A COMPREHENSIVE ANALYSIS OF MULTI-LEVEL FACTORS AFFECTING INDIVIDUALS WALKING TO TRANSIT STATIONS IN THE CITY OF LOS ANGELES, CALIFORNIA

A Dissertation

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JUNPING XU

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Chair of Committee,	Shannon Van Zandt
Co-Chair of Committee,	Kenneth Joh
Committee Members,	Douglas F. Wunneburger
	Xuemei Zhu
Department Head,	Forster Ndubisi

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ABSTRACT

To decrease auto use and encourage public transit usage, transit-oriented development has been growing in importance. However, a few existing studies have examined the travel modes to transit stations. This research addresses this gap of knowledge by examining multi-level factors, including socio-demographic factors of individuals, socioeconomic characteristics, built environment attributes, and safety factors influencing walking to transit stations in the city of Los Angeles, California.

This study primarily relies on travel survey data from the Post-Census Regional Household Travel Survey conducted from 2001 to 2003 by the Southern California Association of Governments. In the first phase, this research uses bivariate linear regression models to examine the disparities of the built environment across the station areas. The results indicate that the street light density and sidewalk completeness are lower in neighborhoods with higher percentages of Blacks or Hispanics. The density of tree coverage is higher in neighborhoods with higher median household income.

The second phase of this study employs four binary logistic regression models to predict the odds of walking to transit stations. The results indicate that the distance to transit stations and the availability of transit parking have significant negative impacts on the likelihood of walking to transit stations. Pedestrian amenities, such as street lights, tree shade, and sidewalk completeness increase the odds of walking to stations. Land use

mixture is a positive factor for predicting walking to transit stations. The greater diversity of land uses increase the chances of walking to transit stations.

In summary, for promotion of walking to transit stations, this study suggests the strategies, such as increasing sidewalk completeness, street light density, street tree density, and land use mixture. Decreasing the parking lots around stations would discourage driving to stations. Meanwhile, more public attention is necessary to improve the pedestrian facilities in the minority or poor neighborhoods.

DEDICATION

To my family, my dissertation committee, and my friends, thank you all for the support while I'm studying abroad. It is a difficult but happy and critical period in my life.

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NOMENCLATURE

BART – Bay Area Rapid Transit

CDC – Center for Disease Control and Prevention

LADOT – Los Angeles Department of Transportation

GIS – Geographic Information System

TOD– Transit Oriented Development

USGS – United States Geological Survey

SCAG – Southern California Association of Governments

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1. **INTRODUCTION**

1.1 Background

Physical inactivity is a serious health challenge, contributing to obesity, cardiovascular diseases, certain cancers, diabetes, and mental disorders (Dishman, Washburn, & Heath, 2004). Since only a small percentage of the population walks or bicycles as part of their daily travel trips, and most travel trips are accomplished by automobile, the United States has become a nation of sedentary people (Frumkin, Frank, & Jackson, 2004).

In 2003, only 52.8% of American adults met the public health recommendation of at least 30 minutes of moderate vigorous activity per day for five days a week (Besser & Dannenberg, 2005). Meanwhile, the transportation sector was responsible for 13% of Greenhouse Gas (GHG) emissions and 23% of CO_2 emissions from global energy consumption (Global Environment Facility Scientific and Technical Advisory Panel, 2010). If current trends continue, transport energy use and Carbon Dioxide emissions are projected to increase by close to 80% by 2050 (Global Environment Facility Scientific and Technical Advisory Panel, 2010).

For public health and environmental reasons, urban planners, transportation planners, health professionals and environmental scientists all advocate and support active transportation (e.g., walking, biking and transit). Transit use is classified as active travel due to the involvement of walking at one or both ends of the trip (Ewing & Cervero, 2010). In recent years, it has been recognized that walking to transit stations can encourage people to engage in more physical activity in their daily lives (Besser & Dannenberg , 2005; Maghelal, 2007). Meanwhile, walking to transit stations is also proposed as one of the strategies to increase the use of transit (Maghelal, 2007).

This study aims to identify the significant factors that impact travel modes of individuals to transit stations in the city of Los Angeles, California. The transit network of Los Angeles extends to various neighborhoods with a wide range of demographic, physical, and economic characteristics (Center for Transit-Oriented Development, 2010). The center of transit-oriented development aims to create well-designed transit-oriented districts around stations in the city of Los Angeles, which would increase the amount of residents' daily physical activity and support affordable transportation and healthy lifestyles (Center for Transit-Oriented Development, 2010). This research has similar goals and the findings of this study would have the potential to provide suggestions for policy makers to improve transit-oriented development.

1.2 Current Research Gaps and Significance

Since the mid-1990s, researchers have paid more attention to walking access trips and environmental determinants (Greenwald and Boarnet, 2002; Cervero, 2002; Ewing & Cervero, 2010; Frank et al., 2005; Frank et al., 2010; Sallis, 2009). However, transit station access trips were understudied and only a few studies investigated walking behavior to transit stations (Maghelal, 2007; Park, 2008).

Previous studies have also shown knowledge gaps. In the early days, some of the research included many socio-demographic factors but quite limited built environment variables, such as the study by Korf and colleagues in 1979, Schlossberg and Brown's research in 2004, and Besser and Dannenberg's study in 2005. Maghelal's work in 2007 had developed a comprehensive list of built environment attributes in his study, but had quite limited socio-demographic variables and the sample size were relatively small. Park's study in 2008 made a detailed survey on street-level factors of the built environment and used such micro-level built environment attributes to predict walking to transit stations. However, due to the time-consuming nature of data collection, he only included one station as in the study. Therefore, this study aims to address existing gaps of knowledge through a comprehensive analysis of both socio-demographic and built environment factors using multiple data sources and ensuring an adequate sample size.

1.3 Dissertation Structure

This dissertation is comprised of five chapters. Chapter one is a brief introduction, which states the research background, current knowledge gaps and the significance of this research. Chapter two reviews literature on travel modes to transit stations and correlates of general walking behavior. It further explains the gaps in current research and summarizes the built environment and socio-demographic correlates of walking that have been identified in previous literature. Chapter three establishes the conceptual framework based on the previous knowledge and develops the research design. Chapter four provides the descriptive analysis of study variables and the correlations among independent variables. It also presents results about disparities of built environment attributes across the station areas and findings from binary logistic models that predict walking to stations. Finally, chapter five concludes the findings, discusses the limitations and offers suggestions for the future research.

2. LITERATURE REVIEW

Until recently, only a few studies investigated the travel behavior to transit stations. However, there have been a growing number of studies about the built environment correlates and socio-demographic correlates. The literature reviewed in this dissertation were selected by several criteria: (1) the research examined walking to or from transit stations in any population; (2) if not, the study examined the attributes of built and social environment or individual demographic status support walking; (3) articles written in English and published in peer-reviewed journals, released dissertations and public government documents.

The number of studies about walking to transit stations is limited (including dissertations) and most of them were published in the past ten years. The studies on environment correlates of walking are in hundreds and most were published in the last two decades. There are four parts in this section: (1) previous studies on transit access modes; (2) built environment correlates of walking behavior; (3) socio-demographic correlates of walking behavior; (4) the interactions between built environment and socio-demographic correlates.

2.1 Previous Studies on Transit Access Modes

2.1.1 Overview of Previous Studies

Although access trips to transit stations are receiving more attention from the public than ever, there has been relatively little research on access trips to the station, and only a few studies have included walking as a mode choice. This dissertation will summarize their research purpose, research design, methodology, results and limitations.

The earlier studies were conducted by Korf and colleagues in the late 1970s (Korf et al., 1979). The authors tried to develop a conceptual framework of access mode choice using a multi-nominal logistic model. Due to data availability, they only used a limited number of socioeconomic and built environment variables. They found that trip distance and car ownership were significant correlates of walking access trips (Korf et al., 1979).

Cervero (1995) studied walking trips to Bay Area Rapid Transit (BART) stations and the impacts of station area characteristics of access modes (Cervero, 1995). By using aggregated socioeconomic and built environment variables from each station area, Cervero conducted multivariate regression analyses to predict walking and driving mode shares to the station. His study found that a greater land use mix and limited parking supply at the station had significant impacts on the access modes to transit stations

(Cervero, 1995). Due to limited availability of the data, this study analyzed limited built environment factors.

Another similar study of the Bay Area Rapid Transit (BART) stations was conducted by Loutzenheiser (1997). This research focused on rapid transit stations and aimed to improve the knowledge of both physical and social factors, particularly the urban design factors. The binomial logit model was used to analyze survey data from BART riders over a 2-day period. Results showed that for every additional distance of 0.3 miles from the station, the probability of walking decreased by 50 percent (Loutzenheiser, 1997). Car ownership and availability of parking at transit stations were inversely and significantly related to walking to the stations (Loutzenheiser, 1997). Except the distance and availability of parking lots around stations, there was no other significant indicator in urban design factors to influence walking to stations.

Later, Schlossberg and Brown (2004) employed walkability indicators to compare Transit Oriented Communities in Portland, Oregon. The primary indicators they used were street network classification and pedestrian catchment area (PCA). However, they did not include other important built environmental factors, such as density and land use mixture, which are important factors influencing individual travel behavior (Kockelman, 1997; Frank & Pivot, 1994).

Besser and Dannenberg (2005) investigated the daily physical activity by American solely through walking to and from transit. They used 2001 National Household Travel Survey data. They concluded that minorities, people with low-income, and people living in urban areas with high density more likely walk to transit daily (Besser & Dannenberg, 2005).This is an important study about walking to and from transit, but it did not include built-environment factors in their analysis.

Maghelal (2007) developed objective measures of the built environment to test pedestrian variables on walking to transit. His study areas are transit oriented communities at quarter-mile and half-mile distances from the Dallas Area Rapid Transit (DART) stations. He selected 32 built environment variables through literature review and employed GIS analysis and Bootstrap principal component analysis to find which measured variables significantly affect the walking behavior to transit. The results revealed that density factors were the only principal components that significantly predicted walking to transit station at quarter-mile distance from the station (Maghelal, 2007). At the half-mile distance, there did not report any significant for walking to transit (Maghelal, 2007). Although his study considered the applicable statistical methods, however, the number of built environment variables (n=32) is a bit more compared with the sample size (20 stations).

Park (2008)'s dissertation measured and evaluated path walkability through field audit and survey methods. Over thirty variables were tested in his research and he achieved a comprehensive analysis for path walkability. However, this research gathered travel data from only one transit station area and the findings are not generalizable.

2.1.2 Summary

From the early studies, it is not difficult to summarize their common findings of significant predictors for walking to stations, such as trip distances, auto availability or car ownership, parking supply around stations, population and residential density, and land use mixture. However, due to data availability, most of them used limited built environment factors to predict the walking behavior to stations and even ignore some important ones, such as Korf and colleagues' study in the late 1970s, Schlossberg and Brown's research in 2004, and Besser and Dannenberg's research in 2005. Maghelal (2007) developed a comprehensive list of built environment factors to test pedestrian variables on walking to transit. However, the number of built environment variables (n=32) is a bit more compared with the sample size (20 stations). Although his study considered the applicable statistical methods, finally, he only found that density factors are significant predictors at a quarter - mile distance from the station but none significant predictor at half-mile buffer.

