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RISK ASSESSMENT OF NON-MOTORIZED ACCESS TO RAIL TRANSIT STATIONS

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DISCLAIMER

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16. Abstract

Over the past decade, the agency has undertaken multiple efforts to better understand the various components that contribute to safety for vulnerable road users. One major destination type that attracts a large number of pedestrians and cyclists is transit stations. In fact, all transit riders are pedestrians at some point along their journey, making it even more important to promote safe access to and from transit stations. Using a combination of electronic and on-site data collection this study examines characteristics of the transportation and built environments of 39 intersections near 21 rail transit stations in Weber, Davis, Salt Lake, and Utah Counties against non-motorized crash data. Based on a typology from the UTA First/Last Mile Strategies Study, the data analysis determined that several factors differed significantly across station types. The analyses determined that the number of non-residential driveways and large building setbacks were correlated to a significant increase in non-motorized crashes and train-related near miss incidents. Multi-use path access, youth population percentage, and the percentage of people using transit for work trips were negatively correlated to non-motorized crashes. The results of this study show the importance of context sensitivity. All of the analyses identified key significant differences between the station types. Because of this spatial variation, there is not a one-size-fits-all approach to addressing safe access. The key differences identified in this study should be used as a blueprint for creating a customized non-motorized improvement plan for each site type.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CBD	Central Business District
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
MNL	Multinomial Logistic Regression
TOD	Transit-Oriented Development
UDOT	Utah Department of Transportation
UTA	Utah Transit Authority
VIF	Variance Inflation Factors

EXECUTIVE SUMMARY

Pedestrian and bicycle safety has become an important priority area for the Utah Department of Transportation (UDOT). Over the past decade, the agency has undertaken multiple efforts to better understand the various components that contribute to safety for vulnerable road users. One major destination type that attracts a large number of pedestrians and cyclists is transit stations. In fact, all transit riders are pedestrians at some point along their journey, making it even more important to promote safe access to and from transit stations. This research seeks to comprehensively analyze non-motorized safety in accessing fixed rail transit stations by identifying: 1) What are the characteristics of the road network surrounding each station, and which bicycle and pedestrian components are represented?; 2) Is there a correlation between station site characteristics and nearby non-motorized crash risk, including both crashes and near misses with the trains?; 3) How can non-motorized safety and comfort in accessing rail stations be improved?

Data was collected and analyzed for 39 intersections surrounding 21 rail stations in Weber, Davis, Salt Lake, and Utah Counties. The sample included both TRAX and FrontRunner Stations, with at least one station being included from each line. Data was collected using a combination of electronic data collection (air photo, GPS, U.S. Census, etc.) and multiple site visits. Data included transportation system characteristics, built-environment characteristics, demographics (within ¼ mile of the station), and transit station characteristics. Additionally, on-site counts were conducted of pedestrians and cyclists accessing each station, and an intercept survey was administered to a sample of 64 non-motorists to acquire travel behavior information and attitudes and perceptions associated with their transit use.

Using the station typology presented in the UTA First/Last Mile Strategies Study, each of the stations in the sample was coded based on station type. Statistical analyses identified that several factors differed across the different stations types. They include: speed limit, roadway widths, presence of raised center medians, presence of street trees, number of non-residential driveways, station orientation, presence of TOD, percentage of the population under age 18, commute trip frequencies by mode, and prevalence of bicycle and pedestrian crashes.

A number of complex regression models were also employed to identify correlations between transportation system, built-environment, station, and demographic characteristics and the number of bicycle and pedestrian crashes and near miss incidents with transit trains. The analyses determined that the number of non-residential driveways near an intersection was positively correlated to both bicycle and pedestrian crash rates as well as near-miss and crash incidents involving trains. Building setbacks were positively correlated to a significant increase in pedestrian crashes and train-related near-miss and crash incidents. Multi-use path access was negatively correlated to pedestrian crashes.

Several population characteristics were significantly correlated to the number of crashes. Youth population (under age 18) and the percentage of the surrounding population who walk or take transit to work were significantly correlated to the number of near-miss incidents. Areas with a larger youth population and a large number of people who walk to work were significantly more likely to exhibit higher numbers of near-miss incidents, while areas with large transit commuter populations had significantly fewer near misses.

The results of this study show the importance of context sensitivity. All of the analyses identified key significant differences between the station types. Because of this spatial variation, there is not a one-size-fits-all approach to addressing safe access. The key differences identified in this study should be used as a blueprint for creating a customized non-motorized improvement plan for each site type.

It is recommended that improvements along transit station access corridors be tailored to the station and user types described in this analysis. Several criteria apply across the board regardless of station type as they apply in general to walkability and promoting a human scale environment. These include an environment that is: attractive (e.g., trees are present, litter and graffiti are absent), barrier-free (e.g., free from debris and overgrown shrubbery), safe from perceived crime and excess traffic, diverse in land-use types, full of amenities (e.g., stores, restaurants, plazas, and water features) and pedestrian infrastructure (e.g., crosswalks, benches), and in which destinations are close by (Forsyth and Southworth, 2008). Emphasis should also be paid to providing a transition zone from major roadways where system users (pedestrians, cyclists, and motorists) sense a shift from an arterial environment to a multi-modal access point.

1.0 INTRODUCTION

1.1 Problem Statement

Pedestrian and bicycle safety has become an important priority area for the Utah Department of Transportation (UDOT). Over the past decade, the agency has undertaken multiple efforts to better understand the various components that contribute to safety for vulnerable road users. This has included analysis of: characteristics of the built environment that affect pedestrian and cyclist safety, circumstances surrounding pedestrian fatalities, pedestrian and cyclist crossing behaviors, and an examination of how motorized vehicles interact with bicyclists and pedestrians at intersection crossings. One major destination type that attracts a large number of pedestrians and cyclists is transit stations. In fact, all transit riders are pedestrians at some point along their journey, making it even more important to promote safe access to and from transit stations. Although UDOT is not directly responsible for conditions at fixed rail stations, they do perform oversight of rail crossing safety and maintain state roadways, some of which surround rail stations. It is important for roads around rail transit stations to promote safety, visibility, and ease of use for pedestrians and bicyclists.

1.2 Objectives

This research examined geometric design and built-environment characteristics surrounding rail transit stations along the Wasatch Front. It built upon prior UDOT bicycle and pedestrian intersection safety research, as well as the Utah Transit Authority (UTA) *First/Last Mile Strategies Study*, to comprehensively analyze non-motorized safety in accessing fixed-rail transit stations. The following research questions were addressed specifically:

- What are the characteristics of the road network surrounding each station and what bicycle and pedestrian components are represented?
- Is there a correlation between station site characteristics and nearby non-motorized crash risk, including both crashes and near misses with the trains?
- How can non-motorized safety and comfort in accessing rail stations be improved?

The recommendations from this work will help UDOT, UTA, and other agencies promote non-motorized safety and provide infrastructure that complements station amenities.

1.3 Scope

This study utilized data collected from 21 light rail and commuter rail stations in Weber, Davis, Salt Lake, and Utah Counties. Using a combination or aerial photos, GIS data collection, and on-site visits, additional built environment and transportation system data was collected for 36 intersections surrounding those stations. Non-motorized crash data was compiled for those same 36 intersections. Demographic data was also collected for residents living within ¼ mile of each station using current U.S. Census projections. A profile of each station was created by using both quantitative and qualitative observational methods. Finally, UTA crash and near miss incident data was collected near each station.

1.4 Outline of Report

The report is organized into six sections, as follows: Section 2 provides a brief literature review examining walkability, access to transit, and a summary of the current state of knowledge regarding pedestrian and bicycle safety near rail stations. Section 2 also includes a description of the study methods and justifications. Section 3 presents the study data collected and provides summary characteristics for the crash reports. Section 4 presents both qualitative and quantitative analysis of the observed non-motorized travel behavior. Section 5 provides conclusions based upon the data provided in the previous sections and Chapter 6 outlines the author's recommendations for implementation.

2.0 RESEARCH METHODS

2.1 Overview

A thorough literature review was performed on non-motorized travel behavior with a particular emphasis on behaviors that increase crash risk. This chapter provides background information on community walkability, personal safety, and non-motorized access to transit. It also includes a discussion of the research methods employed and the justification for each.

2.2 Background

Contemporary urban and transportation planning treats urban form, land use, and transportation facilities in a way that promotes active transportation modes such as walking, biking, and transit. Many studies have examined associations between the built environment and travel behavior (for a meta-analysis of this subject, see Ewing and Cervero, 2010). In particular, safe and comfortable access to transit stations encourages transit use and walking (Ewing and Cervero, 2010; Handy et al., 2005; Pikora et al., 2003). Walking and bicycling, in turn, are related to positive outcomes in the realm of personal health (Besser and Dannenberg, 2005; Brown, et al., 2005; Cooper et al., 2008; Ewing, et al., 2003; Frank, 2000; Handy, et al. 2002; Pate, et al., 1995; Saelens, et al., 2014; Sallis, Frank et al. 2004; Rojas-Rueda et al., 2011) and economic vitality (Whitehead et al., 2006; Burden et al., 2011). Some studies also show benefits and positive spillover effects for regional economies due to improving bikeability and walkability around transit stations (Park, S. et al., 2014).

Active transportation modes (walking and bicycling) have low mode shares in most U.S. cities, with the percentage of Americans walking to work decreasing over recent decades and the percentage of Americans bicycling to work modestly increasing (McKenzie, 2014). The Salt Lake Metropolitan Area exhibits higher walking and bicycling mode shares than many other regions nationwide. For example, 2014 data shows that for commuting purposes 5.9% of Salt Lake City residents walk, 2.8% bicycle, and 7.9% use public transportation (McKenzie, 2014; U.S. Census Bureau, 2015). UTA began service on its first light-rail line (TRAX) in 1999 with commuter rail service (FrontRunner) following in 2005. TRAX and FrontRunner have the potential to increase walking and bicycling rates near station areas.

2.2.1 Walkability

Forsyth and Southworth (2008) provide a useful and thorough definition of a walkable urban environment that is applicable to both walking to transit stations and walking in general. A walkable environment, they posit, is one that is attractive (e.g., trees are present, litter and graffiti are absent), barrier-free (e.g., free from debris and overgrown shrubbery), safe from perceived crime and traffic, diverse in land-use types, full of amenities (e.g., stores, restaurants, plazas, and water features) and pedestrian infrastructure (e.g., crosswalks and benches), and in which destinations are close by.

A 2010 Salt Lake City-based study found that people are more likely to use (and walk to) light rail if they live on a more walkable block, as measured by micro-level characteristics such as density, diversity of land uses, attractiveness, and perceived safety. In the same vein, they also found that a less walkable block on the path from home to station can be an obstacle to walking to transit (Werner, et al., 2010).

Even with a more walkable environment, people are limited in the distance they are willing to walk to a transit station The transit industry typically assumes a ¼ mile to ½ mile catchment area (Brown and Werner, 2008; Kim, et al., 2007). In Kim et al.'s 2007 study of St. Louis, the average "airline" distance, or distance measured as the crow flies, to walk to stations was 0.47 miles The actual walking distance was likely greater due to available walk paths. In a study based in Calgary, the average walking distance to suburban stations was greater than the average walking distance to urban stations (0.4 miles compared to 0.2 miles) (O'Sullivan and Morrall, 1996). Kim, et al. (2007) found a similar but more modest effect in St. Louis with walking distances of 0.49 and 0.40 miles to suburban and urban stations, respectively. Regardless of whether the station is urban or suburban, Kuby et al. (2004) noted that transit ridership increases when a station has more employment opportunities within a walkable distance.

