THE BUILT ENVIRONMENT & TRANSIT USER EXPERIENCE AT SEMI-OUTDOOR EMERALD EXPRESS BUS RAPID TRANSIT STATIONS

by

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THESIS ABSTRACT

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This research studied the relationship between transit users' travel experience and the built environment bus rapid transit (BRT) stations. The study recorded attributes of the built environment and user perceptions at eight Emerald Express stations between Eugene and Springfield, Oregon as case studies. It found that of the attributes studied, transit users' satisfactions of pedestrian accessibility had strong correlations with their preference of using EmX over a car. It also found that users perceived stations in built environments with spare street shading and commercial land-uses as less safe, and were also less satisfied with weather protection at stations with low street shading. The study found Universal Thermal Climate Index (UTCI) and Predicted Mean Votes (PMV) to mostly identify the same categories of thermal stress. The study developed a rating system to evaluate station performance based on quantitative attributes and suggests short and long term improvements to improve semi-outdoor bus stations.

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CHAPTER I

INTRODUCTION

1.1 Introduction

In the United States alone, approximately 140 million people use bus rapid transit per year among twenty-one cities and 628 kilometers of bus rapid transit (brtdata.org). Transit users spend a considerable part of their journey out of the vehicle in walking to and from stations, making transfers, and waiting at stations. Despite the importance of this out of vehicle portion of the journey on users' overall transit experience, few researchers have focused on this. Adverse weather conditions and unsafe waiting environments can increase peoples' perceived stress related to the use of transit (Iseki, Ringler, Taylor, Miller, & Smart, 2007). Researchers have either focused on the built environment around transit stations, user thermal comfort at the stations or the users' perceptions of transit stations based on design attributes. Iseki et al., (2007) have studied how transit users evaluate stations based on station attributes. Few researchers have focused on the street network around transit stations for pedestrians (Schlossberg, Dill, Ma, & Meyer, 2013) and few researchers have studied transit users' thermal comfort at semi-outdoor bus stations (Matzarakis et al., 2006).

This research builds on existing methodologies for a holistic approach to study how transit users' experience outside the vehicle relates to the built environment. To do this, the research studied eight Springfield bound bus stations of Emerald Express (EmX) bus rapid transit system (BRT) in Eugene, Oregon, and their built environments as case studies. For each case study, the research recorded attributes and user perceptions of the built environment, and studied correlations between perceptions of satisfaction and attributes of the built environment to identify perceived problems and solutions. The research analyzed perceptions of importance to identify the improvement priority of station attributes.

For attributes of the built environment this research recorded Density, Diversity, Accessibility and Design, which have been studied in previous literature on the relationship between travel behavior and the built environment (Ewing & Cervero, 2010). For user perceptions, the research recorded user perceptions of satisfaction and importance of weather protection, safety, amenities and accessibility of the stations (Iseki et al., 2007) of a total of 162 respondents at EmX stations.

Results of this study add to the existing body of research on travel experience and the built environment, provide data on thermal comfort at semi-outdoor EmX BRT stations, and identify improvement priorities of station attributes. These results could be valuable for improving user satisfactions at EmX stations, and shaping the design of future semi-outdoor BRT stations and their surroundings.

1.2 Thesis Objectives

The primary objective of this thesis is to add to the existing body of research on the relationship between transit users' experience and the built environment at semi-outdoor bus stations. The research identifies perceived problems and solutions by studying correlations between the recorded attributes and user perceptions of satisfaction at semi-outdoor Emerald Express bus rapid transit stations. The research identifies improvement priorities of attributes at the stations and analyzes correlations between user satisfactions and modal preference between a car and EmX at the case study stations. These results can be helpful in improving users' satisfaction at the stations, influencing the designs of future BRT stations along with their environments, and influencing preference of bus rapid transit among users.

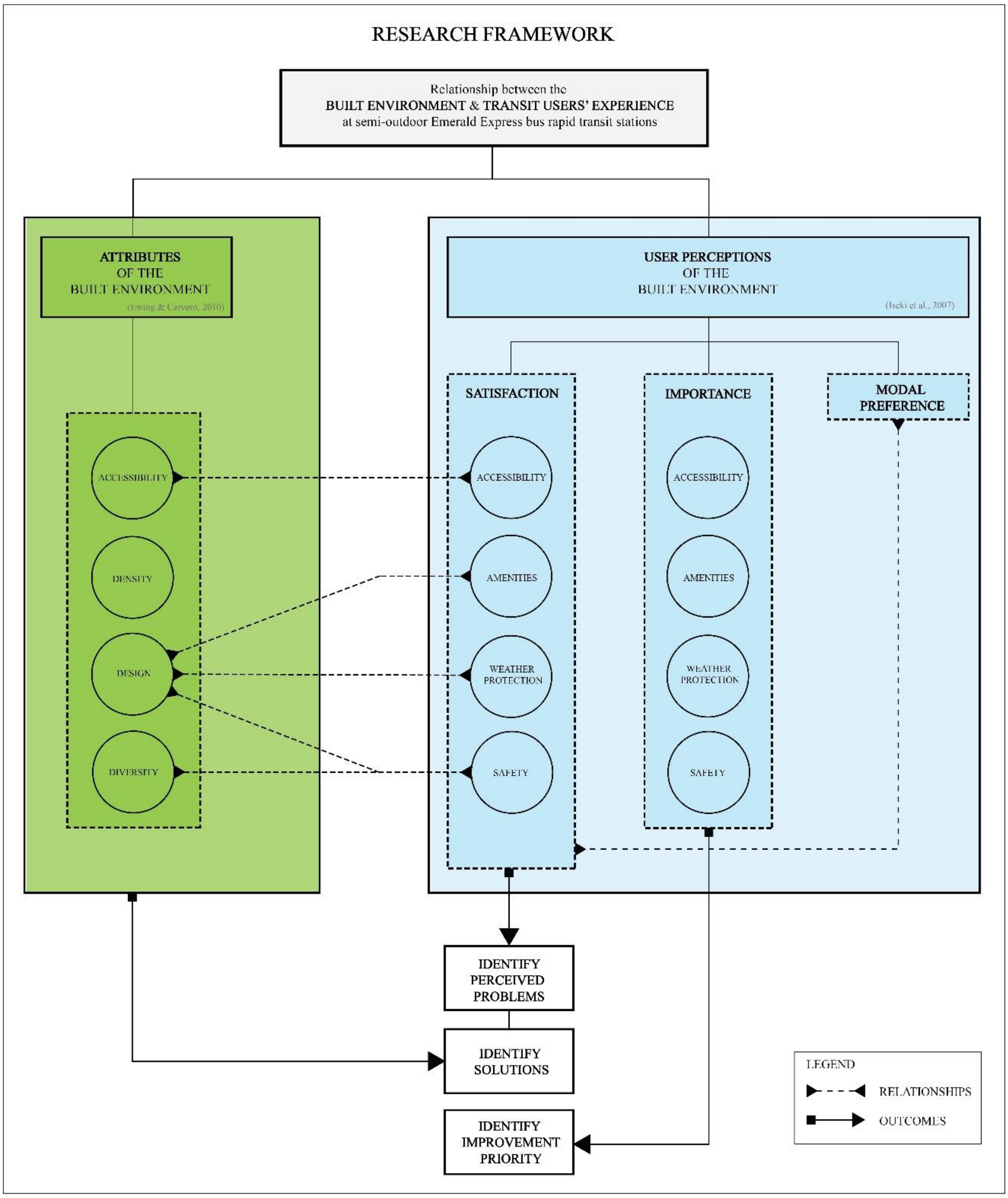


Figure 1: Framework of research

1.3 Research Questions

In order to achieve the objectives of the research, this thesis addresses the following questions:

1. How do transit users' out of vehicle experience correlate to the built environment at semi-outdoor Emerald Express bus rapid transit stations?

In this study, transit users' experience is studied by their perceptions of satisfaction related to attributes of the built environment. In order to study the above correlation, this study addresses the following secondary concerns:

   a. How do users' satisfaction with accessibility of stations correlate to pedestrian accessibility as measured by pedestrian catchment zone ratios around EmX stations?
   b. How do users' satisfaction with safety at the stations correlate to design attributes of street shading as measured by sky view factor and proportion of commercial land-use around EmX stations?
   c. How do users' satisfaction with weather protection at the stations correlate to design attributes of street shading as measured by sky view factor and percentage of canopy shade at EmX stations?

2. How do users' satisfaction with accessibility, safety, weather protection and amenities at EmX stations correlate to their preference of EmX?
3. How do users' perceptions of importance and satisfaction identify the priority and need for improvement among station attributes?
4. How do the thermal assessment indices Universal Thermal Climate Index (UTCI) and Predicted Mean Votes (PMV) identify categories of users' thermal stress across semi-outdoor EmX BRT stations?

1.4 Research Limitations

This research builds on existing research methodologies for a holistic study on the relationship between transit users' out of vehicle experience and attributes of the built environment at Emerald Express bus rapid transit stations in Eugene, Oregon. This study recorded attributes of the built environment and user perceptions at the stations related to a few attributes identified in previous literature. It should be noted that there may be many more factors that could influence transit users' out of vehicle experience which are beyond the scope of this study. The research recorded user perceptions of a total of 162 paper survey respondents but the sample sizes for this study were different at each station because of the difference in the response rates. For research on users' thermal comfort at the stations, this research made measurements of climate data for each station at different times of each day, so the thermal environment is not compared across stations but across months for each station.

1.5 Thesis Organization

This thesis is divided into five chapters. Chapter 1 includes the introduction to the research, the thesis objectives, research questions and research limitations. Chapter 2 presents an overview of existing literature on the impacts of weather and built environment on travel behavior, and thermal comfort research at semi-outdoor environments. Chapter 3 describes the methodologies used for this research. Chapter 4 presents the results, analysis and discussions of the research findings. Chapter 5 presents conclusions and recommendations for future work related to the user experience at semi-outdoor bus rapid transit stations and user thermal comfort at semi-outdoor bus stations.

CHAPTER II

OVERVIEW OF PREVIOUS RESEARCH

2.1 Introduction

This chapter provides an overview of previous literature on the relationship between the built environment and travel behavior, and impacts of weather conditions on travel behavior. The chapter identifies transit stations as semi-outdoor environments and provides an overview of existing thermal comfort research at semi-outdoor environments. It also introduces the methods used for assessing thermal comfort conditions in semi-outdoor environments and outlines the thermal assessment indices that are used in this thesis.

2.2 The built environment and travel behavior

According to some researchers, the built environment is defined as a combination of physical features of urban design, transportation systems and land-use that influence human activities (Handy et al., 2002; TRB and Institute of Medicine 2005). Researchers have studied a variety of characteristics as a measure of the built environment to investigate the relationship between them and people's travel behavior. The choice of characteristics used as a measure are influenced by the availability of data, along with other research concerns (Handy, Boarnet, Ewing, & Killingsworth, 2002). To study the relationship between travel behaviour and the built environment, Handy et al., (2002) haved used density, land-use diversity, connectivity of street networks, scale of streets and visually appealing qualities as a measure of the built environment. Similarly, Ewing and Cervero (2010) have organized characteristics of the built environment into five Ds namely; **density** of activities, population, employment or built area, **diversity** of land uses, **design** of the street network, proportion of street intersections, street scale, average block size, weather protection, pedestrian-oriented design features, **destination** accessibility on a regional or local scale, and the **distance** to transit (Ewing and Cervero, 2010). Greenwald and Boarnet (2001) found a positive association between walking and characteristics of the built environment such as higher densities, land-use mix, and street connectivity.

This thesis studies the relationship between the portion of a transit user's journey that is spent outside a transit vehicle required to make the trip, and the spatial, thermal and design characteristics of the physical environment. Transit users spend a considerable part of their journey walking to stations, making transfers, waiting, and walking to their destinations. As a result, street connectivity around stations can impact a transit user's perceptions of the burdens involved in using the transit, and influence their choice of doing so. A well connected street network around stations can reduce some of these burdens, and improve passenger experience as well as the overall effectiveness of the transportation system (Iseki et al., 2007). Schlossberg, Dill, Ma, & Meyer (2013) suggest using street intersection density as a measure of connectivity and walkability around stations.

2.3 Weather and travel behavior

According to Khattak and De Palma (1997) weather conditions impact a traveler's choice of the mode of transport. Weather conditions can influence the quality of transit service by causing changes in the schedule, influencing the time required to access stations and the total travel time (Hofmann and O'Mahony, 2005). Adverse weather conditions can cause service delays, or even cancellations, resulting in reduced transit ridership (Outwater et al., 2011; Guo, Wilson, & Rahbee, 2005; Changnon, 1996). The influence on transit ridership varies with the time of the day, the season, day of the week, the mode of transit (Cohen, Williams, & Cravo, 2009), and station design characteristics (Singhal, Kamga, & Ysazici, 2014).

Singhal et al. (2014) investigated the impact of weather on transit ridership based on characteristics of stations such as weather protection, multi-modal connection, ease of station accessibility and the waiting time. They found that in New York, transit ridership for above ground transit stations was generally more sensitive to weather conditions of high temperatures, wind and rain as compared to underground stations that were inherently weather protected. On the other hand, conditions of snow more negatively affected the underground stations due to limited accessibility. (Falzarno, Hazlett, & Adler, 2000). In Pierce County, Washington, rain negatively impacted bus ridership in all four seasons, low temperatures affected ridership in winters and winds in spring and autumn seasons. (Stover and McCormack 2012). Rain also caused a decreased of bus ridership in Chicago by 2.1% and Chicago Transit Agency (CTA) ridership by 3-5% (Changnon, 1996). Transit riders particularly perceive waiting times to be more difficult in uncomfortable conditions such as unfavorable weather and in environments they perceive as insecure (Iseki et al., 2007). According to a survey conducted in Salt Lake City, Utah, 12% transit riders avoided transit in adverse weather given an alternate choice of travel mode (Outwater et al. 2011). Similarly, Chicago Transit Authority rapid users ranked weather protection as the most important characteristic of a transit station. The thermal comfort at bus stations is as important as the internal environment of a bus for the overall quality and experience of a journey (Matzarakis et al., 2006). The next section reviews existing literature on thermal comfort at bus stations, identified as semi-outdoor environments for this thesis.

2.4 Thermal comfort at semi-outdoor conditions

In the past decade, thermal comfort research in outdoor and semi-outdoor environments has gained interest (Taleghani, Sailor, Tenpierik, & van den Dobbelsteen, 2014; Andreou, 2013; Lai, Guo, Hou, Lin, & Chen, 2014; Makaremi, Salleh, Jaafar, & GhaffarianHoseini, 2012; Goshayeshi, Shahidan, Khafi, & Ehtesham, 2013; Krüger and Rossi, 2011; Honjo, 2009; Johansson, 2006; Ali-Toudertet & Mayer, 2006; Nikolopoulou et al., 2003; Nikolopoulou et al., 2001) to promote public participation in outdoor urban spaces (Makaremi et al. 2012; Thorsson et al. 2004; Ahmed 2003).

In outdoor and semi-outdoor thermal comfort studies, some researchers have used surveys to evaluate people's perceptions of the thermal environment, taking into account their clothing and activity levels along with measurements of the thermal conditions using portable weather stations (Spagnolo and de Dear, 2003; Makaremi et al., 2012; Nikolopoulou, Baker, and Steemers, 2011; Nakano et al., 2006; Lai et al., 2014; Chun et al., 2005; Nagara et al., 1996). Other researchers have focused on a purely physiological approach by measuring thermal conditions and calculating thermal indices to predict the human thermal comfort (Taleghani et al., 2014; Abdel-Ghany et al., 2014; Andreou, 2013; Hwang et al., 2011; Honjo, 2009). Johansson et al. (2014) provide a comprehensive review of the existing outdoor thermal comfort studies on the measurement instruments, survey methods for subjective thermal perception, measurement protocols for the climatic conditions and thermal indices for different climatic and geographic locations, but conclude that the protocols used for outdoor comfort research lack standardization.

Hwang et al., (2011) have made thermal measurements to investigate the seasonal variations of shading in urban streets in Taiwan and also used hourly weather data in *RayMan* software to predict the long term thermal comfort conditions by calculating the Physiologically Equivalent Temperature (PET) thermal index. They also calculated the sky view factor (SVF) using fish-eye photographs in *RayMan* to measure the shading of urban streets and related this to the thermal index in these streets. The researchers concluded that the street shading had changing seasonal effects on the thermal comfort and that PET could be used to demonstrate thermal comfort conditions in such environments. Andreou (2013) studied the effects of street geometry, trees, orientation, wind speed and surface reflectance on thermal comfort conditions in urban streets. The researcher used on-site measurements of air temperature, humidity and wind speed to calculate the mean radiant temperature (MRT), PET and SVF in *RayMan* software. The author found that the street height and width ratios could affect thermal conditions in streets by affecting the level of shade from solar radiation in different orientations.

Thermal comfort at semi-outdoor transit stations

A number of researchers provide a review of thermal comfort studies in semi-outdoor conditions or transitional spaces (Spagnolo et al., 2003; Hui et al., 2014; Ghaddar et al., 2011; Potvin, 2000; Chun et al., 2005; Chun and Tamura, 2004; Goshayeshi et al., 2013) Transitional or semi-outdoor spaces can be defined as spaces that have unstable dynamic climatic condition, similar to outdoor conditions and can be broadly divided into spaces connected to a building such as atriums, courtyards, and those that are separate like shelters or pavilions (Chun et al., 2004). Transit stations like bus stations that provide shelter in the form of a roof shade can be categorized as semi-outdoor spaces (Matzarakis et al., 2006; Chun et al., 2004). Despite the importance of comfort from weather conditions at transit stations for the overall experience of the passengers (Singhal et al., 2014; Iseki et al., 2007) and success of a transit system, (Matzarakis et al., 2006; Bryan, 2001) few studies have focused on thermal comfort at transit stations (Matzarakis et al., 2006; Nakano et al., 2006; Chun et al., 2004; Bryan, 2001). Since regulating such environments artificially is difficult, researchers suggest the use of passive design strategies to provide thermally comfortable conditions for the waiting passengers (Matzarakis et al., 2006; Bryan, 2001).

Matzarakis et al.(2006) conducted thermal comfort research at five bus shelters in Taiwan. They carried out meteorological measurement at these stations along calculations of MRT, thermal indices (PET and SET), and SVF in *RayMan* software using fish-eye photographs for each station. SVF gives a measure of shade from solar radiation, the lower the SVF value, the better the shade. The researchers found that the *RayMan* model provides a good method for estimating thermal comfort conditions at these stations and that bus shelters that provide better shading (lower SVF) have better thermal comfort conditions for the context of Taiwan. They suggest that designers should take local sunlight patterns into account to use passive design strategies for improving thermal comfort at such stations. Bryan (2001) developed a methodology for determining the outdoor design criteria for transit stations for Central Phoenix/East Valley Light Rail Transit (CP/ EV LRT) in Arizona. Cook et al. (2003) suggest lowering of surface temperatures to improve thermal comfort conditions at semi-outdoor transit stations in Arizona. They conducted a research for

Valley Metro Rail in Phoenix, Arizona to determine the best materials and assemblies for light rail stations that could provide the lowest surface temperatures under high air temperatures and made recommendations of materials for Valley Metro Rail stations to improve thermal comfort for the passengers.

Thermal comfort theory and assessment

According to ASHARE Standard 55-1992, human thermal comfort is defined as "that condition of the mind that expresses satisfaction with the thermal environment." It is affected by the following parameters: a person's metabolic activity (Met), clothing level (Clo), air velocity (V_A), relative humidity (RH), air temperature (T_A), and mean radiant temperature (MRT) (Fanger, 1970).

Johansson et al. (2014) provide a comprehensive review of 26 studies on the instruments and protocols for outdoor thermal comfort research. Due to a lack of standardization of instruments and protocols for outdoor thermal comfort research, a variety of equipment and methods have been in previous research (Johansson et al., 2014; Chen and Ng, 2012) especially for the measurement of air velocity and mean radiant temperature (MRT), which are often too complicated or expensive. Most thermal comfort standards and guidelines such as ASHRAE Standard 55 (2010) and ISO 7730 (2005) are meant for indoor thermal comfort research and cannot be applied directly to outdoor or semi-outdoor conditions (Johansson et al., 2014; Mayer and Höppe, 1987). Due to the lack of an internationally applicable standard protocol for thermal comfort research in outdoor or semi-outdoor conditions, researchers have adapted these standards to use in outdoor and semi-outdoor conditions. An exception to these standards are the German engineering guidelines (Mayer, 1998) VDI 3787

(2008) which are for guidelines for outdoor conditions (Johansson et al., 2014). The following sections of this chapter elaborate thermal assessments methods further.

Mean Radiant Temperature (MRT)

Mean radiant temperature (MRT) is one of the most important variables in measuring thermal comfort (Mayer and Hoppe, 1987). It is defined as the "uniform temperature of an imaginary enclosure in which radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure." (ASHRAE, 1997) It accounts for the effect of heat loss and gain due to all surface temperatures and has been calculated in outdoor environments in a variety of ways which are often too expensive or complicated. A simple yet fairly accurate method of calculating MRT is to use a globe thermometer using a temperature probe and ping pong ball painted grey to measure the globe temperature (Thorsson, Lindberg, Eliasson, & Holmer, 2007). The mean radiant temperature can then be calculated using the measured globe temperature, air temperature, air velocity, according to the ISO 7726 standard (Lai et al., 2014; Thorsson et al., 2007; Kuehn et al.1970) :

$$T_{mrt} = \left[(Tg + 273.15)^4 + \frac{1.1 \times 10^8 V_a^{0.6}}{\varepsilon D^{0.4}} \times (T_g - T_a)\right]^{1/4} - 273.15 \qquad (1)$$

Where T_g is the globe temperature (^{o} C), V_a is the air velocity (m/s), D is the globe diameter (m), ε is the globe emissivity (0.95), Ta is the air temperature (^{o}C).