Most of the previous studies used aggregated data to measure the built environment factors at the neighborhood level. Admittedly, the aggregate data has limitation to measure the built environment compared with disaggregate data at the street-level. Park

(2008) used street-level data to measure the walking paths to stations, but he only employed one station as the study unit. Although street-level data is important for measuring built environment, the difficult and time-consuming measurements would limit the number of units of analysis, which could not draw general findings.

2.2 Built Environment Correlates of Walking Behavior

The widely accepted definition of the built environment was stated by Handy and her colleagues in 2002, which comprised the nexus of urban design, land use, and the transportation system (Handy et al., 2002; Popkin et al., 2005; Neville et al., 2004; Saelens & Handy, 2008). "Urban design" usually includes the arrangement and appearance of physical elements (e.g., buildings, facilities etc.) (Handy et al., 2002). "Land use" typically refers to the distribution of activities across space, including residential, commercial, office, industrial, and other activities (Handy et al., 2002). The "transportation system" incorporates the transportation infrastructure, such as roads, sidewalks, bike paths, railroad, and transportation services (Handy et al., 2002).

To date, there are more than 200 built-environment and travel behavior studies (Ewing and Cevero, 2010). Before the 1990s, most studies focused on the motorized travel modes (Park, 2008). Since the early 1990s, some transportation researchers have taken the lead in studying walking behavior and tried to test how environmental factors affect walking (Cervero 2003; Greenwald and Boarnet 2002; Handy 1996). In recent years, environment correlates of walking has proliferated and more researchers are paying attention to the walking and related health benefits (Cevero, 1996; Ewing et al., 2008; Frank, 2000; Frank & Engelke, 2001; Handy et al., 2002; Humpel, Owen, & Leslie, 2002; Kahn, et al., 2002; Lee & Moudon, 2004; McCormack et al., 2004; Owen et al., 2004; Saelens & Handy, 2008).

Cevero (1996) indicated that land use diversity was a very important predictor of walking. Ewing and Duncan (2003) proposed that walking increased with higher proximity, density and connectivity. A review of fourteen studies by Popkin and colleagues in 2005 supported the consistent correlates of between built environment and walking, such as high residential density, street connectivity and mixture of land use (Popkin et al., 2005). However, the causality relationship between built environment and walking was still under debates and the least progress had been made in recent years (Saelens and Handy, 2008).

2.2.1 Measurements of Built Environment

This dissertation will measure several Built Environment Variables. Therefore, it is necessary to get an overview of measurements in different built environment factors. Built environment measurements include three categories, including subjective and objective measures: (1) perceived (self-reported) environment measures; (2) systematic observations or audits to quantify built environment factors objectively; (3) analyzed with GIS using existing data sets (Brownson et al., 2001). The perceived or self-reported measures could get more subjective data, such the sense of places; while GIS-derived measures can help overcome reliability problems on self-reported measures (Maghelal, 2007).

The built environment could be divided into three scales: region, community or neighborhood, pedestrian or street environment (Gallin, 2001; Landis et al., 2001; Evans et al., 1997). The regional scale is not applied in this study, thus it would not be stated hereafter. The following part would state the measures of the built environment at the neighborhood level and street level.

2.2.1.1 Neighborhood Level (Macro-Level)

Cervero and Kockelman (1996) developed built environment measures from a variety of variables for neighborhoods-- density, diversity, and design (3Ds). Ewing and Cevero later expanded and refined the 3Ds measures to five dimensions (See Table 2.1).

Table 2.1 Five Dimensions

Name of Five Ds	Description of Five Ds
Density	It is measured as the variable of interest per unit of area.
Diversity	It measures the number of different land uses in a given area and the degree to which they are represented in land area, floor area, or employment. Entropy measures of diversity, wherein low values indicate single-use environments and higher values represent more varied land uses.
Design	It includes street network characteristics within an area. Measures include average block size, proportion of four-way intersections, and number of intersections per square mile. Design is also occasionally measured as sidewalk coverage; average building setbacks; average street widths, street trees, or other physical variables that differentiate pedestrian-oriented environments from auto-oriented ones.
Destination	It may be regional or local (Handy, 1993). The gravity model of trip attraction measures destination accessibility.
Distance	It is usually measured as an average of the shortest street routes from the residences or workplaces to the nearest rail station or bus stop in an area.

Source: Ewing & Cervero, 2010, p.267

The 5Ds above classify the individual factors of the built environment into five groups and became five major indicators. The following is a list of built environment variables at the neighborhood level drawn from literatures and based on the 5Ds. They are grouped into density, mix of land uses, connectivity of the street network, infrastructures of walking environment, safety of neighborhoods, and aesthetic qualities of neighborhoods.

1. Density—Density is usually defined as population, employment, or housing units per unit of area. Population density is among the most consistent positive correlates of walking trips (Cervero and Gorham, 1995; Cervero, 1996).

2. Land Use Mix— Land use mix is defined as the distributions of different land uses within a given area (Handy et al., 2002). A mixed-use neighborhood includes various land uses. Kockelman (1997) and other researchers found that the closer proximity to jobs or services encourage more walking. Cervero and Kockelman (1996) introduced "dissimilarity index", which divided a neighborhood into cells and counted the cells with different land use. Frank and his colleagues (2005) used the 'land use mix index' and this formula is widely accepted (Frank et al., 2005; Frank et al., 2009; Maghelal, 2007, Zhu, 2008, Sallis et al., 2009).

3. Connectivity of the Street Network-- In planning practice, it can be measured in many ways, such as the number of intersections per square mile (Handy, 1996), the number of intersections per mile of road (Maghelal, 2007), average block length, the ratio of straight-line distance between two points and the distance along the network (Hess, 1997). Dill (2004) provided a comprehensive review of the measures in the existing literatures. Based on Dill's work in 2004, Yi (2008) summarized the measures of street connectivity listed in the Table 2.2.

Table 2.2 Street Connectivity Indicators

Street Connectivity	**Definitions**	**Literature Using this Measure**
Block Length	Length from curb on one side of block to curb on the other side	Cervero & Kockelman, 1996
Block Density	Number of blocks per unit of area	Lee & Moudon, 2004
Intersection Density	Number of four-way intersections per unit of area	Cervero & Kockelman, 1996; Dill, 2004; Lee & Moudon, 2004
Street Density	Linear miles of streets per unit of land	Dill, 2004; Lee & Moudon, 2004
Connected Node Ratio	Total number of street intersections divided by total number of intersections and cul-de-sacs	Dill, 2004
Link Node Ratio	Number of links such as roadway or pathway segments divided by the number of nodes being intersections or the ends of dead-end streets	Dill, 2004
Alpha Index	Number of actual closed circuits to the maximum number of circuits	Dill, 2004
Gamma Index	Number of links in the network divided by the maximum possible number of links between nodes	Dill, 2004

Source: Yi, 2008

4. Infrastructures--Some empirical evidence suggests some infrastructure (e.g., existence of sidewalk continuity) increase the number of walking trips (King et al., 2002). Meanwhile, some researchers found that better pedestrian infrastructure, such as

conditions of sidewalks, was related to higher pedestrian walking rates when other environmental characteristics were constant (Cervero & Kockelman, 1996; Saelens, et al., 2003; Stringham,1982).

5. Safety—The safety factors for walkers include social safety (e.g., crime rate) and transportation safety, such as average traffic volume, traffic speed limits, signal density of street crossings and traffic crash rates (Cunningham et al., 2004; Humpel et al., 2002; Lee & Moudon, 2004; Popkin et al., 2005; Maghelal, 2007; Moudon & Lee, 2003; Moudon, 2007).

6. Aesthetic qualities -- The aesthetic qualities include the design of buildings, trees and the shade they provide; and the availability of public amenities such as benches and lighting (Ewing, et al., 1994; Ewing, et al., 2006; Handy et al., 2002; Heath et al., 2006; Humpel, 2002; Keppel et al., 2005; Owen et al., 2004).

Generally, the groups of factors listed above cover most characteristics of the built environment in the neighborhoods. However, is there any index that can be easily measured if the built environment encourages walking? After years of discussions, Frank and colleagues (2005) proposed 'walkability index', which has been widely accepted and applied to many recent studies for measuring the walkability of built environment (Sallis et al., 2009). The 'walkability index' incorporates four parameters: net residential density, intersection density, retail floor area ratio and land-use (see Table 2.3) (Frank et al., 2005). The formula was based on prior evidence and expressed as follow:

Walkability Index= [(2 x z-intersection density) + (z-net residential density) + (z-retail floor area ratio) + (z-land use mix)] (Frank et al., 2005).

The parameters in the formula would be addressed in Table 2.3. The street connectivity z-score was weighted by a factor of two within the walkability index, which was based on prior research results (Saelens et al., 2003; Sallis et al., 2004).

Table 2.3 Walkability Index Parameters

Parameters	**Measurements of Parameters**	**Data Source**
Net residential density	The ratio of residential units to the land area devoted to residential use	US Census data and related geographic (TIGER) files (US Bureau)
Land use mix	Indicates the degree to which a diversity of land use types is presented. Land-use Mix = $-\left[\left(\sum_{1}^{n}(p_i)\ln(p_i)\right)/\ln(n)\right]$ p-proportion of sq. ft of land use i, n-number of land uses Values will be normalized between 0 and 1.	Land-use GIS data (Local Government)

Table 2.3 Continued

Parameters	Measurements of Parameters	Data Source
Street connectivity	It measures by the ratio between the number of true intersections (3 or more legs) to the land area in acres.	The network (e.g. street, road) GIS data from transportation sections of local government website
Retail floor area ratio	The retail building square footage divided by retail land square footage. The rationale was that a high ratio indicated smaller setbacks, and less surface parking.	Parcel and land use GIS data.

Source: Frank et al., 2005

2.2.1.2 Street Scale (Micro-Level)

Some studies have tried to measure the micro-level or street level variables of the walking environment, such as the Pedestrian Level-of-Service (LOS) (Dixon, 1996; Landis et al., 2001; Gallin, 2001), the Transit Friendliness Factor (Evans, 1997), the Environmental Scale Evaluation (Saelens et al., 2003), and the Walking Suitability Assessment. One notable effort by Boarnet and colleagues is the development of the Irvine-Minnesota Inventory (Boarnet et al., 2006). This research produced an extensive list of built environment attributes –162 items in four different categories: accessibility, perceived safety from traffic and crime, and level of pleasure (Boarnet et al., 2006).

GIS and field audit techniques have both been employed in the street-level walking environment. A study conducted by Rodriguez and Joo (2004) used GIS analysis to determine the density, travel time, presence of walking and biking paths, sidewalk availability, and local topography to analyze the pedestrian behavior. Lee and Moudon (2006) used a large number of micro-level attributes of urban form through a custom-made GIS tool in their analysis.

Ewing and Handy (2006) used qualitative urban design concepts based on expert panel studies. They invited experts in urban design and planning field to evaluate the selected variables for urban design attributes (Park, 2008).

Park (2008) did a comprehensive analysis of street-level factors impacting travel modes to the transit station. In his findings, the sidewalk environment (e.g., street trees, brighter luminosity, and special pavements), the width of buffer zones for traffic, the ratio of building-to-building distance to building height and the commercial use on the first floors of buildings were the significant factors impacting walking to the transit station (Park, 2008).