2.2.2 Personal Safety

Safety – both real and perceived – is a significant factor for walking and bicycling to stations. A handful of studies have looked at the issue of safety with regard to public transit, but few of them focused on rail stations. We know from existing research that safety is a key factor in whether or not people, particularly women, choose to walk or bike to rail stations. It has long been recognized that women are more conscious of their environments after dark (Gordon, et al., 1980; Stanko, 1995; Yavuz and Welch, 2010). This sensitivity to light conditions and vulnerability to potential crime affects their use of public transit after dark as they are less likely to walk, or even drive, to stations when alternatives such as being dropped off and picked up exist (Kim, et al., 2007).

Safety from motorized vehicles is a concern in addition to safety from crime. Proper pedestrian and bicycle facilities increase both perceived and actual safety through a variety of ways, such as creating greater physical separation, imposing barriers between motorized traffic, and creating a more psychologically comfortable environment (Pucher, et al, 2010).

2.2.3 Accessing Transit

Access to a private vehicle and a driver's license combine to make it much less likely for a person to walk or bicycle to (and more likely to park at) a transit station. Additionally, suburban stations with park-and-ride facilities are less likely to attract pedestrians and riders connecting via bus and more likely to attract individuals who park or are picked up/dropped off (Kim, et al., 2007). This is probably related to both distance and land-use effects.

Bicycling can be combined with transit in a number of ways, including transporting a bicycle aboard transit, riding a bicycle to a station and parking it there, and using bike sharing along with transit. Due to the limited capacity of individual buses and light-rail cars to accommodate bicycles, bicyclists typically ride further to get to a rail station than they do after getting off the train (Krizek and Stonebraker, 2010). In at least one study, based in the Netherlands, bicycling was found to be the preferred mode to the departure station and walking was the preferred mode from the arrival station (Rietveld, 2010). In early 2017 UTA announced they will be making considerable investments to add additional rail cars on Frontrunner lines to accommodate bicycles in order to promote bicycle access to rail transit.

Bronz, et al. (2009) found that efforts to increase rail service are generally oriented toward benefitting the rail line instead of increasing accessibility. Within the Dutch context, once a certain level of transit service has been achieved, it was determined that improvements to access (such as decreasing distance and time to stations) were more important in increasing ridership than additional improvements in transit service. Although there are definite differences between the Dutch and American contexts, this is an important consideration for increasing active transportation in tandem with transit ridership on the Wasatch Front.

2.3 Study Methods

This research employed a number of statistical analysis methods, including summary statistics and multinomial regression models, to describe trends in the data as well as make predictions regarding correlation and causality between variables. Each method is described in detail below and was selected based on its appropriateness for use with study-specific data and the research questions and hypotheses.

2.3.1 Summary Statistics

Summary statistics are used to provide a quick and simple description of the data without any predictive component or significance testing. They include mean (average), median (center point of data), mode (most frequently occurring value), minimum value, maximum value, value range, standard deviation, and frequency percentages. Summary statistics were used in this analysis to provide context for the fatal crash data, describe crash report limitations, and summarize common characteristics in fatalities, pedestrian and bicyclist fault, and day/time analysis.

2.3.2 Pearson’s Chi-Square Test

A Chi-Square test is used on categorical data to compare an observed distribution to a theoretical one (measuring goodness of fit) for one or more categories. The events included must be mutually exclusive (e.g., weather cannot be clear and raining at the same time) and have a total probability of 1 (Greene, 2015).

Model:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where

χ^2 is the chi-square value
Σ is the summation sign
O is the observed frequency
E is the expected frequency

2.3.3 Analysis of Variance

Analysis of Variance (ANOVA) is a statistical technique that assesses whether or not the means of several groups are equal. A one-way ANOVA analyzes just one independent variable. The null hypothesis for an ANOVA is that there is no significant difference among the groups. The alternative hypothesis assumes that there is at least one significant difference among the groups. After cleaning the data, the researcher must test the assumptions of ANOVA, then calculate the *F*-ratio and the associated probability value (*p*-value).

The one-way analysis of variance model is:

$$\mathbf{Y} = \boldsymbol{\mu}_{\mathbf{i}} + \boldsymbol{\varepsilon}\text{, where}$$

- **Y** is the quantitative dependent variable, usually called the response variable in ANOVA
- $\boldsymbol{\mu}_{\mathbf{i}}$ is the true mean value of the dependent variable for the i^{th} population, where there are ***k*** populations.
- **ε** is the random error in the response not attributable to the independent variable. As in regression, the error is assumed to be normally distributed with constant variance.

2.3.4 Multinomial Logistic Regression

Multinomial logistic regression (MNL) is used to predict a nominal dependent variable given one or more independent variables. It is sometimes considered an extension of binomial logistic regression to allow for a dependent variable with more than two categories. As with other types of regression, multinomial logistic regression can have nominal and/or continuous independent variables and can have interactions between independent variables to predict the dependent variable (Greene, 2015). Dependent variables with M categories require the calculation of M-1 equations, one for each category relative to the reference category, to describe the relationship between the dependent and independent variables.

Model:

If the first category is the reference, then, for M=2,…,M,

$$\ln \frac{P(Yi = m)}{P(Yi = 1)} = \alpha_m + \sum_{k=1}^{K} \beta_{mk} X_{ik} = Z_{mi}$$

Hence, for each case, there will be M-1 predicted log odds, one for each category relative to the reference category. When there are more than 2 groups, for m=2,…,M,

$$P(Y_i = m) = \frac{exp(Z_{mi})}{1 + \sum_{h=2}^{M} exp(Z_{hi})}$$

For the reference category,

$$P(Y_i = 1) = \frac{1}{1 + \sum_{h=2}^{M} exp(Z_{hi})}$$

Assumptions:

- The dependent variable is measured at the nominal level
- There are one or more independent variables that are continuous, ordinal, or nominal (including dichotomous variables)
- Observations are independent and have mutually exclusive and exhaustive categories
- There is no multicollinearity
- There is a linear relationship between any continuous independent variable and the logit transformation of the dependent variable
- There are no outliers, high leverage values, or highly influential points

When interpreting an MNL model, one of the response categories is used as a baseline or reference cell. Log-odds are then calculated for all other categories relative to this baseline, and then the log-odds become a linear function of the predictors.

MNLs were used to identify any significant relationships between conflict levels at crossings (among pedestrians/bicyclists and motorized vehicles) and both individual travel behavior and built environment characteristics.

2.4 Summary

A great deal of research has examined relationships between walkability, bikeability, walking and biking to transit stations, and transit ridership. The association between the built environment and travel behavior has long been established as well as the fact that close proximity to transit stations increases walking. Three major research existing veins directly apply to this study: walkability, personal safety, and accessing transit. A majority of walkability research has identified that an area's attractiveness directly correlates to the amount of walking people do and the safety of the environment. Attractiveness can include the presence of street trees, freedom from barriers, diversity of land-uses, and the presence of adequate pedestrian infrastructure. The research has also identified that individuals are willing to walk anywhere from ¼ to ½ mile to a transit station if the environment is attractive and supports walking. Several factors have been shown to support personal safety for individuals walking or biking to transit. They include lighting, separation from traffic, and an environment that promotes psychological comfort. That is, an environment that promotes the perception of safety for non-motorists. Lastly, studies have shown that stations with more parking experience fewer people walking and biking to the station.

This research employed a number of statistical analysis methods to describe trends in the data as well as make predictions regarding correlation and causality between variables. Each method was selected based on its appropriateness for study-specific data and the research questions and hypotheses.

3.0 DATA COLLECTION

3.1 Overview

This chapter discusses the data collected for the research and presents an overview of descriptive characteristics for each of the analysis sites. The overview includes intersections selected for analysis, a summary of their characteristics, a description of demographics surrounding these locations, and a general discussion of transit station access.

3.2 Site Identification

Based upon spatial distribution, ridership, traffic, concentration of non-motorized access, and contextual feedback provided by the project's technical advisory committee (TAC), 21 rail stations were selected for inclusion in the study's sample. Table 1 shows each station along with its location (county) and transit lines serviced.

Table 1. Sample Rail Stations

Station	County	UTA Line Access
Millcreek	Salt Lake	Blue, Red
Meadowbrook	Salt Lake	Blue, Red
Murray Central	Salt Lake	Blue, Red, FrontRunner
Ballpark	Salt Lake	Green, Blue, Red
University South Campus	Salt Lake	Red
Library	Salt Lake	Red
City Center	Salt Lake	Green, Blue
Redwood Junction	Salt Lake	Green
1940 W. North Temple	Salt Lake	Green
North Temple Bridge	Salt Lake	Green, FrontRunner
Bingham Junction	Salt Lake	Red
4800 W. Old Bingham Highway	Salt Lake	Red
Daybreak Parkway	Salt Lake	Red
Sandy Civic Center	Salt Lake	Blue
Ogden	Weber	FrontRunner
Clearfield	Davis	FrontRunner
Layton	Davis	FrontRunner
Woods Cross	Davis	FrontRunner
Lehi	Utah	FrontRunner
Orem Central	Utah	FrontRunner
Provo Central	Utah	FrontRunner

This research evaluated non-motorized access conditions surrounding 13 stations in Salt Lake County, one in Weber County, three in Davis County, and three in Utah County. Figure 1 shows the UTA rail system map with black stars designating study stations. Effort was made to ensure that a representative geographic cross section was included in the sample, and that all service lines and rail types were represented. The Sugarhouse Streetcar line was omitted due to the limited number of stations and the lack of additional streetcar lines for comparison.