Thermal Indices

Previous research on thermal comfort has introduced over a hundred thermal indices, mostly developed for use in indoor thermal comfort studies (Blazejczyk et al., 2012). Broadly, these indices are divided into rational and empirical indices

(McIntyre, 1980). Rational indices are based on the heat balance principles, while empirical indices are based on subjective responses. Empirical indices are beyond the scope of this research. Of the rational indices, more commonly used indices in recent outdoor comfort research are physiological equivalent temperature (PET), predicted mean vote (PMV) & standard effective temperature (SET). Of these, PMV and SET are intended mainly for indoor conditions. PET and the fairly recent universal thermal climate index (UTCI) (Blazejczyk et al., 2013) are intended for use in outdoor environments (Johansson et al., 2014). However, since PET does not take clothing and activity levels into account, it cannot be used independently for assessing thermal conditions (Spagnolo et al. 2003; Höppe 1999) and is not calculated for this research.

Predicted Mean Votes (PMV)

Fanger (1970) assumed that the thermal environment, clothing and activity levels determined a person's thermal sensations and recorded people's these sensations on ASHRAE's seven-point scale in climate controlled experiments. From the results, he developed predicted mean votes (PMV) as an index to rate people's level of thermal comfort or discomfort in indoor conditions for given clothing, activity levels, and climatic conditions. PMV is one of the indices recommended in ISO 7730 (2005), ASHRAE Standard-55 (2010) and VDI 3787 (2008) German guidelines (Johansson et al., 2014). As Fanger (1970) developed PMV for indoor conditions, it cannot be directly used in outdoor thermal comfort research (Johansson et al., 2014; Lai et al., 2014; Chun et al., 2004) Jendritzky and Nübler (1981) made modifications to PMV to use in outdoor thermal comfort research. This modified model of PMV is known as Klima-Michel Model (KMM). Matzarakis et al. (1997) used this the modified PMV model to study conditions of heat stress in Greece. Many researchers have used PMV in outdoor and semi-outdoor thermal comfort studies (Matzarakis et al., 1997; Nikolopoulou et al., 2001; Thorsson et al., 2004). It can be calculated in *RayMan* software, distributed freely online by the authors (Matzarakis et al. 2000). RayMan complies with German guidelines VD-3787 (1998) for outdoor conditions. The following table shows the thermal perceptions and physiological stress level for corresponding PMV values. (Matzarakis et al., 1998)

Table 1: PMV and corresponding thermal perception and grades of physiological stress according to Jendritzky et al., (1990) Matzarakis and Mayer (1997).

PMV (°C)	Thermal Perception	Physiological Stress Level
	Very Cold	Extreme cold stress
-3.5		
	Cold	Strong cold stress
-2.5		
	Cool	Moderate cold stress
-1.5		
	Slightly Cool	Slight cold stress
-0.5		
	Comfortable	No thermal stress
0.5		
	Slightly Warm	Slight heat stress
1.5		
	Warm	Moderate heat stress
2.5		
	Hot	Strong heat stress
3.5		
	Very Hot	Extreme heat stress

Universal Thermal Climate Index (UTCI)

Jendritzky, Maarouf, and Staiger (2001) describe the basis of development for UTCI, making it universally applicable. In 2009, a Commission under the International Society of Biometeorology developed the Universal Thermal Climate Index (UTCI) with international collaboration under European Cooperation in Science and Technical Development - COST Action730 (2005-2009) (Blazejczyk, Jendritzky, and Bröde, 2013). According to Blazejczyk et al., (2013) UTCI is applicable for all climate and geographical locations and is represented as a temperature index, making it easy for people to relate to. The Universal Thermal Climate Index (UTCI) is based on multi-node Fiala thermoregulation modal (Fiala et al., 2012). This model includes both perceptions and physiological aspects in determining human thermal comfort conditions. It takes the active (thermoregulatory) and passive systems (anatomy) of the human body into account. UTCI is defined as “the air temperature of the reference condition causing the same model response as actual conditions.” (Błażejczyk et al., p. 7). The model is represented by an average aged male with a body weight of 73.5 kg. The IBS Commission has defined the following for the reference condition; mean radiant temperature is equal to the air temperature, an air velocity of approximately 0.5 m/s at 10 m and 0.3 m/s at 1.1m, and water vapor pressure that corresponds to a 50% relative humidity or a constant 20 hPa vapor pressure for air temperatures above 29^{o}C. The metabolic rate was assumed to be 2.3 MET ($\cong 135\ \mathrm{W/m^2}$) (Blazejczyk et al., 2013).

Krüger and Bröde (2013) studied the relationship between urban morphology and outdoor thermal comfort conditions in Curitiba and Glassgow. They used sky view factor (SVF) as a measure of urban morphology and calculated the UTCI for outdoor environments to determine the extent to which UTCI could be used to determine the impacts of urban design on the microclimate and thermal comfort for people. They calculated SVF using fish-eye photographs in *RayMan* software and UTCI using proceedures developed by Brode et al. (2012). According to Krüger et al. (2013) UTCI can provide a representation of changes in the urban design and microclimate on thermal perceptions. Lai et al. (2014) conducted outdoor thermal comfort research in northern China and found that UTCI predicted thermal comfort conditions well, while PMV provided an overestimate and the thermally acceptable PET ranges for varied with the context.

UTCI can be calculated using a UTCI online calculator or BioKlima 2.6 software that can be downloaded freely from http://www.igipz.pan.pl/Bioklima-zgik.html. It is calculated using the parameters air temperature (T_A), mean radiant temperature (MRT), relative humidity (RH) or water vapor pressure (V_p) and air velocity (V_A). Since the air velocity required for the calculation of UTCI should to be measured at 10 m above ground (Blazejczyk, Jendritzky, & Bröde, 2013), In case the air velocity is measured at a different height, an equation suggested in ASHRAE handbook (1997) to apply for height correction can be used. For the same location but different heights, the following equation can be used (Lai et al., 2014; Hwang et al., 2011; Spagnolo et al., 2003):

$$V_{a10} = V_a \left(\frac{H_{10}}{H_a}\right)^{\alpha} \qquad (2)$$

V_{a10} is the air velocity (m/s) at 10 m above ground.

V_a is the air velocity (m/s) measured by the anemometer for the study.

H_{10} is the height above ground which is 10 m in this case. H_a is the height (m) of the anemometer above ground and α is the mean speed exponent which is specific to the location. The α mean speed exponent has a value of 0.33 for large cities and a value of 0.22 for urban and suburban environment (ASHRAE Handbook Fundamentals

1997). The UTCI range between 18 - 26^{o}C is referred to as a thermally comfortable zone. The calculated UTCI values can be used to determine the corresponding stress level and physiological responses from a table provided by Blazejczyk, Jendritzky, and Bröde (2013).

2.5 Summary

Transit riders spend a considerable time in getting to and from the transit station and waiting at the transit stations. Attributes of the built environment and weather conditions can influence transit users' comfort in using the transit. Adverse weather conditions and seemingly unsafe environments can increase the perceived burdens of such a travel. Above ground transit stations such as bus stations that are semi-outdoor environments are more sensitive to adverse weather conditions as compared to underground stations that are weather protected. But the impact of weather on the comfort of people using transit stations is context specific. To study people's thermal comfort/stress conditions in semi-outdoor environments such as transit stations, research uses thermal assessment methods that are modified from indoor environments.

CHAPTER III

RESEARCH METHODS

3.1 Introduction

This thesis adds to existing literature on the relationship between transit users' experience and the built environment at semi-outdoor bus rapid transit stations. To study this relationship, the research studied eight Springfield bound Emerald Express (EmX) bus rapid transit stations located on the Green line that stretches approximately 4 miles between Eugene and Springfield in Oregon as case studies. The research recorded user perceptions to identify perceived problems and attributes' need for improvement. It also recorded attributes of the built environment to identify solutions. For user perceptions, the study recorded perceptions of satisfaction and importance regarding station attributes used in previous research relating to Accessibility, Amenities, Weather Protection and Safety (Iseki et al., 2007). For attributes of the built environment this research recorded Density, Diversity, Design and Accessibility (Ewing & Cervero, 2010; Ewing et al., 2009). For the built environment, this research measured accessibility by pedestrian catchment zone ratios and street intersection density, density by population density, design by sky view factor, street geometry, canopy shade and thermal environment, and diversity by land uses at the stations. The study recorded users' perceptions regarding pedestrian and bicycle accessibility, amenities of seating, route/schedule information, lighting, weather protection of rain, wind, sun, cold, and safety during the day and night at the case study stations.

To analyze the relationships between attributes of the built environment and users' perceptions, this research used simple linear regression lines in excel. To identify users' thermal comfort at the stations, the research used thermal assessment indices PMV and UTCI. To identify improvement need and priorities of station attributes, the research used a technique called Importance Satisfaction Analysis used by Iseki et al., (2007).

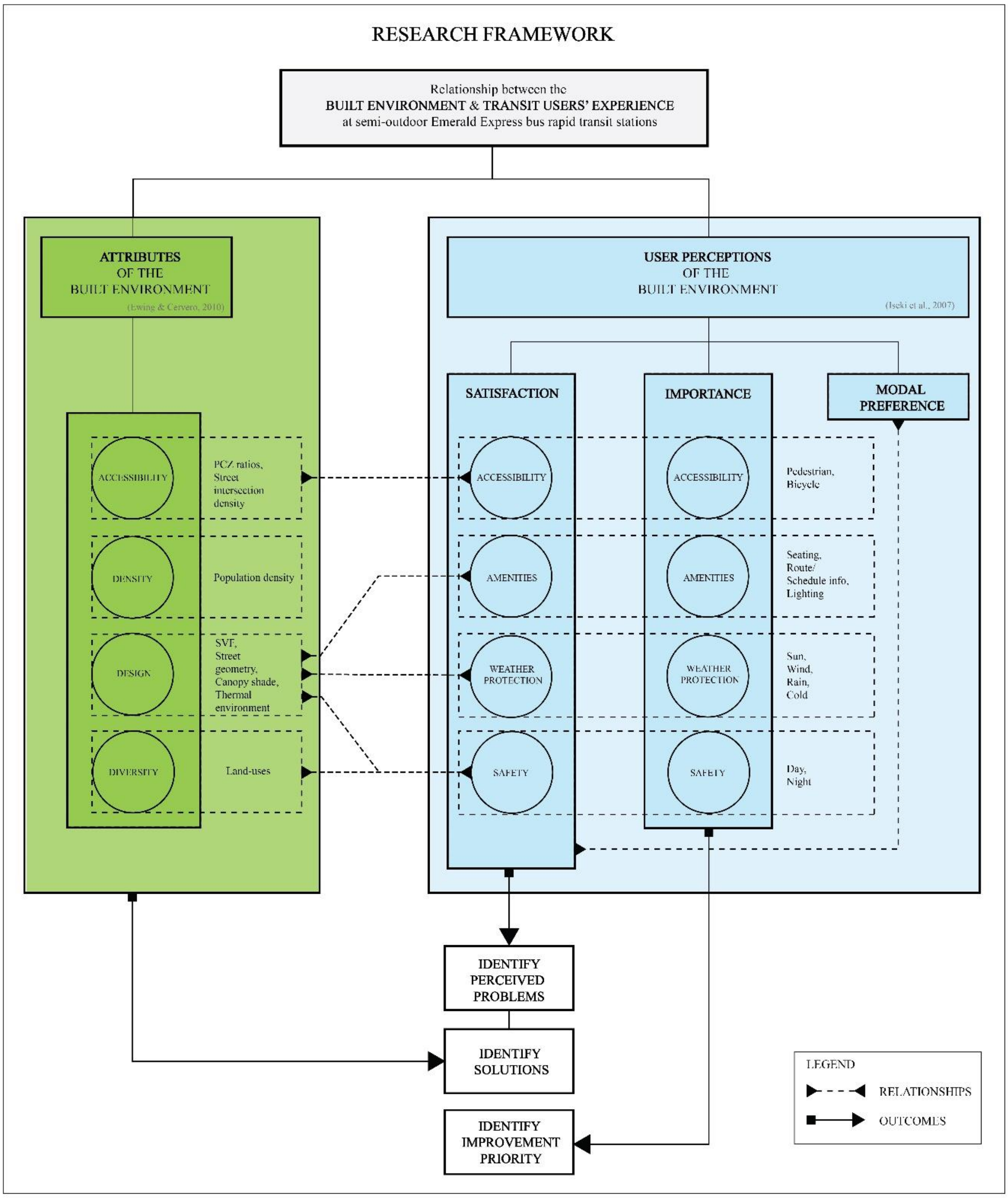
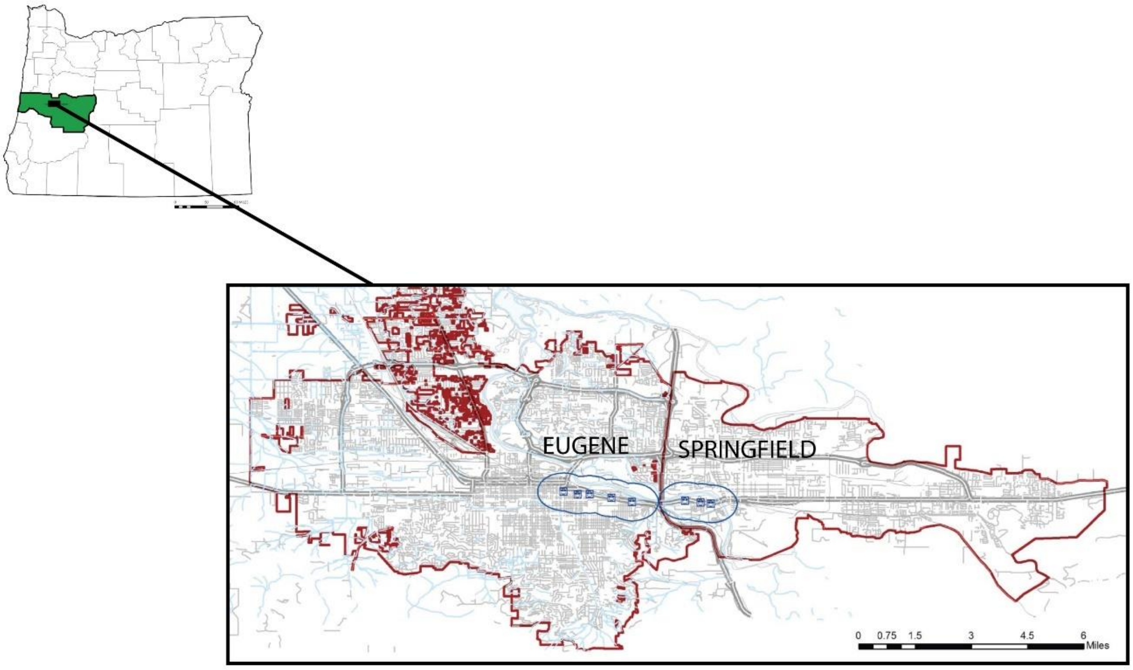


Figure 2: Research Methodology Framework

3.2 Eugene, Oregon



Map 1: Study Area on Oregon State Map

Eugene is a city located in the Pacific Northwest region at the longitude -123.221 and latitude 44.1278, in the state of Oregon in Lane County district (U S Climate Data, 2015). It has an elevation of about 426 ft. (130 m) above sea level. Eugene is the second largest city in Oregon with an approximate area of 41.5 sq. miles, population of approximately 140,000 people, located 120 miles south of Portland, Oregon.

Climate of Eugene

According to the Koppen-Geiger climate classification, Eugene lies in the warm temperate with dry and warm summer climate type (Csb) (Kottek et al., 2006). Between year 2000 and 2015, the average annual temperature of Eugene varied between 51.4^{o}F (10.8^{o}C) as the lowest average temperature recorded in 2008 to

55.5°F (13°C) as the highest average temperature in 2015. The precipitation varied between 21.22" (539mm) recorded in 2013 to highest of 50.21" (1275mm) recorded in 2012 (National Climatic Data Center). Eugene has 4674 heating degree days and 259 cooling degree days (ASHRAE, 2009).

3.3 The Station's Built Environment

3.3.1 Spatial Characteristics

This research used *ArcGIS®* software by Esri version 10.3.1 under advance license type through the University of Oregon for spatial analysis around the study sites. *ArcGIS® and ArcMap™* are the property of Esri. Copyright © Esri. All rights reserved. For more information, see www.esri.com. Data for the maps was made available by the University of Oregon's GIS library, obtained from Land Council of Governments (LCOG). This research built used the research methodology used by Schlossberg, Brown, Bossard, & Roemer (2004) for the analysis of spatial characteristics around the stations described below.

Density

This research created population density maps for a half and quarter mile radius around the study sites to compare the overall density patterns across the study sites. To do this, the csv files for total population estimates for each block group in Lane County within the state of Oregon are obtained from US Census data website http://www.census.gov/ . The block group shape files are obtained from factfinder website http://factfinder.census.gov/. To do this, csv data files data are formatted in excel and 'joined' in *Arc Map* 10.3.1 to the block group shape file in this research. The study calculated shape areas using 'Calculate Geometry' in *Arc Map* and the population density by using ‘Field Calculator’ by dividing the total population of each block group by its area. The units for population density are people per square miles. To visualize the population density distribution on a map, this study used ‘Symbology’ option to create a map with graduated colors for the calculated population densities. On the station scale, this study used Sky View Factor (SVF) as a measure of the density of the immediate built environment at the EmX bus rapid transit stations, (SVF described in section 3.3.2).

Land-use Diversity

This study created land-use maps in *Arc Map* 10.3.1 to analyze the diversity of land-use for an area of a half and quarter mile radius around the EmX stations. The study classified land-uses based on the property classification established by Oregon Secretary of State Archives Division (Ratio Technicians Group and the Department of Revenue, n.d.), and grouped land-uses into broad categories. The study calculated the total areas of the land-use categories to calculate the percentage of the total area associated with each land-use within a half and quarter mile radius for an understanding of land-use mix in the area. The land-use types within a half mile radius if the station are commercial, residential, multi-family, public land and vacant. The label ‘other’ refer to street infrastructure, miscellaneous refer to mostly unbuildable areas.

Pedestrian accessibility

For the purpose of studying pedestrian accessibility of EmX bus stations, this thesis used analysis techniques for spatial indicators of the street network described by Schlossberg, Brown, Bossard, & Roemer (2004) namely street classification, street intersection density and pedestrian catchment zones. The authors suggest that the techniques are applicable for any area in the United States. This thesis used this technique to study the pedestrian accessibility for a half and quarter mile radius around the EmX stations which correspond to a ten and five minutes walking distance. This thesis classified the street network into streets hostile for pedestrians 'Impedance Roads' such as freeways and major arterials, and pedestrian friendly streets in Arc GIS. The hostile streets were removed to determine pedestrian friendly street network This research then used this impedance free street network to created street intersection density maps to analyze the pedestrian accessibility around the stations based on the connectivity of the street network. Street intersections are points in a street network that represent choices of paths for the pedestrians. A higher intersection density of the street network can be considered more connected and pedestrian friendly since it is representative of more path choices for the pedestrians (Schlossberg et al., 2004; Cervero & Kockelman, 1997; Handy, 1996). The street intersection density maps help visualize the location and intensity of the densities in order to analyze the pedestrian accessibility around EmX stations, and identify areas that need more intersections.

To study the walkability of the street network based on the nearness to stations, this thesis also calculated Pedestrian Catchment Zones (PCZs) in Arc GIS software, using a tool extension called 'Network Analyst' in Arc Map (Brown, 2003; Schlossberg et al., 2004). Pedestrian Catchment Zones are coverage areas around a point of interest, (in this case EmX bus stations) that correspond to a ten to five minutes walking distance around a station based on the street network. The pedestrian catchment zones measure how pedestrian friendly or hostile the street network within the catchment zones are, identifying areas than need improvement. This thesis represented PCZs spatially on a map in order to analyze the degree of walkability around the stations and identify the areas that need improvement (Brown, 2003; Schlossberg et al., 2004).

3.3.2 Design Characteristics

Street Geometry

Many researchers have studied the relation between design of the built environment and urban climate, by measuring the street height to width ratios, orientation of streets (Ali-Toudert and Mayer 2007; Ali-Toudert & Mayer, 2006; Ali-Toudert, 2005; Emmanuel, Rosenlund, & Johansson, 2007) and sky view factor as a measure of the complex geometry of the built environment (Andreou, 2013). This thesis used a similar approach to calculate the street geometry by measuring height to width ratios, orientation of the streets and the sky view factors at the case study sites.

Station Design

Researchers have studied thermal comfort conditions in semi-outdoor environments, few of which have also studied transit stations, mentioned in chapter 2. Few researchers have studied the relationship between the designs of the transit station and users' thermal comfort conditions (Lin, Matzarakis, & Huang, 2006; Bryan, 2001). This thesis categorized semi-outdoor EmX bus rapid transit stations into three types based on their location as in the street center or side and boarding function as single or two platforms.