2.2.2 Summary

In the following chapter, this study would choose and measure built environment factors. Table 2.3 was developed through the literature review and most variables were selected from significant factors in the previous studies at the neighborhood level. This study has 55 stations in the investigation and thus the built environment of 55 station areas needs to be measured. The city of Los Angeles does not have data at the street level, therefore, it is unfeasible to get street-level data through field audit in such big areas. Due to the time and resource reasons, this study will only focus on neighborhood level factors. The variables at street level were excluded from the table. Generally, Table 2.4 provides a reference for this study, and the variables employed in this study will be further explained in Chapter 3.

Table 2.4 Summary of Built-Environment Variables and Measurements at the Neighborhood Level

Variables		**Description and Measurement**	**Measurement Type**	**Correlation of Walking**
Distance		Distance to destination	Objective	(+)Korf et al, 1979; Stringham, 1982;Cevero, 1995
Street Connectivity	Intersection Density	Number of street intersections (≥3-way)/total acres of the area	Objective	(+) Popkin et al., 2005 (x) Cevero& Kocklman, 1996; Schlossberg &Brown, 2004
		Number of intersections / total length of road	Objective	(x) Maghelal, 2007
	Street Density	Liner miles of streets per unit of land	Objective	(+) Dill, 2004;Southworth, 1997 (x) Maghelal, 2007
Infrastructure	Sidewalks	Completeness or Coverage Rate (unit: %) = Total length of sidewalk on one or both sides / (total length of road network× 2)	Objective	(+)Hess et al., 1999; Cervero and Kockelman, 1997; Popkin et al., 2005; Zhu, 2008
		Sidewalk Connectivity =Number of intersections with 4 curb-cuts / total number of intersections	Objective	(+)Park,2008 (x) Maghelal, 2007
	Street Lights	Amount of street lights on roads leading to transit station divided by total length of the road	Objective	(+) Park,2008
	Shade (Trees)	Tree canopy within the area/ total acres of the area	Objective	(+)Park,2008
		Sidewalk Length Covered by Tree Canopy	Objective	(+) Maghelal, 2007
	Transit Station Parking	Number of parking spaces available at the station	Objective	(-) Cevero, 1995; Loutzenheiser,1999 (x) Maghelal, 2007
	Pedestrian Crossing Coverage	The total number of pedestrian crossings (regardless of type) divided by the maximum number of possible crossings	Objective	(+) Park, 2008 (x) Maghelal, 2007

Table 2.4 Continued

Variables		Description and Measurement	Measurement Type	Correlation of Walking
	Traffic-signal Density	The total number of signals divided by the maximum number of possible crossings	Objective	(+)Popkin et al., 2005
		Number of traffic signals divided by total miles of streets	Objective	(x) Maghelal, 2007
Land Use Mix	Land Use Mix (range: 0–1)	Land-use Mix = $-\left[\left(\sum_{1}^{n}(p_i)\ln(p_i)\right)/\ln(n)\right]$ p-proportion of sq. ft of land use i, n-number of land uses	Objective	(+) Cevero, 1995; Cevero, 1996; Frank & Pivo 1994; Ewing et al., 2003 (x) Maghelal, 2007
Density	Population Density	Total population/per acre or Total population/Square Mile	Objective	(+) Cevero, 1995; Huston et al., 2003; Maghelal, 2007 (x) Ross and Dunning,1999
	Housing Density	Total housing units/ per acre or Total population/ Square Mile	Objective	(+) Maghelal, 2007, Cevero, 1995 (x) Evenson et al., 2003
	Employment Density	No. of Employment / Sq. Mile	Objective	(x) Badland and Schofield, 2005
Safety	Traffic Crash	(Number of crashes between year X1 and X2)/(total miles of streets × (X2-X1))	Objective	(-) Park, 2008; Zhu, 2008
	Traffic Volume	Average daily traffic count of sampled locations leading to transit station	Objective	(x) Maghelal, 2007, Park,2008
	Percentage of high-speed streets	Total footage of streets with speed limit >30 miles per hour/total footage of all streets	Objective	(x) Maghelal, 2007,Park, 2008
	Crime	(Number of Part-I crimes in year X1 and X2 × 100)/(total acres of the area ×(X2-X1))	Objective	(-)Cunningham et al., 2004; Humpel et al., 2002; Lee and Moudon, 2004

(+) Positive significant correlation (-) Negative significant correlation(x) No significant correlation

2.3 Social and Demographic Correlates of Walking

Ewing & Cervero (2001) reviewed the previous literature and concluded that travel mode choice depends on both socio-demographic characteristics and a function of the built environment, but probably more on socio-demographic status. A large number of studies explored the impact of socio-demographic variables on travel behavior and found significant individual and neighborhood socio-demographic differences in physical activity (Yen and Kaplan, 1998; Denney et al., 2004; Frank et al., 2004; King et al., 2002).

Individuals' education level, age, and household size may determine specific travel behaviors. Some researchers did the comparative studies and found significant differences in travel behavior between different demographic groups in the USA and the UK (Guiliano & Narayan, 2003; Guiliano & Dargay, 2006). They indicated that gender, age and household income all significantly impact the individual travel behavior.

An investigation in the Netherland by Dieleman and colleagues (2002) indicated that persons with the highest level of education tend to have the lowest automobile use is. Frank and his colleagues (2010) also confirmed that people with lower education levels walking less frequently. Meanwhile, Frank and colleagues (2010) suggested that the demographic variables are dominant factors to prioritize the non white and low household income groups at higher obesity risk with less walking.

Income, one important indicator, has an effect on automobile possession and use (Guiliano & Dargay, 2006) and some researchers reported that income may be with a possible quadratic effect on travel behavior (Boarnet and Crane, 2001). Although a number of studies showed that lower income and decreased car ownership have been found as the significant elements for taking transit, the relationship is not always straightforward (Guiliano & Dargay, 2006). For example, in Toronto, residents in wealthy communities use transit at much higher levels compared to those in low-income neighborhoods (Guiliano & Narayan, 2003).

Gender is a significant factor impacting travel behavior in many studies (Polk, 2003). Compared with men, women are more likely to adopt sustainable travel behaviors. Polk (2003, 2004) found a significant correlates of sustainable travel patterns and gender in her study in Sweden in 1996. They indicated that women were more positive towards ecological issues and they were more willing to reduce car use than men. Moriarty and Honnery (2005) and Olaru with colleagues (2005) found that women did shorter average travel distances than men. In the study of Best & Lanzendorf (2005), they found that women drove less for work than men but drove more for shopping and childcare. This finding was also confirmed by Boarnet & Sarmiento (1998) in their study of southern California.

Household characteristics were also found to be a major influence on travel behavior in a number of studies. Ryley (2005) studied 2910 households in Edinburgh, Scotland. His research stated that the households with children highly depended on cars and driving is their primary travel mode. The households having students, the unemployed and part-time workers without children used more non-motorized transportation (Ryley, 2005). On the contrary, families with retirees and high-income owners were willing to drive instead of non-motorized transportation (Ryley, 2005).

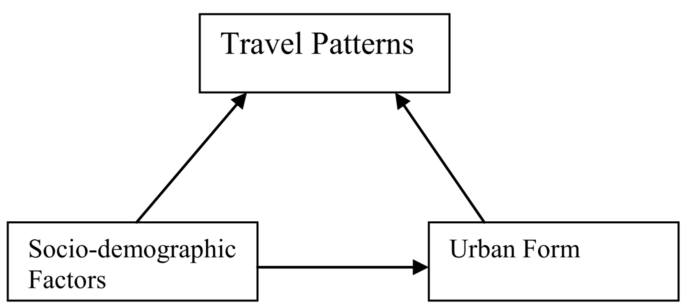
Dieleman et al. (2002) studied the travel behavior using the Netherlands National Travel Survey in 1996. The major findings of this study were that higher income households were more likely to use cars and the families with children were more likely to use cars than families without children (Dieleman et al., 2002). Besser and Dannenberg (2005) used 2001 National Household Travel Survey data to estimate the daily level of physical activity through walking to and from transits. The survey employed random-digit sampling and performed bivariate analysis and multivariate analysis and concluded that minorities and people with low-income were more likely to walk to transit daily (Besser & Dannenberg, 2005).

Generally, although the previous studies had variations of study backgrounds and methodologies, there are some consistent findings. The income, age, ethnicity, household size and employment status are the important indicators that impact the walking behavior.

2.4 Interactions between Built Environment and Socio-demographic Factors

It seems difficult to isolate the impacts of the built environment and socio-demographic on individual's travel behavior. Boarnet and Crane (2001) proposed the intervening relationship between density and demographic characteristics of households (Boarnet and Crane, 2001). In the existing literature, the problem of the interactions between socio-demographic variables and urban form characteristics was only mentioned but a few have attempted to test it (Pouyanne, 2010). A direct causal relationship between socio-demographic characteristics and urban form could be explained in the following way: individuals' characteristics can determine their location choice in a specific environment and such environment would impact their travel behavior (see Figure 2.1).

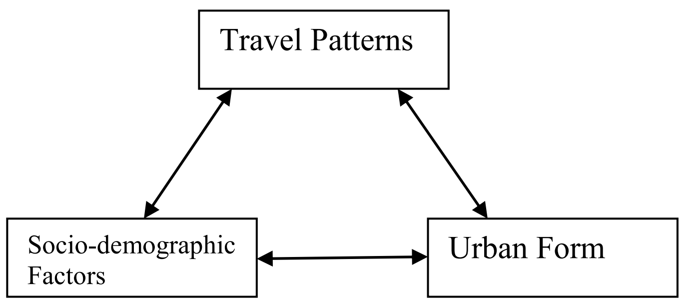
Figure 2.1 The Causality Between Socio-demographic Characteristics and Urban Form



Source: Pouyanne, 2010

Furthermore, Pouyanne (2010) also proposed a conceptual model of 'triangular relationship' (See Figure 2.2), which is a kind of circuit but without causal theory. The double arrows do not mean the direction of causality and only reflect the uncertainty of the relationships (Pouyanne, 2010).

