2. LITERATURE REVIEW FINDINGS – NON-MOTORIZED ACCESS AND TRANSIT RIDERSHIP

This chapter outlines the results of a literature review that evaluated factors relating "access to transit" to "ridership increases." The project team conducted research to assess if, and how, bicycle and pedestrian improvements around transit stops/stations may be correlated with a change in transit ridership. The results of this research informed the data collection plan and regression modeling, which are described in subsequent chapters. In general, the literature review revealed a substantial amount of research on how the built environment and transportation infrastructure influences people's choice to walk and bicycle. However, there is less research on how pedestrian/bicycle infrastructure accessing transit affects ridership. That being said, the literature did indicate several important factors that are correlated with non-motorized access and transit ridership. The factors and some specific examples cited in the literature are summarized in **Table 1**. The sources of these findings and their applicability to this project are described in more detail below.

Table 1: Summary of Influential Access to Transit Factors

Factor	***Examples of Influential Factor***	***Citation***
Connectivity at transit destinations, lighting at transit origin stations	4-way intersections within one mile of workplace destinations, number of streetlights per 1,000 feet of shortest walking distance from residence to nearest stations	Cervero, 2007
Walkability index in station catchment areas	Land use density, land use mix, number of intersections per acre	Ryan and Frank, 2009
Route directness	Street network connectivity	Schlossberg, 2007
Increase in on- and off-site bicycle infrastructure	On- and off-street facilities within station bike shed, on-site amenities at transit stations, parking policies at stations	Cervero, 2012
On-board bicycle accommodations	Number of buses on applicable routes with bike racks or other facilities	FHWA, date unknown

Transit Oriented Development's Ridership Bonus: A Product of Self-Selection and Public Policies, *Robert Cervero, Environment and Planning Journal, 2007*

This study evaluated which factors influence work-trip transit ridership for residents living near rail lines in California. The analysis indicated that certain variables had "significant marginal influences" on mode choice. While, in general, workplace variables such as flextime schedules were the most influential, connectivity levels at the destination were also significant factors. The desire to live in an area close to transit was also an indicator of transit ridership. Streetscape improvements, parking provisions, and other physical design elements of station area housing apparently did not influence whether station area residents took transit for work trips. Housing density around station areas made the biggest difference in adding trips to the transit system. Among Californians living within one-half mile of rail stations, only one urban design variable had significant influence on whether people biked or walked to the station: street lighting density. This had "modest predictive powers." Statistics are available in the report, located at: http://www.transitwiki.org/TransitWiki/images/6/6d/Cervero_TOD.pdf.

Based on Cervero's research, two variables are of interest for this study:

- Proportion of intersections that are 4-way or more within 1 mile of a station or stop
- Number of street lights per 1,000 feet of shortest walking distance from residence to nearest station

Pedestrian Environments and Transit Ridership, *Sherry Ryan and Lawrence Frank, Journal of Public Transportation Vol 12 No 1, 2009*

This study utilized data from the San Diego region to assess relationships between transit ridership and the quality of pedestrian environments around bus stops. The study authors defined the station catchment area as a half-mile along the street network from each transit stop. The analysis showed a "significant and expected" relationship between bus ridership and walkability. However, although the walkability variable was deemed statistically significant, it explained only 0.5% of variation in ridership. Descriptive statistics for socioeconomic and built environment variables and walkability index equations are provided in the report at: http://reconnectingamerica.org/assets/Uploads/JPT12-1Ryan.pdf.

According to the authors, the walkability index (equation provided in the paper) is a combination of the following factors:

- Land use density, measured through net residential density in station area buffer, and average retail floor-to-area ratio (FAR) in station area buffer
- Land use mix, a factor of the number of different land uses in the station buffer and the proportion of acres of each land use within the station buffer area
- Street network pattern, number of intersections per station area buffer acre

Based on this research, several connectivity/land use variables are of interest for this study:

- Population and employment density around stops and stations
- Number of intersections around stops and stations

Source: How Far, By Which Route, and Why? A Spatial Analysis of Pedestrian Preference, *Marc Schlossberg et. al., Mineta Transportation Institute, 2007*

This study does not address relationships between the pedestrian environment and transit ridership but does identify key factors influencing why people choose certain routes and how far they are willing to walk to transit. Survey responses indicated that people walk on average 0.5 miles to access rail transit. Other data cited by the authors note that people in suburban areas are more willing to walk longer distances (average of 0.4 miles versus 0.2 miles) than similar people in urban areas to reach high-frequency transit. According to the survey, the most important factor in choosing a walking route is directness (minimizing time and distance). Secondary factors are safety, attractiveness of the route, sidewalk quality, and absence of long waits at traffic lights. The study authors equated "safety" to the presence of adequate traffic control devices at crossings, as well as slower traffic speeds. Geographic data were not collected as part of this study. The study can be found online at: http://transweb.sjsu.edu/MTIportal/research/publications/documents/06-06/MTI-06-06.pdf

Based on this research, three variables are of interest for this study:

- Route directness – the ratio between the straight line distance and the actual network distance between a transit stop and a parcel or point
- Presence of sidewalks on arterial streets
- Signalized crossings of arterial streets

Bike-and-Ride: Build It and They Will Come, *Cervero et al, working paper 2012*

This study analyzed multiple BART stations for bike access and how changes to the on- and off-site bicycle environments between 1998-2008 influenced access-to-transit mode split. The BART stations were characterized by typologies (urban, urban with parking, balanced intermodal, intermodal-auto reliant, or auto-dependent).