Sky View Factor

Sky view factor is a measure of sky visible which affects the amount of radiation at any location. It is a dimensionless factor with a value of 1 for an entirely unobstructed sky view and 0 for a completely covered or obstructed view of the sky (Chapman & Thornes, 2004). Many researchers have used sky view factor as a measure of complexity of the built environment in the study of urban climate (Tan, Wong, & Jusuf, 2013; Kruger, Minella, & Rasia, 2011; Krüger & Bröde, 2013; Lin, Matzarakis, & Hwang, 2010) and suggest a strong relation between air temperature and sky view factor in a built environment (Svensson, 2004). Some researchers have used sky view factor to study thermal comfort at semi-outdoor bus shelters and found that SVF could affect thermal comfort conditions (Lin et al., 2006). Based on past literature, Kruger et al. (2011) suggest that there are many ways of calculating the sky view factor. Some of these methods involve modelling the built environment to account for the height-width ratios and street orientations, while others involve using fish-eye photographs (Steyn, 1980).

This research uses fish-eye photographs and *RayMan* software to calculate the sky view factor (Taleghani et al. 2014; Krüger and Bröde 2013; Kruger et al. 2011; Matzarakis et al. 2010; Lin et al., 2006; Matzarakis, Rutz & Mayer, 2006). The height at which these fish-eye photographs are taken affects the value of sky view factor calculated (Svensson, 2004). This research used a digital SLR Canon EOS 5D camera with a sigma EXDG 8mm fish-eye lens, fixed on a tripod stand to capture fish-eye photographs at 33" above the surface, roughly at the same height and location at which the globe temperature was measured for the calculation of the mean radiant temperature.

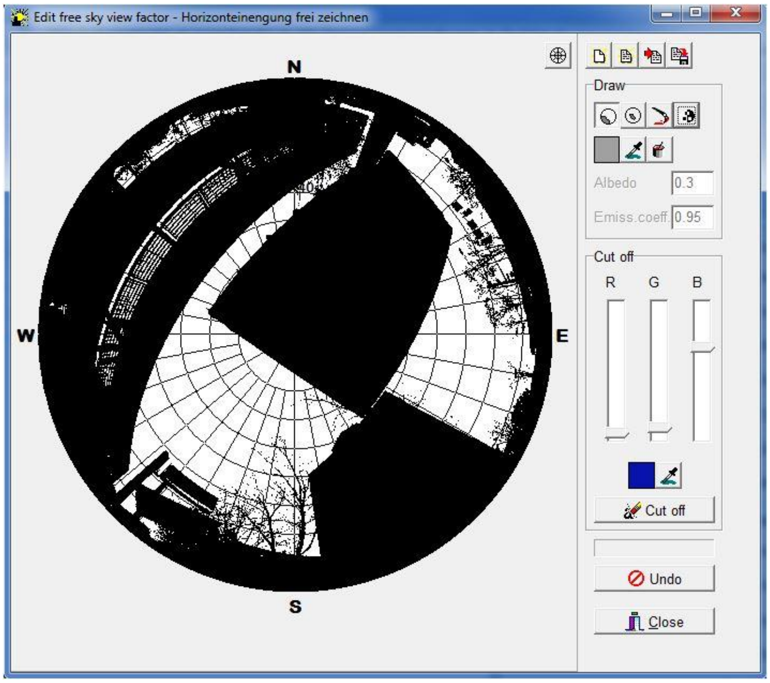


Figure 3 *RayMan* 1.2 window for calculating Sky View Factor.

3.4 Thermal Environment

Climate Data Measurement

As mentioned in chapter 2, the six parameters that affect human thermal comfort are air temperature (T_A), air velocity (V_A), relative humidity (RH), mean radiant temperature (MRT), a person's clothing insulation (Clo) and metabolic activity (Met) (Fanger, 1970). For this research, a portable micro-weather station, using sensors mounted on a tripod stand measured the air temperature, relative humidity, air velocity and the globe temperature. The research used globe temperature to calculate mean radiant temperature, and ASHRAE Handbook to get relevant values for clothing insulation and metabolic activity (ASHRAE, 1997). These measurements were used to calculate thermal indices (PMVand UTCI) for the assessment of the thermal environment at the respective EmX bus stations.

Measurement Instrument

This research used a portable micro-weather station to make meteorological measurements. The weather consisted of two Onset HOBO U-12-012 data loggers mounted on a tripod with a solar radiation shield to protect the data loggers from direct solar radiation and rain, a REED SD 4214 hot wire anemometer and a globe thermometer. It was designed to be light weight to be easily carried to the research sites. This research used a globe thermometer made using an Onset TMC6-HD probe fitted in a 0.4m (40mm) diameter ping-pong ball painted flat grey (RAL-7001) (Thorsson, Honjo, Lindberg, Eliasson, & Lim, 2007). One Hobo U-12-012 data logger recorded the air temperature and relative humidity through its internal channels, while the other also recorded the globe temperature using its external channel connected to the globe thermometer. Two data loggers were used as a safety measure to check for any malfunctioning in the equipment. REED hotwire anemometer recorded the air velocity using a Scan Disk memory card. This micro-weather station recorded all measurements at a 1-minute interval. It measured air temperature and relative humidity at a height of 0.6m (23.6”), the globe temperature at 0.8m (33”), and the air velocity at 1.2m (47”) above the surface of the EmX bus station platforms.

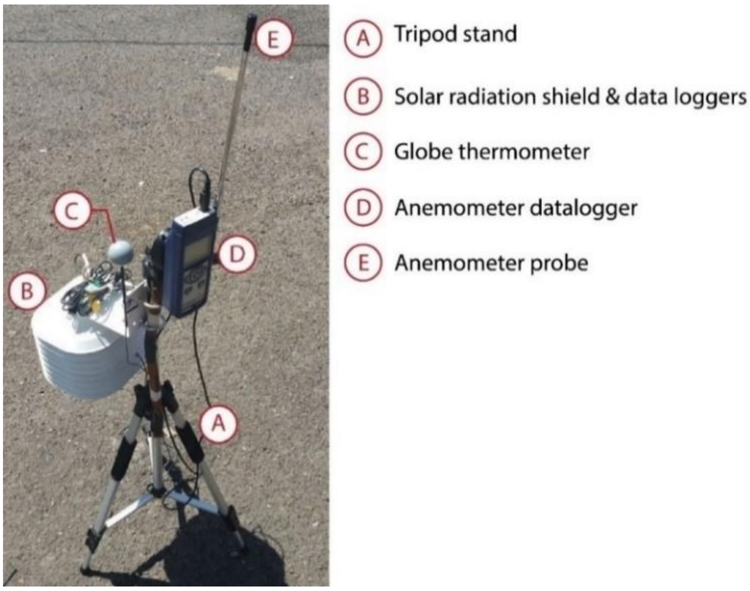


Figure 4: Portable weather station

Measurement Period

The measurement period for this research began in May 2015 and ended in March 2016. The research measured climate data for two consecutive days every month between 9:00 a.m. and 6:00 p.m. On day one of the measurement campaign, the study recorded climate data at High Street Station between 9:00 a.m. - 11:00 a.m., followed by Hilyard Station between 11:15 a.m. - 1:15 p.m., Dads' Gates Station between 1:20 p.m. – 3:20 p.m. and Agate Station between 3:30 p.m. – 5:30 p.m. One day two, the study recorded climate data at Walnut Station, Glenwood Station, Lexington Station and McVay Station in the same order and time periods.

Mean Radiant Temperature

A 150 mm black copper globe thermometer, often used for indoor thermal comfort research (ISO 7730, 1998) reaches equilibrium in approximately 20-30 minutes (Spagnolo and de Dear 2003; (ISO 7730, 1998), hence it is not suitable for use in outdoor environments (Spagnolo and de Dear 2003). According to Thorsson et al. (2007), a globe thermometer made using a flat grey painted ping-pong ball painted gray is a fairly accurate, simple, cheap and mobile method that can be used for the estimation of mean radiant temperature in complex outdoor urban environments. For this research, the mean radiant temperature is calculated using the measured globe temperature, air temperature, air velocity and the equation (1) with a globe emissivity of 0.3 for a grey ping pong ball (Pantavou et al., 2014). Re-calibrating this equation can further improve the calculations of mean radiant temperature for outdoor conditions but this recalibration is specific to location and the equipment used.(Tan, Wong, Jusuf, & Chiam, 2015; Johansson et al., 2014; Thorsson et al., 2007). It should be noted that the units for the diameter should be consistent in the equation. For the equation mentioned by Thorsson et al., (2007), if air velocity is in meters per second, the diameter should be in meters.

Measurement Protocol

This research recorded thermal measurements and conducted paper surveys of riders simultaneously at each of the eight outbound EmX bus stations located on the Green Line connecting Eugene to Springfield. A portable micro-weather station recorded the thermal measurements for approximately two hours at each of the eight EmX bus stations selected for this research for two consecutive days every month from May 2015 to March 2016, between 9:00 a.m. and 6:00 p.m. each day. The research followed the following protocol:

1. The HOBO U-12-012 data loggers were pre-set to automatically start recording measurements at 8:50 a.m. on day one.
2. On day one, the micro-weather station was carried to EmX Springfield bound High Street Station.

3. The pre-set HOBO U-12-012 data loggers automatically started recording measurements of air temperature, globe temperature and relative humidity while the anemometer was manually started to record air velocity at approximately 9:00 a.m.
4. While waiting at the bus station for the thermal measurements, paper surveys were handed out to the passengers. The protocol for conducting paper surveys is described earlier in this thesis.
5. The measurements were recorded for approximately two hours after which the anemometer was stopped and the micro-weather station was carried to the next bus station. The procedure was repeated at the following stations namely; Hilyard Street Station, followed by Dads' Gates Station and Agate Station. At each station the weather station was placed roughly at the same location for the study, under the shade of the bus station.
6. The data was retrieved from HOBO U-12-012 data loggers using HOBOware software and exported into an excel sheet. Air velocity data was retrieved using a memory card reader connected to a PC and copied into an excel sheet.
7. On day two, the micro-weather station was carried to Walnut Station and the same protocol was repeated followed by Gleenwood Station, Lexington Station, and McVay.
8. The formatted data was then used to calculate thermal indices for the assessment of the thermal comfort at the bus stations.

Data Processing

This research used HOBOware software to retrieve the recorded measurements from HOBO U-12-012 data loggers and a memory card reader to retrieve air velocity measurements from the anemometer. It excluded the first 30 minutes of recorded measurements at the first station and first fifteen minutes on the following stations for both days of the measurement campaigns to allow sensors to come to equilibrium with the ambient conditions following the travel. The data from the HOBO U-12-012 data loggers was matched using timestamp with the air velocity data and formatted in Microsoft Excel. The study used equation (1) to calculate the mean radiant temperature and calculated the mean, median, mode, standard deviation, maximum and minimum values at each station.

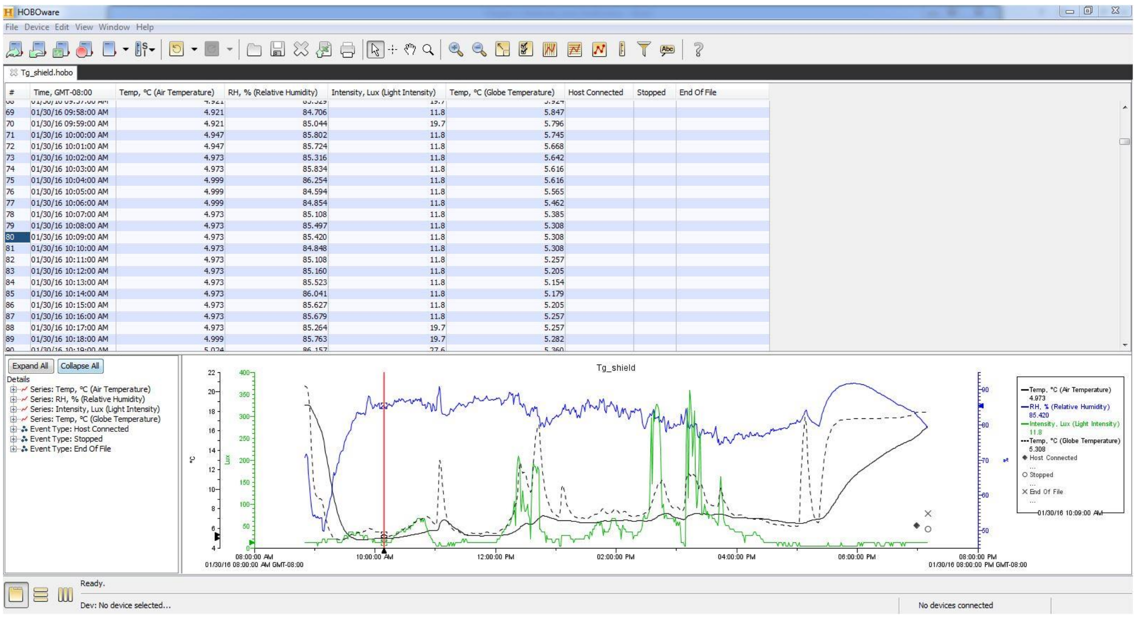


Figure 5 Screenshot of retrieving data from HOBO data logger.

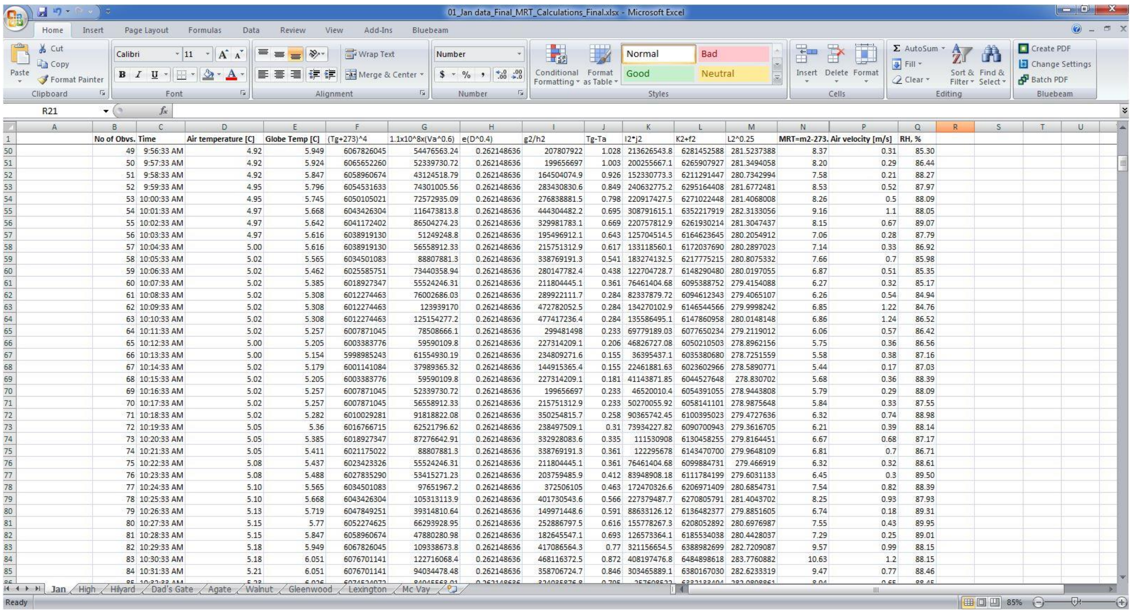


Figure 6 Screenshot of data formatting in excel.

Calculation of Thermal Assessment Indices

As described in chapter 2, this research calculated the thermal indices Predicted Mean Vote (PMV) and Universal Thermal Climate Index (UTCI) for the assessment of the thermal environment and user thermal comfort at EmX bus stations. For the calculation of thermal indices PMV and UTCI, this research categorized months into four seasons according to Oregon's climate and assigned a suitable clothing insulation value for each season in Eugene, Oregon. The research used the metabolic activity of a person standing in a relaxed position 126W (1.2 met or 70 W/m^2) was for all seasons. This research used *RayMan* software version 1.2 to calculate PMV (Matzarakis et al. 2000) and determined thermal stress sensations for the calculated PMV values from the table 1. The research used a software called *BioKlima* version 2.6 to calculate UTCI. *BioKlima* is a Windows software made freely available for use by the authors. It can be used to calculate 57 different bioclimatic indices (Blazejczyk, Jendritzky, and Bröde 2013). The input data variables for the calculation of UTCI in this study were the month, day of the month, hour (0-23), minutes (0-60), air temperature (^{o}C), relative humidity (%), air velocity at 10m (m/s), mean radiant temperature (^{o}C), clothing insulation value (clo), latitude (degree. minute) and metabolism (W/m^2). The research used a color coded assessment scale available at http://www.utci.org/utci_doku.php to analyze conditions of thermal stress for calculated UTCI values using in MS Excel. This research used a comparable color coded scale to represent thermal comfort conditions for PMV values to create heat maps for each study site for the period of study.

UTCI (°C) range	Stress Category
above +46	extreme heat stress
+38 to +46	very strong heat stress
+32 to +38	strong heat stress
+26 to +32	moderate heat stress
+9 to +26	no thermal stress
+9 to 0	slight cold stress
0 to -13	moderate cold stress
-13 to -27	strong cold stress
-27 to -40	very strong cold stress
below -40	extreme cold stress

PMV (C)	Thermal Perception	Stress Category
+4	Very Hot	Extreme Heat Stress
+3	Hot	Strong Heat Stress
+2	Warm	Moderate Heat Stress
+1	Slightly Warm	Slight Heat Stress
0	Comfortable	No Thermal Stress
-1	Slightly Cool	Slight Cold Stress
-2	Cool	Moderate Cold Stress
-3	Cold	Strong Cold Stress
-4	Very Cold	Extreme Cold Stress

Figure 7: UTCI (Blazejczyk, Jendritzky, and Bröde 2013) and PMV (Jendritzky et al., 1990; Matzarakis and Mayer, 1997) color coded assessment scales

3.5 User Surveys

Survey Tool

In order to determine people's perceptions of satisfaction at EmX bus rapid transit stations, this research used a paper survey originally developed by Iseki et al. (2007) to evaluate the transit stations and stops in Los Angeles, California. This research modified the survey to meet the requirements of the study and was approved by the Office for the Protection of Human Subjects at University of Oregon as minimal risk research on 09-03-2015. The study was submitted under the protocol number 07272015.027 and title ‘Evaluating the Built Environment and Overall User Comfort and Perceptions at Bus Rapid Transit (Emerald Express) Stations in Eugene, Oregon. (See Appendix-B, Survey Tool). The survey was tested to be completed in approximately 2 minutes by passengers waiting at the EmX bus rapid transit stations. The survey had two parts; the first included questions on demography, purpose of the trip, frequency of the trip, how people got to the station and their preference of making the trip by car or EmX. The second part of the survey asked respondents to identify their satisfaction and importance of station amenities, weather protection, safety, and pedestrian or bicycle access of the stations on a Likert scale from 1 to 4, 1 being the least satisfied and unimportant (Iseki et al., 2007). A total of 162 surveys were completed. This research formatted the surveys in MS Excel and used *SAS studio* for statistical analysis and to determine an Importance-Satisfaction Rating at each station as was done by Iseki et al., (2007). *SAS studio* is an online freely available software for statistical analysis.

Survey Protocol

1. After receiving the approval, the research conducted the paper surveys using a clip board and pen at each EmX bus station simultaneously while recording the thermal measurements.
2. Each paper survey included a briefly verbal and written explanation of the research purpose, and that participation was voluntary and anonymous.
3. The surveyed population was a random sample based on who was present at the stations and volunteered to participate for the entire length of the study.
4. Each participant filled out one survey and handed it back after completing it.
5. The research formatted the paper surveys using Google Forms and MS Excel. The research used SAS studio an online software for statistical analysis and to get the Importance-Satisfaction ratings for each EmX bus station.

Survey Limitations

The research was limited on the availability and willingness of passengers to participate at some bus stations. As a result, the initial goal of 25 surveys per station could not be achieved at some of these bus stations namely; Gleenwood, Lexington and McVay.

Survey Analysis

This research used an analysis technique called Importance-Satisfaction/Performance Analysis as used by Iseki et al., (2007) to analyze the survey responses. This analysis technique was originally developed by Martilla & James, (1977) as a marketing research technique and has since been used to analyze customer satisfaction of services in many fields such as tourism, health care and people's image of cities and suggest marketing strategies for improvement (Hudson & Shephard, 1998; Joppe, Martin, & Waalen, 2001; Joppe, Martin, & Waalen, 2001).

The number of respondents that responded ‘4=Very Important’ and ‘3=Important’ were added to calculate the percentage of respondents for whom an attribute was important. Similarly, the percentage of respondents who were satisfied with an attribute were calculated by adding those that identified ‘4=Strongly Agree’ and ‘3=Agree Somewhat’ in the paper surveys. According to their importance and satisfaction ratings, the station attributes were plotted on a quadrant plot. The arithmetic mean (average) of the importance and satisfaction ratings was used to determine the axis in the quadrant plots. Attributes that the respondents identified with above average importance and satisfaction ratings were good enough but should be maintained consistently because of their priority among users, identified as ‘Prioritize Maintenance’. Attributes that respondents identified with below average satisfaction ratings and above average importance ratings were identified as needing improvement; quadrant labelled ‘Improve’. Attributes that respondents identified with below average importance and satisfaction ratings were less important; quadrant labelled ‘Low Priority’. Attributes that respondents identified with above average satisfaction ratings and below average importance ratings were identified ‘Well Satisfied’ and not needing improvement. This analysis also calculated an Importance-Satisfaction Rating (IS Rating) by multiplying the importance and (1-satisfaction ratings). The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction with it. The lower the IS rating, the lesser the higher the respondents’ satisfaction of it and the lesser the importance, indicating lower need for improvement (Iseki et al., 2007, p. 32-33).

This research used simple linear regression lines fitted in excel to study the relationship trends between users' perceptions of satisfaction and attributes of the built environment.