Figure 2.2 Triangular Relationship



Source: Pouyanne, 2010

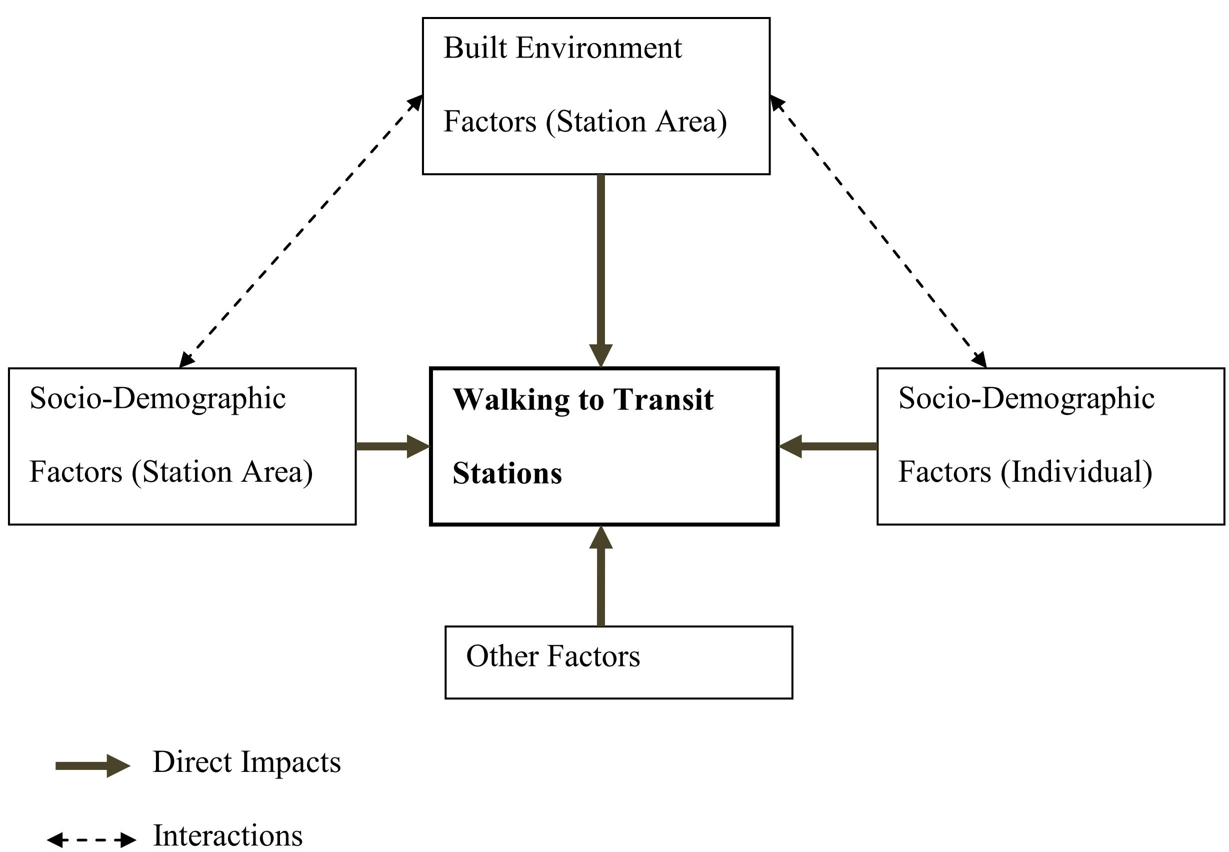
3. METHODOLOGY

3.1 Conceptual Framework

Walking to transit stations is one of the travel behavior researches. Most previous research of walking to transit has involved the similar conceptual models as other travel behavior research (Park, 2008). Cevero (1995) conceptualized the physical environmental factors and individual socio-demographic factors as two main determinants of walking to transit stations. Maghelal (2007) had both physical environment and individual's socio-demographic factors in his conceptual model, and also introduced attitude factors in the conceptual model, such as the preference of individuals. Like most previous research, the objective of this research is to examine the factors impacting walking to transit stations. Meanwhile, this study also investigates the disparities of built environment attributes across the station areas. This study would introduce groups of predictors, including socioeconomic, built environment factors of station areas and socio-demographic factors of individuals, as well as other factors getting from previous studies.

Based on previous discussions of conceptual models and the objective of this research, the study developed its own conceptual model (see Figure 3.1). In this model, the dark gray arrows represent the direct impacts from predictors to the dependent variable (walking to transit stations); while dashed lines means the interactions between the predictors. Socioeconomic, built environment factors in station areas and socio-demographic factors of individuals, as well as other factors all impact the outcome variable directly. The specific built environment of neighborhoods may attract specific characteristics of the population to reside in. Meanwhile, the socioeconomic environment and residents with different socio-demographic status could influence the constructions of the built environment.

Figure 3.1 Conceptual Model



3.2 Research Questions and Hypothesis

The objectives of this study achieved by pursuing the following specific questions and followed by the null hypotheses of these questions:

Question 1: Are there disparities in walkability of the built environment across the station areas with differing economic status and ethnic composition?

Hypothesis 1: There does not exist any disparity in built environment across the station areas with different economic status and ethnic composition.

Question 2: Do transit type and travel destinations affect transit users' walking to transit stations or bus stops?

Hypothesis 2: Transit type and travel destinations do not significantly impact transit users' choice of walking to transit stations or bus stops.

Question 3: Do the racial compositions and median household income of the stations/stops areas impact transit users' walking behavior to transit station or bus stops?

Hypothesis 3: The racial compositions and median household income of the transit stations/ bus stops areas do not significantly affect transit users' walking to transit stations or bus stops.

Question 4: Do socio-demographic characteristics of the transit users impact their choices of walking to transit stations or bus stops?

Hypothesis 4: There are not any socio-demographic characteristics of the transit users significantly impact their walking to transit stations or bus stops.

Question 5: Do built-environment attributes around transit stations impact the transit users' walking to the stations or bus stops?

Hypothesis 5: There are not any built environment attributes significantly affect transit users' walking to transit stations or bus stops.

Question 6: Do safety factors around transit stations impact the transit users' walking to the stations or bus stops?

Hypothesis 6: There are not any safety factors significantly impact transit users' walking to transit stations or bus stops.

3.3 Research Design

3.3.1 Study Area

The study area is the city of Los Angeles, which is the most populous city in the state of California with a population of 3,792,621 in 2010 (Los Angeles County Metropolitan Transportation Authority, 2012). Based on the number of daily riders, the city's light rail system is the second busiest in the states and the subway system is the ninth busiest in the country (Los Angeles County Metropolitan Transportation Authority, 2012). The rail system includes the subway lines (Red and Purple) and the light rail lines (Gold, Blue, Expo, and Green) (Los Angeles County Metropolitan Transportation Authority, 2012) (See Table 3.1 and Figure 3.1). For the bus system, there are almost 200 different lines, including Local, Rapid, Express and BRT (bus rapid transit) services. The bus lines cover every major destinations and provide connections to Metro Rail stations (See Table 3.2) (Los Angeles County Metropolitan Transportation Authority, 2012).

Figure 3.2 The Rail System and Metro Links in Los Angeles

Source: http://media.metro.net/riding_metro/maps/images/rail_map_future.gif

Table 3.1 Los Angeles Metro Rail Service

Metro Rail Service	Number of Stations	Opened Year	Ridership (September,2012)	Termini
Metro Blue Line **	22	1990	92,120/weekday	Transit Mall(north)/Metro Center(south)
Metro Red Line*	14	1993	15,5940/weekday	North Hollywood (west)/Union Station (east)
Metro Green Line**	14	1995	46,393/weekday	Redondo Beach (west)/
Metro Gold Line**	21	2003	41,987/weekday	Atlantic (south)/Sierra Madre Villa (north)
Metro Purple Line*	8	1993	15,5940/weekday	Welshire (west)/Union Station (east)
Metro Expo Line**	12	2012***	20,656/weekday	Culver City (west)/Metro Center (east)

* Subway Lines
* * Light Rail Lines
*** Only a part of the Expo line has operated and the rest will open in 2015
Source: Los Angeles County Metropolitan Transportation Authority, 2012

Table 3.2 Los Angeles Metro Bus Service

Metro Bus Service		Number of Stations	Opened Year	Street Stop	Termini
Metro Transitway*	Metro Orange Line	18	2005	None	North Hollywood (East) Warner Center Transit Hub (West) Chatsworth(North)
	Metro Silver Line	9	2009	10 Stops (northbound) & 11 Stops (southbound	North Hollywood (west)/Union Station (east)
Metro Local	Painted orange	n/a	n/a	frequent stops	along major streets throughout the city
Metro Rapid	Painted red	n/a	n/a	offers fewer stops and expedited travel times	along the city's major streets
Metro Express	Painted blue	n/a	n/a	offers reduced stop service.	along the city's freeway systems

* Metro Transitway (Metro Liner) is a bus rapid transit system with two lines operating on dedicated or shared-use busways
Source: Los Angeles County Metropolitan Transportation Authority, 2012

As one of the most economically and ethnically diverse regions in the country, Los Angeles's transit station areas encompass a wide range of demographic, physical, and economic characteristics (Center for Transit-Oriented Development, 2010). The transit network of Los Angeles extends to various neighborhoods with different household income levels, different rates of car ownership and diverse ethnic composition (Center for Transit-Oriented Development, 2010). Table 3.3 illustrates the demographic characteristics in regional, city and transit station areas (half-mile buffers of stations). It indicates that households with lower incomes and lower rates of car ownership tend to live closer to transit stations and take more transit trips or other non-motorized trips than other households.

Table 3.3 Regional, City, and Station Areas Demographic Characteristics, 2000

Measure	Los Angeles County	City of Los Angeles	Los Angeles Station Areas*
The percentage of trips to work by taking transit, walking, and biking	8%	14%	24%
Percentage of households with 0 or 1 car	46%	57%	66%
Median Household Income	$45,280	$36,687	$29,726
Percentage of Renter Households	46%	61%	73%
Average Household Size	3.00	2.83	3.02

*All the half mile buffers centered by stations
Source: Center for Transit Oriented Development, 2010

3.3.2 Survey and Population

This research used the data from the Post Census Regional Household Travel Survey funded by the Southern California Association of Governments (SCAG). They contracted NuStats to collect the data and it was conducted between spring 2001 and spring 2003 (SCAG, 2003). The households were randomly sampled and contacted by telephone for recruitment into this study (SCAG, 2003).The sampling frame was established in ten-digit telephone numbers from working banks in the SCAG region (SCAG, 2003). All of these population surveys used Random Digit Dial (RDD) methods via telephone. All participating households members were required to use travel logs to record all trips for an assigned 24-hour (or 48-hour) period (from 3 a.m. to 2:59 a.m.) (SCAG, 2003). Travel data were retrieved using CATI (Computer-Assisted Telephone Interview) and interviewers tried to speak with individual household members as much as possible to avoid proxy interviews (Southern California Association of Governments, 2003).

According to the 2000 census, the households in the SCAG region totals 5,386,491 occupied housing units. The probability selection frame and procedures may create unequal selection probabilities, and those probabilities were corrected with weights. The weight for Los Angeles County is 0.0318 (222,191 telephone numbers drawn from a universe of 6,971,600 household telephone numbers = 0.0318).

The survey relied on the willingness of households to record their travel activities. The overall response rate is low and only 25 percent, which is due to the complex survey process and a growing number of households for which English is not their first language (SCAG, 2003). The survey provided Spanish choice. As a result, the populations for whom first languages are not either English or Spanish were under-represented. In total, 17,775 households completed recruitment and retrieval activities (SCAG, 2003). There is a total of 2097 records of transit users (home to stations) with complete boarding address information and 745 records of them were from the city of Los Angeles.

To understand the differences of the populations in the census, the survey sample and transit users of the survey, table 3.4 compared their socio-demographic characteristics. The population of transit users has the highest percentages of blacks, Hispanics, females, and the unemployed rate in the three populations. Meanwhile, it has the lowest median household income in the three populations. Thus, the minorities, female and individuals with low-household income are more likely to take transit. Since some minorities did not have landlines at home and they could not participate in the survey, the survey sample has a bit higher percentage of whites and lower percentages of blacks and Hispanics than the census. For the same reason, the survey sample also has a bit higher median household income than other two groups.