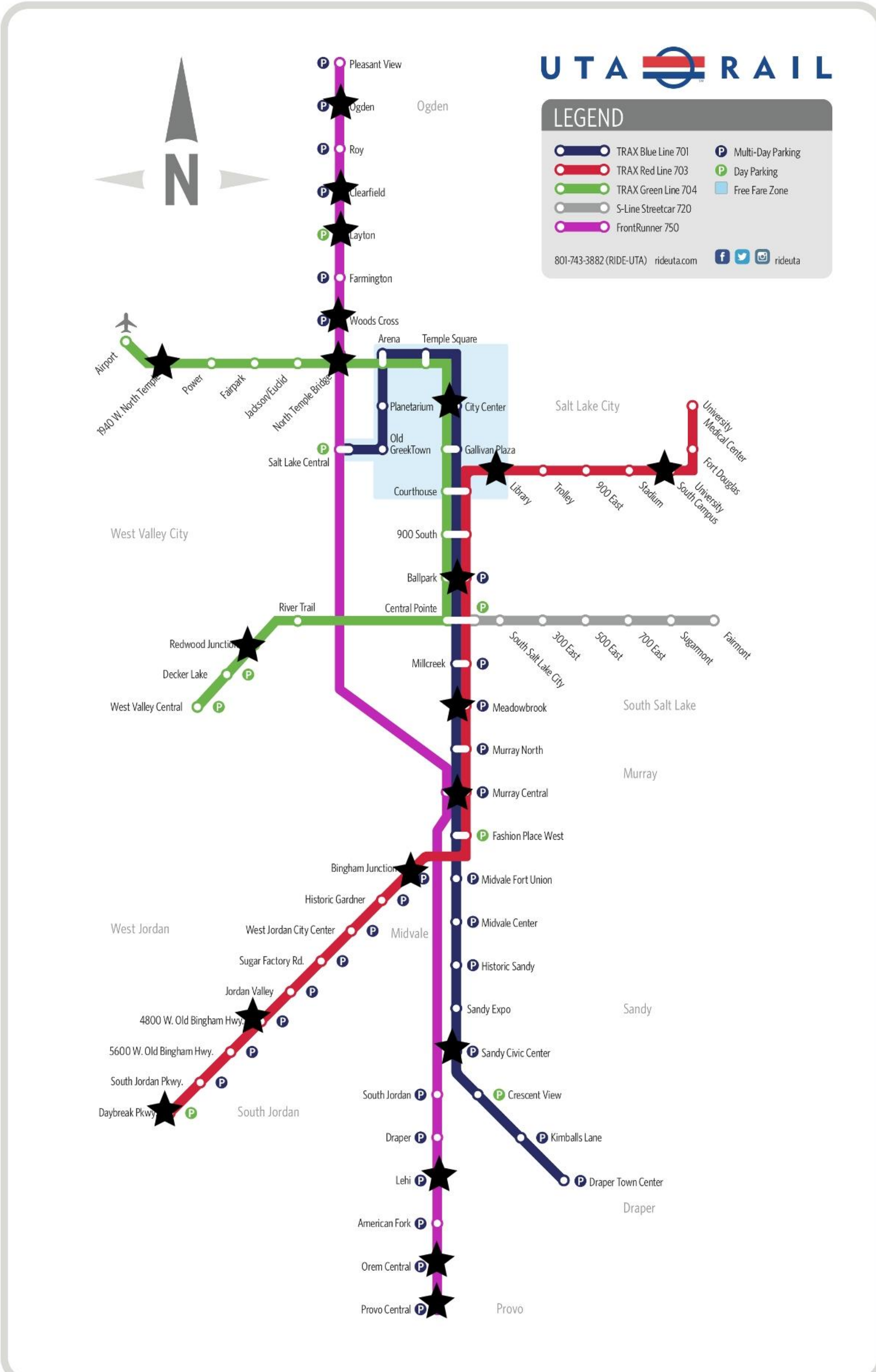

Figure 1. Sample Rail Station Locations

3.2.1 System and Environment Data Collection

Because UDOT does not have jurisdiction over the transit stations themselves, this study focused on the surrounding roadways that provide non-motorized access to each station. Table 2 displays a comprehensive list of characteristics for each study site based on existing bicycle and pedestrian safety literature and prior UDOT research (Burbidge, 2012, 2014, 2015). A data dictionary is included in Appendix A to provide more detailed descriptions of each of these characteristics and how they were measured

Table 2. Intersection Inventory Characteristics

Transportation System Characteristics	**Built Environment Characteristics**	**Demographic Data**
# of Roadway Legs (max of 4)	# Sidewalks	Median income (within ¼ mile)
Speed Limit	Sidewalk Widths	% Population <18 (within ¼ mile)
Number of Lanes	Pedestrian Approaches (#)	% Population >65 (within ¼ mile)
Roadway Width	Land-Use (Res, comm, mixed)	% Population who bike to work
Bike Lanes	Street Trees	% Population who walk to work
Control (signal, stop sign, etc.)	Building Setback (feet from curb)	% Population who take transit to work
Signal Timing	Bus stops (within ¼ mile)	
Dedicated Left Turn Lane	Non-Residential Driveways (within ¼ mile)	**Transit Station Characteristics**
Dedicated Right Turn	Multi-Use Paths (within ¼ mile)	Vehicle Parking (# spaces)
Raised Center Median	Freeway On/Off Ramps (within ¼ mile)	Bicycle Parking yes/no)
# of Through Lanes	Environment Classification*	Station Orientation (toward street, parking lot, etc.)
Crosswalks		
Pedestrian Signals		
Pedestrian Signal Timing		

**Based upon the classification given in the UTA First and Last Mile Study*

The original intent was to collect data from two intersections near each transit station. However, that was not always possible at every location because some stations are located in areas with only a single major access point. This presents unique implications for accessibility, a complete discussion of which is included in Chapter 4. In all, data was collected for the 36 intersections shown in Table 3.

Table 3. Proximal Study Intersections

Transit Station	Intersection Coordinates
Millcreek	3300 S./300 W.
	3300 S./West Temple
Meadowbrook	3900 S./Howick Street
	3900 S./West Temple
Murray Central	Cottonwood St./Woodrow St.
	Cottonwood St./5100 S.
Ballpark	1300 S./300 W.
	1300 S./West Temple
University South Campus	South Campus Dr./1800 E.
	South Campus Dr./1725 E.
Library	400 S./300 E.
	400 S./200 E.
City Center	South Temple/Main St.
	100 S./Main St.
Redwood Junction	Decker Lake Blvd./Decker Lake Dr.
	Research Way/Redwood Rd.
1940 W. North Temple	North Temple/1950 W.
	North Temple/Redwood Rd.
North Temple Bridge	North Temple/400 W.
	North Temple/600 W.
Bingham Junction	Coliseum Way/Bingham Junction Rd.
	Tuscany View Rd./Bingham Jct. Blvd.
4800 W. Old Bingham Highway	Old Bingham Highway/4800 W.
Daybreak Parkway	Duckhorn Dr./Grandville Ave.
Sandy Civic Center	Beetdigger Blvd./Sego Lily Dr.
Ogden	23rd St./Wall Ave.
Clearfield	Main St./1000 E.
Layton	Layton Pkwy./Main St.
	Gentile St./Main St.
Woods Cross	770 S./800 W.
	1000 S./800 W.
Lehi	Executive Pkwy./Ashton Blvd.
Orem Central	800 S./Geneva Rd.
	1000 S./Geneva Rd.
Provo Central	600 S./Freedom Blvd.
	750 S./Freedom Blvd.

The following sub-sections summarize the data collected through the intersection inventories and present qualitative and quantitative analyses comparing relative intersection risk. All inventory data presented in the tables was acquired through the comprehensive site inventories and measurements unless otherwise cited.

3.3 Electronic Data Collection

Data was collected using a combination of field visits and aerial photograph analyses. Transportation system characteristics were measured using multiple methods. First, analysts measured each component using a combination of Google Earth and ArcGIS Pro with Google Licensed Imagery (GLI). GLI provides statewide aerial photography with a resolution of six inches or better with a horizontal positional accuracy to achieve or exceed one meter (C90) in most areas without significant vertical relief (Utah AGRC, 2017). The Google License provides color aerial photography, typically collected within 3 years, from the spring, summer, or fall. This level of resolution helps to ensure precision in data collection and analysis.

Signal data was collected on site, and signal timing for traffic lights and pedestrian countdown timers was acquired from the Signals Engineer in each applicable UDOT Region office. Preliminary built environment and station characteristic data were collected using the aerial photos described above. However, all preliminary data was confirmed through site visits (described in Section 3.4 below). Each intersection was visited in person at least twice to conduct precision confirmation measurements and to collect additional data. This ensured that any changes to the built environment of station areas were incorporated into the dataset and subsequent analysis.

3.3.1 Intersection Characteristics

Tables 4 and 5 outline the roadway, signal, and crossing characteristics including the mean and range (minimum and maximums) for comparison.

Table 4. Summary of Basic Roadway Characteristics

Characteristic	Mean	Minimum	Maximum
Speed Limit (mph)	32.2	20	45
Number of Lanes	4.44	2	7
Roadway Width (feet)	70.38	28	119
Bike Lanes	-	No=50%	Yes=50%
Non-Residential Driveways (within ¼ mile)	21.06	0	60
Multi-Use Paths (within ¼ mile)		No=72%	Yes=28%

A majority of the rail stations included in the study are located on arterials with higher speed limits. However, there are a small number located in primarily residential areas on lower speed roads. One station (City Center) is located in the heart of the Central Business District (CBD) with limited automobile traffic access and a speed limit of 20. The central city locations typically have smaller widths and right-of-way while the more suburban stations have wider right-of-way and roadway widths. The roadways with higher speed limits are also typically wider. The sample was split with regard to bicycle access. Half of the stations had bicycle lanes on adjacent roads while half did not. A large majority of the transit stations in the study (72%) have access to multi-use paths within a ¼ mile of the station, which can contribute to safe access for active transportation users.

As prior research has shown, non-residential access near intersections can increase the risk of non-motorized travelers being involved in a crash (Burbidge, 2012, 2014, 2015). Only 10 of the 36 intersections examined had fewer than 10 non-residential access points within a ¼ mile (28%), while 10 intersections had more than 30 access points within ¼ mile (28%).

Table 5. Intersection Signal and Crossing Characteristics

Characteristic	Mean	Minimum	Maximum
Signal Timing (n=29)	42.79	8	112
Dedicated Left Turn Lane	-	No=11%	Yes=89%
Dedicated Right Turn	-	No=33%	Yes=66%
Raised Center Median	-	No=53%	Yes=47%
# of Through Lanes	3.21	2	6
Crosswalk	3.31	0	4
Pedestrian signals	-	No=25%	Yes=75%
Pedestrian Signal Timing (Sec)	20.85	13	28
N=36			

As shown in Table 5, 26 of the intersections included in this evaluation were signalized. The remaining 10 were controlled by one or more stop signs. A majority of locations had dedicated left and right turn lanes, and nearly half provided raised center medians either right at the intersection or on the roadway leading up to it. Road width and number of lanes varied widely. The sites ranged from roads with one through lane in each direction to having three through lanes in each direction. A large majority of locations had crosswalks on every leg of the intersection but seven (17%) did not.

Three out of four sites provided pedestrian signals and countdown timers, and the average amount of time given for pedestrians to cross was 20.85 seconds. When standardizing the countdown timer by the width of the roadway, or the distance required for a pedestrian to cross, the average required walking speed for roadway clearance was 3.59 feet per second (2.45 mph). Prior research has shown that the average adult can cover 4.11 feet per second (2.8 mph), with older adults walking slightly slower (3.89 feet per second - 2.65 mph) than younger adults (Knoblauch, Pietrucha, and Nitzburg 1996). Of the intersections included in the analysis, seven would require a pedestrian to walk faster than average (4.11 feet/second) to cross in the provided signal time. This poses a critical risk to the safety of pedestrians accessing or leaving the station.

Built environment characteristics varied across the sample. As shown in Table 6, only about half of the sites evaluated had street trees along the corridor. Street trees have been correlated to a reduced incidence of pedestrian crashes (Burbidge, 2012). The average sidewalk width in the sample is 7.85 feet, which is nearly double the standard 4-foot sidewalk required by most municipal code in Utah. The narrowest sidewalks were found near the Woods Cross and Meadowbrook stations, while the widest were located in the CBD near the City Center station. Building setbacks near the stations were substantial with an average setback of 85 feet. Buildings near the City Center station had no setback from the sidewalk, while the roadways feeding Murray Central Station are located near large parking lots and far from any buildings (872 and 304 feet). When those two sites are removed from the analysis the average setback drops to 57.37 feet (min= 25 feet, max=136 feet).