3.6 Summary

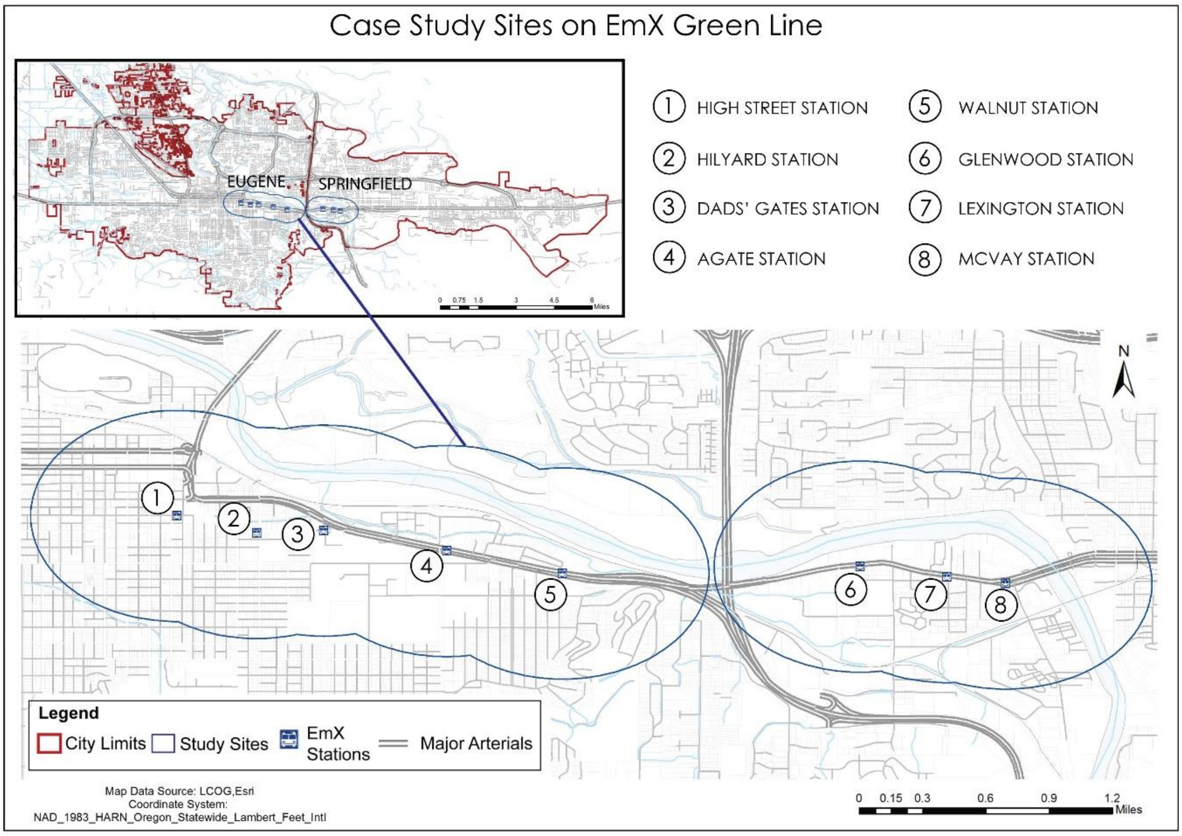
This chapter described the geographical location and context of the case study sites. It outlined the research framework and presented the methodologies used to study attributes of the built environment, along with the survey techniques used to determine users' perceptions at Emerald Express bus rapid transit stations. The protocols, software and instruments used for each part were introduced. The methods for retrieving, formatting and analyzing the data were also described.

CHAPTER IV
RESULTS, ANALYSIS & DISCUSSIONS

4.1 Introduction

This chapter presents the results, analysis and discussions of the attributes of the built environment and user perceptions at the EmX BRT stations. First it presents the survey demographics and respondent's travel behavior for all stations combined. It then divides each station's results and analysis into three sections: the station design and it's built environment, assessment of the thermal environment and analysis of survey responses. The order of the stations in this chapter is the order in which they occur between Eugene and Springfield Station namely; High Street Station, Hilyard Station, Dads' Gates Station, Agate Station, Walnut Station, Glenwood Station, Lexington Station and McVay Station.

The station and it's built environment present results and analysis of the street geometry, sky view factor, station designs characteristics, population density, land use diversity and pedestrian accessibility. Assessment of the thermal environment presents measurements of climate data at the stations and identification of thermal stress categories at the stations. The survey results section presents respondents' demographic information, their travel behavior regarding and the importance-satisfaction analysis to identify perceive problems and priorities of improvement among station attributes based on users' importance and satisfaction ratings.



Map 2: Location of the selected EmX Stations for the research

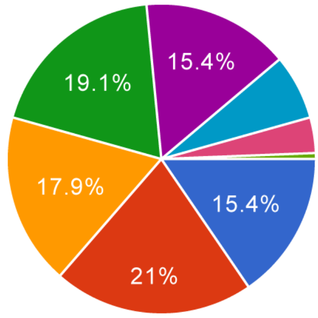
4.2 Survey Information

Survey Demographics

This study conducted 162 paper surveys. Table 2 shows the number of surveys conducted at each station. Since participation in the surveys was voluntary and station specific, the number of surveys conducted at each station reflects the availability and willingness of respondents to participate.

Table 2: Number of surveys completed per station

Station	Frequency	Percentage
High Street Station	25	15.4%
Hilyard Station	34	21.0%
Dads' Gate Station	29	17.9%
Agate Station	31	19.1%
Walnut Station	25	15.4%
Glenwood Station	11	6.8%
Lexington Station	6	3.7%
McVay Station	1	0.6%
Total	**162**	**100%**



Of the total 162 survey respondents, a majority of 56% identified themselves as females and 40 % as males. Five respondents did not specify the gender and one identified as 'Other'. A majority of 53% respondents identified themselves in the age group of 20-29 years. Approximately the same number of respondents identified themselves within the age groups of 10-19 and 30-39 years. Figure 8 shows the age distribution of the survey respondents.

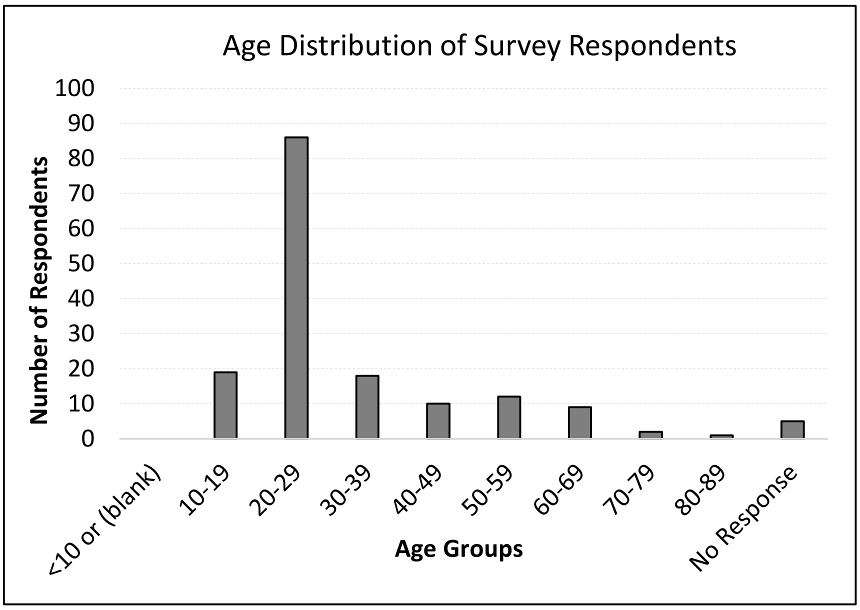


Figure 8: Age distribution of survey respondents.

Of the total 162 survey respondents, three did not identify their ethnicity/race. A majority of 51.8% respondents identified themselves as Anglo/White, approximately 29% identified themselves as Asian/ Pacific Islander and 9.3 % identified as Hispanic/Latino.

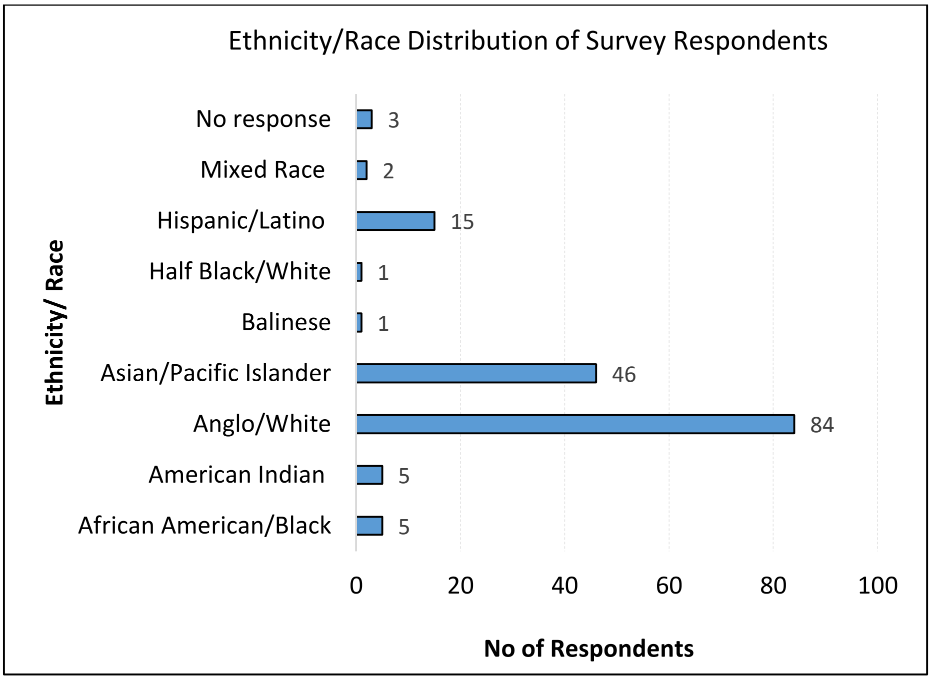


Figure 9: Distribution of Ethnicity/Race of Survey Respondents

Respondents' Travel Behavior

Of the total 162 survey respondents, approximately 80% specified that they rode EmX at least 3 days a week. A major purpose of the respondent's trip was for 'college/school' and for 'work/job'. Figure 10 shows that a majority of survey respondents usually walked to stations and from the stations. Results indicate that more people took a bus to get to their destination as compared to on their way to the station. Figure 11 shows that of all the respondents, slightly greater number of people preferred EmX to cars for making the particular trip.

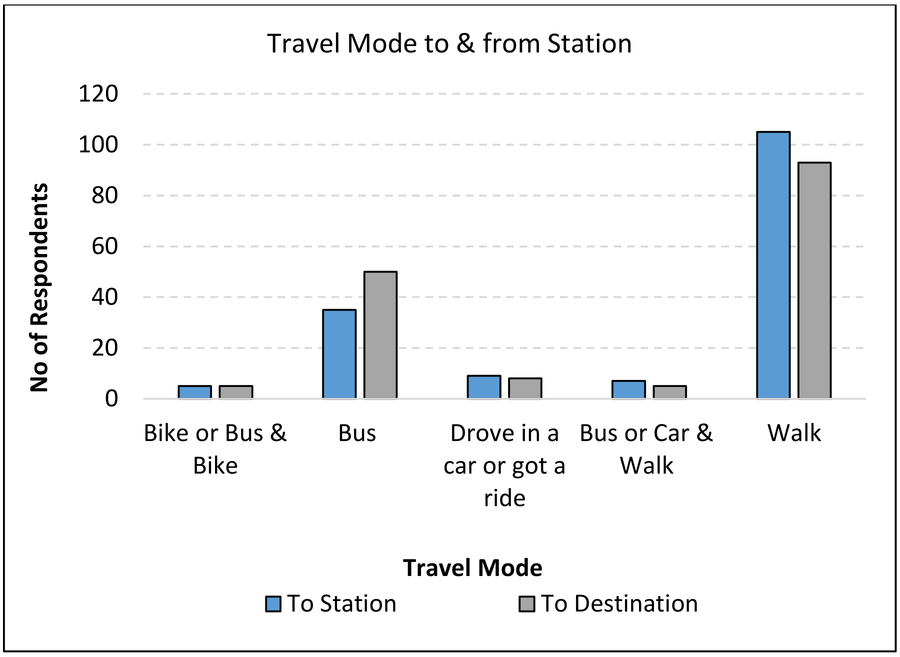


Figure 10: Mode of travel to & from stations

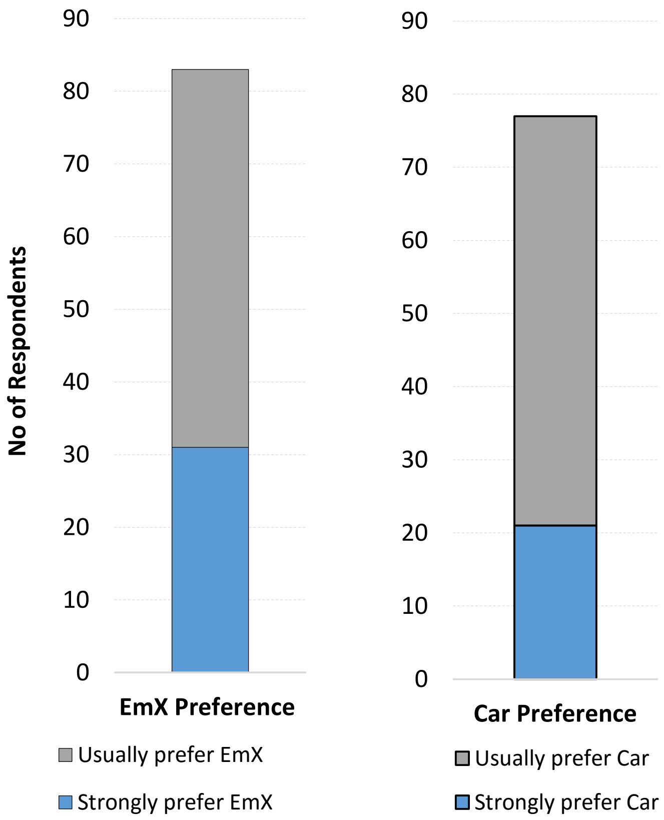


Figure 11: Modal Preference for the trip

4.3 High Street Station

4.3.1 The Station and Built Environment

Street Geometry

High Street Station is located between High and Mill Streets on East 10th Ave. It serves Springfield bound EmX buses. The platform faces a seven floor (approx. 78 feet high) luxury apartment building about 46 feet south of the station. Between the station platform and this apartment building, trees varying between 60 to 70 feet height line the street. To the north, the station is bordered by University of Oregon Downtown Baker Center which is a two floor high building (approx. 26 feet high) about 12 feet away. The height to width ratio of the street at roughly the center of the station is between 1:3 and 1:1 as shown in Figure 13. The buildings on either sides of the station block distant views across the street creating a sense of enclosure. The sky view factor (SVF) provides a measure of the shading at High Street Station, which is a result of the station canopy structure as well as the density of built environment around the station. Here, density of the built environment is a result of building height and spacing as well as presence of trees and other structures. The maximum value of SVF can be one. A lower value indicates a higher density of the built environment. At High Street Station, the SVF is 0.274.

Figure 12: Aerial View of High Street Station. Source: Google Earth Pro

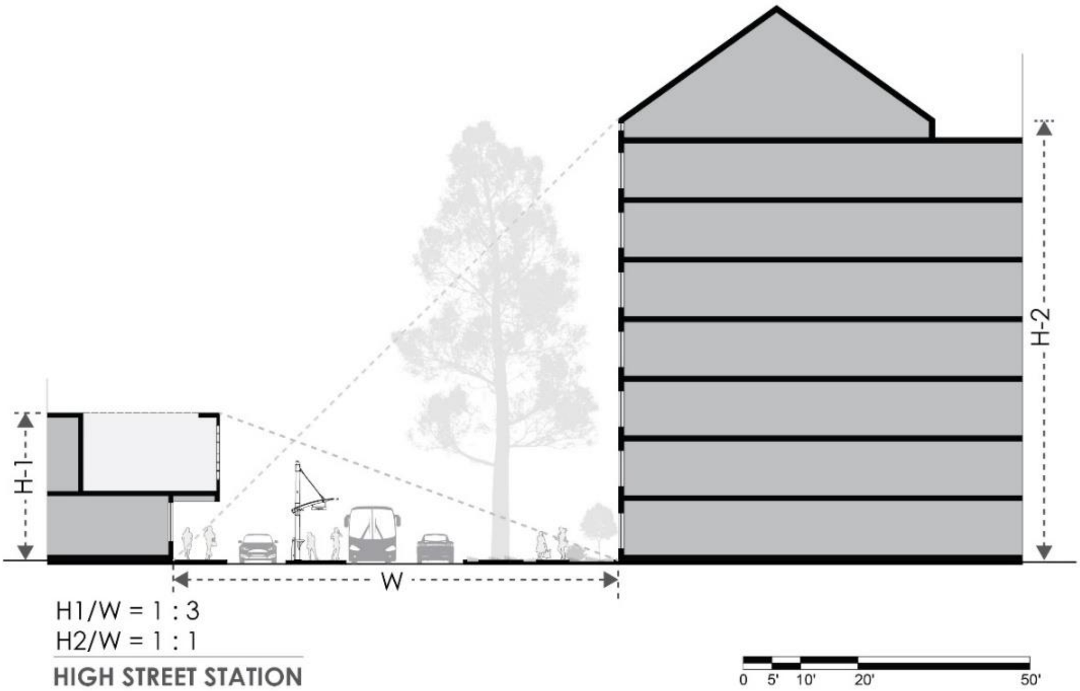


Figure 13: Street Height-to-Width Ratio

0.274

Figure 14: SVF at High Street Station

Station Description

This station is a center island station with a single boarding platform, connected to the sidewalk via a crosswalk at the west end. The station platform is oriented north south, with the boarding platform facing south. The station canopy structures (30’-6” in linear length) cover 16.5 % area of the platform. The platform is 73’-0” long and 14’-0” wide. The station has 7’-4” linear length of seating, real time bus schedule, bike rack, bus route information, trashcans and a ticketing booth.

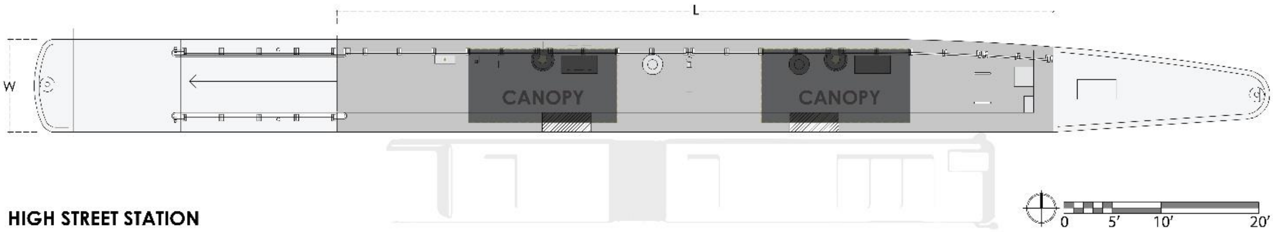


Figure 15: Plan of High Street Station

Density

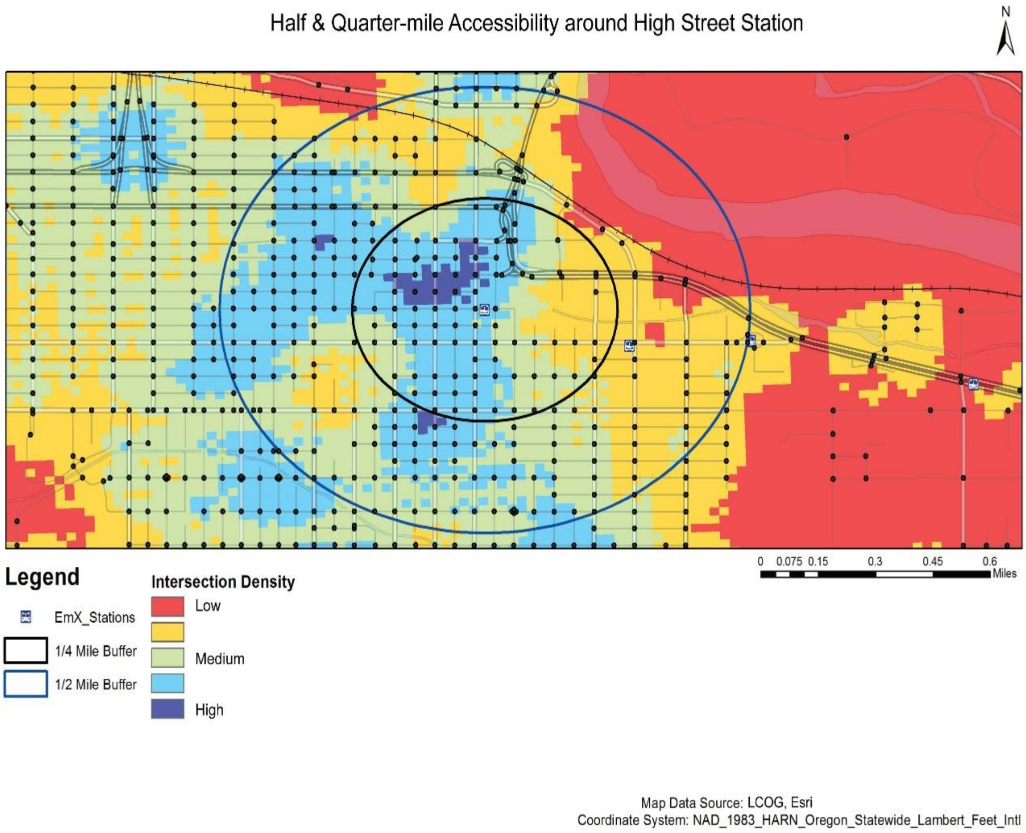
The population density for the block groups around a half-mile radius of Dads’ Gates Station varies between 1475 to 98,933 people per square mile. (See Appendices, A)

Diversity

The land-use map clearly shows that the area within a half-mile of the station is predominantly commercial in use covering up to 47.25 % of the total area around station. Within a half-mile radius from the station there are more residential uses compared to within a quarter mile. University of Oregon Baker Downtown Center is located across the street to the north of High Street Station and High Street Terrace luxury apartments are located to the south of the station.