Table 3.4 The Comparisons of Socio-demographic Characteristics of Three Populations

City of Los Angeles		Census 2000	Survey Sample	Transit Users in the survey
Racial Composition	White Percentage	32%	33.7%	28.3%
	Black Percentage	11.7%	10.6%	16.1%
	Hispanic Percentage	31.8%	30.9%	39.2%
Median Age		31	32	34
Gender	Female	50.2%	50.8%	56.7%
	Male	49.8%	49.2%	43.3%
Median Household Income		36687 dollars	37511 dollars	33294 dollars
Unemployed Rate		9.3%	9.1%	12.8%

Source: United States Census, 2000; SCAG, 2003.

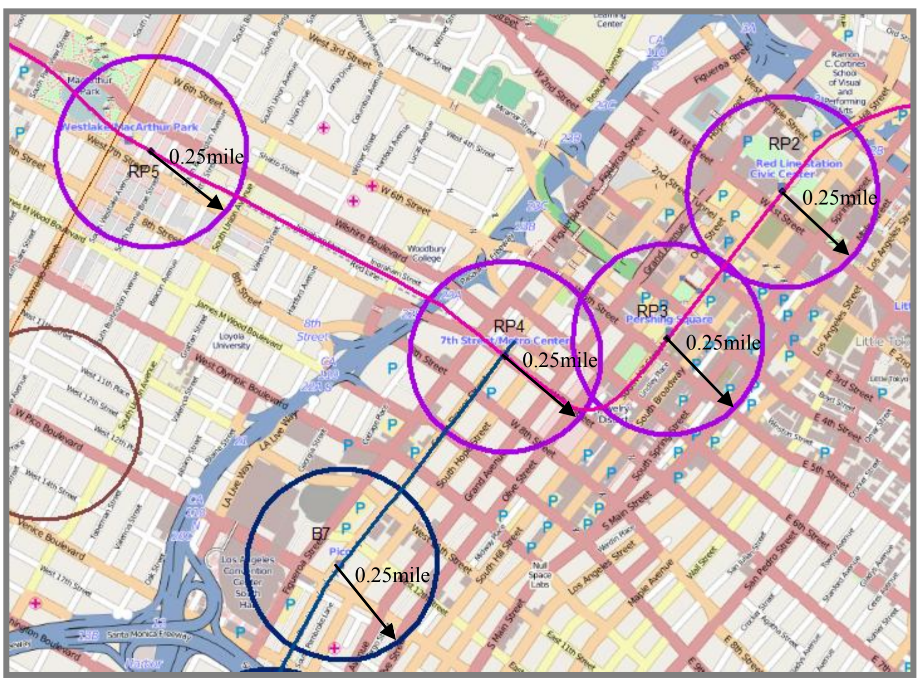
3.3.3 Unit of Analysis

Maghelal (2007) used half mile and quarter mile buffers centered by the rail stations in Dallas as the unit of analysis in his research. However, the most commonly used walking distance to both bus stops and rapid transit stations is 400 meters (0.25 miles) (O'Neill et al. 1992; Zhao et al. 2003). Since this study would cover both rail stations and bus stops, the appropriate walking distance is quarter mile. Therefore, this research defines quarter mile buffer centered around each station as the spatial unit of analysis (see Figure 3.2).

The objective measurements -- Geographic Information Systems (GIS) would be employed to measure built environment characteristics in each spatial unit of analysis.

The GIS data were achieved through multiple resources, including Los Angeles County GIS portal, Los Angeles County Sheriff, City of Los Angeles Department of Transportation (LADOT), and U.S. Geological Survey (USGS). The network analyst tool would be employed to measure the connectivity of streets; the proximity tool (buffer) and extract tool (clip) extract the attributes in quarter mile buffers; and the summarize function in the attribute table gets the results we need.

Figure 3.3 Units of Analysis



Source: City of Los Angeles Department of Transportation (LADOT), 2000; U.S. Geological Survey (USGS) , 2000

3.3.4 Variables and Measurements

The independent variables or predictors were selected based on a literature review (see chapter 2). Table 3.5 stated the variables, their descriptions and sources. There are four groups of independent variables: other variables, socioeconomic characteristics of station areas, socio-demographic characteristics of individuals, and built environment and safety attributes of station areas. They would be stated as follows.

Table 3.5 Variables, Descriptions and Sources

Variable	**Description (Variable Coding)**	**Data Source**
Dependent Variables		
Walking to Transit Stations	walking=1, other travel mode=0	SCAG Post Census Household Travel Survey
Independent Variables		
Group 1: Other Factors		
Transit Type	Rapid Lines=1; Local Buses=0	SCAG Post Census Household Travel Survey
Traveler's Destinations	Utilitarian*=1; Recreational=0	SCAG Post Census Household Travel Survey
Group 2: Socio-economic (station area)		
Race	1 Non-Hispanic White 2 Hispanic 3 African American 4 Asian/Pacific Islander 5 Other races	Census 2000
Median Household Income	The number of income in dollars	Census 2000
Group 3: Socio-demographic (individual)		
Number of Household Vehicles	The Number of Household Vehicles	SCAG Post Census Household Travel Survey

Table 3.5 Continued

Variable	Description (Variable Coding)	Data Source
Age	Years of age	SCAG Post Census Household Travel Survey
Gender	Male=1;Female=0	SCAG Post Census Household Travel Survey
Ethnicity	Non-Hispanic White=1; Others=0	SCAG Post Census Household Travel Survey
Education	1 11th grade or less 2 High school graduate 3 2 years of college/Associates Degree 4 4 years of college/Bachelors degree 5 Post-Graduate	SCAG Post Census Household Travel Survey
Household Income	Total Household Income (2000) 1 Less than $10,000 2 $10,000 to 49,999 3 $50,000 to $74,999 4 $75,000 or more	SCAG Post Census Household Travel Survey
Employment	1= employed; 0 unemployed	SCAG Post Census Household Travel Survey
Group 4: Built Environment		
Residential Density	Total population/total acres of the area**	Census 2000
Infrastructures	Completeness of Sidewalks= Total miles of sidewalks/(total miles of streets × 2)	USGS Aerial Photograph (2003)
	Street lights Coverage Density= Number of street lights /total length of streets	Los Angeles County GIS data portal
	Trees Coverage Density= Number of trees along streets / total length of streets	Los Angeles County GIS data portal
	Transit Station Parking: Available=1; Not Available=0	Los Angeles County Metropolitan Transportation Authority (Metro)
	Street Density= Total miles of streets/total acres of the area	Los Angeles County GIS data portal
	Intersection Density= Number of street intersections (≥3-way)/total acres of the area	Los Angeles County GIS data portal

Table 3.5 Continued

Variable	Description (Variable Coding)	Data Source
Land Use Mix	Land-use Mix = $-\left[\left(\sum_{1}^{n}(p_i)\ln(p_i)\right)\right]$ p-proportion of sq. ft of landuse i, n-no. of land uses	Department of City Planning, Los Angeles City
Crime rate	Year(2000) Part I Crimes per10,000 population	Los Angeles County Sheriff
Pedestrian Collision	Year 2000 Number of pedestrian Collision /miles of streets	City of Los Angeles Department of Transportation (LADOT)

* Utilitarian: go home, shopping, work or work-Related, school or other school activities, medical, post office or bank

**The area of one circle with the radius of 0.25 miles is 125.6 acres

The census data were aggregated at the census block group level or tract level, but a tract is too big for the unit of analysis of (quarter mile buffer centered by a station).

Thus, this research uses census block groups to get the socioeconomic data, such as population, race, and household income. However, the boundaries of units of analysis cannot be exactly matched with census block groups. Most units incorporate some parts of block groups. Figure 3.3 gives an example to explain how to solve this problem. The shape with red outline represents a census block group and the purple circle is a unit. The area inside the unit is filled with shade lines. To get census data of the area inside the unit, the area weight is employed and it was stated in the following formula.

Weight= area of the census block group inside the unit*/ total area of a census block group

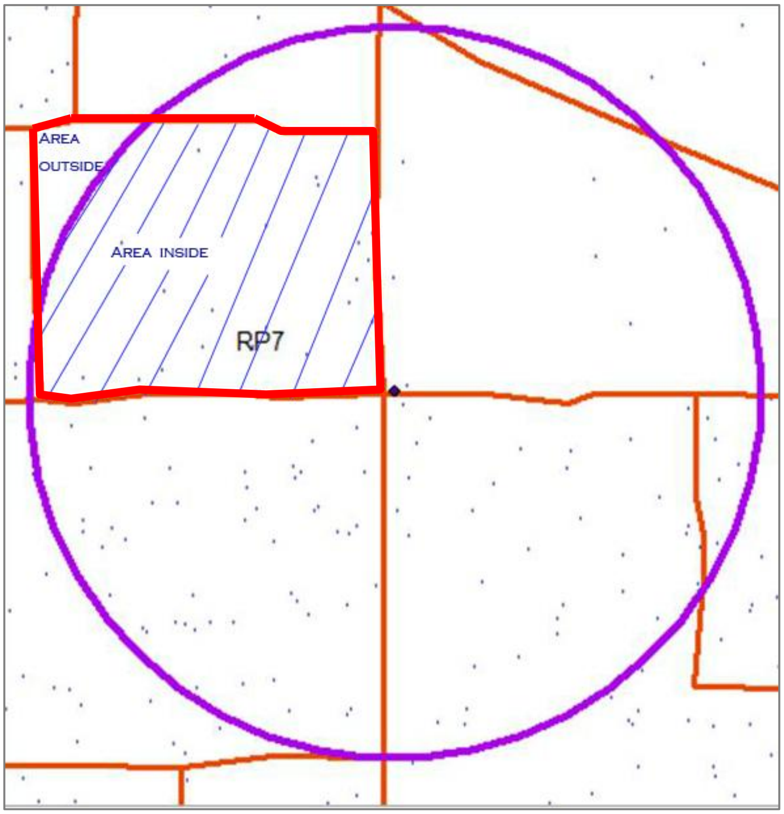
*The unit is a quarter mile buffer centered by a transit station or a bus stop

Using the weight multiplies the census data of this block group to get the data inside the unit. For the sample block group in figure 3.4, the population inside the unit could be gotten through the following formula:

$$Population_{inside} = Population_{blockgroup} \times Weight^{*}$$

*weight= area inside the unit (in shade lines)/ total area of the census blockgroup (in red outline)

Figure 3.4 The Method to Get Census Data Inside the Unit



Source:United States Census, 2000; City of Los Angeles Department of Transportation (LADOT), 2000

For other census blocks in this unit (see figure 3.3), it is the same process as the sample blockgroup to get their population data inside the unit. Finally, sum up all the population data of blockgroups inside the unit to get the total population of this unit.

There are the same process as population to get other census data of this unit, such as race and household income.

3.3.5 Data Analysis

This study used multi-level factors, including built environment factors, socio-demographic characteristics of individuals, socio-demographic factors of station areas and other factors (transit type and destinations) to predict transit users' walking to transit stations in the city of Los Angeles. There are two parts of analysis in this study and would be explained below.

