evidence from Austin, TX. *Transportation, 33*(1), 1-20.

Cao, X., Mokhtarian, P., & Handy, S. L. (2009). Examining the Impacts of Residential Self-Selection on Travel Behaviour: A Focus on Empirical Findings. *Transport Reviews, 29*(3), 359-395.

Cervero, R., & Carolyn, R. (1995, July 01). Travel Choices in Pedestrian Versus Automobile Oriented Neighborhoods. California.

Cervero, R., & Gorham, R. (1995). Commuting in Transit Versus Automobile Neighborhoods. *journal ofthe American Planning Association*, *61*(2), 210-225.

Cervero, R., & Gorham, R. (2009). Commuting in Transit Versus Automobile Neighborhoods. *Journal of the American Planning Association*, 210-225.

Cervero, R., & Kockelman, K. (1997). Travel Demand and the 3Ds :Density, Diversity and Design. *Transportation Research - D*, *2*(3), 199-219.

Cervero, R., & Michael, D. (2003, September). Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Area. *American Journal of Public Health* |, *93*(9), 1478-1483.

Clifton, K. J., Currans, K. M., & Muhs, C. D. (2012). *Contextual Influences on Trip Generation.* Oregon Transportation Research and Education Consortium (OTREC).

Clifton, K. J., Currans, K. M., & Muhs, C. D. (2013). Evolving the Institute for Transportation Engineers' Trip Generation Handbook: A Proposal for Collecting Multi-modal, Multi-context, Establishment-level Data. *Transportation Research Record*, 107-117.

Clifton, K. J., Currans, K. M., & Muhs, C. D. (2015). Adjusting ITE's Trip Generation Handbook for Urban Context. *The Journal of Transport and Land Use*, 1-25.

Crane, R. (2000, August). The Influence of Urban Form on Travel: An Interpretive Re view. *Journal of Planning Literature, 15*(1), 3-23.

Currans, K. M., & Clifton, K. J. (2015). Using household travel surveys to adjust ITE trip generation rates. *The Journal of Transport and Land Use*, *8 NO 1*, 85–119.

De-min, Z., Jian-chun, X., Radke, J., & Lan, M. (2004). A Spatial Cluster Method Supported by GIS for Urban-Suburban-Rural Classification. *Chinese Geographical Science*, 337-3.

Dill, J. (2003). Transit Use and Proximity to Rail Results from Large Employment Sites in the San Francisco, California, Bay Area. *Transportation Research Record*, 19-24.

Dill, J. (2008). Transit Use at Transit-Oriented Developments in Portland, Oregon, Area. *Transportation Research Record, 2063,* 159-167.

Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record*, 87-114.

Ewing, R., & Cervero, R. (2010). Travel and the Built Environment: A Meta Analysis. *Journal of the American Planning Association, 76*(3), 265-294.

Forsyth, A. (2012). Defining Suburbs. *Journal of Planning Literature*, 270-281.

Frank, L. &. (2008). *The Built Environment and Health: A Review.* Calgary: City of Calgary.

Frank, L. D., & Engelke, P. O. (2001). The Built Environment and Human Activity Patterns: Exploring the Impacts of Urban Form on Public Health. *Journal of Planning Literature, 16*(2), 202- 218.

Giles-Corti, B., Foster, S., Shilton, T., & Falconer, R. (2010). *The co-benefits for health of investing in active transportation.* New South Wales Public Health Bulletin.

Handy, S. L. (1993). Regional Versus Local Accessibility: Implications for Nonwork Travel. *The University of California Transportation Center, 234*.

Handy, S. L. (1996a). Methodologies for Exploring the Link Between Urban Form And Travel Behavior. *Transportation Research Part D: Transport and Environment, 1*(2), 151-165.

Handy, S. L. (1996b). Travel Behavior Issues Related to Neo-Traditional Developments—A Review of the Research. *Presented at TMIP Conference on Urban Design, Telecommuting, and Travel Behavior, FHWA, U.S. Department of Transportation*.

Handy, S. L. (1996c, April). Understanding Link Between Urban Form and Travel Behavior. *Journal of Planning Education and Research, 15 No 3*, 183-198.

Handy, S. L. (1996d). Urban Form and Pedestrian Choices: Study of Austin Neighborhoods. *Transportation Research Record*, 135-144.

Handy, S. L. (2006). The Road Less Driven. *Journal of the American Planning Association, 72*(3), 274-278.

Handy, S. L., & Clifton, K. J. (2001). Local shopping as a strategy for reducing automobile travel. *Transportation, 28(4)*, 317-346.

Handy, S. l., Boarnet, M. G., Ewing, R., & Killingsworth, R. E. (2002). How the Built Environment Affects Physical Activity Views from Urban Planning. *American Journal of Preventive Medicine, 23*(2S), 64-73.

Hess, P. M., Moudon, A. V., Synder, M. C., & Stanilov, K. (1999). Site Design and Pedestrian Travel. *Transportation Research Record, 1674*, 9-19.

Hobbs, F., & Stoops, N. (2002). *Demographic Trends in the 20th Century.* U.S. Census Bureau.

Jae Seung Lee . Christopher Zegras, E. B.-J. (2014). Does urban living influence baby boomers' travel behavior? *Journal of Transport Geography*, 21-29.

Kitamura, R., Mokhtarian, P. L., & Laidet, L. (1997). A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. *Transportation 24*, 125-158.

Leck, E. (2006). The Impact of Urban Form on Travel Behavior: A Meta-Analysis. *Berkeley Planning Journal, 19*(1), 37-58.

Litman, T. (2014). *Introduction to Multi-Modal Transportation Planning.* Victoria Transport Policy Institute.

Litman, T. (2015). *Evaluating Public Transportation Health Benefits.* Victoria Transport Policy Institute.