Accessibility

The pedestrian catchment zones for a quarter and half-mile radius around the station show that the street network is good for walking. The maps show that the street network further away from the station is denser as compared to within a quarter mile. This indicates that the walkability for a quarter mile radius around the station is lower as compared to within a half-mile radius. Map 3 shows that to the west of the station, intersection density is mostly high within a quarter mile distance and varies from high to medium up to a half-mile. To the east of the station, street intersection density decreases further from the station from medium to low. This indicates better pedestrian access to the station to the west and south (blue areas in the map) as compared to the east of the High Street Station.



Map 3: Street Intersection Density around High Street Station

4.3.2 Thermal Comfort Assessment

In this section, the thesis summaries the measured climate data at each research site for a ten-month long period. It identifies the thermal stress categories according to the calculated assessment indices Predicted Mean Votes (PMV) and Universal Thermal Climate Index (UTCI) in order to identify the seasons for which the thermal conditions are outside the thermal comfort zone.

Thermal Environment

This thesis measured and recorded climate data at High Street Station for approximately two hours a day, one day a month for a period of ten months from June 2015 and to March 2016. At High Street Station, the study recorded values of air temperature (T_A), globe temperature (Tg), air velocity (V_A), and relative humidity (RH) between 9 am and 11 am for each measurement campaign (See Chapter 3, Research Methods). Table 3 shows a statistical summary of the recorded seasonal climate data. For a summary of the recorded monthly climate data, see Appendix - D.

The highest mean air temperature of 20.20 ^{o}C occurred in the month of July and the lowest in December (4.64 ^{o}C) making a wide range of 16 ^{o}C. The mean value of the mean radiant temperature (MRT) was also the highest (39.06 ^{o}C) for the month of July and the lowest (7.06 ^{o}C) for the month December with a wider range of 22 ^{o}C. Table 3 shows that the air temperatures fluctuated the most in winters (approximate range of 8 ^{o}C) and MRT fluctuated the most in summers. The lowest mean radiant temperature of -1.54 ^{o}C was recorded in the month of February with the highest recorded air velocity. The highest mean relative humidity (89.95 %) was recorded in the winter season and the lowest (49.85 %) in the summer season in July with the highest recorded air temperature. The mean relative humidity during the winter season was approximately 18 % higher than for the summer season. Results show that the range of air velocity is widest for winters but the values for mean air velocity indicate that the air velocity varies only slightly throughout the seasons.

Findings indicate that for the highest recorded air velocity and relative humidity, the recorded air temperature, globe temperature and mean radiant temperature were lowest and vice versa.

Table 3: Seasonal Statistical Summary at High Street Station

Season		Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	Mean	19.64	23.63	34.06	0.71	61.30
	Maximum	21.32	30.72	71.53	2.35	69.01
	Minimum	17.32	18.11	20.33	0.08	49.85
	Range	4.00	12.62	51.20	2.27	19.16
Fall	Mean	12.60	13.40	16.48	0.89	73.33
	Maximum	15.10	15.94	25.47	2.50	78.69
	Minimum	10.25	10.35	9.46	0.17	68.04
	Range	4.86	5.59	16.02	2.33	10.65
Winter	Mean	6.89	7.39	8.90	0.88	79.45
	Maximum	11.47	12.20	19.60	4.72	89.95
	Minimum	3.99	3.93	-1.54	0.14	65.88
	Range	7.48	8.26	21.14	4.58	24.07
Spring	Mean	10.30	14.07	27.04	0.79	70.45
	Maximum	11.59	16.08	42.12	1.77	75.85
	Minimum	8.47	10.25	16.08	0.13	64.83
	Range	3.12	5.84	26.03	1.64	11.02

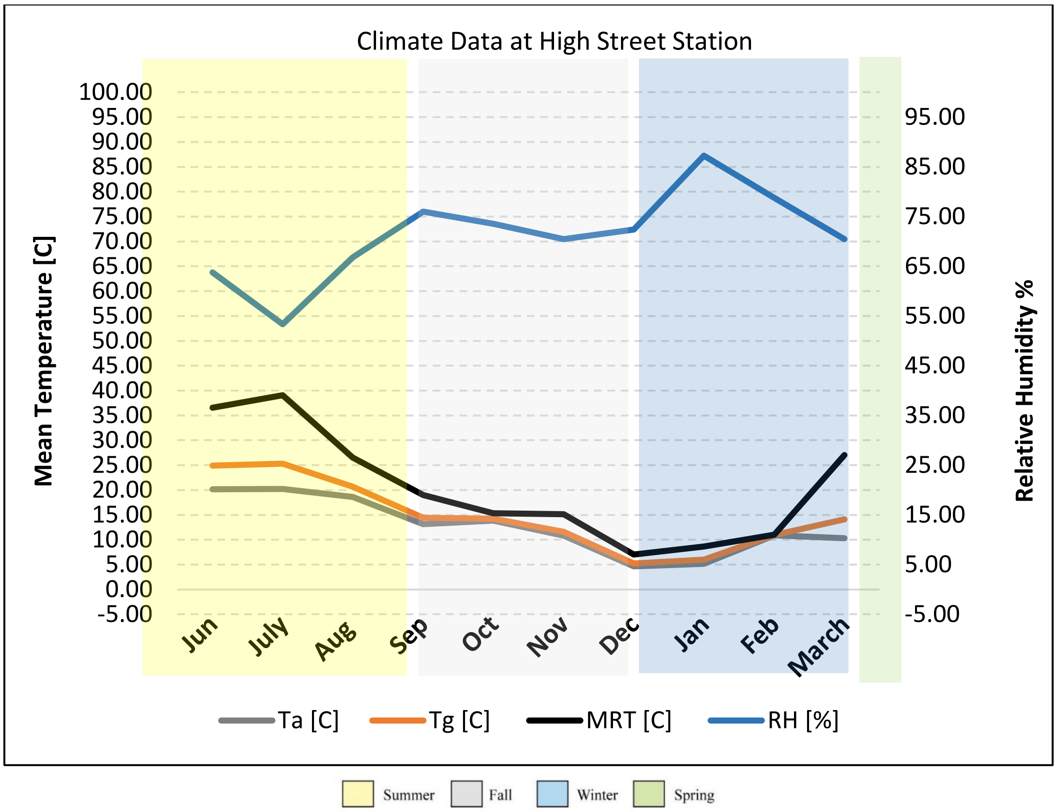


Figure 16: Recorded climate data at High Street Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating the assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at High Street Station was thermally comfortable during summer and below the comfort zone for fall, winter and spring. The coldest thermal conditions were identified in the 'Moderate Cold Stress' category for the month of November. The months identified in the 'Slight Cold Stress' category had small differences of less than 0.6 ^{o}C between 'Moderate Cold Stress' and 'Slight Cold Stress'. According to UTCI heat map, the environment at High Street Station for summer, fall and spring were thermally comfortable i.e.

under 'No Thermal Stress', and under 'Slight Cold Stress' in winters. The difference between the thermal stress categories of 'No Thermal Stress' and 'Moderate Heat Stress' in summers was between 0.8 to 5 °C, indicating that these conditions could be under heat stress.

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
High Street Station	0.74	0.78	-0.48	-1.64	-1.56	-2.54	-1.91	-1.85	-1.42	-1.55

Figure 17: PMV Thermal Stress Heat Map

UTCI (°C) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
High Street Station	25.16	25.16	20.85	14.58	14.53	10.59	6.21	7.01	7.66	15.71

Figure 18: UTCI Thermal Stress Heat Map

4.3.3 Survey Results

This thesis used a survey technique used by Iseki, Ringler, Taylor, Miller, & Smart (2007). The analysis method is called importance-satisfaction analysis (IS Analysis) that has also been used in other studies to study customer satisfaction in various fields. This thesis used surveys to study people's comfort in using EmX stations in the study area based on their importance and satisfaction of attributes related to the use of these stations. (See Chapter 3, User Surveys)

Demographic Information

Of the total 25 survey respondents at High Street Station, a majority of 14 respondents identified themselves as females. The highest number of respondents (17) identified themselves between the age group of 20-29 and 30-39 years. Results show that the majority of respondents were Anglo/White (52%) and Asian/ Pacific Islanders (24%).

Respondents' Travel Behavior

A majority of 80 % respondents at High Street Station rode EmX frequently between three to seven days. Most of the respondents made the trip for work/job (40%) and college/school (20%). Among the respondents, the highest number of people walked to and from the station or took the bus. Results indicate that in comparison to getting to the station, a greater number of people walked from the station to their destinations. Results show that a greater number of respondents at High Street Station prefer EmX to a car (60% of the total respondents) for the trip.

Importance-Satisfaction Analysis

This thesis used importance-satisfaction analysis to study people's comfort in using EmX bus stations based on the importance and satisfaction of attributes associated with the use of the stations. For explanation of this analysis method see Chapter 3, Research Methods, Survey Analysis.

Figure 19 shows the importance and satisfaction ratings of respondents at High Street Station related to attributes of weather protection (wind, sun, rain and cold), station facilities (seating, route/ schedule information and lighting), pedestrian and bicycle access, and perceptions of safety (during the day and night) at the station. Results show that respondents at High Street Station identified almost all attributes at 50 % or higher importance ratings. According to the analysis, respondents identified protection from rain, route/schedule information, station lighting, pedestrian accessibility of stations, and safety during day and night as important attributes. Findings indicate that these are good enough but need to consistent maintenance because of their importance for station users. Findings show that the respondents were extremely satisfied with bicycling access and protection from the sun, and that protection from rain at needs improvement at High Street Station.

The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction. The lower the IS rating, the lesser the importance of an attribute and the higher the satisfaction rating. (Iseki et al., 2007) Figure 20 shows the IS ratings of attributes associated with the use of stations. The figure is a funnel chart that indicates the priority of improvement of attributes. It shows that the need for improvement of protection from wind, cold and rain were of higher priority as compared to other attributes at High Street Station, however the highest IS rating is less than 50 %. This indicates that the need for improvement is not very high and respondents are generally satisfied with the station. The figure shows that improvement of safety at night and station lighting are of equal priority.

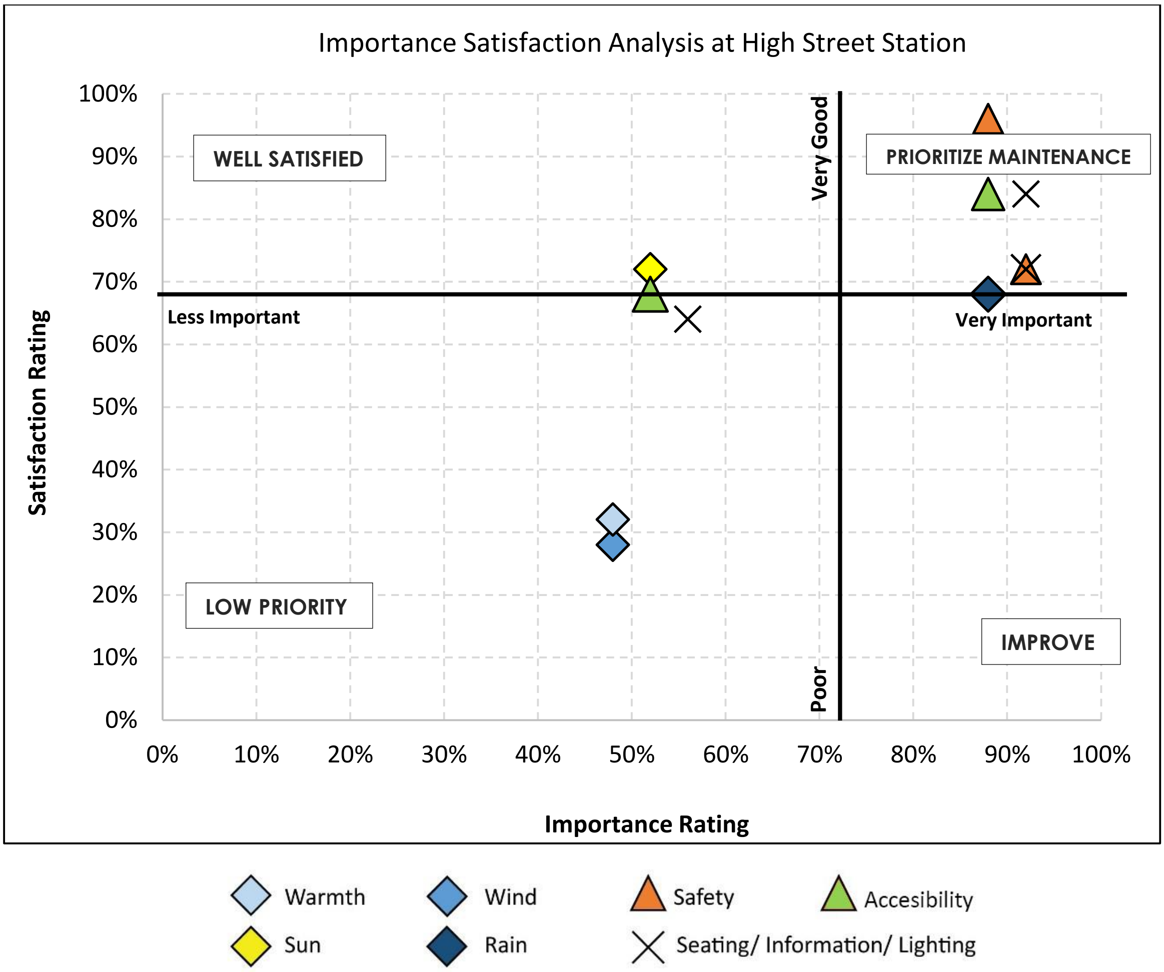


Figure 19: Importance and Satisfaction Ratings of station attributes according to the respondents at High Street Station

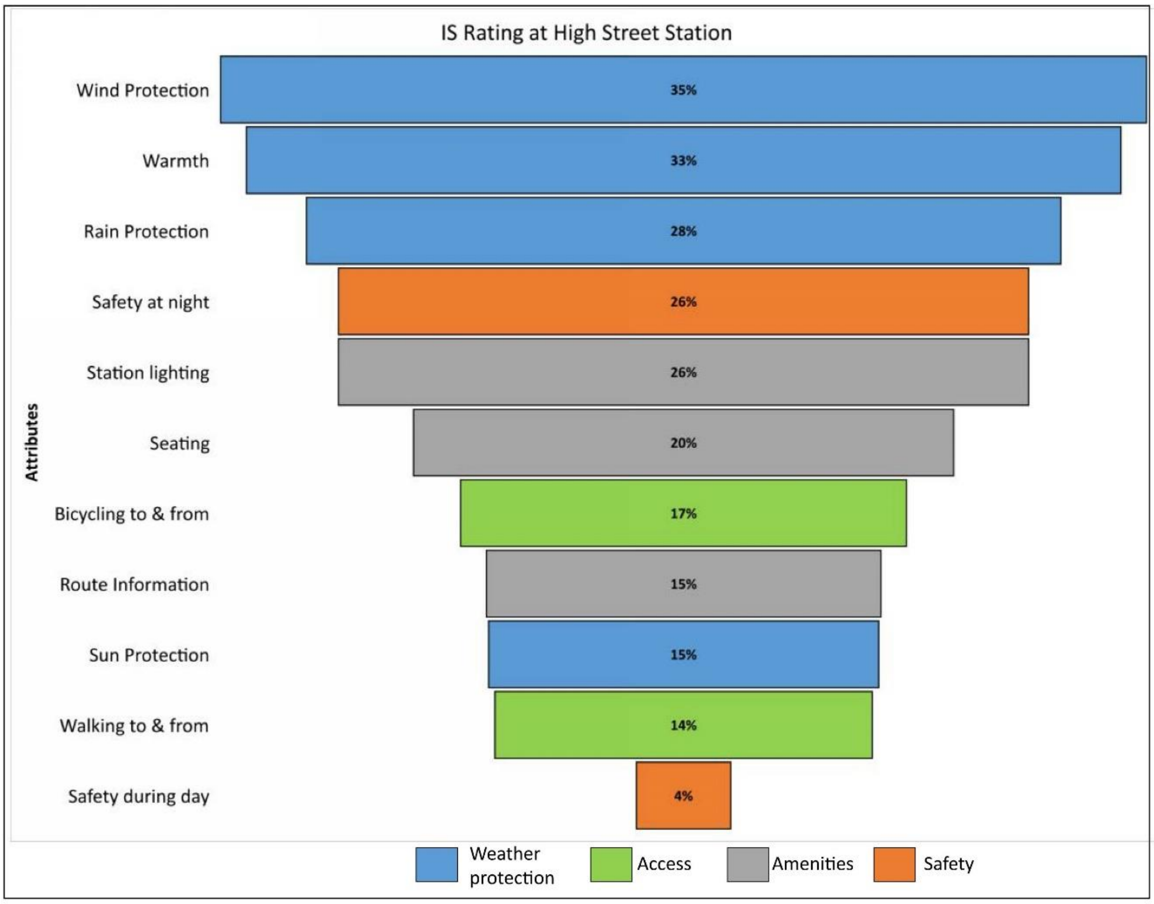


Figure 20: IS-Ratings at High Street Station

4.4 Hilyard Station

4.4.1 The Station and Built Environment

Street Geometry

Hilyard Station is located between Hilyard and Patterson Streets on East 11th Ave. Apartments and fraternity housing are located to the north of the station. A five floor high building (approx. 60 feet high), Sacred Heart Medical Center is located about 185 feet from the south of the station. The street geometry at roughly the center of the station is between 1:4.8 and 1:7.5. Since the buildings are set back with surface parking occupying the street front, the sense of enclosure here is not very strong. Sky view factor (SVF) provides a measure of the shading at Hilyard Station, which is a result of the station canopy structure as well as the density of the built environment around the station. Here the density of the built environment is a result of building height, spacing, presence of trees and other structures. The maximum value of SVF can be 1. A lower value indicates a higher density of the built environment. At Hilyard Station, the SVF is 0.258.

Figure 21: Aerial View of Hilyard Station. Source: Google Earth Pro

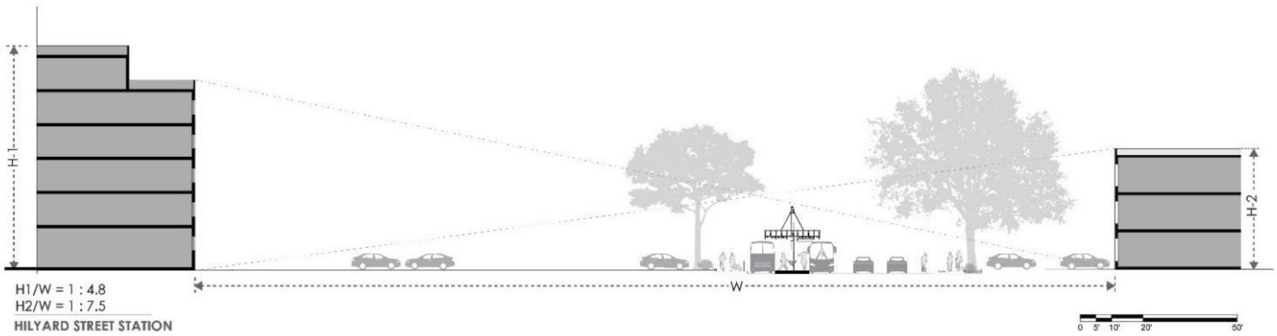


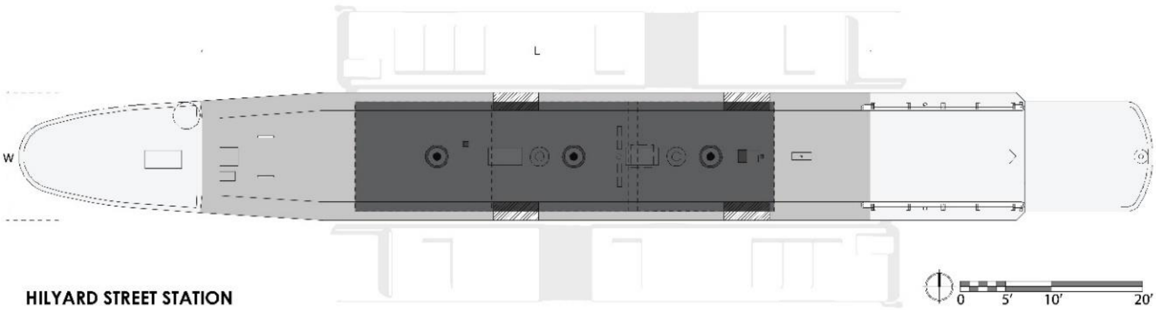
Figure 22: Street Height-to-Width Ratio

0.258

Figure 23: SVF at Hilyard Station

Station Description

This station is a center-island station with two boarding platforms to serve Springfield and Eugene bound EmX buses each. The station platforms face north & south and are accessible from the sidewalk via a crosswalk at the east end. The station canopy structures (46'-0" linear length) cover 54.5% area of the platform. The platform measures 73'-4" in length and 14'-0" in width. The station has 7'-4" linear length of seating, real time bus schedule, bike rack, bus route information, trashcans



and a ticketing booth.