3.3.5.1 Examine the Disparities in the Building Environment Attributes Across Station Areas

To examine the disparities across station areas with different racial compositions and median household income, I would discuss the appropriate statistical method at first. The ANOVA (Analysis of Variance) is a tool that tests the differences between the means of two or more categorical groups. T-test only measures the differences of means between two groups. Both of them are the statistical models to predict a continuous outcome on the basis of one or more categorical predictor variable (Platt, 1998). The linear regression model is quite similar with the ANOVA, but the linear regression model predicts a continuous outcome on the basis of one or more continuous predictor variables (Platt, 1998). In this data set, the independent variables, the percentage of black and the percentage of Hispanic are continuous variables in percent and the median household income is the continuous variable in dollars. The dependent variables, built environment attributes and safety factors, are continuous variables. Therefore, linear regression models would appropriate method to predict the built environment attributes and safety factors of station areas by race percentages and median household income (see the model 1). Additionally, the household income was coded in 10,000 dollars in the regression models because one dollar increase or decrease has no meaningful to the models. IBM SPSS 19.0 would be the software to be employed for the linear regression model.

$$y_i = b_0 + b_1 x_i \qquad (1)$$

3.3.5.2 Predict the Likelihood of Walking to Transit Stations

Logistic regression was first proposed in the 1970s as an alternative to overcome the limitations of ordinary least squares (OLS) regression in handling dichotomous outcomes (Peng and So, 2002). Wuensch and Poteat (1997) stated that the binary logistic regression models would be used when the dependent variable is a dummy variable (coded 0, 1) and predictor variables are categorical or continuous. In this study, the dependent variable is a dummy variable (walking to station or not, coded 1 or 0) and we would like to predict the likelihood of walking to transit stations by both continuous and categorical predictors. Therefore, the binary logistic regression models will be the appropriate one to do the analysis in this research.

There are four groups of predictors in the analysis, including built environment attributes (both continuous and categorical variables), individual socio-demographic attributes (both continuous and categorical variables), socioeconomic attributes of station areas (continuous variables) and other variables (transit type and travel destinations) (categorical variables). Here, one group of predictors would be added in the new model in a stepwise approach and final four logistic regression models were produced. The models (2), (3), (4) and (5) would be stated as follows. The first model has only other variables; the second model has both other variables and socioeconomic attributes of station areas; the third one has three groups of predictors while adding the socio-demographic factors of individuals in; and the fourth model or final model adds the group of built environment predictors. The explanatory power of the dependent variable of each model could be indicated by the model fit statistics, which would be explained in the Chapter four.

$N=\beta_0+ \beta_1 A+\mu$ ……………………………………………………………… (2)

N=Walking to transit

A=Other Variables (transit type and travel destination)

μ = regression error term

$N=\beta_0+ \beta_1 A_+ \beta_2 C$ ……………………………………………………………….(3)

N=Walking to transit

A=Other Variables (transit type and travel destination)

C= Socio-Demographic Variables of Units of Spatial Analysis

μ = regression error term

$N=\beta_0+ \beta_1 A + \beta_3 C + \beta_2 S + \mu$ ………………………………………………………..(4)

N=Walking to transit

A=Other Variables (transit type and travel destination)

C= Socio-Demographic Variables of Units of Spatial Analysis

S= Socio-Demographic Variables of Individuals

μ = regression error term

In the final Model, walking to transit is regressed on four groups of independent variables:

$N=\beta_0+ \beta_1 A + \beta_3 C + \beta_2 S + \beta_4 B+\mu$……………………………………………………(5)

N=Walking to transit

A=Other Variables (transit type and travel destination)

C= Socio-Demographic Variables of Units of Spatial Analysis

S= Socio-Demographic Variables of Individuals

B=Built Environment Variables

μ = regression error term

In this study, the individuals nest in the station areas. There are two levels of the dependent variables: individuals and station areas. Therefore, Hierarchical Linear

Modeling (HLM) is another potential statistical method could be applied in this study, which analyzes variance in the outcome variables when the predictor variables are at varying hierarchical levels (Woltman et al., 2012).

This study would have two level models:

Leve1 1 contains information about individuals: other factors and socio-demographic characteristics.

.

Level 2 contains information about station areas: socioeconomic and built environment attributes.

No matter how many levels in the modeling, the outcome variables are always at level 1 (Woltman et al., 2012). In this study, the outcome variable is the individuals' access mode to transit stations. HLM better supports analysis of a continuous dependent variable for the Hierarchical effects[1] and repeat measures[2] (Garson, 2013). However, the dependent variable in this study is a dummy variable. Therefore, the binary logistical

---

[1] Hierarchical effects: "For when predictor variables are measured at more than one level (ex., reading achievement scores at the student level and teacher–student ratios at the school level; or sentencing lengths at the offender level, gender of judges at the court level, and budgets of judicial districts at the district level). The researcher can assess the effects of higher levels on the intercepts and coefficients at the lowest level (ex., assess judge-level effects on predictions of sentencing length at the offender level)" (Garson, 2013, p.4).

[2] Repeated measures: "For when observations are correlated rather than independent (ex., before–after studies, time series data, matched-pairs designs). In repeated measures, the lowest level is the observation level (ex., student test scores on multiple occasions), grouped by observation unit (ex., students) such that each unit (student) has multiple data rows, one for each observation occasion" (Garson, 2013, p.4).

regression model is more suitable than HLM to predict the probability of walking to transit stations.

4. DATA ANALYSIS AND RESULTS

4.1 Descriptive Analysis

Descriptive analysis was performed for quarter-mile distance from the rail stations and bus stops. Mean and Standard Deviation (SD) were calculated for the 22 independent variables and they are displayed in Table 4.1. The socio-demographic variables were obtained through SCAG survey and Census data. The built environment variables were all objective ones and measured using Geography Information System (GIS). The average sidewalk completeness is 44.29%; the average street density is 185.69 miles per acre; the street light density is around 40 (39.62) per mile; the trees (along streets) coverage density is around 44 (44.29) per mile; the residential density is around 18 (17.64) people per acre; the average land use mix index is 0.61 and the intersection (>= 3 ways) density is 0.24 (0.2378) per acre.

Table 4.1 Descriptive Statistics of Independent Variables

Independent Variables	N*	Description or Coding	Mean	Std. Deviation
Travel Destination (c)	745	1=Utilitarian; 0=Recreational	.80	.398
Transit Type (c)	745	1=Rapid Lines; 0= Local Buses	.85	.354
Age	745	Years of age	38.82	14.637
Gender	745	1=male;0=female	.37	.484
Household Income (2000) (c)	745	1 Less than $10,000 2 $10,000 to 49,999 3 $50,000 to $74,999 4 $75,000 or more	2.11	.876
Vehicle Number of Household	745	The Number of Household Vehicles	.85	.833
Employment Status (c)	745	1= employed; 0= unemployed	.44	.24
Ethnicity (c)	745	1=Non-Hispanic White 0=Others	.18	.385
Education (c)	745	1 11th grade or less 2 High school graduate 3 2 years of college/Associates Degree 4 4 years of college/Bachelor's degree 5 Post-Graduate	2.56	1.268
Black percentage	55	Number of Black/Total Population of Each Unit*100%	16.45%	17.648%
Hispanic Percentage	55	Number of Hispanic/Total Population of Each Unit*100%	35.51%	20.558%
Median Household Income	55	the Income in dollars	48489.53	26468.576
Street lights Density	55	Number of street lights /total length of streets (miles)	39.62	16.073
Trees Coverage Density	55	Number of street trees /total length of streets (miles)	44.29	17.596
Transit Station Parking (c)	55	1-Avaliable 0- Not Available	.53	.499

Table 4.1 Continued

Independent Variables	N*	Description or Coding	Mean	Std. Deviation
Street Density	55	Total miles of streets/total acres of the area	185.69	658.32
Intersection Density	55	Number of street intersections (≥3-way)/total acres of the area	.26	.106
Land Use Mix	55	Land-use Mix = $-\left[\left(\sum_{1}^{n}(p_i)\ln(p_i)\right)/\ln(n)\right]$ p-proportion of sq. ft of landuse i, n-no. of land uses	.61	.183
Residential Density	55	Total population/total acres of the area	17.64	7.708
Distance (100 feet)	745	The distance from home to transit stations	15.64	6.832
Sidewalk Completeness	55	Total miles of sidewalks/(total miles of streets × 2)*100%	44.29%	17.59%
Yearly Crime Rate 2000(100,000 population)	55	Year(2000) Part I Crimes** per10,000 population	31.01	15.654
Pedestrian Collision (2000)	55	Year 2000 Number of pedestrian Collision /Lenght of streets (miles)	6.90	2.732

(c) Categorical Variables
*745 is the total number of individuals; 55 is the total number of transit stations and bus stops
** Part-I crimes include criminal homicide, forcible rape, robbery, aggravated assault, burglary, larceny-theft, motor-vehicle theft, and arson.

4.2 Tests of Correlations

Bivariate correlation was performed to look at the correlation of 10 built environment and safety variables (see Appendix A). In the final analysis, although the Pearson Correlation results (sig) showed that there were some significant correlations at the 0.01 level and 0.05 level, however, all the coefficients (r) is below 0.4, which are low correlations.

4.3 Disparities in Walkability of Built Environment and Safety Attributes Across Station Areas

The bivariate linear regression models were used to predict each built environment and safety attribute by the racial compositions and median household income of station areas respectively (See Table 4.2). The independent variables: the percentage of black, the percentage of Hispanic and median household income is all continuous variables. While more dependent variables are continuous variables, including street light density, tree coverage density, intersection density, land use mix, residential density, sidewalk completeness, yearly crime rate and pedestrian collision rate. In the final results, the street light density was the sole built environment attribute that significantly impacted by both the racial percentages and median household income. With one percentage increase in black proportion, there is a decrease of 0.238 street lights per mile. The correlation is similar with Hispanic. With one percentage increase in Hispanic, there is a decrease of 0.233 street lights per mile. While 10,000 dollars increase, there increase 2.969 street lights per mile. Thus, the percentage of black or Hispanic population had a negative association with the street light density, while the median household income had a positive effect on street light density. In other words, the street light density is lower in the communities with a high percentage of black or Hispanic and low median household income. Another built environment attributes, the percentage of sidewalk completeness, is significantly associated with the percentage of black or Hispanic. With one percentage increase in black, 0.333 percent in sidewalk completeness decreased. With one percentage increase in Hispanic, 0.274 percent in sidewalk completeness decreased. Therefore, the percentage of sidewalk completeness is low in the communities with a high percentage of black or Hispanic. The tree coverage density is only significantly impacted by the median household income. With an increase of 10,000 dollars in median household income, there would increase 8 (7.538) trees per mile. In other word, the tree coverage density would be high in higher median household income communities.

4.4 Examination of Factors Impacting Walking to Transit Stations

This section would use binary logistic analysis to test the hypothesis 2, 3, 4, 5, and 6 raised in chapter 3. The hypotheses are as follow and would be tested one by one:

Hypothesis 2: Transit type and travel destinations do not significantly impact transit users' walking to transit stations or bus stops.

Hypothesis 3: The race compositions and median household income of the transit stations/ bus stops areas do not significantly affect walking to transit stations or bus stops.

Hypothesis 4: There are not any socio-demographic characteristics of the transit users significantly impact their walking to transit stations or bus stops.

Hypothesis 5: There are not any built environment attributes significantly affect transit users' walking to transit stations or bus stops.

Hypothesis 6: There are not any safety factors significantly impact transit users' walking to transit stations or bus stops.