Table 6. Built Environment Characteristics

Characteristic	Mean	Minimum	Maximum
Street Trees	-	No=45%	Yes=55%
Sidewalk Width (feet)	7.85	4	21
Building Setbacks (feet)	85.21	0	305
Land-Use	19.4% Residential 50% Commercial 22% Mixed-Use 2.8% Industrial 5.5% Institutional		
N=36			

3.3.2 Crash and Near Miss Data

For each of the intersections evaluated in this study, non-motorized crash data was identified using UDOT's SafeMap tool – a comprehensive data analytics system that stores and allows queries of statewide crash data. All crashes occurring within 100 yards of one of the 36 study intersections between January 1, 2010 and December 31, 2016 involving a bicycle or pedestrian was flagged and tallied. An additional dataset provided by the UTA Safety Division included all crashes and near misses that occurred between transit trains and pedestrians or cyclists within ¼ mile of each station. This data was collected between January 1st and November 30th, 2017. The UDOT and UTA data described above is displayed in Table 7.

Table 7. Non-Motorized Crashes

Transit Station	Intersection Coordinates	Bicycle Crashes*	Pedestrian Crashes*	Transit Vehicle**
Millcreek	3300 S./300 W.	4	6	9
	3300 S./West Temple	5	8	
Meadowbrook	3900 S./Howick Street	6	3	8
	3900 S./West Temple	1	1	
Murray Central	Cottonwood St./Woodrow St.	1	7	27
	Cottonwood St./5100 S.	1	4	
Ballpark	1300 S./300 W.	2	3	20
	1300 S./West Temple	4	4	
University South Campus	South Campus Dr./1800 E.	2	1	1
	South Campus Dr./1725 E.	0	0	
Library	400 S./300 E.	4	5	2
	400 S./200 E.	1	5	
City Center	South Temple/Main St.	2	1	8
	100 S./Main St.	0	0	
Redwood Junction	Decker Lake Blvd./Decker Lake Dr.	1	0	2
	Research Way/Redwood Rd.	4	1	
1940 W. North Temple	North Temple/1950 W.	0	3	11
	North Temple/Redwood Rd.	6	1	
North Temple Bridge	North Temple/400 W.	1	6	1
	North Temple/600 W.	4	1	
Bingham Junction	Coliseum Way/Bingham Junction Rd.	0	1	7
	Tuscany View Rd./Bingham Jct. Blvd.	0	3	
4800 W. Old Bingham Hwy.	Old Bingham Highway/4800 W.	0	0	0
Daybreak Parkway	Duckhorn Dr./Grandville Ave.	0	0	1
Sandy Civic Center	Beetdigger Blvd./Sego Lily Dr.	0	0	3
Ogden	23rd St./Wall Ave.	4	4	4
Clearfield	Main St./1000 E.	2	2	17
Layton	Layton Pkwy./Main St.	0	0	3
	Gentile St./Main St.	3	1	
Woods Cross	770 S./800 W.	0	0	0
	1000 S./800 W.	0	0	
Lehi	Executive Pkwy./Ashton Blvd.	0	0	5 (1)
Orem Central	800 S./Geneva Rd.	1	0	6
	1000 S./Geneva Rd.	0	0	
Provo Central	600 S./Freedom Blvd.	1	0	7
	750 S./Freedom Blvd.	0	0	
		n=60	n=71	n=143

*Non-motorized crash data is protected under 23 USC 409. Source: UDOT, 2010-2016
**Transit vehicle near miss and crash data provided by UTA Safety Division; Jan-Nov 2017 (fatalities shown in parentheses)

Within the sample as a whole, there were 131 non-motorized crashes recorded over the 7-year window. Approximately 46% of these crashes (60) involved one or more cyclists while the remaining 54% involved at least one pedestrian (71). During 2017 (Jan-Nov) there were 143 near miss and crash incidents between UTA trains and non-motorists at the study stations, including one fatality at the Lehi Station when a FrontRunner train struck a pedestrian.

3.3.3 Station Characteristics

This research required examination of the layout and characteristics of the stations themselves. Table 8 summarizes these characteristics. The first characteristic measured was whether the station provided on-site car parking, and if so, the number provided. Approximately two-thirds of the stations provided on-site parking facilities, with an average number of 443 spaces. The smallest parking lot (Layton) contained space for 64 vehicles, while the largest (Murray Central Station) provided 1,099. Bicycle parking was available at 66% of the stations. However, due to the nature of bicycle parking, it was not possible to accurately estimate how many bicycles could be accommodated at each site. Approximately 62% of stations faced toward a parking lot. Slightly fewer than half of stations were located in areas striving to create Transit Oriented Development (TOD) patterns.

Table 8. Station Characteristics

Characteristic	Mean	Minimum	Maximum
On-Site Parking	-	No=33%	Yes=67%
Car Parking (# spaces)*	443	64	1,099
Bicycle Parking	-	No=33%	Yes=67%
Station Orientation	38% Sidewalk 62% Parking Lot		
Transit Oriented Development	47%		
UTA Classification**	11% Urban 28% Multi-Modal 11% Institutional 19% Suburban Non-Residential 14% Suburban 17% Auto-Dependent		
N=36			

**Average based only on stations with car parking*
***Typology from the UTA First/Last Mile Strategies Study (UTA, 2015)*

Each station was also classified based on its typology in the UTA First/Last Mile Strategies Study. The study was conducted in an effort to “identify a short list of strategies that would be most effective at increasing transit ridership" (UTA, 2015). Through that effort, all UTA rail stations were classified into one of the six general typologies shown in Table 9. This table demonstrates that the study provides a good cross-section of typologies for further examination. While the goal of this study is not to evaluate or affect transit ridership, these typologies are useful for examining built-environment characteristics relative to safe non-motorized access in different urban/suburban environments.

Table 9. UTA Station Typologies

UTA Typology	Sample Stations
Urban	City Center Library
Multi-Modal	1940 W. North Temple North Temple Bridge Redwood Junction Ballpark Millcreek
Institutional	University South Campus Orem Central
Suburban	Bingham Junction 4800 W. Old Bingham Hwy Provo Central
Suburban Non-Residential	Ogden Meadowbrook Murray Central Sandy Civic Center Lehi
Auto-Dependent	Clearfield Layton Woods Cross Daybreak Parkway

3.3.4 Local Demographics

Demographics have been shown to strongly correlate to both transit ridership and non-motorized transportation. "The two principal markets that remain for public transit systems are downtown commuters and transit dependents – people who are too young, too old, too poor, or physically unable to drive" (Garrett and Taylor, 1999). With this in mind, the key demographics shown in Table 10 were measured within ¼ mile of each transit station.

The mean income for households within ¼ mile of the study transit stations was $44,927, which is approximately 74% of the median income ($60,727) and double the poverty level ($22,350) of the state of Utah as a whole (U.S. Census, 2010). Three stations had populations with an average income within 10% of the poverty level –University South Campus station, which is surrounded by a large amount of student housing, and the Ogden and Library Stations, which are both located in areas with limited and aging housing supplies of mostly smaller rental units. The stations with the highest mean household income were Daybreak Parkway ($90,551) and 4800 West Old Bingham Highway ($82,772), which are both located in areas with a great deal of new larger single-family home construction.

Table 10. Station Area Demographics

Station	Median HH Income	% Pop Age <18	% Pop Age >65	% Walk to Work	% Bike to Work	% Transit to Work
Utah State Average	**$60,727**	**31.5**	**9.0**	**2.5**	**0.9**	**2.5**
Millcreek	$33,487	26.1	3.5	1.4	0.0	9.9
Meadowbrook	$33,487	26.1	3.5	1.4	0.0	9.9
Murray Central	$54,035	22.9	6.8	7.8	1.1	3.7
Ballpark	$39,579	37.8	5.1	0.7	2.6	4.0
University South Campus	$24,643	16.4	3.8	23.6	0.3	23.9
Library	$21,129	17.0	17.2	10.5	8.3	10.5
City Center	$40,357	5.4	20.3	21.2	3.6	16.9
Redwood Junction	$40,686	34.4	7.2	3.2	0.4	4.3
1940 W. North Temple	$35,410	30.9	19.1	2.0	0.3	6.9
North Temple Bridge	$42,426	20.2	8.1	4.1	2.0	12.8
Bingham Junction	$46,013	24.2	21.5	1.6	0.3	6.1
4800 W. Old Bingham Highway	$82,772	29.7	6.0	1.3	0.1	4.4
Daybreak Parkway	$90,551	32.1	3.4	1.7	0.5	6.4
Sandy Civic Center	$70,378	20.3	10.2	2.1	1.5	2.5
Ogden	$24,240	13.4	7.6	6.7	1.3	6.3
Clearfield	$38,582	34.2	11.7	4.9	0.9	3.0
Layton	$50,798	37.4	10.0	1.5	0.0	4.5
Woods Cross	$71,683	32.7	6.7	4.6	1.8	2.0
Lehi	$74,779	54.5	0.2	0.4	1.1	5.1
Orem Central	$67,686	13.2	2.5	9.0	1.6	4.2
Provo Central	$31,318	23.6	5.8	4.2	4.8	1.7
***Mean*=**	**$44,927**	**24.01**	**8.0**	**6.18**	**1.56**	**7.44**

Source: U.S. Census

According to the U.S. Census (2010), 31.5% of Utah's population is under age 18 and 9% is over age 65. The station areas with the highest percentage of minors are Lehi, Ballpark, Layton, Redwood Junction, Clearfield, Woods Cross, Daybreak Parkway, and 1940 West North Temple. The neighborhoods surrounding these stations generally have either a high number of small rental homes and apartments or newer single-family homes. Stations near a higher concentration of seniors include Bingham Junction, City Center, 1940 West North Temple, and

Library. These areas again are located near a higher volume of rental units and older homes, which may appeal to seniors if they choose to downsize or age in place.

Active transportation commute patterns were clustered in certain areas. The station areas with the highest percentage of individuals walking to work included South Campus Station, City Center, and Library. This is likely due to the large number of students living and working near campus, individuals who self-select to live close to work in the CBD, and those who live in small rental units without access to cars. Other areas with a high percentage of walk commuting included Orem Central, Murray Central, and Ogden.

Percentages of individuals cycling to work were relatively low across the sample. However, Library, Provo Central, and City Center did have significantly higher rates of cycle commuters living within 1/4 mile.

UTA and other local planning organizations are promoting TOD, which encourages focused development around rail stations to enable people to use transit as their primary mode of transportation (Liu, Porter, and Zlatkovic, 2017). Statewide only 2.5% of workers commute by transit. Within this sample, populations living within ¼ mile of stations met or exceeded the state average for transit commute trips with the exception of Woods Cross and Provo Central. Both of these stations are located in isolated areas without easy access or proximal development (this is discussed in detail in the analysis section). Four areas with greater than 10% transit mode share (four times the state average) were identified: University South Campus, City Center, North Temple Bridge, and Library. It should be noted that two of these stations (University South Campus and Library) were also recognized as having populations with relatively low household incomes. These residents may be reliant on transit as their exclusive mode of transportation and may have chosen to live near transit based on a lack of other transportation options.

3.4 On-Site and Rider Data Collection

Each study station area was visited at least two separate times. The first visit was intended to confirm built environment and transportation system data previously collected electronically. The second site visit was used to evaluate user experience and monitor non-motorized access to stations.

3.4.1 Site Visits and Field Work

On-site distance measurements were taken for sidewalks and roadway widths using a Rolatape measuring wheel. Building setbacks were also confirmed using both the Rolatape and a handheld laser measuring tool. A visual scan was used to confirm on-site parking and to evaluate station orientation. Land use was also validated along with transportation system characteristics such as left and right turn lanes.