Figure 24: Plan of Hilyard Station

Density

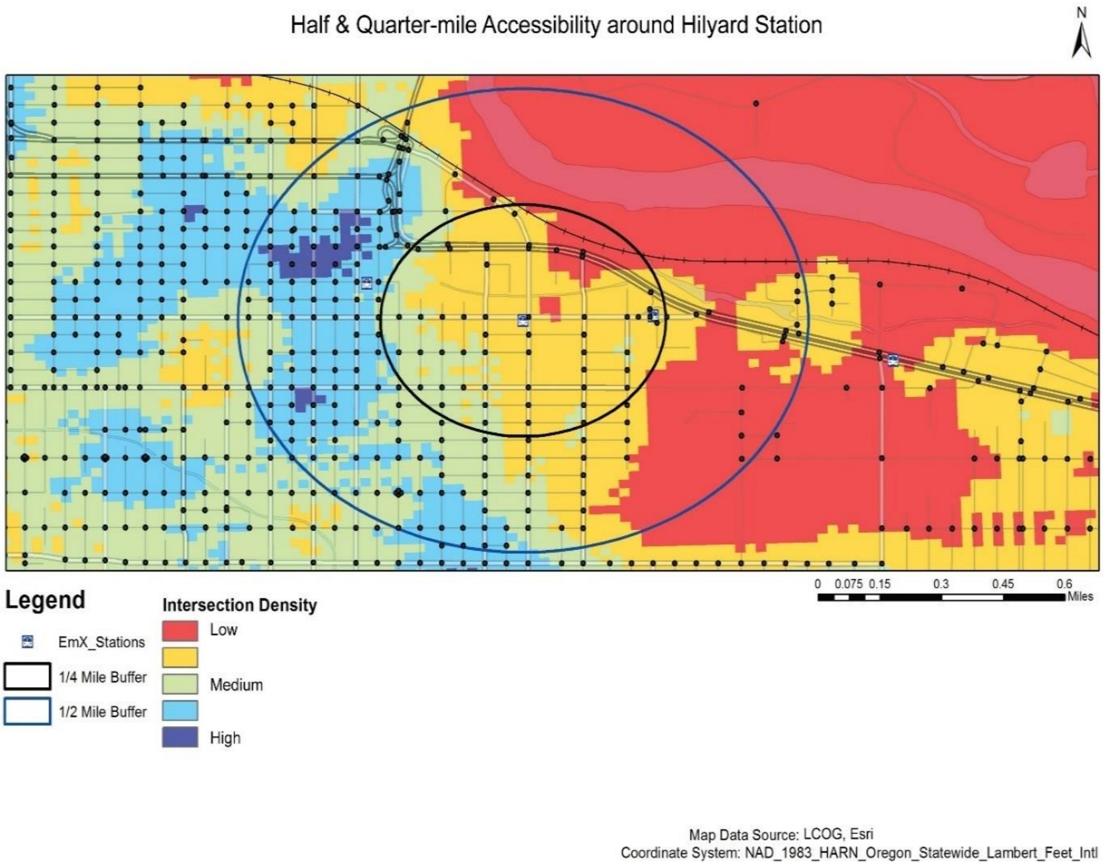
The population density for the block groups around a half-mile radius of Hilyard Station varies between 4024 to 98, 933 people per square mile (See Appendix-A).

Diversity

The land-use maps clearly show that the area within a half-mile of the station is predominantly commercial in use covering up to 43 % of the total area around station. Fraternity and student housing apartments are located to the north of the station. Sacred Heart Medical Center is located immediately to the south of the station.

Accessibility

The pedestrian catchment zones (PCZs) for a quarter and half-mile radius around the station show that the street network is fairly good for walking, but not as good as around High Street Station. The higher the PCZ ratios, the better the walkability of the street network. Results show a higher PCZ ratio for a quarter mile radius around the station compared to a half-mile radius. This indicates that the street network closer to the station is more walkable. Map 4 shows that within a quarter-mile around the station, the street intersection density is between medium and low. Within a half-mile radius of Hilyard Station, the street intersection density is higher to the west and south of the station as compared to the east. This indicates better pedestrian access to further from the station, more specifically to the west and south.



Map 4: Street Intersection Density around Hilyard Station

4.4.1 Thermal Comfort Assessment

Thermal Environment

This thesis measured and recorded climate data at Hilyard Station for approximately two hours a day, one day a month for a period of ten months from June 2015 to March 2016 (See Chapter 3, Methods). At Hilyard Station, the study recorded climate data (T_A, V_A, T_g & RH) approximately between 11:15 a.m. and 1:15 p.m. for each measurement campaign. Table 4 shows a statistical summary of the recorded seasonal climate data. For a summary of the monthly climate data, see appendix, D.

The highest mean air temperature occurred in the month of August 2015 (25.42 ^oC) and the lowest in January 2016 (5.84 ^oC). The mean value of the mean radiant temperature was highest (60.88 ^oC) for the month of October and the lowest (15.08 ^oC) for the month January making the fluctuations approx. twice that or air temperatures. Table 4 indicates that T_A, Tg, MRT and RH fluctuated the most in Fall. The highest mean relative humidity (74 %) occurred in winter and the lowest (51 %) in summer. The mean relative humidity during the winter season was approximately 23 % higher than for the summer season. Findings show that the range of air velocity is widest for winters but the values for mean air velocity indicate that the air velocity remains more of less the same.

Table 4: Seasonal Statistical Summary at Hilyard Street Station

Season	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	Mean	24.58	26.58	31.02	0.69	50.99
	Maximum	27.11	29.41	39.93	2.88	60.81
	Minimum	22.03	24.10	24.67	0.00	39.99
	Range	5.08	5.32	15.25	2.88	20.81
Fall	Mean	16.95	21.58	35.18	0.82	60.23
	Maximum	23.14	34.07	88.75	2.67	74.06
	Minimum	12.44	13.43	12.89	0.00	45.59
	Range	10.70	20.65	75.86	2.67	28.47
Winter	Mean	8.86	12.05	21.65	0.63	74.31
	Maximum	12.92	17.20	55.82	3.64	90.00
	Minimum	5.21	5.41	5.70	0.15	63.67
	Range	7.72	11.79	50.12	3.49	26.33
Spring	Mean	14.88	18.58	28.92	0.72	55.31
	Maximum	16.23	24.32	63.01	2.44	58.43
	Minimum	13.38	16.73	19.61	0.17	52.82
	Range	2.85	7.59	43.40	2.27	5.62

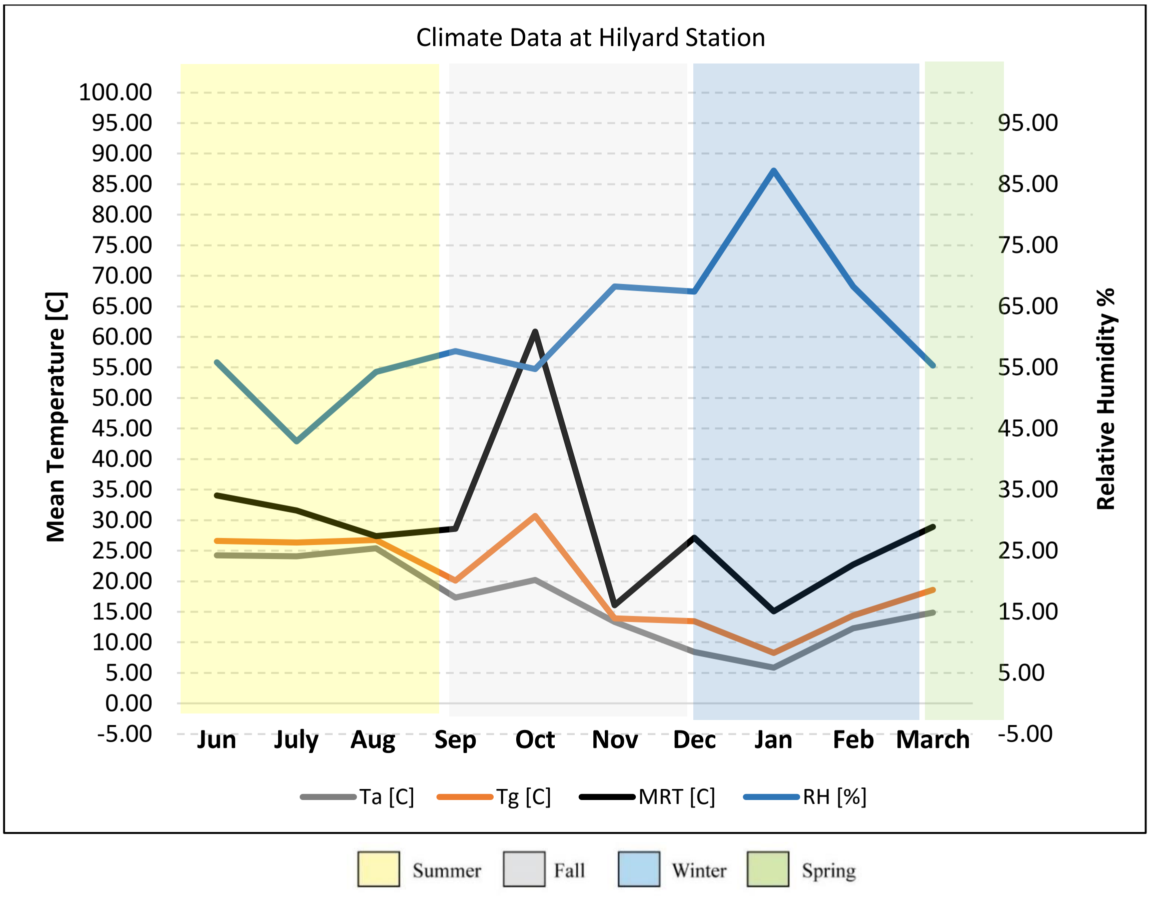


Figure 25: Recorded climate data at Hilyard Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating the assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at Hilyard Station was under thermal stress for four out of the ten months of the study. In summers, while two out of three months were thermally comfortable, the difference between 'No Thermal Stress' and 'Slight Heat Stress' is a small difference of 0.07 and 0.2 ^{o}C. Thermal conditions in June and October were identified under the category of 'Slightly Heat Stress' and 'Moderate Heat Stress'. In winters, the thermal environment at Hilyard Station was identified under 'Slight Cold Stress' in January but thermally comfortable for December and February. This study identified the environment at Hilyard Station under the categories of the highest heat and cold stress in fall. According to UTCI, eight out of ten months were thermally comfortable. While only June and October were in the 'Moderate Heat Stress' category, the months of July and August were very close to 'Moderate Heat Stress'.

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Hilyard Station	1.02	0.93	0.81	-0.30	2.38	-1.83	-0.52	-1.25	-0.63	-0.57

Figure 26: PMV Thermal Stress Heat Map

UTCI (°C) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Hilyard Station	26.53	25.43	25.57	20.50	30.88	13.69	10.52	10.52	14.94	18.89

Figure 27: UTCI Thermal Stress Heat Map

4.4.2 Survey Results

Demographic Information

Of the total 34 survey respondents at Hilyard Station, a majority of 19 respondents identified themselves as females. The highest number of respondents (16) identified themselves between the age group of 20-29 years, and eight identified themselves in the age group 10-19 years. Results show that equal number of respondents identified themselves as Anglo/White (35%) and Asian/ Pacific Islanders (35%).

Respondents' Travel Behavior

Approximately 71% survey respondents at Hilyard Station rode EmX frequently between three to seven days. Most of the respondents made the trip for shopping/errands (30%) and for college/school (24%). Results show that more respondents (approximately 68 %) respondents walked to Hilyard Station in comparison to 38 % who walked to their destinations. More people took the bus to get to their destination, while more people walked to get to the station. Results show that a greater number of respondents at Hilyard Station prefer to a car over EmX to make the trip, making up to 53% of the total respondents.

Importance – Satisfaction Analysis

Figure 28 shows respondents' importance and satisfaction ratings at Hilyard Station related to attributes of weather protection (wind, sun, rain and cold), station facilities (seating, lighting and route/ schedule information), pedestrian and bicycle access, and perceptions of safety (during the day and night).

Results indicate that the users identified protection from rain & cold, route/ schedule information, station lighting, pedestrian & bicycle access of the station, seating, and safety both during the day and night at 50 % or higher importance rating. Of these attributes, respondents at Hilyard Station identified protection from wind, cold stress and seating as attributes that they were not satisfied with and thought were not very important. This indicates that these attributes were not very important for the respondents. Findings indicate that pedestrian access, safety during the day & night, protection from rain, route/ schedule information and station lighting were important attributes for respondents that they were satisfied with. This indicates that these attributes were good enough but need to be maintained consistently because of their importance. Respondents at Hilyard Station had a high satisfaction with protection from the sun and bicycle access of the station. These attributes had lower than average importance ratings which indicates that according to the respondents, these attributes do not need improvement at Hilyard Station. The study did not find any attributes in the lower right hand quadrant of the plot. This indicates that according to the respondents' ratings of attributes, the study did not identify attributes that needed improvement at Hilyard Station.

The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction. The lower the IS rating, the lesser the importance of an attribute and higher satisfaction rating. (Iseki et al., 2007) Figure 29 shows the IS ratings of attributes associated with the use of the station. The figure is a funnel chart that indicates the priority of improvement of attributes at Hilyard Station. It shows that according to the respondents' ratings, the improvement of protection from wind and cold had a higher improvement need over other attributes and should be prioritized.

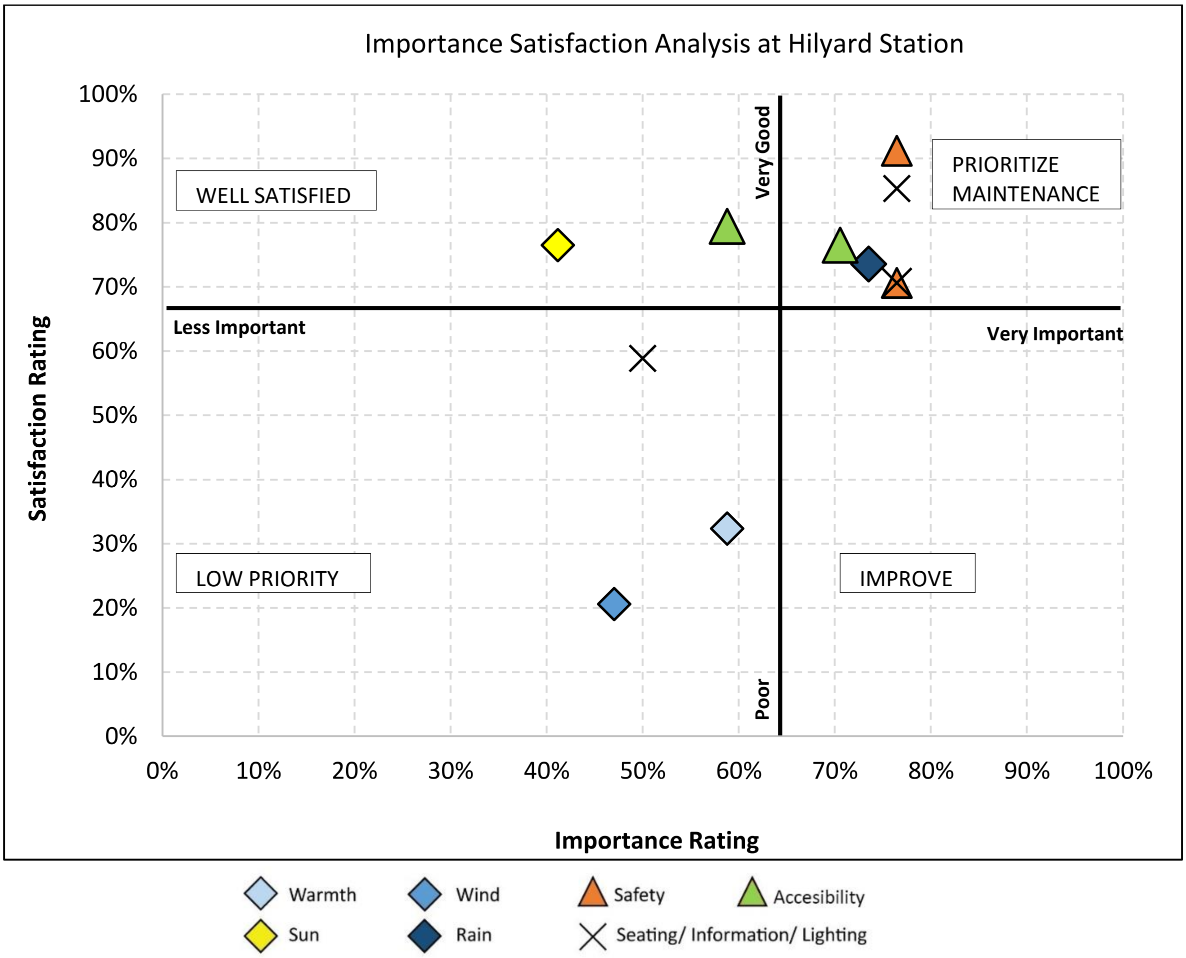


Figure 28: Importance & Satisfaction Ratings of station attributes according to respondents at Hilyard Station

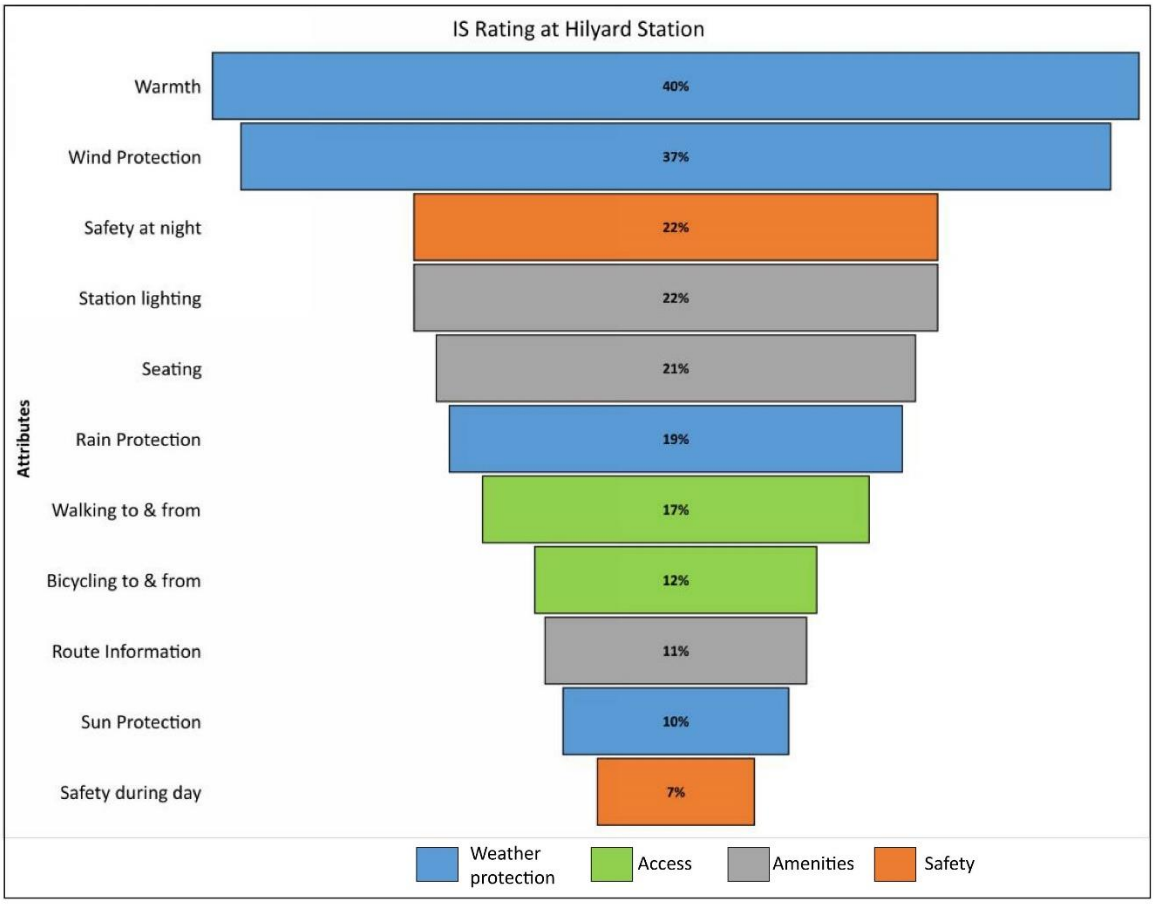


Figure 29: IS Rating at Hilyard Station

4.5 Dads' Gates Station

4.5.1 The Station and Built Environment

Street Geometry

Dads' Gates Station is located on East 11th between Kincaid Street and Franklin Boulevard. The station gets its name from the historic entrance gates of the University of Oregon called Dads' Gates, located to the south of the station. There is a considerable amount of vegetation around the station, with trees ranging between 38 to 87 feet high. The north platform faces a surface parking lot and North West Christian University. There are very few buildings, so the station has open views of the surroundings. In this case, this study determined the height-to width ratio of the street through the height of trees between 1:4 and 1:5.2. Sky view factor (SVF) provides a measure of the shading at Dads' Gates Station which is a result of the station canopy structure, the density of buildings and presence of trees around the station. SVF can have a maximum value of 1, indicating sparsely built environment. At Dads' Gates Station, the SVF is 0.288.