Several stations in the study experienced significant increases in bicycle mode share access to transit, attributed to infrastructure investments. For instance, Ashby Station in Berkeley increased its bicycle mode share from 7.4% in 1998 to 11.7% in 2008 and significantly expanded its bike access shed through multiple improvements such as:

- Doubling the amount of bike infrastructure surrounding the station
- Including the opening of the bike boulevard network in Berkeley
- Addition of ramps facilitating bike access to the station
- Including bike-rack parking spaces, secure/enclosed lockers, and a self-serve bike station
- Added parking fees for cars ($1/day in 2008, whereas previously there was no charge)

In addition, Fruitvale station increased its bike mode share from 4.3% to 9.9% from 1998-2008 and increased the bike shed traveled by commuters to/from the station. Built environment changes included:

- Increase in the mileage of bike paths, lanes, and routes surrounding the station
- Wayfinding guiding cyclists to the station entrance

- Provision of attended bike station, secure parking, repair services, and short-term rentals as well as bike racks and lockers.
- Added parking fees for cars

Relating these variables to the non-motorized connectivity analysis, we identified the following variables:

- Bicycle infrastructure (paths, lanes, and routes) within a three-mile buffer of stations/stops
- Bicycle parking at the station

The working paper may be found online at:
http://its.berkeley.edu/publications/UCB/2012/VWP/UCB-ITS-VWP-2012-5.pdf.

While the papers above help identify built environment and land use factors that link transit ridership with non-motorized access, each of the papers used different methodologies to explore relationships and the variables considered were not consistent. Because of this variability, it is not possible to determine the relative impact of each of the key variables identified above. For example, is a high intersection density more closely correlated to high walk/bike mode share than sidewalk coverage? To better understand these relationships, we evaluated several papers on factors that influence what modes people use to travel. The two most relevant papers are summarized below.

Source: NCHRP Project 08-78a Estimating Bicycling and Walking for Planning and Project Development: Practitioner Guidebook, *Renaissance Planning Group et. al., Transportation Research Board, August 2013*

This study provides guidance on how to estimate walking and bicycling trips for transportation planning applications. The study focuses on several factors that are important in predicting pedestrian and bicycle trips:

- Age, income, gender
- Trip purpose
- Land use and built environment

- Facilities and infrastructure
- Natural environment (climate, temperature variation, terrain)

Given the wide range of topics in this study, the project team focused on the land use/built environment and facilities/infrastructure sections, since those are most closely aligned with the non-motorized connectivity analysis. The results indicate that the following factors are most relevant for this study:

- Street/intersection density
- Direct routes to destinations
- Sidewalks on arterial streets
- Controlled arterial crossings
- Non-arterial bike routes

The NCHRP study also identified variables of lesser importance including presence of sidewalks on local roads, bike lanes on arterial roads, and pavement quality. Many of these variables were also highlighted in some of the earlier studies that are summarized above.

Source: INDEX 4D Method: A Quick Response Method of Estimating Travel Impacts from Land-Use Changes, *Criterion Planners and Fehr & Peers, US Environmental Protection Agency, October 2001*.

Most of the more recent studies have summarized the built environment related to non-motorized connectivity using very simple measures such as intersection density and street density. In reviewing these studies, intersection/street density is chosen because it correlates fairly well with walk/bike mode shares and, most importantly, it is easy to obtain and measure the data. While this study is older, it evaluated a more complete (yet more data-intensive) measure of non-motorized connectivity—the "design index." The design index is a combination of street network density, sidewalk completeness, and route directness. The authors performed regression analysis to determine which elements of the design index are most closely correlated with additional non-motorized travel. The results indicate that street network density has the strongest correlation, followed by route directness and sidewalk completeness.

While this study did not identify any additional pieces of data that would be helpful for this study, it did suggest a quantitative relationship between some key non-motorized connectivity variables. This research was helpful in setting up the initial regression models for this study, which are described later.

LITERATURE REVIEW SUMMARY FINDINGS

While many studies have addressed access to transit and walkability or bikeability in various forms, few have sought to directly link specific improvements to transit ridership changes. Of the available research, Cervero's 2012 working paper and Ryan's 2009 analysis for the Journal of Public Transportation may be the best resources for assessing how active transportation improvements could potentially affect ridership. Ryan's analysis may be more appropriate given its focus on bus transit rather than rail transit routes; however, it limits its focus to pedestrian access only and it does not account for bicycle infrastructure improvements.

Based on these findings, the project team identified the following variables that would be the focus of this study[1]:

- Intersection density
- Land use density (population and employment)
- Street/sidewalk density
- Route directness index
- Bicycle facility density/coverage
- Signalized arterial crossing density

The next chapter highlights the data collection process to obtain the information to calculate the connectivity variables above for the entire study area.

[1] Street lighting would have been ideal to include in the data set, but as described later in this document, the data were not available across the study area.