The second site visit was conducted to evaluate non-motorized access to each station from the perspective of a non-motorized traveler, to count non-motorists accessing the stations, and to administer travel behavior intercept surveys to pedestrian and bicyclists. Table 11 shows the dates and times for the secondary site visits.

Table 11. On-Site Data Collection Schedule

Transit Station	Count Date	Time*
Millcreek	June 30, 2017	1630-1830
Meadowbrook	July 13, 2017	1630-1830
Murray Central	July 14, 2017	1630-1830
Ballpark	July 13, 2017	1630-1830
University South Campus	July 12, 2017	1700-1900
Library	June 23, 2017	1700-1900
City Center	June 22, 2017	1445-1645
Redwood Junction	June 23, 2017	1445-1645
1940 W. North Temple	June 22, 2017	1700-1900
North Temple Bridge	July 17, 2017	1630-1830
Bingham Junction	June 28, 2017	1630-1830
4800 W Old Bingham Highway	June 29, 2017	1630-1830
Daybreak Parkway	July 6, 2017	1630-1830
Sandy Civic Center	July 11, 2017	1630-1830
Ogden	July 18, 2017	1630-1830
Clearfield	July 19, 2017	1630-1830
Layton	July 20, 2017	1630-1830
Woods Cross	July 18, 2017	1630-1830
Lehi	June 21, 2017	1445-1645
Orem Central	June 20, 2017	1445-1645
Provo Central	June 20, 2017	1700-1900

**All times are shown on a 24-hour scale*

Non-motorist access counts were conducted in two-hour increments at each station. Project staff attempted to document all pedestrians and bicyclists accessing the station. Extra care was taken to differentiate between those who arrived by car and walked from the parking lot and those who actually walked to the station from another origin. Despite this care, some non-motorists may have gone uncounted, while some individuals who arrived by car may have inadvertently been included in the count.

Table 12 shows the raw counts for each station during the data collection windows. The sample is broken down by gender and mode. “Other” modes included rollerblades and skateboards. All data collection took place in June and July on sunny or partly cloudy days.

Table 12. Non-Motorized User Counts

Transit Station	Bike Female	Bike Male	Pedestrian Female	Pedestrian Male	Other	Total
Millcreek	6	44	138	222	3	**413**
Meadowbrook	3	29	144	224	2	**402**
Murray Central	6	40	299	477	12	**834**
Ballpark	5	19	48	80	0	**152**
University South Campus	4	9	43	100	0	**156**
Library	3	2	91	124	1	**221**
City Center	4	18	202	293	0	**517**
Redwood Junction	0	2	17	43	0	**62**
1940 W. North Temple	1	2	54	83	0	**140**
North Temple Bridge	8	34	303	760	3	**1,108**
Bingham Junction	1	14	85	148	2	**250**
4800 W Old Bingham Highway	0	15	71	136	1	**223**
Daybreak Parkway	2	13	70	122	2	**209**
Sandy Civic Center	1	4	12	19	1	**37**
Ogden	3	15	95	183	2	**298**
Clearfield	2	6	52	103	0	**163**
Layton	2	22	76	148	5	**253**
Woods Cross	1	8	18	30	2	**59**
Lehi	1	1	8	17	0	**27**
Orem Central	3	4	27	46	0	**80**
Provo Central	3	13	119	166	0	**301**
Totals	**59**	**314**	**1,972**	**3,524**	**36**	**5,905**

The stations with the highest numbers of non-motorists were North Temple Bridge, Murray Central, and City Center. The lowest non-motorist traffic volumes were reported at Lehi, Sandy Civic Center, and Woods Cross. There were five times more male cyclists than female, and nearly twice as many male pedestrians. Only 19% of cyclists were wearing a helmet at the time of observation, and 80% of helmet wearers were male. It should be noted that the Murray Central Station is surrounded by an extremely large amount of parking. The parking lot extends across 10+acres around the Intermountain Medical Center. There is a very high likelihood that many of the pedestrians counted within this study actually parked somewhere in this parking lot and walked to the station rather than walking from a primary destination. Section 5.3 describes this limitation in greater detail.

During the second site visit, a researcher approached non-motorized travelers and invited them to participate in a brief user survey while they waited for their train. The survey first asked travelers to identify the station location, date, time, and their access mode (bicycle, pedestrian or other). Participants were then asked the following:

- Home zip code

- Purpose of transit trip
    - Work Commute
    - School
    - Recreation
    - Shopping
    - Personal Business/Other

- How frequently they have walked to the train station in the past month
    - First time
    - 0-5 times
    - 6-10 times
    - 11-20 times
    - Daily

- During which seasons they walk to the station
    - All year
    - Summer
    - Fall
    - Winter
    - Spring

- How far they walked/biked to get to the station (distance or time)

- How far they will walk/bike once they exit the train (distance or time)

- What improvements they would like to see around the station to make it easier to walk or bike
    - Wider Sidewalks
    - Better surfaces
    - Better street crossings
    - More shade trees
    - Benches
    - Access to shops, etc.
    - More bike lanes

- Separate bike paths
- More sidewalks

- Other comments

A total of 64 completed intercept surveys were collected and Table 13 provides summary statistics for them. Approximately 60% of people were using transit for a work trip and about 16% each were traveling for school or recreation purposes. A majority of respondents accessed transit by foot or bicycle more than six times per month (63.5%), and more than half reported walking or biking to transit year-round (59%).

Table 13. Intercept Survey Summary Results

	Response (%)
Trip Purpose	
Work Commute	60.3
School	15.9
Recreation	15.9
Shopping	4.8
Personal Business/Other	3.2
Active trip to access transit per month	
First Time	11.1
0-5-times	25.4
6-10 times	17.5
11-20 times	31.7
Daily	14.3
Seasons in which respondents walk	
Summer	95.1
Fall	77.0
Winter	59.0
Spring	78.6
Access Distance (miles)	
Min	0.00
Max	37.17
Mean	1.60
Egress Distance (miles)	
Min	0.00
Max	25.00
Mean	1.67
Desired improvements around station	
Wider sidewalks	14.3
Better surfaces	15.9
Better street crossings	33.3
More shade trees	71.4
Benches	23.8
Access to shops, etc.	6.3
More bike lanes	12.7
Separate bike paths	17.5
More sidewalks	6.3
	n= 64

The majority of respondents stated that they would like more shade trees (71.4%), followed by better street crossings (33.3%) and benches for resting (23.8%). Only 6.3% mentioned a need for more sidewalks, which suggests that sidewalks are adequate surrounding the stations. However, 30.2% responded that bike lanes or separate bike paths would make it easier for them to access the station by bicycle.

3.5 Data Quality

All intersection signal data (traffic signals and pedestrian countdowns) was acquired from UDOT traffic operations engineers in the applicable region offices. Signal times were provided for peak hours to best represent the busiest time of day for a given location and the amount of time pedestrians, bicyclists, and drivers would have at those times to navigate and clear the intersections.

Collecting non-motorized user counts was difficult for a number of reasons. First, the researchers on site could not definitively see every person who approached the station from every direction. This created several inherent data internal validity issues. The most obvious is the potential for under-counting or “missing” people who walked or biked to the station. The counterpart would be the possibility of over-counting. This would include counting persons who may have driven to the parking lot or a location near the station but were then seen walking to the station and were counted as a pedestrian. Pedestrians were much more likely to be over counted than cyclists because a cyclist is less likely to drive to the station and then take their bike on board (although this does occasionally happen). Over-counting of pedestrians is most likely to occur at stations with large parking lots where many people must still walk relatively long distances after parking.

Another data quality issue relates to intercept survey validity. Participants were selected at random but many refused to participate. This led to some self-selection bias. Additionally, the sample size at each location was so small that the survey could not yield significant results and should not be viewed as representative of all non-motorists who ride transit. That being said, the results do provide some qualitative insight into rail station access, potential barriers, and suggestions for improving the overall rail transit experience for pedestrians and cyclists.

3.6 Summary

A sample of 21 rail transit stations was selected by the researchers and TAC based on geographic dispersion and representation of each UTA transit line. Using a combination of aerial photos, GIS analysis, and site visits, characteristics of the transportation system and built environment surrounding each station were compiled.

Stations were located on both major arterials and residential streets. More than 70% of rail stations in the sample were within ¼ mile of a multi-use path. Intersections near the sample stations had a very large number of non-residential access points within ¼ mile, which may lead to safety issues for non-motorized travelers. A majority of the intersections studied were signalized and 10 were controlled only by a stop sign.

All of the signalized intersections are equipped with a pedestrian countdown signal, and an evaluation of the allotted time standardized by roadway width determined that a majority of locations allow enough time for someone walking at an average pace (4.11 feet per second) to cross. At seven locations pedestrians would be required to walk faster than average to clear the intersection, and those crossing Wall Avenue at 23rd Street near Ogden Station would be required to cross at 7.5 feet/second to avoid exposure to traffic. Built environment characteristics varied across the sample with approximately half having street trees along the roadway. Building setbacks averaged 57 feet from the sidewalk (after removing the min and max outliers). The data shows that sidewalks are narrower near suburban stations than they are in the CBD area.

The sample cross-section includes a variety of station types as defined by the UTA *First/Last Mile Strategies Study*. Approximately 62% of stations are oriented toward a parking lot rather than a sidewalk or pedestrian access point. The mean income of residents living within ¼ mile of the rail transit stations in this study was $44,927, which equates to 74% of the median household income for the state of Utah, and nearly double the poverty level. The lowest income populations lived near the Library and University South Campus stations, while the highest income populations were located near the Daybreak and 4800 West Old Bingham Highway stations.

Data was collected both electronically and on-site. Site visits were conducted in June and July (2017) and were used to validate and confirm the electronic data, conduct counts for non-motorized travelers accessing the stations, and conduct intercept surveys with non-motorists. Survey results found that a majority of active travelers are accessing transit for work trips. A large majority of pedestrians and bicyclists travel actively during the summer months and more than half walk or bike to the station year-round. Respondents stated that shade trees, improved street crossings, benches, more bike lanes, and separate bike paths would make it easier for them to walk and bike to the station.

4.0 DATA EVALUATION

4.1 Overview

This section includes analysis of all site data. First, descriptive statistics are provided describing the road network surrounding each station and the bicycle and pedestrian components that are represented. Next, statistical methods are used to identify significant correlations between transportation characteristics, built environment characteristics, demographics, and nearby non-motorized crashes (and near misses with the transit trains).

4.2 Analysis of Variance

A brief overview of infrastructure is provided in Chapter 3. This section provides a more thorough statistical analysis.

4.2.1 Variation in Transportation System Characteristics

First, an ANOVA model was conducted to determine if there was a significant correlation between transportation system characteristics and station type. The model found that several characteristics differed significantly between the station types, including speed limit (f=4.193, p=.005), average roadway width (f=4.60, p=.003), average sidewalk width (f=5.76, p=.001), and the presence of a raised center median (f=3.184, p=.020).

As shown in Table 14, roadways surrounding the most urban rail stations had slower speed limits, and speed limit increased as the stations became more suburban and auto dependent. Roadway widths became progressively narrower as the stations became less urban. Urban sidewalks were significantly wider than those in the suburban and auto dependent areas. Raised center medians were present in all the urban intersections, but were less frequent the more suburban the stations became.