Table 4.2 Results from Binary Linear Regression Models Predicting Built Environment and Safety Attributes[a]

Dependent Variables	**Black Percentage (%)**			**Hispanic Percentage (%)**			**Median Household Income (10,000 Dollars)**		
	p	t	Coefficient	p	t	Coefficient	p	t	Coefficient
Street lights Density	**.032**	**-2.202**	**-.283***	**.037***	**-2.144**	**-.233***	**.032**	**2.206**	**2.969***
Trees Coverage Density	.107	-.1.641	-.566	.132	-1.529	-.446	**.044**	**2.603**	**7.538***
Street Density	.078	1.796	.958	.245	1.175	.538	.120	1.580	.063
Intersection Density	.078	1.795	.958	.245	1.538	.538	.091	-1.175	-5.732
Land Use Mix	.180	-1.360	-.002	.676	-.421	-.001	.829	-.217	-.002
Residential Density	.469	-.730	-.072	.223	1.223	.102	.385	.875	.008
Sidewalk Completeness	**.024**	**-2.325**	**-.333***	**.030**	**-2.332**	**-.274***	.457	.749	.663
Yearly Crime Rate 2000 (100,000 population)	.510	-.664	-.119	.129	-1.541	-.229	.897	-.130	-.137
Pedestrian Collision Rate (2000)	.074	-1.820	-.041	.926	.093	-.002	.244	1.177	.157

a. These are bivariate linear regression models respectively

*p<0.05

Table 4.3 Results of Four Binary Logistic Regression Models Predicting Walking to Transit Stations

Independent Variables	MODEL 1			MODEL 2			MODEL 3			MODEL 4		
	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR
Other Variables												
Travel Destination (c) (Utilitarian=1)	**.000**	**-1.349**	**.260*****	**.000**	**-1.384**	**.250*****	**.000**	**-1.499**	**.223*****	**.000**	**-1.518**	**.219*****
Transit Type (c) (Rapid Transit=1)	**.001**	**-.805**	**.447*****	**.002**	**-.736**	**.456*****	**.001**	**-.876**	**.417*****	.084	-0.553	.575
Socio-Demographic Variables of Station Areas												
Black Percentage (%)				.135	.009	1.009	.107	.010	1.010	.064	.020	1.021
Hispanic Percentage (%)				.073	.011	1.011	.121	.007	1.007	.162	.008	1.008
Median Household Income (10,000 dollars)				.195	.141	1.152	.048	**.242**	**1.274***	.004	**.492**	**1.636*****
Socio-Demographic Variables of Individuals												
Number of Household Vehicle							**.002**	**-.335**	**.716*****	**.026**	**-.264**	**.768***
Household Income (10,000 dollars)							**.000**	**-.383**	**.682*****	**.000**	**-.488**	**.614*****
Age							.053	-.022	.992	.052	-.029	.989
Gender(c) (Male=1)							.690	-.072	.930	.051	-.254	.776

Table 4.3 Continued

Independent Variables	MODEL 1			MODEL 2			MODEL 3			MODEL 4		
	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR
Employment(c) (Employment=1)							.508	-.116	.890	.621	.137	1.099
Ethnicity(c) (Non-Hispanic White=1)							**.001**	**-1.086**	**.338*** **	**.000**	**-.864**	**.421*** **
Education (c)[1]							.016			.063		
Education (1)							.065	-.647	.523	.280	-.400	.670
Education (2)							.067	-.918	.399	.052	-.813	.443
Education (3)							.573	-.198	.820	.636	-.174	.841
Education (4)							.057	-.667	.508	.172	-.511	.600
Built Environment and Safety Variables												
Street lights Density (Number of lights per mile)										**.022**	**.027**	**1.040***
Street Trees Coverage Density (Number of trees per mile)										**.042**	**.007**	**1.007***
Transit Station Parking(c) (Parking Available=1)										**.015**	**-.531**	**.588***

Table 4.3 Continued

Independent Variables	MODEL 1			MODEL 2			MODEL 3			MODEL 4		
	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR
Land Use Mix (0-1)										**.028**	**.135**	**1.145***
Residential Density (Total population per acre)										.429	.007	1.007
Street Density (Total miles of streets per acre)										.180	.002	1.002
Intersection Density (Number of street intersections (≥3-way) per mile)										.224	.175	1.186
Distance (100 feet)										**.000**	**-.081**	**.922*****
Sidewalk Completeness (%)										**.004**	**.020**	**1.020*****
Yearly Crime Rate 2000 (Part I Crime2per10,000 population)										.774	-.001	.997
Pedestrian Collision 2000 (Number of Pedestrian Collision per mile)										.545	-.028	.973

Table 4.3 Continued

Independent Variables	MODEL 1			MODEL 2			MODEL 3			MODEL 4		
	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR	p	Coeff.	OR
Constant	.000	2.327	10.242	0.001	1.447	4.252	.001	.867	2.472	.845	.261	1.299
Number of observations		745			745			745			745	
Model Fit												
-2 Log likelyhood	942.614			916.402			859.704			751.809		
Nagelkerke R2	0.081			0.125			0.216			0.370		

(c) Categorical Variables
*p<0.05, **p<0.01, ***p<0.001
[1] Categories of Education: 1. 11th grade or less; 2. High school graduate; 3. 2 years of college/Associates Degree; 4. 4 years of college/Bachelor's degree 5. Postgraduate (**Reference Group**)
[2]Part-I crimes include criminal homicide, forcible rape, robbery, aggravated assault, burglary, larceny-theft, motor-vehicle theft, and arson.

The four binary logistic regression models to test the hypotheses above and the results are shown in Table 4.3. To determine which factors are significant ones that impacted the walking behavior to transit stations, four binary logistic regression models were employed to do the analysis. The first model only had one group of predictors and the following models added one more group of predictors each time. The final model (model 4) had all of the four groups' indicators. The significant variables and their changes in the models would be reported and explained hereafter.

The first model only had travel destination and transit type as the predictors, both of which were significant factors to predict the walking behavior to stations. Traveling to utilitarian destinations decreased 74% in the odds of walking to stations compared with traveling to recreational destinations. Traveling destination maintained statistical significance in all of the four models. Taking rapid transit decreased 55.3% in the odds of walking to stations compared with taking the bus. Transit type was a significant factor in the first three models but lost significance in the final model.

The socioeconomic variables of station areas included black percentage, Hispanic percentage and median household income. When adding the socioeconomic variables of station areas in the second model, none of them were significant. To provide a meaningful interpretation of the results, the household income variable was coded $10,000 units. The median household income variable turned significant one in model 3 and one level increased in the median household income would increase 27.4% in the odds of walking to stations. It became more significant in the final model, with a one level increase in the median household income increasing 63.6% in the odds of walking to stations. However, the percentage of black and percentage of Hispanic was not significant in the following models.

Comparison with Model 1 and Model 2, both Model 3 and final model have socio-demographic factors of individuals. In Model 3, ‘vehicle number of households’, ‘household income’, and ‘ethnicity’ were the significant indicators to impact walking behavior to stations. With one vehicle increase in the household, 28.4% in the odds of walking to stations decreased. The car ownership in the household had been tested as an important variable for encouraging driving and decreasing walking in early studies. It kept significant in the final model and with one vehicle increase in the household, 23.2% in the odds of walking to stations decreased. To provide a meaningful interpretation of the results, the household income variable was coded $10,000 units. With a $10,000 increase in household income, 31.8% in the odds of the individual walking to stations decreased. In the final model, with a $10,000 increase in household income, 38.6% in the odds of walking to stations decreased. Household income could impact the choice of walking because the high household income could increase the number of household vehicles and other options to stations, such as carpool. Here the ‘ethnicity’ was a dummy variable (white=1). The Whites decreased 66.2% in the odds of walking to stations compared with other races. In the final model, the ethnicity maintained significant and the Whites decreased 57.9% in the odds of walking to stations compared with other races.

The final model (model 4) has four groups of predictors and it is the only one incorporating built environment and safety attributes compared with other models. There were total six significant built environment factors to predict walking to stations. The distance and percentage of sidewalk completeness were the two most significant ones. The 'distance' is the spatial distance from the departure origin to the station destination and the unit in this analysis is 100 feet. With a one hundred feet increase in distance, it decreases 7.8% in the odds of walking to stations. The walking distance was discussed in Chapter two and some earlier researchers found that the majority travelers walked maximum distances between 3,643 feet (0.69 mile) and 5280 feet (1 mile) (Wener & Evans., 2007; Park, 2008). Thus the length of distance to the transit station is critical for walking behavior due to individuals' physical endurance no matter what other encouraging facilities are. While one percentage increased in the sidewalk completeness, 2% in the odds of walking to stations increased.

The 'street lights density', 'trees coverage density', 'transit station parking' and 'land use mix' were other four built environment factors that impact the walking to stations significantly. Street lights are essential street facilities for the safety of walkers at night and trees shade is important for walking in summer. While adding one street light per mile, 4% in the odds of walking to stations increase. When adding one street tree per mile, 0.7% in the odds of walking to stations increase. Land use mix was reported as a critical indicator in a number of studies for encouraging walking and attracting walkers. In this analysis, every 0.1 increase in the land use mix index (0-1), increased 14.5% in the odds of walking to stations. Consistent with previous findings, the availability of sidewalks to stations decided the possibility of walking to stations. The stations with parking would decrease the 41.2% at odds of walking to stations compared with the stations without parking.

Generally, under the Model Summary, -2 Log Likelihood statistic measures how poorly the model predicts the outcome variable-- the smaller the statistic the better the model (Cohen et al., 2003). In Model 1, -2 Log Likelihood statistics is 942.61, and it decreased in Model 2 (916.402) after adding socioeconomic factors of station areas. It continually decreased in Model 3 (859.704) while adding socio-demographic variables on individuals. When added the built environment and safety attributes in Model 4, the -2 Log Likelihood decreased to 751.809. It is obvious that the groups of predictors added in Model 2, Model 3 and Model 4 continually improved the predictive power of the dependent variable.

The Nagelkerke R-square is an adjustment of the Cox & Snell and the maximum value is equal to 1.0 (Cohen et al., 2003). Overall, high values are better than low values, with higher values suggesting that the model fits increasingly well (Cohen et al., 2003). In Model 1, Nagelkerke R-square is 0.081, which means that 8.1% of the variation in dependent variable (walking to stations) could be explained by the predictors (transit type and travel destination). In Model 2, Nagelkerke R-square is increasing to 0.125, which means after adding in socio-economic predictors of station areas, the variations of dependent variable (walking to stations) could be explained 12.5% by the Model 2 and increased 4.4% compared with Model 1. The Nagelkerke R-square in Model 3 is 0.216, which explained 21.6% of the variations of dependent variable (walking to stations) after adding socio-demographic factors of individuals in and increased 9.1% compared with Model 2. In the final Model (Model 4), Nagelkerke R-square is 0.370. The final Model incorporated built environment and safety predictors in and explained 37% variation of the dependent variable, which increased 15.4% compared with Model 3.

5. DISCUSSION AND CONCLUSION

5.1 Discussion

Walking to transit stations is an important strategy to encourage transit use (Maghelal, 2007; Park, 2008). Today's transit-oriented development practices often increase the density in the areas that close to transit stations and thereby decreasing walking distances to the station (Park, 2008). However, the transit-oriented development was explained as within walking distance to public transit, pedestrian-oriented and mixed-use residential and commercial development (Center for Transit-Oriented Development, 2010). Thus, transit-oriented developments fail to be fully considered if only increasing the density and shorten walking distances (Park, 2008). This research tries to contribute to this field through conducting a comprehensive analysis of walking to the transit station, which include built environment characteristics of station areas.