Litman, T. (215). *Evaluating Transportation Equity Guidance For Incorporating Distributional Impacts in Transportation Planning.* Victoria Transport Policy Institute.

Lund, H. M., Cervero, R., Wilson, & W, R. (2004). *Travel Characteristics of Transit-Oriented Development in California.* California: Caltrans Transportation Grant "Statewide Planning Studies"—FTA Section 5313 (b).

Nelson, M. C., Gordon-Larsen, P., Song, y., & Popkin, B. M. (2006). Built and Social Environments Associations with Adolescent Overweight and Activity. *American Journal of Preventive Medicine*, 109-117.

Rajamani, J., Bhat, C. R., Handy, S., Knaap, G., & Song, Y. (2003). Assessing the impact of urban form measures on nonwork trip mode choice after controlling for demographic and level-of-service effects. *Transportation Research Record: Journal of the Transportation Research Board*, *1831*(1), 158-165.

(1996). *Report 16 Transit and Urban Form.* Washington, D.C.: National Academy Press.

Rodriguez, D. A., & Joo, J. (2009). The relationship between non-motorized mode choice and the local physical environment. *Transportation Research Part D*, *9*, 151-173.

Saelens, B. E., & Handy, S. L. (2008). Built Environment Correlates of Walking: A Review. *Medicine & Science in Sports & Exercise*, *40*(S), S550-S567.

Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literatures. *Environment and Physical Activity*, *25*, 80-91.

Sallis, J. F., Frank, L. D., Saelens, B. E., & Katherine, K. M. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. *Transportation Research Part A*, 249-268.

Schneider, R. J. (2013). Measuring transportation at a human scale: An intercept survey approach to capture pedestrian activity. *The Journal of Transport and Land Use*, *6 NO 3*, 43-59.

Schneider, R. J. (2015). Local environment characteristics associated with walking and taking transit to shopping districts. *The Journal of Transport and Land Use*, *8 NO. 2*, 125–147.

Seskin, S. N., Cervero, R., & Zupan, J. (1996). *NCHRP Report No. 16: Transit and Urban Form.* Washington, D.C.: National Academy Press.

Wang, Q., & Su, P. (2011). Modeling the Impact of Smart Growth on Travel Choices: An Enhanced Travel Demand Forecasting Approach. *International Conference of Chinese Transportation Professionals*, 4372-4384.

Zhang, M. (2004). The Role of Land Use in Travel Mode Choice: Evidence from Boston and Hong Kong. *Journal of the American Planning Association*, 344-360.

APPENDIX A: RESULTS FROM CORRELATIONAL ANALYSIS

Table A-1: Correlational Coefficients for Pooled Model (N=78):

Variable	Number of Transit Corridors	Number of High-Frequency Transit Stops	Access to Rail	Length of Bike Facilities	Intersection Density	Lot Coverage	Retail and Service Employment Index	Employment Density	Person and Employment Density	Population Density
Number of Transit Corridors	1	.941**	.571**	.799**	.622**	.749**	.781**	.933**	.934**	.469**
Number of High-Frequency Transit Stops		1	.473**	.804**	.753**	.831**	.844**	.939**	.956**	.605**
Access to Rail			1	.542**	.301**	.396**	.471**	.539**	.531**	0.217
Length of Bike Facilities				1	.777**	.816**	.862**	.810**	.846**	.593**
Intersection Density					1	.899**	.828**	.683**	.727**	.643**
Lot Coverage						1	.921**	.819**	.851**	.605**
Retail and Service Employment Index							1	.837**	.887**	.699**
Employment Density								1	.988**	.437**
Person and Employment Density									1	.558**
Population Density										1
Note	** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)									

Table A-2: Correlational Coefficient for Urban Model (N=56):

Variable	Number of Transit Corridors	Number of High-Frequency Transit Stops	Access to Rail	Length of Bike Facilities	Intersection Density	Lot Coverage	Retail and Service Employment Index	Employment Density	Person and Employment Density	Population Density
Number of Transit Corridors	1	.957**	.634**	.818**	.675**	.759**	.777**	.934**	.938**	.394**
Number of High-Frequency Transit Stops		1	.551**	.787**	.731**	.787**	.811**	.951**	.959**	.473**
Access to Rail			1	.650**	.429**	.498**	.533**	.608**	.609**	0.226
Length of Bike Facilities				1	.757**	.792**	.845**	.825**	.855**	.441**
Intersection Density					1	.893**	.855**	.765**	.777**	.332*
Lot Coverage						1	.918**	.838**	.854**	.386**
Retail and Service Employment Index							1	.840**	.888**	.616**
Employment Density								1	.990**	.346**
Person and Employment Density									1	.462**
Population Density										1
Note	** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).									

Table A-3: Correlational Coefficients for Suburban Model (N=22):

Variable	Number of Transit Corridors	Number of High-Frequency Transit Stops	Access to Rail	Length of Bike Facilities	Intersection Density	Lot Coverage	Retail and Service Employment Index	Employment Density	Person and Employment Density	Population Density
Number of Transit Corridors	1	.404	.435*	.266	.247	.099	.317	.342	.221	.147
Number of High-Frequency Transit Stops		1	.213	-.093	.177	.421	.488*	-.138	.071	.377
Access to Rail			1	.236	.008	-.05	.338	.490*	.355	0.062
Length of Bike Facilities				1	.229	-.073	.448*	.304	.273	.203
Intersection Density					1	.161	.272	-.153	.136	.273
Lot Coverage						1	.421	.077	.142	.299
Retail and Service Employment Index							1	.348	.331	.149
Employment Density								1	.478*	-.282
Person and Employment Density									1	.487*
Population Density										1
Note	** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)									