Table 14. Transportation System Characteristics by Station Type

Characteristic	Urban	Multi-Modal	Inst.	Suburban Non-Res	Suburban	Auto Dep.
Speed Limit (mph)	22.5	32.0	32.5	35.0	33.0	35.00
Number of Lanes	4.85	5.02	4.06	5.54	4.00	3.72
Roadway Width (feet)	86.81	82.55	64.25	64.58	57.60	60.65
Presence of Bike Lanes	100%	60%	50%	29%	60%	17%
Left Turn Lane	75%	100%	100%	100%	80%	67%
Dedicated Right Turn Lane	75%	70%	75%	86%	40%	50%
Raised Center Median	100%	70%	50%	29%	0%	33%
Pedestrian Countdown (sec)	20.25	21.70	20.50	22.00	18.00*	19.25
Average Sidewalk Width (feet)	14.75	6.85	8.75	6.71	6.40	6.83
	n=4	n=10	n=4	n=7	n=5	n=6

*Only one intersection in this category was signalized

These results are somewhat intuitive and expected. Roadways located near more suburban stations are likely to be higher speed arterials located further away from large residential areas. Although the urban roadways are wider, they provide wider sidewalks and more bike lanes for non-motorized travelers. In addition to applications as pedestrian refuges, medians provide access management and conflict point mitigation benefits.

4.2.2 Variation in Built-Environment Characteristics

A second ANOVA model examined correlations between station type and the built environment characteristics listed in Table 15. The presence of street trees (f=3.420, p=.015) and non-residential driveways (f=4.462, p=.004) differed significantly between the station types. As stations became less urban, the presence of street trees decreased. The only exception was the suburban stations group, which had trees on all neighboring streets. The presence of non-residential driveways was greater in urban and multi-modal areas. Suburban and auto-dependent stations had far fewer vehicle access points near the intersections.

Table 15. Built Environment Characteristics by Station Type

Characteristic	Urban	Multi-Modal	Inst.	Suburban Non-Res	Suburban	Auto Dep.
Land-Use*	50% Com 50% MU	90% Com 10% MU	25% Res 25% MU 50% Inst	14.3% Res 85.7% Com	40% Res 60% MU	50% Res 16.7% Com 16.7% MU 16.7% Ind
Street Trees	100%	60%	50%	29%	100%	17%
Building Setback from Sidewalk (feet)	17.5	64.1	87.1	218.8	50.8	38.2
Non-Residential Driveways (within ¼ mile)	24.0	36.5	12.5	19.7	11.6	8.5
Access to Multi-Use Paths (within ¼ mile)	0%	30%	25%	43%	40%	17%
	n=4	n=10	n=4	n=7	n=5	n=6

*Land uses include Res= Residential, Com=Commercial, Ind=Industrial, Inst=Institutional, and MU=Mixed Use

4.2.3 Variation in Station Characteristics

A third ANOVA model was used to evaluate differences in station characteristics by station type. Station orientation (*f*=4.151, *p*=.006) significantly differed by station type. Table 16 demonstrates that urban, multi-modal, and institutional stations tended to face the surrounding sidewalk, while the stations in suburban and auto dependent areas faced the parking lot. Bicycle parking significantly differed by station type as well (*f*=8.118, *p*=.000). The suburban and auto-dependent stations provided bicycle parking while the urban stations did not.

Table 16. Stations Characteristics by Station Type

Characteristic	Urban	Multi-Modal	Inst.	Suburban Non-Res	Suburban	Auto Dep.
Vehicle Parking Spaces	0.0	127.50	489.00	642.00	387.67	381.25
Bicycle Parking	0%	40%	50%	100%	100%	100%
Station Orientation (stations facing sidewalk)	100%	60%	50%	14%	20%	0%
Transit Oriented Development	100%	30%	50%	14%	80%	50%
	n=4	n=10	n=4	n=7	n=5	n=6

The presence of TOD development varied significantly by station type (*f*=2.604, *p*=.045). However, a subsequent binary logit model found that none of the UTA station types were a significant predictor of TOD. In other words, a station's location and classification could not accurately predict whether or not the area would exhibit TOD.

4.2.4 Variation in Demographics

A fourth ANOVA model identified a significant correlation between youth population and station type (f=7.158, p=.000). Table 17 shows that suburban stations have a significantly larger youth population than urban and institutional stations. This fits a typical demographic profile of U.S. metro areas where families with children tend to live in more suburban areas.

Table 17. Demographics by Station Type

Characteristic	Urban	Multi-Modal	Inst.	Suburban Non-Res	Suburban	Auto Dep.
Median Household Income	34,450	37,059	46,164	44,426	47,848	62,349
Population under age 18	6.85	27.50	14.80	26.60	25.98	31.08
Population over age 65	9.05	7.64	3.15	5.51	11.38	8.08
	n=4	n=10	n=4	n=7	n=5	n=6

4.2.5 Variation in Commute Behavior

A fifth ANOVA was used to evaluate variation in journey to work patterns across station types. The test found significant variation between stations for all commute types. Table 18 shows that populations living near urban and suburban stations made significantly more bicycle commute trips, while residents near institutional, suburban non-residential, and auto dependent stations made very few (f=3.544, p=.012). Areas surrounding urban and institutional stations saw significantly more walking (f=14.933, p=.000) trips. Areas near urban, multi-modal, and institutional stations had the highest percentages of transit commute trips (f=2.701, p=.013).

Table 18. Journey to Work and Non-Motorized Crashes by Station Type

Characteristic	Urban	Multi-Modal	Inst.	Suburban Non-Res	Suburban	Auto Dep.
Bike to Work (%)	4.75	1.02	0.95	0.87	2.56	0.83
Walk to Work (%)	15.93	2.44	16.30	3.94	4.52	3.13
Transit to Work (%)	11.02	8.33	14.05	5.87	4.18	3.73
	n=4	n=10	n=4	n=7	n=5	n=6

4.3 Non-Motorist Crash Risk

The second goal of this research was to identify correlations between the transportation and built environments surrounding each station and the incidence of crashes between motorized vehicles and non-motorists.

4.3.1 Variation in Crash Risk by Station Type

First an ANOVA test was performed to determine if there was a significant difference in the number of pedestrian and bicycle crashes by station type. The analysis found that there was significant variation in both pedestrian (f=2.467, p=.055) and cyclist (f=2.701, p=.039) crashes by station type. Table 19 shows that both bicycle and pedestrian crashes were more prevalent at intersections near urban, multi-modal, and suburban non-residential stations. There was not significant variation in the number of transit vehicle near misses by transit station type, meaning that they represent random and equal distribution.

Table 19. Non-Motorized Crashes by Station Type

Characteristic	Urban	Multi-Modal	Inst.	Suburban Non-Res	Suburban	Auto Dep.
Number of Bicycle Crashes*	1.75	3.10	0.75	1.86	0.20	0.83
Number of Pedestrian Crashes*	2.75	3.30	0.25	2.71	0.80	0.50
Transit Vehicle Near Misses**	5.0	8.6	3.5	9.6	2.8	5.3
	n=4	n=10	n=4	n=7	n=5	n=6

*Data represents the average number of crashes (by mode) from 2010-2016
**Transit near miss data compiled Jan-Nov 2017

4.3.2 Crash Risk and Transportation System Characteristics

A multinomial regression technique using least squares found that no transportation characteristics included in the model were significantly correlated to the number of bicycle crashes near each station. Collinearity statistics and Variance Inflation Factors (VIF) were used with each model to identify and reduce the potential for autocorrelation within the analysis. Additionally, non-motorized counts from the site visits were included in each model to control for volume and exposure.

Table 20. Bicycle Crashes and Transportation System Characteristics

Characteristic	β	t	Sig.
Constant	-	0.631	0.537
Speed Limit (mph)	-0.030	-0.293	0.774
Average Number of Lanes	1.046	1.065	0.304
Average Roadway Width	-0.052	-0.837	0.416
Presence of Bike Lanes	-1.204	-0.954	0.355
Peak Signal Time (sec)	-0.012	-0.320	-0.754
Left Turn Lanes	-1.177	-0.332	0.744
Right Turn Lanes	0.760	0.451	0.658
Raised Center Median	2.220	1.286	0.218
Number of Through Lanes	0.226	0.290	0.776

Pedestrian Countdown (sec)	-0.057	-0.449	0.625
Sidewalk Width	-0.173	-0.900	0.388
	n=36		R^2=0.33

A second model was employed to evaluate pedestrian crashes. Results are displayed in Table 21. Once again, none of the transportation system characteristics were significantly correlated to pedestrian crash rates at intersections surrounding the stations.

Table 21. Pedestrian Crashes and Transportation System Characteristics

Characteristic	β	t	Sig.
Constant	-	0.519	0.611
Speed Limit (mph)	-0.087	-0.756	0.461
Average Number of Lanes	1.254	1.007	0.330
Average Roadway Width	-0.077	-0.983	0.341
Presence of Bike Lanes	0.645	0.161	0.874
Peak Signal Time (sec)	0.008	0.161	0.874
Left Turn Lanes	-0.804	-0.179	0.860
Right Turn Lanes	-0.175	0.258	0.936
Raised Center Median	0.565	0.258	0.800
Number of Through Lanes	0.306	0.310	0.312
Pedestrian Countdown (sec)	0.055	0.378	0.711
Sidewalk Width	-0.165	-0.669	0.514
	n=36		R^2=0.326

A third regression model examined the relationships between system characteristics and near miss and crash incidents involving transit trains and pedestrians or cyclists around each station. The model found that after controlling for the presence of transit trains in the area (number of trains per hour at each station), no transportation system characteristics significantly correlated to an increase in near miss incidents. The R^2 value was very high (0.836), representing high goodness of fit. This means that 82% of the variation in train near misses and crashes could be accounted for by model variables.

Table 22. Transit Vehicle Near Misses and Transportation System Characteristics

Characteristic	β	t	Sig.
Constant	-	-0.972	0.376
Speed Limit (mph)	0.102	0.275	0.795
Average number of lanes	-2.259	-0.313	0.739
Average roadway width	-0.028	-0.932	0.930
Presence of bike lanes	-8.177	-1.320	0.244
Peak signal time (sec)	0.056	0.361	0.733
Left turn lanes	3.947	0.416	0.695
Right turn lanes	3.947	0.416	0.695
Raised center median	-9.331	-1.589	0.173
Number of through lanes	4.358	0.675	0.530
Pedestrian countdown (sec)	1.105	2.056	0.095
Sidewalk width	0.281	0.276	0.793
Number of Trains (per hour)	0.263	0.703	0.513
	n=36		R^2=0.836

4.3.3 Crash Risk and Built-Environment Characteristics

The next set of analyses sought to identify significant relationships between the built environment and non-motorized crashes. Three linear regression models were employed, once again using least squares and VIF corrections. The first model evaluated correlations between the built environment and the prevalence of bicycle crashes near stations. The analysis found that non-residential driveways were significantly correlated to bicycle crashes. The greater the number of non-residential driveways within ¼ mile of an intersection, the greater the number of bicycle crashes (see Table 23). This may be due to driveways creating more opportunities for conflict between turning cars and bicycles traveling straight.