Although a great number of multiple disciplinary studies have been done, there are still lacking the causal link that built environment associated with the walking (Cervero, 2002; Ewing and Cervero; 2010; Frank et al., 2005; Frank et al., 2010; Park, 2008; Sallis, 2009). This study is one of the researches that are looking for more empirical evidences to examine the built environment correlates of walking. In the final findings, built environment variables explain more variance of walking behavior to transit stations than other groups of variables. This finding supports that built environment characteristics of station area have the most significant impacts on walking behavior to transit stations. The walking infrastructure, such as street lights, trees coverage and sidewalks are significant encouraging indicators for walkers. Higher street light density, tree coverage density and completeness of sidewalks increase the possibilities of walking to transit stations. The land use mix is reported that higher mixture of land use increases the odds of walking to transit stations. However, the availability of transit station parking has negative correlations with walking to transit stations. Decreasing parking lots around the stations would increase the odds of walking to transit stations and also increase the possibility to take transit.

Besides building environment characteristics of the station area, this study also reported that median household income of station area has a positive impact on walking to the transit station. The higher median household neighborhoods may have a safer and more comfortable walking environment. The first part of chapter four has examined disparities of built environment and safe attributes across station areas with different racial compositions and median household income. The findings indicated that there existed disparities of pedestrian facilities, such as street lights, sidewalks and tree coverage across the station areas. The street lights density and completeness of sidewalks are lower in communities with higher percentages of blacks or Hispanics. The neighborhoods with higher median household income may have more friendly- walking environment, such as high street lights and tree coverage density.

5.2 Limitations of This Study

5.2.1 Limitations of Methodology

The units of analysis are quarter mile buffers centered by the stations in this study, thus the researcher used GIS to measure the built environment attributes, safety factors, and socioeconomic characteristics in these areas. However, in the data set, some individuals may walk over quarter mile (e.g., half mile, or even more) to stations. Therefore, the built environment attributes, safety factors and socioeconomic characteristics measured in quarter mile buffers are not sufficient to capture the actual domain of the built environment . Since there is no real walking route information of individuals in the data set and, it is impossible to capture the accurate built environments that they have experienced.

This study covered all rail stations in the city of Los Angeles, however, only a quite small percentage of bus stops were covered. The primary reason might be like that this research only catch up the home to station records, but the bus users were often transferred from other transportation modes (e.g., rail) instead of departure from their home directly. Another major reason is the missing or uncompleted information to identify bus stops, which is due to the difficulty to identify the specific addresses of a bus stop compared with a rail station. Although the number of bus stops is quite limited, we still find interesting phenomena that bus users are more likely to walk to stops than the rail takers. If it is possible in future, an ideal survey for this study purpose could only focus on the population of transit users. We might need a different sampling framework and process but can get more records for bus users through more efforts in this field.

Self-selection is a critical factor in travel behavior. Even though residents live in a walkable environment, they may not walk only due to their own intentions (Cao et al., 2007; Cao et al., 2009). There is no self-selection information in the survey and it is impossible to redo it. However, it could be added in future research.

5.2.2 Limitations of Data Source

The data were achieved from the travel survey by the Southern California Association of Governments from 2001 to 2003. There exist some limitations of the data source and they would be addressed as follows:

1. Coverage Bias: The survey population was households with telephones in the SCAG region; however, Census 2000 data indicates that there are 1.6% of occupied housing units without telephones in the SCAG region (Southern California Association of Governments, 2003). This survey population and sampling frame under-presents the households without telephones (SCAG, 2003).

2. Low Response Rate: The overall response rate was low with only 25 percent, which is primarily due to the complexity of interview processes. (SCAG, 2003). Some households selected did not participate in the survey finally or individual household members failed to answer items in the interview (SCAG, 2003).

3. Data Quality: Most households recorded their trips through diary instruments, in which respondents recorded each trip for a specific time period (SCAG, 2003). Although the travel diaries were used, there is a well-documented occurrence for under-reporting of trips by survey respondents, especially for walking trips (SCAG, 2003).

5.3 Conclusion

This study showed that the built environment around transit stations has a significant impact on walking to transit stations. Improving the pedestrian environment would increase the likelihood of walking to stations, such as increasing sidewalk completeness, adding more street lights and trees, increasing mixed-use of residential and commercial development and decreasing the parking lots around transit stations. These findings would be the potential suggestions for policy makers to enhance transited-oriented development. Meanwhile, this study also examined the disparities of built environment attributes across station areas with different racial compositions and median household income. The results indicated that the walking-support infrastructure, such as street lights density and sidewalk completeness, were lower in the neighborhoods with minority or lower median household income. The tree coverage density was higher in higher median household neighborhoods than that in lower household income neighborhoods. This research highlights not only the significant indicators to encourage walking to transit stations, but also identifies disparities of these indicators across neighborhoods with different socioeconomic characteristics.

The findings of this study are consistent with most previous researches. For examples, Cevero (2001) suggested that the role of built environment characteristics around a station was critical to increase walking trips to stations. This study reports that built environment variables explain more variance of walking behavior to transit stations than other groups of variables. This would be helpful in providing suggestions in the urban planning field. Cevero (1995) and Loutzenheiser (1997) found that parking availability at the station might be a significant factor discouraging walking to the station. This study also gives the same result that parking lots around stations decrease the possibility of walking to stations. Wener and colleagues (2007) and Park (2008) suggested that walking distance is one of the critical determinants for walking and the residential developments closed to transit stations encourage the residents to take transit and make it possible to walk to transit. This study reports that the distance to transit station is a negative significant factor correlates of walking. Park (2008) indicated that continuity of sidewalk is a significant factor encouraging walking to stations. The completeness of sidewalks is also a positive significant factor for walking to stations in this study. Meanwhile, as previous researches stated, the pedestrian amenities and high mixed land use are important for walking (Cevero, 1995; Cevero, 2001; Maghelal, 2007; Park, 2008). In this research, street lights and trees coverage are significant variables encouraging walking to stations; and higher mixture of land use significantly encourages walking to stations. The street lights make it safe to walk at night and trees coverage could make it comfortable to walk in summer. The mixed land use may provide commercial spaces at the first floors of buildings, which could attract more walkers.

Generally, the consistent findings could encourage policy makers paying more attention to the significant factors and their applications in reality. The potential suggestions for creating a walkable environment around transit stations could be addressed as follows:

(1) To encourage residents walking to stations, the residential developments are better closing to transit stations.

(2) To create an encouraging walking environment, the policy makers should give more attention for making sidewalk continuity.

(3) Increase the street light density to make a safe walking at night.

(4) Increase tree coverage along the sidewalks to make a comfortable walking environment in the summer.

(5) Increase the mixture of residential and commercial development to attract more residents to walk.

(6) Decrease transit station parking and make it less possible to drive to stations.

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APPENDIX A CORRELATIONS OF INDEPENDENT VARIABLES IN BINARY LOGISTICAL MODELS

		Streetlights Density	TreesCoverag eDensity	StationParkin g	LandUseMix	StreetDensity	Intersection Density	Residential Density	Distance (feet)	percentage ofsidewalk compeletnes s	YearlyCrime Rate2003100 000populatio n	Pedestrian Collision2000	Blackpercenta ge	Hispanic Percentage
StreetlightsDensity	Pearson Correlation	1	-.119**	-.321**	.270**	-.210**	.236**	-.115**	-.072*	.158**	-.034	.015	.036	.062
	Sig. (2-tailed)		.001	.000	.000	.000	.000	.002	.050	.000	.358	.687	.329	.090
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
TreesCoverageDensity	Pearson Correlation	-.119**	1	-.052	.357**	-.272**	-.335**	.151**	-.089*	-.369**	-.201**	.233**	-.240**	-.134**
	Sig. (2-tailed)	.001		.153	.000	.000	.000	.000	.015	.000	.000	.000	.000	.000
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
StationParking	Pearson Correlation	-.321**	-.052	1	-.095**	.115**	-.042	-.280**	.088*	-.175**	-.044	-.005	.007	-.111**
	Sig. (2-tailed)	.000	.153		.009	.002	.256	.000	.016	.000	.230	.895	.846	.002
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
LandUseMix	Pearson Correlation	.270**	.357**	-.095**	1	-.069	-.291**	.221**	-.050	-.027	-.132**	-.144**	-.117**	.010
	Sig. (2-tailed)	.000	.000	.009		.059	.000	.000	.175	.463	.000	.000	.001	.785
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
StreetDensity	Pearson Correlation	-.210**	-.272**	.115**	-.069	1	-.108**	-.019	-.045	.317**	-.166**	-.240**	.056	-.072*
	Sig. (2-tailed)	.000	.000	.002	.059		.003	.602	.224	.000	.000	.000	.129	.050
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
IntersectionDensity	Pearson Correlation	.236**	-.335**	-.042	-.291**	-.108**	1	-.301**	-.018	-.233**	.227**	-.051	.011	.222**
	Sig. (2-tailed)	.000	.000	.256	.000	.003		.000	.619	.000	.000	.168	.772	.000
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
ResidentialDensity	Pearson Correlation	-.115**	.151**	-.280**	.221**	-.019	-.301**	1	-.043	.065	-.070	.047	.122**	.023
	Sig. (2-tailed)	.002	.000	.000	.000	.602	.000		.242	.078	.058	.203	.001	.539
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
Distance (feet)	Pearson Correlation	-.072*	-.089*	.088*	-.050	-.045	-.018	-.043	1	-.012	.129**	-.072*	.062	.022
	Sig. (2-tailed)	.050	.015	.016	.175	.224	.619	.242		.737	.000	.048	.091	.546
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
percentage ofsidewalk compeletness	Pearson Correlation	.158**	-.369**	-.175**	-.027	.317**	-.233**	.065	-.012	1	-.119**	-.189**	.099**	-.098**
	Sig. (2-tailed)	.000	.000	.000	.463	.000	.000	.078	.737		.001	.000	.007	.007
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
YearlyCrime Rate2003100000populati on	Pearson Correlation	-.034	-.201**	-.044	-.132**	-.166**	.227**	-.070	.129**	-.119**	1	-.009	.047	.153**
	Sig. (2-tailed)	.358	.000	.230	.000	.000	.000	.058	.000	.001		.813	.204	.000
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
PedestrianCollision2000	Pearson Correlation	.015	.233**	-.005	-.144**	-.240**	-.051	.047	-.072*	-.189**	-.009	1	.023	-.133**
	Sig. (2-tailed)	.687	.000	.895	.000	.000	.168	.203	.048	.000	.813		.534	.000
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
Blackpercentage	Pearson Correlation	.036	-.240**	.007	-.117**	.056	.011	.122**	.062	.099**	.047	.023	1	-.191**
	Sig. (2-tailed)	.329	.000	.846	.001	.129	.772	.001	.091	.007	.204	.534		.000
	N	745	745	745	745	745	745	745	745	745	745	745	745	745
HispanicPercentage	Pearson Correlation	.062	-.134**	-.111**	.010	-.072*	.222**	.023	.022	-.098**	.153**	-.133**	-.191**	1
	Sig. (2-tailed)	.090	.000	.002	.785	.050	.000	.539	.546	.007	.000	.000	.000	
	N	745	745	745	745	745	745	745	745	745	745	745	745	745