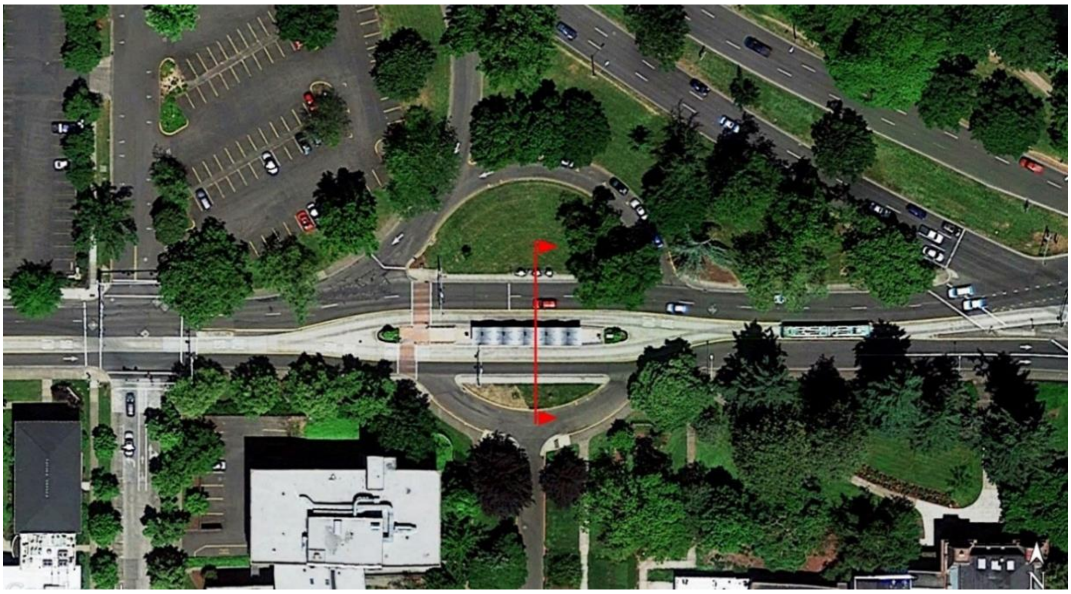


Figure 30: Aerial View of Dads' Gates. Source: Google Earth Pro

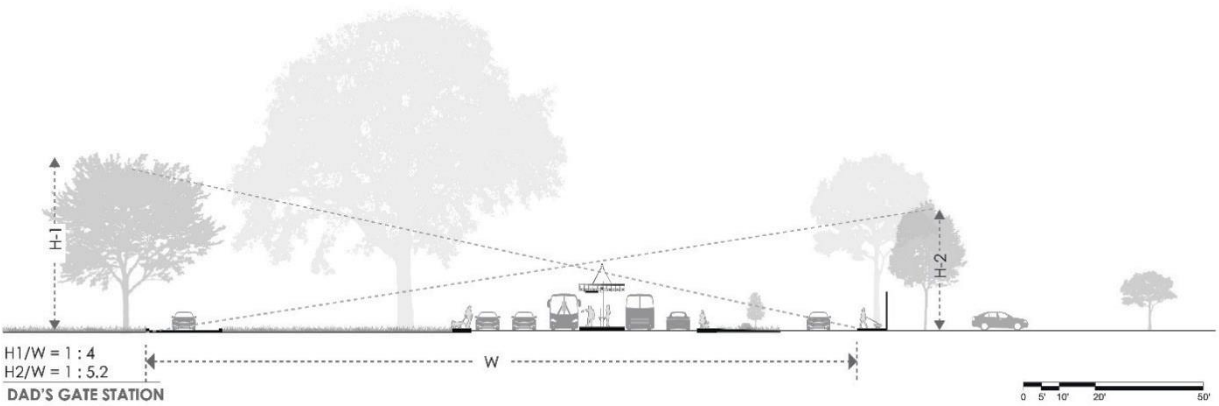


Figure 31: Street H/W Ratio

Figure 32: SVF at Dads' Gates Station

Station Description

This station is a center-island station with two boarding platforms to serve Eugene and Springfield bound EmX buses each. The station platforms are oriented north-south. The station is accessible from the sidewalk via a crosswalk at the west end. The station canopy structures (76'-0" linear length) cover 63.5 % area of the platform. The platform is 103'-9" long and 14'-0" wide. The station has 11'-0" linear length of seating, real time bus schedule, bike rack, bus route information, trash cans and a ticketing booth.

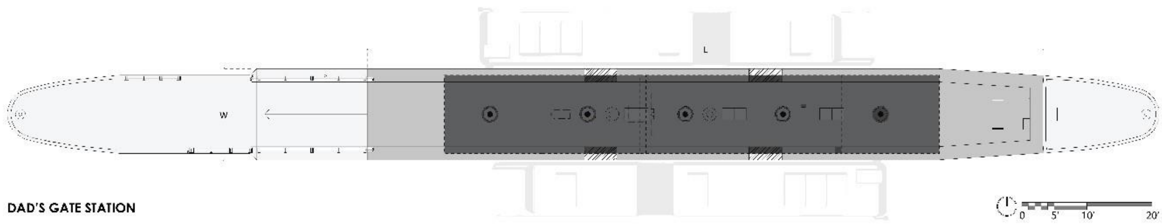


Figure 33: Plan of Dads' Gates Station

Density

The population density for the block groups around a half-mile radius of Dads' Gates Station varies between 4024 to 98,933 people per square mile (See Appendix-A).

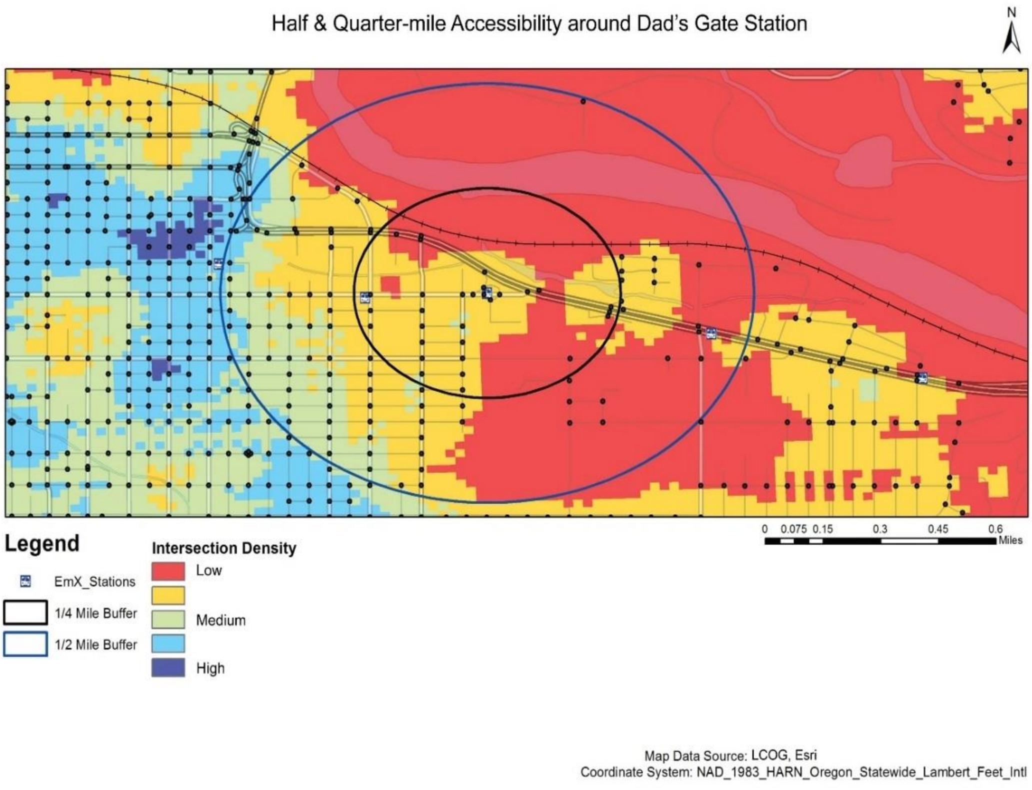
Diversity

The land-use maps clearly show that the area within a half-mile of the station is predominantly commercial in use covering up to 43.83 % of the total area around station. Commercial uses are more concentrated within a quarter mile of the station as compared to within a half-mile radius. Within a half-mile radius from the station multifamily and residential uses are more as compared to within a quarter mile.

University of Oregon is located south of the station and the Willamette River to the north.

Accessibility

The pedestrian catchment zones for a quarter and half-mile radius around the station show that the street network 'moderate' for walkability. The maps show that the street network further from the station is denser as compared to within a quarter mile. This indicates that the walkability for a quarter mile radius is lower compared to a half-mile radius around Dads' Gates Station. Map 5 shows that the street intersection density increases to the south west of the station but decreases to the north, east and south. This indicates poor pedestrian access to the station in the areas marked red in the map and fair to medium pedestrian access in the areas marked yellow to green.



Map 5: Street Intersection Density around Dads' Gates Station

4.5.2 Thermal Comfort Assessment

Thermal Environment

This thesis measured and recorded climate data at Dads' Gates Station for approximately two hours a day, one day a month for a period of ten months from June 2015 to March 2016. At Dads' Gates Station, the study recorded the air temperature, globe temperature (Tg), air velocity (V_A), and relative humidity (RH) approximately between 1:20 p.m. and 3:20 p.m. for each measurement campaign. (See Research Methods) Table 5 shows a statistical summary of the recorded seasonal climate data. For a summary of the recorded monthly climate data see appendix- D.

The highest mean air temperature of 29.03 ^{o}C occurred in June 2015 and the lowest in January (6.81 ^{o}C). The highest mean value of the mean radiant temperature occurred in October (58.57 ^{o}C) and the lowest (11.48 ^{o}C) in January. Table 5 shows that the widest range of Ta, Tg, Va and RH occurred in fall. The highest mean relative humidity (88.21 %) was recorded in the winter season and the lowest (35.63 %) in the fall season in the month of October with the highest recorded air velocity and mean radiant temperature. Findings show that the range of air velocity is widest in the fall season, particularly in the month of October.

Table 5: Seasonal Statistical Summary at Dads' Gates Station

Season	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	Mean	28.03	29.55	32.70	0.67	45.04
	Maximum	30.50	32.64	41.53	2.92	52.36
	Minimum	26.06	27.43	27.18	0.00	37.65
	Range	4.43	5.21	14.34	2.92	14.71
Fall	Mean	19.38	22.51	33.21	1.00	55.80
	Maximum	26.87	35.58	96.87	4.75	82.45
	Minimum	12.82	12.58	10.14	0.15	35.63
	Range	14.04	23.00	86.72	4.60	46.82
Winter	Mean	9.88	11.00	14.76	0.62	69.14
	Maximum	13.28	16.13	35.47	2.71	88.21
	Minimum	6.59	6.97	7.78	0.18	51.44
	Range	6.70	9.16	27.69	2.53	36.77
Spring	Mean	18.00	23.16	40.21	0.97	52.39
	Maximum	19.22	28.07	74.05	3.12	56.93
	Minimum	16.56	18.25	22.28	0.16	46.25
	Range	2.66	9.83	51.78	2.96	10.68

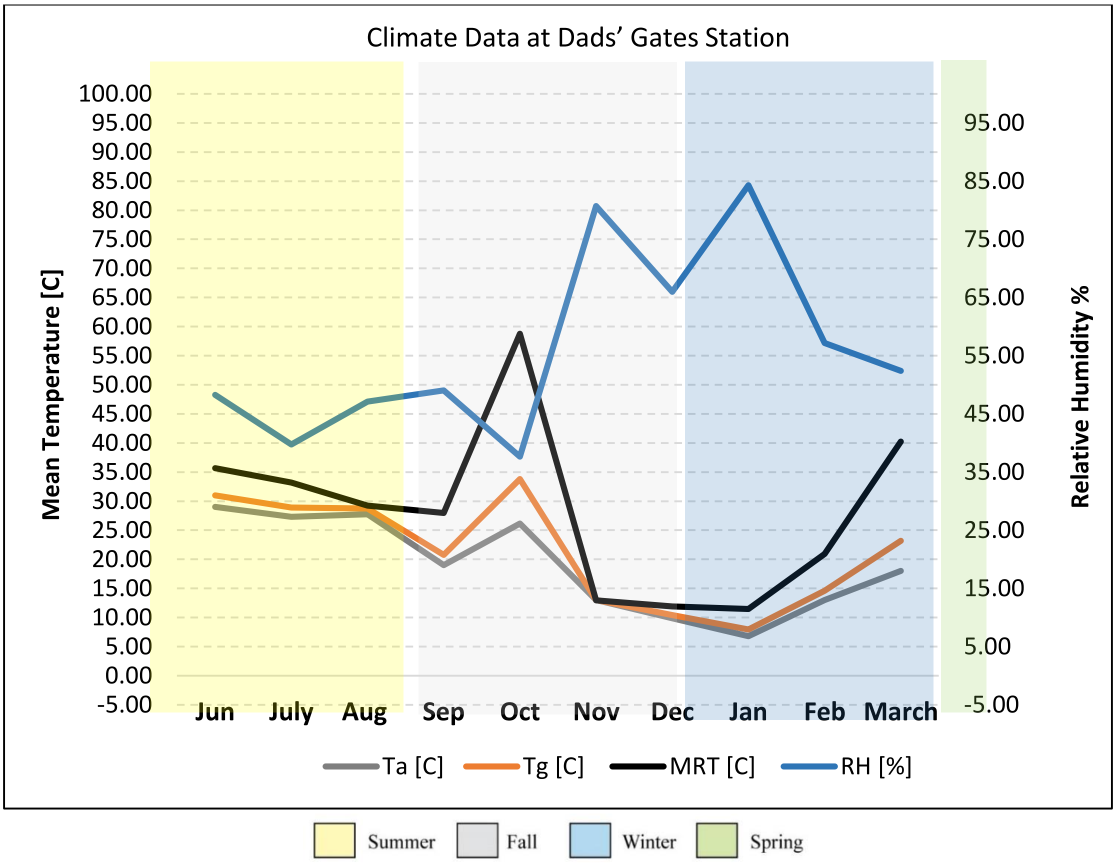


Figure 34: Recorded climate data at Dads' Gates Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating the assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at Dads' Gates Station was under thermal stress for seven out of the ten months of the study period. The coldest thermal stress was identified in the 'Slight Cold Stress' category for November in Fall, and December and January in winters. Even though thermal conditions for winters indicate 'No thermal Stress' in February, there is a small difference of 0.4 °C between no thermal stress and cold stress. Results show that in summers, the environment at Dads' Gates Station was under heat stress ranging from 'Moderate Heat Stress' to 'Slight Heat Stress'. In fall, the environment was thermally comfortable in September, under 'Moderate Heat Stress' in October and 'Slight Cold Stress' in November. According to the UTCI heat map winter, spring and most of fall was thermally comfortable. The month of October was identified under 'Strong Heat Stress' category and summer in the 'Moderate Heat Stress' category at Dads' Gates Station.

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Dads' Gates Station	2.09	1.49	1.31	-0.39	2.95	-1.80	-1.17	-1.47	-0.61	0.40

Figure 35: PMV Thermal Stress Heat Map

UTCI (°C) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Dads' Gates Station	30.58	27.85	27.53	19.64	32.95	13.43	11.00	9.48	14.72	23.45

Figure 36: UTCI Thermal Stress Heat Map

4.5.3 Survey Results

Demographic Information

Of the total 29 survey respondents at Dads' Gates Station, a majority of 17 respondents identified themselves as females. The highest number of respondents (19) identified themselves between the age group of 10-19 and 20-29 years. Results show that the majority of respondents were Anglo/White (76%) and Hispanic/Latino (14%).

Respondents' Travel Behavior

Of the survey respondents at Dads' Gates Station, 90 % rode EmX frequently between three to seven days. Most of the respondents made the trip for college/school (38%) and work/job (28%). Among the respondents, the highest number of people walked to and from the station or took the bus. Results indicate that in comparison to getting to the station, a greater number of people walked from the station to their destinations. Results show that a greater number of respondents at Dads' Gates Station (55%) preferred a car over EmX for the trip.

Importance – Satisfaction Analysis

Figure 37 shows the respondents' importance and satisfaction ratings at Dads' Gates Station related to attributes of weather protection (wind, sun, rain and cold), station facilities (seating, route/ schedule information and lighting), pedestrian and bicycle access, and perceptions of safety (during the day and night) at the station.

Results indicate that the users identified all but protection from the sun as attributed with an importance rating above 50 %. Of these characteristics, the respondents at Dads' Gates Station had low satisfaction with protection from wind and cold. The importance rating of these attributes was higher than 50 % and close to the respondents' average importance rating. This indicates that these attributes could be improved at Dads' Gate Station. Findings indicate that safety during the day, safety at night, station lighting, route/ schedule information, walking to & from the station and protection from rain were attributes that respondents identified as important and were satisfied with. This indicates that these attributes were good enough but need to be maintained consistently because of their high importance. Respondents at Dads' Gates Station were satisfied with bicycle access of the station, protection from the sun and seating. This indicates that these attributes do not need improvement at Dads' Gates Station.

The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction. The lower the IS rating, the lesser the importance of an attribute and higher satisfaction rating. (Iseki et al., 2007) Figure 38 shows respondents' IS ratings of attributes associated with the use of Dads' Gate Station. This figure is a funnel chart that indicates the improvement priority of attributes at Dads' Gate Station. It shows that improvement of protection from wind and cold was higher as compared to other attributes.

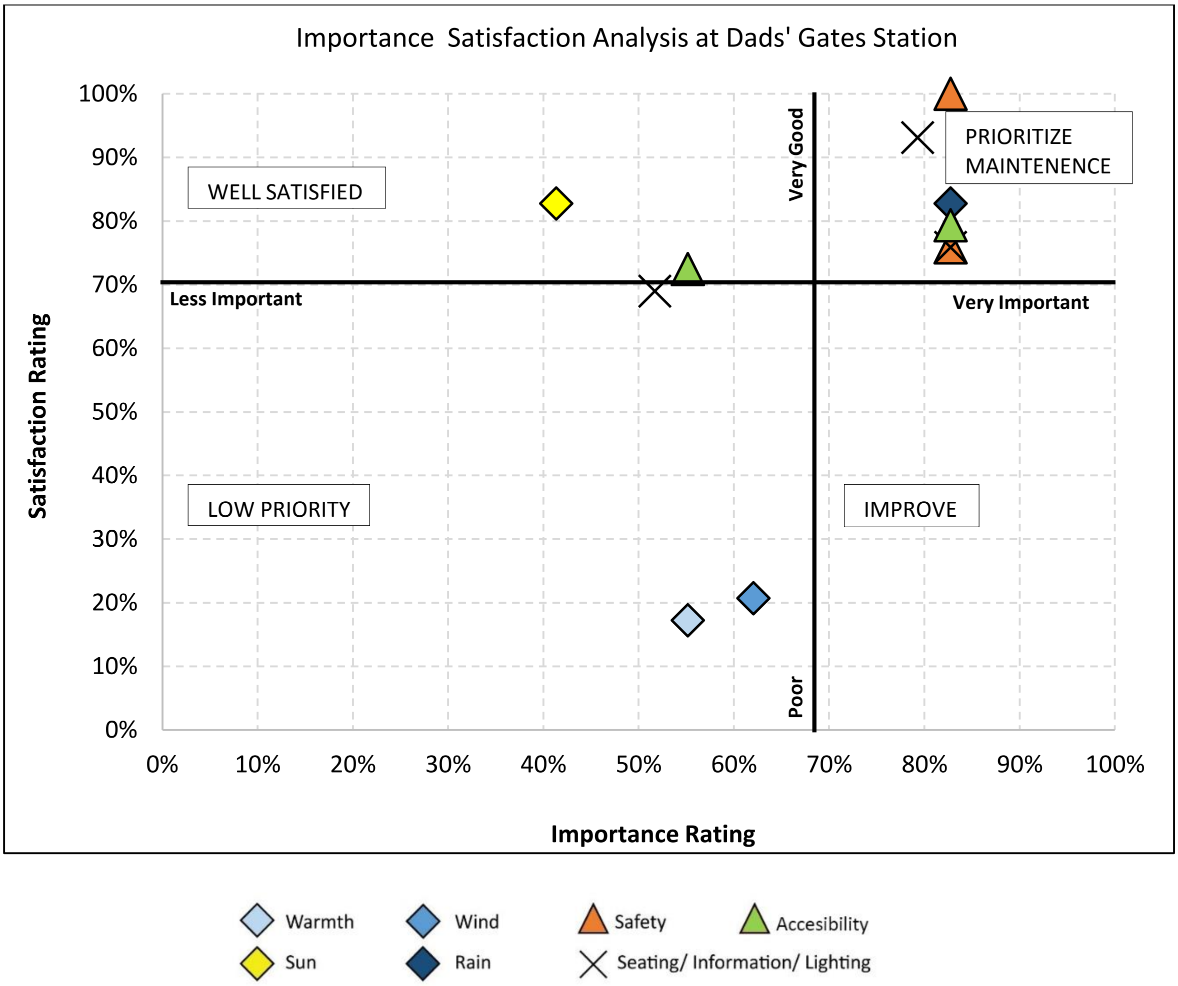


Figure 37: Importance & Satisfaction Ratings of station attributes according to respondents at Dads' Gates Station

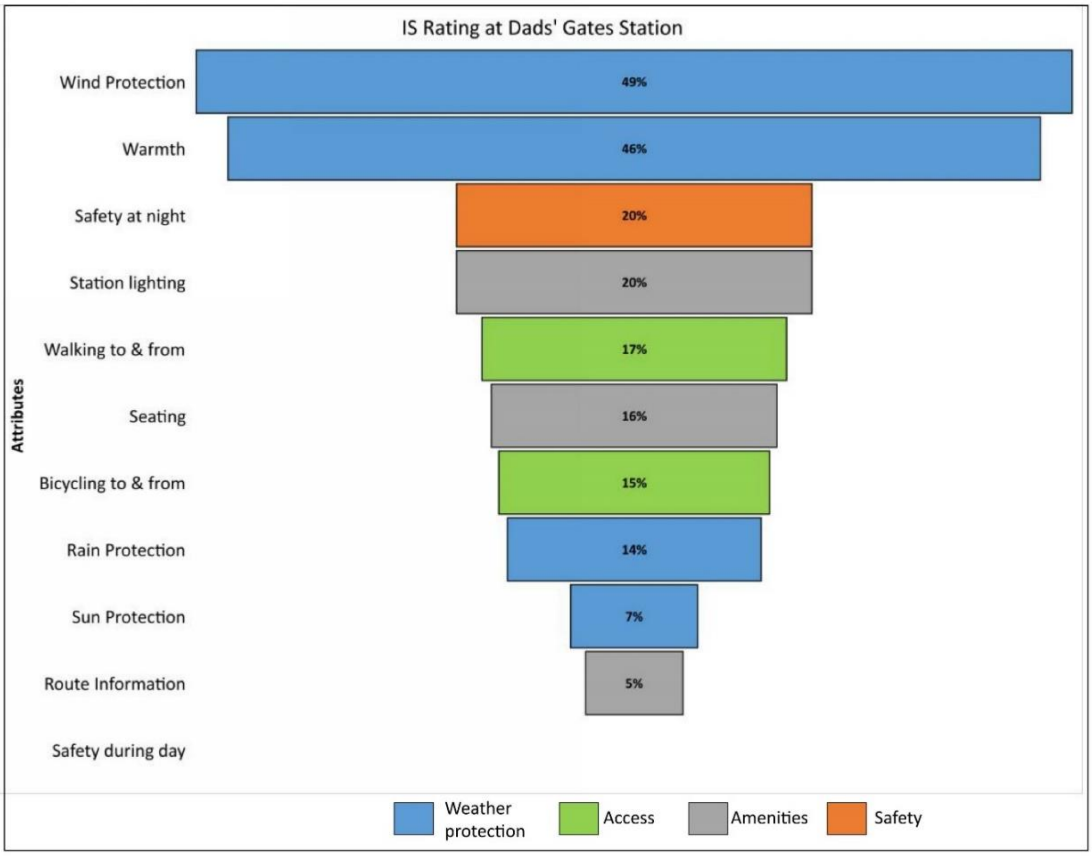


Figure 38: IS Rating at Dads' Gates Station

4.6 Agate Station

4.6.1 The Station and Built Environment

Street Geometry

Agate Station is located on Franklin Boulevard between Agate and Villard Street. To the north-east, the station platform faces an approximately 28 feet high motel building called Best Western. The south-west platform serves Springfield bound EmX buses and faces the University of Oregon's Jaqua Academic Center for student athletes, a glass façade building approximately 40 feet high. The height-to width ratio of the street roughly at the center of the station is approximately 1:8.4 and 1:4.6. Figure 13. Sky view factor (SVF) provides a measure of the shading at Agate Station which is a result of the station canopy structure, density of buildings and trees around the station. The maximum value of SVF can be 1 which indicates a sparsely built environment. At Agate Station, the SVF is 0.371.