Table 23. Bicycle Crashes and Built Environment Characteristics

Characteristic	β	t	Sig.
Constant	-	0.256	0.800
Street Trees	0.190	0.337	0.738
Building Setback (feet)	0.000	0.117	0.908
Non-Residential Driveways (within ¼ mile)	0.070	4.313	0.000
Multi-Use Path Access (within ¼ mile)	-0.366	-0.618	0.541
	n=36		R^2=0.560

The next model (Table 24) evaluated the impact of built environment characteristics on pedestrian crashes. It revealed that building setback, non-residential accesses within ¼ mile, and multi-use path access were all significantly correlated to pedestrian crashes. Large building setbacks were correlated to a significant increase in pedestrian crashes. Likewise, as the number of non-residential driveways increased, the number of pedestrian crashes increased significantly. Conversely, access to multi-use paths within ¼ mile was significantly correlated to a reduction in pedestrian crashes.

Table 24. Pedestrian Crashes and Built Environment Characteristics

Characteristic	β	t	Sig.
Constant	-	-0.533	0.598
Street Trees	0.598	1.015	0.318
Building Setback (feet)	0.008	3.838	0.001
Non-Residential Driveways (within ¼ mile)	0.080	4.665	0.000
Trail Access (within ¼ mile)	-1.244	-2.242	0.054
	n=36		R^2=0.536

These results are consistent with other research. A greater number of access points increases exposure for pedestrians and cyclists to motorized traffic. Large building setbacks increase the visual width of the roadway, which may reduce drivers' situational awareness. Narrower streetscapes provided by close building frontages shrink drivers' visual space, improve visibility, and contribute to traffic calming. Additionally, multi-use path access in an area has been shown in prior research to improve non-motorist safety. This is likely due to increased visibility of non-motorists and higher pedestrian volumes attracted by pathway infrastructure.

The third regression model sought to identify correlations between the built environment and near miss and crash incidents between transit trains and non-motorists, while controlling for the presence of transit trains (number of trains per hour at each station). The model revealed that building setbacks were positively correlated with the number of near miss incidents with trains, as shown in Table 25.

Table 25. Transit Vehicle Near Misses/Crashes and Built Environment Characteristics

Characteristic	β	t	Sig.
Constant	-	0.546	0.593
Street Trees	-2.389	-0.901	0.382
Building Setback (feet)	0.017	2.354	0.033
Non-Residential Driveways (within ¼ mile)	0.081	1.050	0.310
Trail Access (within ¼ mile)	-1.652	-0.572	0.575
Number of Trains (per hour)	0.483	2.109	0.052
	n=36		R^2=0.642

4.3.4 Crash Risk and Station Characteristics

Additional data models were run to determine if specific station characteristics such as the presence of TOD, car and bicycle parking, and station orientation were correlated to crashes or near misses with trains around transit stations. However, none of the statistical models found any significant correlations between station characteristics and non-motorized crashes.

4.3.5 Crash Risk and Demographics

The last set of analyses focused on identifying relationships between demographic data and crashes. A least squares regression model was employed using a Durban-Watson test, which measures serial correlation in the residuals (above *n* standard deviations). Results for the models are shown in Tables 26, 27, and 28.

Table 26. Bicycle Crashes and Population Characteristics

Characteristic	β	t	Sig.
Constant	-	4.088	0.000
Median annual household income (dollars)	-4.425E-5	-2.585	0.015
Population under age 18 (%)	-0.062	-1.735	0.093
Population over age 65 (%)	-0.126	-2.439	0.021
Bike to work (%)	-0.055	-0.352	0.727
Walk to work (%)	-0.174	-2.428	0.022
Transit to work (%)	0.049	0.605	0.550
			R^2=0.441
Durban-Watson	2.673		n=36

Bicycle crashes were significantly negatively correlated to income, senior population, and the percentage of residents who walk to work. Areas with higher median incomes had significantly fewer bike crashes near transit stations than those with lower incomes. Additionally, areas with a larger percentage of seniors and higher rates of walking to work saw significantly fewer bike crashes. There could be several reasons for this. One possibility is that areas with a larger senior population may experience fewer cycling trips in general, leading to less exposure for cyclists. The significant relationship between high rates of walking to work and fewer bike crashes could be explained in several ways. One possibility is that more people walking means fewer people bicycling. Another possibility is that more people walking increases motorists' awareness of all modes of non-motorized travel.

Table 27. Pedestrian Crashes and Population Characteristics

Characteristic	β	t	Sig.
_Constant	-	2.559	0.016
Median annual household income (dollars)	-4.048E-5	-1.670	0.106
Population under age 18 (%)	-0.072	-1.440	0.161
Population over age 65 (%)	-0.005	-0.063	0.950
Bike to work (%)	0.043	0.196	0.846
Walk to work (%)	-0.184	-1.811	0.081
Transit to work (%)	0.073	0.635	0.530
		R^2=0.261	
Durban-Watson	1.746	n=36	

Analyses of pedestrian crashes revealed that none of the population/demographic characteristics were significantly correlated to pedestrian crashes or near miss and crash incidents involving non-motorized modes and transit trains.

Table 28. Transit Vehicle Near Misses/Crashes and Population Characteristics

Characteristic	β	t	Sig.
_Constant	-	1.252	0.231
Median annual household income (dollars)	0.00	-1.732	0.107
Population under age 18 (%)	0.285	2.417	0.031
Population over age 65 (%)	0.269	1.201	0.251
Bike to work (%)	-0.802	-1.089	0.296
Walk to work (%)	0.979	3.106	0.008
Transit to work (%)	-1.238	-3.687	0.003
Number of Trains (per hour)	-1.528	5.196	0.000
		R^2=0.756	
Durban-Watson	2.094	n=36	

A final analysis correlated demographic characteristics to near miss incidents with a transit train while controlling for the number of trains passing through a station per hour. Youth population (under age 18), and the percentage of the surrounding population who walk or take transit to work were significantly correlated to the number of near miss incidents. Areas with a larger youth population and a large number of people who walk to work were significantly more likely to exhibit higher numbers of near miss incidents, while areas with large transit commuter populations had significantly fewer near misses. The number of transit trains that come through a station each hour was also significantly positively correlated to near miss incidents.

4.4 Summary

The data analysis identified that several factors differed across the different station types. They include: speed limit, roadway widths, presence of raised center medians, presence of street trees, number of non-residential driveways, station orientation, presence of TOD, percentage of the population under age 18, commute trip frequencies by mode, and prevalence of bicycle and pedestrian crashes.

A number of complex regression models were employed to identify correlations between transportation system, built-environment, station, and demographic characteristics and the number of bicycle and pedestrian crashes and near miss incidents with transit trains. The analyses determined that the number of non-residential driveways near an intersection was positively correlated to both bicycle and pedestrian crash rates as well as near miss and crash incidents involving trains. Building setbacks were positively correlated to a significant increase in pedestrian crashes and train-related near miss and crash incidents. Multi-use path access was negatively correlated to pedestrian crashes.

Several population characteristics were significantly correlated to the number of crashes. Youth population (under age 18), and the percentage of the surrounding population who walk or take transit to work were significantly correlated to the number of near miss incidents. Areas with a larger youth population and a large number of people who walk to work were significantly more likely to exhibit higher numbers of near miss incidents, while areas with large transit commuter populations had significantly fewer near misses.

5.0 CONCLUSIONS

5.1 Summary

This research examined geometric design and built-environment characteristics that may influence pedestrian and cyclist safety near Wasatch Front rail transit stations. This was done by identifying characteristics of the stations themselves and the road networks surrounding each station. The research sought to identify correlations between station site characteristics and nearby non-motorized crash risk, including both crashes and transit train-related collisions and near misses. Additionally, the research sought to determine how non-motorized safety and comfort in accessing rail stations could be improved.

This study utilized data collected from 21 light and commuter rail stations in Weber, Davis, Salt Lake, and Utah Counties. Using a combination or aerial photos, GIS data collection, and on-site visits, additional built environment and transportation system data was collected for 36 intersections surrounding those stations. A database of demographic data was also collected for residents living within ¼ mile of each station using current U.S. Census data. Non-motorized crash data for the 36 intersections was compiled along with UTA's data for train-related crashes and near miss incidents near each station.

Data was analyzed using a combination of qualitative observational techniques, ANOVA tests, and complex regression methods, including controls for serial correlation and spatial autocorrelation.

5.2 Findings

While the findings of this research are not revolutionary, they do complement existing UDOT research on pedestrian and cyclist safety while offering insights into providing safe access for non-motorists near rail transit stations.

5.2.1 Spatial Variation Across Station Types

UTA's *First/Last Mile Strategies Study* identified six unique rail station typologies along the Wasatch Front: urban, multi-modal, institutional, suburban non-residential, suburban, and auto dependent. These typologies were the basis for variation analysis in this study.

Of the 47 different variables measured in the study, 12 differed significantly by station type (26%). Of the transportation system characteristics evaluated, speed limit, roadway width, and presence of raised center medians differed significantly. Roadways surrounding the most urban rail stations had lower speed limits. Speed limit increased as the stations became more suburban and auto dependent. Roadway widths decreased as the stations became less urban.

Sidewalks were significantly wider near urban stations than those in the suburban and auto dependent areas. Historically, most suburban municipalities have had ordinances requiring a 4-foot sidewalk standard with 5-foot pass zones at least every 200 feet in new development (UDOT, 2015). However, as of April 2017, UDOT recommends providing 5-foot sidewalks as a minimum standard when a park strip is present and an 8-foot sidewalk if there is no park strip (UDOT, 2017). More urbanized areas such as the Salt Lake City CBD, where the urban stations in the study are located, require much wider sidewalks to accommodate higher pedestrian volumes and provide a buffer from traffic. Raised center medians were also present in all the urban intersections, again likely due to the higher roadway width and distance required for pedestrians to cross. Medians are less frequent in more suburban and auto-dependent locations.

Several built environment characteristics also significantly differed by station type. As stations become less urban, the presence of street trees decreased. The only exception was suburban stations, which had trees on all neighboring streets. Cities often do not require trees along arterials and sometimes even prohibit them for maintenance reasons. However, 71% of intercept survey respondents stated that their walk or bicycle trip to the station would be improved and feel safer if there were more street trees. The presence of non-residential driveways was greater in urban and multi-modal areas. Suburban and auto-dependent stations had far fewer driveways near the intersections. This finding was unexpected as it is typical to believe that suburban and auto-dependent areas would provide more auto access to the street than the more urban and multi-modal locations. Driveway density is a worthwhile variable to investigate further because prior UDOT research has shown that non-residential access is significantly correlated to an increase in the number of non-motorized crashes, particularly near rail stations where large numbers of people walk or bike to the stations (Burbidge, 2014).

An evaluation of commute characteristics found that populations living near urban and suburban stations made significantly more bicycle commute trips compared to residents near institutional stations and auto dependent stations. Housing is located rather far from the suburban and auto-dependent stations (in most cases) and parking at the stations is plentiful. Individuals choosing to use these stations for commute trips likely drive or are driven to their station. Alternatively, individuals living near institutional stations are more likely to be students (based on the other analysis characteristics) and may not have access to a bicycle, choosing instead to walk to the station located near their housing. This supposition is confirmed by another finding that areas surrounding urban, institutional, and multi-modal stations saw significantly more walking and transit commute trips than the suburban and auto-dependent station areas.

5.2.2 Site Characteristics and Non-Motorized Crashes

Three separate models determined that the number of non-residential driveways within ¼ mile of a station's nearest intersections was positively correlated to an increase in both bicycle and pedestrian crashes, as well as train-related near miss and crash incidents. This is consistent with prior UDOT research findings relating to non-residential driveways and non-motorist safety (Burbidge, 2014), as well as guidance that states (FHWA, 2010):

> "It is desirable to minimize the number of conflict points created with existing and future driveways since more conflict points increase the risk of a crash occurring. The number and type of conflict points at a driveway can be managed by limiting both the amount of access allowed at the driveway (e.g., full-movement, left-in/left-out, right-in/right-out, right-in only or right-out only) and the location of the driveway relative to other driveways in the area."

Building setback distance was also positively correlated to an increase in pedestrian crashes and train-related near miss and crash incidents. This may be due to smaller setbacks leading to lower car speeds, visual narrowing of the street, and increased visibility of pedestrians.

A separate model found that multi-use path access within ¼ mile of the station area was negatively correlated the number of pedestrian crashes. As FHWA (2017) points out:

> “Connected bicycle and walking networks and designated pedestrian zones and amenities can provide safe, reliable, and equitable access to robust transit networks, providing viable and reliable travel options for all.”

Providing multi-use path access near transit stations increases transportation options and allows transit users to approach the station on a separate right-of-way from car traffic, enhancing safety by reducing the potential for conflicts between pedestrians and automobiles.

Several demographic factors were correlated to the number of non-motorized crashes. Median household income, senior population (age 65+), and the percentage of the population walking to work were each negatively correlated to the number of bicycle crashes observed at the intersections near each transit station. In areas with higher senior populations the lower crash rate could be explained as a correlation of exposure. Although none of the non-motorized volumes collected at the stations were significantly correlated to crash rates, it is possible that areas with larger senior populations see fewer cyclists in general due to physical limitations. This could also hold true for the areas that have a higher percentage of the population walking to work. More individuals walking may translate to fewer cyclists and a lower likelihood of seeing bicycle crashes. It is also possible that more people walking increases motorists’ awareness of all non-motorized users, thereby increasing safety for all active transportation modes. Without long-term volume counts at each site it is difficult to make a definitive determination.

Areas with a larger youth population and a large number of people who walk to work were significantly more likely to exhibit higher numbers of near miss incidents, while areas with large transit commuter populations had significantly fewer near misses. Intuitively, individuals who take transit regularly may be more experienced in watching for trains and navigating near the stations which would translate into fewer incidents. The number of transit trains that come through a station each hour was also significantly positively correlated to near miss incidents. This implies that even when controlling for demographics, exposure may be a primary culprit behind near miss incidents relative to other external variables.

5.2.3 Corridor Planning and Context Sensitivity

The results of this study show the importance of context sensitivity. All of the analyses identified key significant differences between the station types. Because of this spatial variation, there is not a one-size-fits-all approach to addressing safe access. The key differences identified in this study should be used as a blueprint for creating a customized non-motorized improvement plan for each site type.

While the number of completed intercept surveys is not substantial and may not be representative of the non-motorist population as a whole, some interesting perspectives can be gleaned from their responses. Over 60% of users walked or cycled to the station as a means of getting to work. Another 16% each of respondents were attributed to people using transit for school or recreation opportunities. Knowing why non-motorists are using transit can help inform facility infrastructure decisions. For example, knowing that a large majority of non-motorists are accessing the stations during typical morning and evening peak periods may influence changes to pedestrian signal timing at intersections near stations.

Another key take-away from the intercept surveys is the frequency of non-motorized trips. Almost half of those surveyed stated that they walk or bike to the station 11 or more times per month. For commuters, that equals approximately half of their workdays. These active individuals are also walking year-round. Nearly all of the respondents reported walking or biking to the station in the summertime, and 75% stated that they walk or bike to the station in the spring and fall. Nearly 60% of those surveyed identified that they walk or bike to transit in the winter. This finding may discredit some commonly held local views about the seasonality of non-motorized travel, and suggests that snow removal and winter maintenance are important. This could include plowing shoulders and shoveling sidewalks along the corridors leading to the stations (not simply the areas around the stations themselves).

Lastly, respondents identified improvements along their route to the stations that would be most helpful for enabling them to walk or bike more safely. While it should be noted that "safety" is not quantified in the context of this survey, responses provide valuable insight into perceptions of what safety means to the individuals using the system. The most frequently cited improvements were adding shade trees (71%), providing better street crossings to access the stations (33%), adding benches (24%), providing grade separated bike paths (18%), improving the surfaces of the sidewalks and shoulders (16%), and providing wider sidewalks (14%).

5.3 Limitations and Challenges

While every effort was made to minimize validity issues within the sample data, there are several factors that contributed to limitations in the final dataset. One significant challenge was the difficulty of isolating pedestrians walking to stations from those arriving by car and simply walking to the station platforms from parking spaces. This challenge made it hard to have confidence in user counts conducted at some stations.

The number of characteristics included within the framework of the study was large. This, combined with the limited number of stations included, placed restrictions on the types of statistical analysis that could be conducted. A larger sample of stations would have provided a more robust analysis. However, more stations would have required a larger research team and budget to accomplish. Specific statistical techniques were used to limit data validity issues, including running separate models for each type of characteristic (e.g., transportation system, built environment, and population characteristics) rather than running all variables in a pooled model structure, which would not have been possible due to the sample size.

Lastly, the sample of intercept data was not as large as anticipated. A large non-response was observed as non-motorists were in a hurry to get to the station and board their train. There may also be some self-selection bias inherent in those who chose to participate in the survey. Future research would benefit tremendously from acquiring responses from a much larger sample of active transportation users.

6.0 RECOMMENDATIONS AND IMPLEMENTATION

6.1 Recommendations

It is recommended that improvements along transit station access corridors be tailored to the station and user types described in this analysis. Several criteria apply across the board regardless of station type as they apply in general to walkability and promoting a human scale environment. As posited by Forsyth and Southworth (2008), a walkable environment is one that is attractive (e.g., trees are present, litter and graffiti are absent), barrier-free (e.g., free from debris and overgrown shrubbery), safe from perceived crime and excess traffic, diverse in land-use types, full of amenities (e.g., stores, restaurants, plazas, and water features) and pedestrian infrastructure (e.g., crosswalks, benches), and in which destinations are close by. Nearly all of these criteria were identified by the respondents of the intercept survey and are substantiated by the analysis in Chapter 4. Emphasis should also be paid to providing a transition zone from major roadways where system users (pedestrians, cyclists, and motorists) sense a shift from an arterial environment to a multi-modal access point.

Non-residential driveways have proven repeatedly to impact non-motorist safety. FHWA has identified several potential access management treatments to improve safety for bicyclists and pedestrians. They identify that the following access management approaches can help to improve pedestrian and bicyclist safety and mobility at access points in the vicinity of urban and suburban intersections (both signalized and unsignalized):

- Provide raised medians on the major roadway to prohibit vehicles from turning left into driveways. This improves pedestrian safety by reducing the number of potential pedestrian-vehicle conflicts.
- Construct a channelized island between the inbound and outbound movements at right-turn-only driveways to provide a pedestrian refuge across the driveways.
- Minimize the width of the driveway as much as possible in order to reduce pedestrian crossing distances (i.e., reduce exposure).
- Place sidewalks and pedestrian driveway crossings so that pedestrians are visible to one another.
- Do not block pedestrian-driver sightlines with landscaping or signage.

- Include bike lanes and signage, as appropriate, to alert bicyclists that motorists may be entering or exiting a driveway and to alert motorists that bicyclists may be crossing the driveway.

In August 2017, the Federal Transit Administration (FTA) released a new *Manual on Pedestrian and Bicycle Connections to Transit* (FTA, 2017). The manual outlines specific recommendations that transit and transportation agencies should take to better accommodate and promote non-motorized access to transit. There are several components that relate directly to the roadways and overall transportation network that feeds stations. They include connected networks, specific components of pedestrian access (sidewalks, crossings, safety, and security), and bicycle access (networks to get to the station and wayfinding). This manual should be consulted and recommendations adopted within UDOT policy to improve existing access and promote safe non-motorist access to rail transit stations across the Wasatch Front. Additional research should also be conducted to further examine stations and surrounding areas based on the FTA "stated principles of connected networks", including:

- Cohesion – how connected is the network in terms of its concentration of destinations and routes?
- Directness – does the network provide direct and convenient access to destinations?
- Accessibility – how well does the network accommodate travel for all users, regardless of age or ability?
- Alternatives – are there a number of different route choices available within the network?
- Safety and security – does the network provide routes that minimize risk of injury, danger, and crime?
- Comfort – does the network appeal to a broad range of age and ability levels and is consideration given to user amenities?

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Appendix A- Data Dictionary for Inventory Data

Table 29. Variable Data Dictionary

Transportation System Characteristics*	
Legs	Number of roadway legs feeding the intersection
Speed	Posted Speed Limit on roadway legs feeding the intersection If speeds differ on multiple legs an average is computed and used
Number of Lanes	Total number of lanes on the roadway, including turn lanes If number of lanes differs on multiple legs an average is computed and used
Roadway Width	Width of the roadway in feet as measured curb to curb
Bike Lanes	The presence of bike lanes on the roadway, either at the intersection or on the roadway immediately leading up to the intersection (within 100 yards) (yes/no)
Signal Type	What type of traffic control is present at the intersection (e.g. stop sign, traffic light, etc.)
Signal Time	The number of seconds in a signal cycle at peak (as provided by the UDOT Traffic Operations Engineers for each region)
Left Turn	The presence of dedicated left turn lanes (yes/no)
Right Turn	The presence of dedicated right turn lanes (yes/no)
Raised Median	The presence of a raised center median on the roadway, either at the intersection or on the roadway immediately leading up to the intersection (within 100 yards) (yes/no)
Number of Through Lanes	The number of travel lanes that proceed through the intersection
Crosswalks	The number of crosswalks present at the intersection divided by the number of roadway legs
Pedestrian Signals	The presence of pedestrian countdown signals at the intersection (yes/no)
Pedestrian Countdown	Number of seconds programmed for the pedestrian crossing interval
Crossing Speed	The width of the intersection divided by the crossing interval (feet per second)
Built Environment Characteristics	
Sidewalks	Number of sidewalks feeding the intersection
Sidewalk Width	Sidewalk width in feet
Land Use	Land-use immediately surrounding the intersection Residential, Commercial, Industrial, Institutional, or Mixed-Use
Street Trees	The presence of street trees along the roadways feeding the intersection (yes/no)
Setback	The number of feet between the curb and the building frontage
Non-Residential Access	The number of non-residential driveways within ¼ mile of the intersection on all roadway legs
Trails	The number of trail access points located within ¼ mile of the intersection on all roadway legs
Transit Oriented Development	The development around the intersection is structured to emphasize access to transit or exhibits other TOD characteristics
Station Characteristics	
Vehicle Parking	Number of vehicle parking spaces located at the station
Bicycle Parking	The presence of bicycle parking at the station (yes/no)
Orientation	The direction the station is facing (parking lot, sidewalk, other)
Other Data	
Income	Median Household Income based on 2010 Census data
Population <18	Percentage of the population under age 18 living within ¼ mile of the station
Population >65	Percentage of the population over age 65 living within ¼ mile of the station
Bike Population	Percentage of the population who report biking to work (U.S. Census)
Walk Population	Percentage of the population who report walking to work (U.S. Census)
Transit Population	Percentage of the population who report taking transit to work (U.S. Census)
Number of Trains	The number of transit trains that pass through each station (per hour)

*If value differs on multiple legs an average is computed and used for analysis