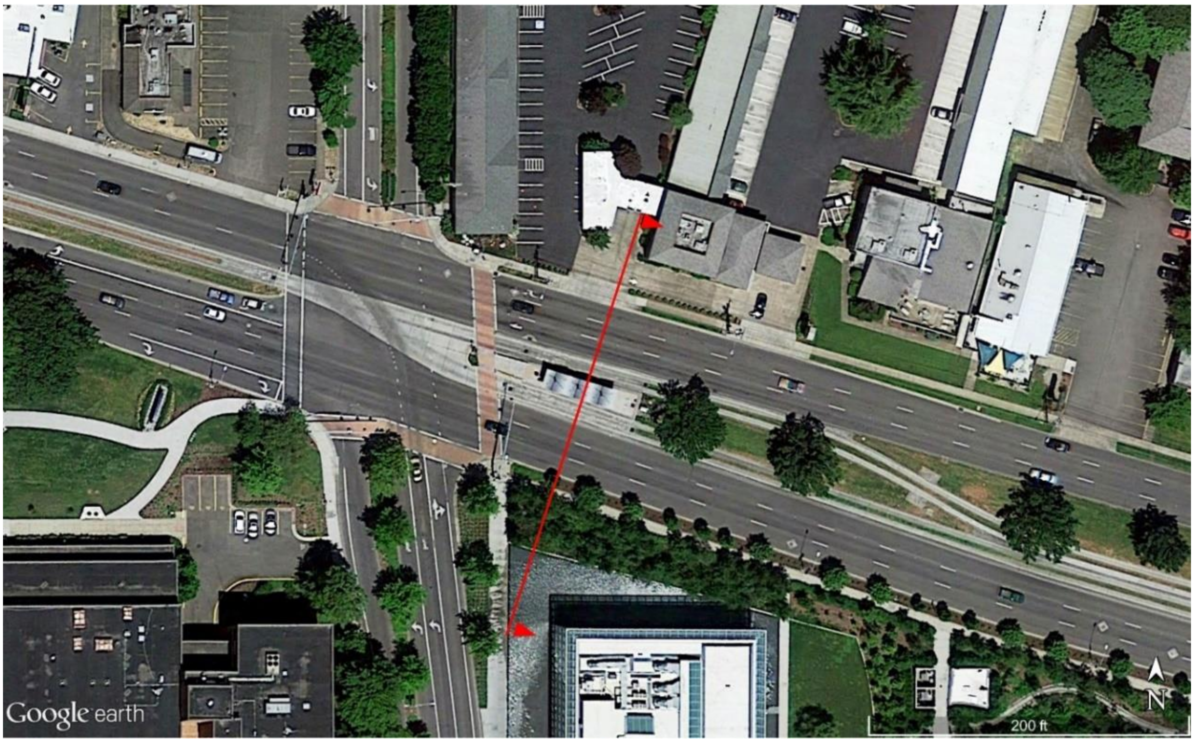


Figure 39: Aerial View of Agate Station. Source: Google Earth Pro

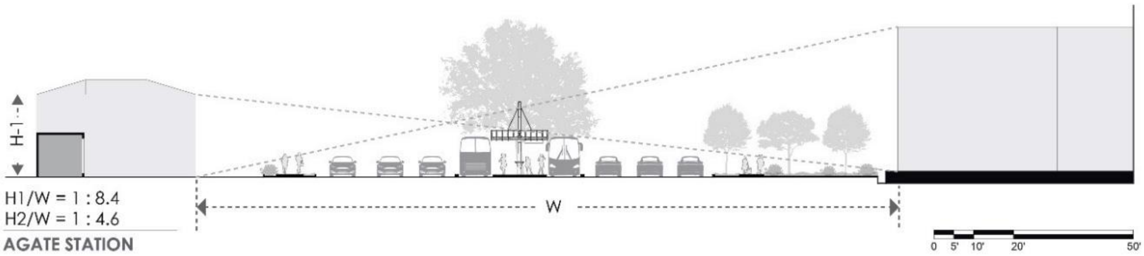


Figure 40: Street Height-to-Width Ratio

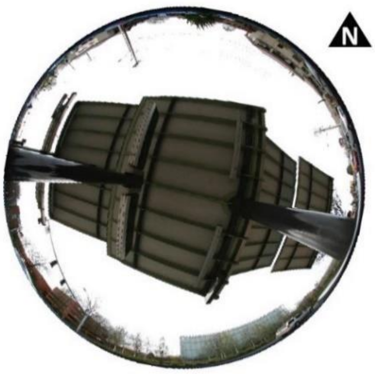


Figure 41: SVF at Agate Station

Station Description

Agate Station is a center-island station with two platforms to serve Eugene and Springfield bound EmX buses each. The station platforms are oriented north-east and south-west. The station is pedestrian accessible from the sidewalks via a crosswalk at the west end. The station canopy structures (46’-0” linear length) cover 43.8% area of the platform. The platform measures 74’-0” in length and 18’-4” in width. The station has 7’-4” linear length of seating, real time bus schedule, bike rack, bus route information, trash cans and a ticketing booth.

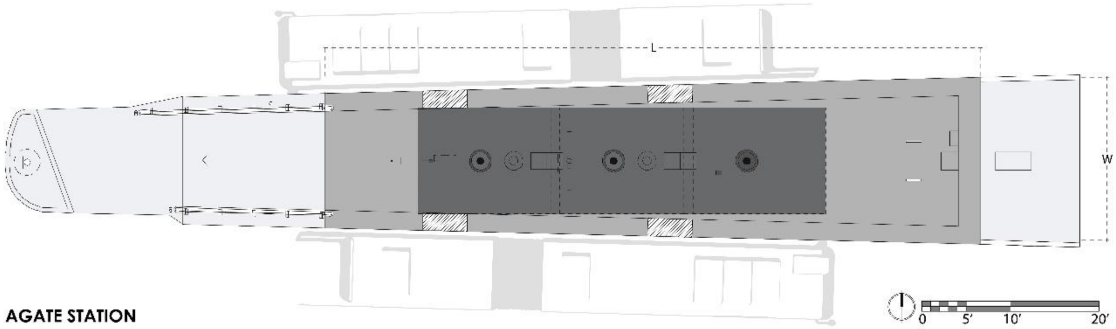


Figure 42: Plan of Agate Station

Density

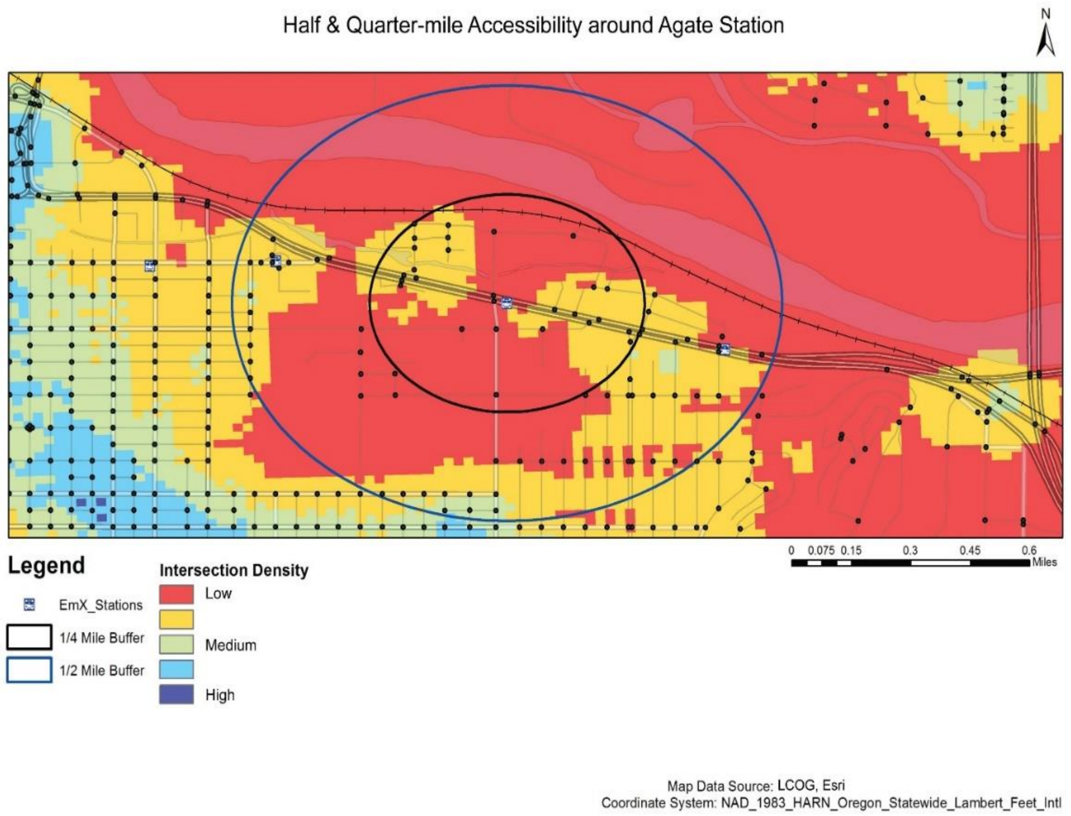
The population density for the block groups around a half-mile radius of Agate Station varies between 1474 to 10,805 people per square mile (See Appendix, Map 4).

Diversity

The land-use maps clearly show that the area within a half-mile of the station is predominantly commercial in use covering up to 45 % of the total area around station. Commercial uses are more concentrated within a quarter mile of the station as compared to within a half-mile radius around Agate Station. Within a half-mile radius from the station there are more residential use as compared to within a quarter mile. A few hotels and restaurants are located to the north of the station. University of Oregon is located to the south of the station.

Accessibility

Pedestrian catchment zone (PCZ) ratios for a quarter and half-mile radius around the Agate Station show that the street network around the station is moderate (between poor and good). Higher PCZ ratios indicate better street network for walking, hence the better the walkability of the street network. Findings indicate that the walkability of the street network around the station is medium for walking for a quarter and half-mile radius. Map 6 shows that the street intersection density around the station is mostly low. This indicates poor pedestrian access around the station for the areas marked in red. The areas marked in yellow indicate slightly better pedestrian access but not below average.



Map 6: Street Intersection Density around Agate Station

4.6.2 Thermal Comfort Assessment

Thermal Environment

This thesis measured and recorded climate data at Agate Station for approximately two hours a day, one day a month for a period of ten months from June 2015 to March 2016 (See Chapter 3, Methods). At Agate Station, the study recorded climate data (T_A, V_A, T_g & RH) approximately between 3:30 p.m. and 5:30 p.m. for each measurement campaign. Table 6 shows a statistical summary of the recorded seasonal climate data. For a summary of the monthly climate data see Appendix-D.

The highest mean air temperature occurred in June 2015 (31.41 ^oC) and the lowest occurred in the month of January 2016 (7.03 ^oC). The mean value of the mean radiant temperature was the highest (38.19 ^oC) in June and the lowest (8.26 ^oC) in January, similar to the trends of air temperature. Table 6 indicates that in this study, the widest range of T_A, Tg, and RH were found in fall The smallest range of T_A, Tg and V_A was found in spring. Findings show the highest recorded mean relative humidity in winters when the mean T_A, Tg, V_A and MRT were lowest.

Table 6: Seasonal Statistical Summary at Agate Station

Season	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	Mean	29.55	29.82	31.66	1.40	40.55
	Maximum	31.84	33.05	40.84	4.56	46.07
	Minimum	28.05	25.14	20.87	0.11	36.70
	Range	3.79	7.92	19.97	4.45	9.37
Fall	Mean	19.14	20.11	23.75	0.94	56.35
	Maximum	27.14	32.20	60.13	4.18	86.34
	Minimum	11.98	11.71	9.10	0.00	33.67
	Range	15.16	20.49	51.04	4.18	52.68
Winter	Mean	9.45	10.01	12.27	0.60	69.08
	Maximum	12.90	16.49	35.24	2.51	82.34
	Minimum	6.56	6.23	4.72	0.15	51.39
	Range	6.34	10.26	30.52	2.36	30.95
Spring	Mean	20.44	22.27	27.53	0.67	36.58
	Maximum	20.89	24.32	43.93	2.33	42.95
	Minimum	19.75	21.32	22.65	0.06	32.20
	Range	1.14	3.00	21.28	2.27	10.75

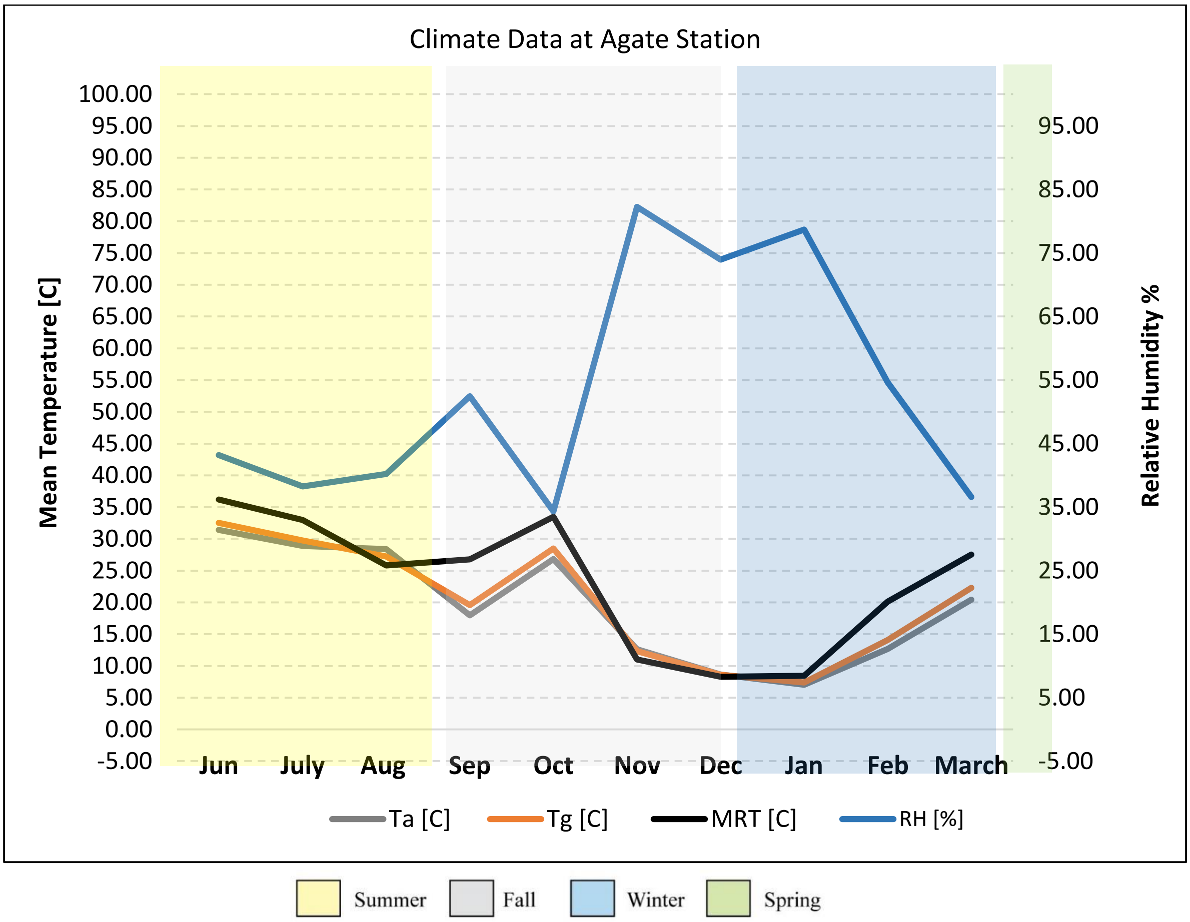


Figure 43: Recorded climate data at Agate Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating the assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at Agate Station was under thermal stress for seven out of ten months of the study period. The coldest thermal stress was identified in the 'Moderate Cold Stress' category for November in Fall, and 'Slight Cold Stress' in the months of December and January in winters. Results show that the environment at Agate Station was under heat stress ranging from 'Slight Heat Stress' to 'Moderate Heat Stress' in summers. In fall, the environment was under 'Slight Heat Stress' in October, and under cold stress in November. While the environment was thermally comfortable in September, the environment the difference between no thermal stress and slight cold stress was less than 0.5 ^{o}C. According to UTCI, the environment in summer was under maximum heat stress in June in the 'Strong Heat Stress' category and in the 'Moderate Heat Stress' category in July and under no thermal stress in August by a difference of approximately 1 ^{o}C. Results indicate that the environment at Agate Station was very close to heat stress in August. In fall, the environment was identified in the 'Moderate Heat Stress' category for October and in the 'Slight Cold Stress' category for January in winters.

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Agate Station	2.44	1.63	1.02	-0.61	1.42	-2.03	-1.23	-1.52	-0.80	0.10

Figure 44: PMV Thermal Stress Heat Map

UTCI (°C) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Agate Station	32.02	28.31	25.28	18.57	26.91	12.37	9.82	8.61	13.29	21.27

Figure 45: UTCI Thermal Stress Heat Map

4.6.3 Survey Results

Demographic Information

Of the total 31 survey respondents at Agate Station, a majority of 22 respondents identified themselves as females. The majority of 21 respondents identified themselves between the age group of 20-29 years. Results show that the majority of respondents were Anglo/White (55 %) and Asian/Pacific Islander (36 %).

Respondents' Travel Behavior

A majority of 78 % respondents at Agate Station rode EmX frequently between three to five days. Most of the respondents made the trip for college/school (35 %) and work/job (23 %). Among the respondents, the highest number of people walked to and from the station or took the bus. Results indicate that more people walked to get to the station in comparison to travelling from the station to their destinations. Results show that the majority of respondents at Agate Station (55%) preferred to ride EmX over a car for the trip.

Importance – Satisfaction Analysis

Figure 46 shows the respondents' importance and satisfaction ratings at Agate Station related to attributes of weather protection (wind, sun, rain and cold), station facilities (seating, route/ schedule information and lighting), pedestrian and bicycle access, and perceptions of safety (during the day and night) at the station.

Results show that respondents identified protection from rain & cold, safety during the day and night, pedestrian & bicycle access of the station, station lighting and route/ schedule information at importance ratings greater than 50 %. Of these attributes, respondents at Agate Station identified protection from wind, cold and sun as less important attributes (lower than average importance rating) that they were not satisfied with. This indicates that these attributes could be improved at Agate Station. Findings indicate that protection from rain, safety at night, safety during the day, station lighting, route/ schedule information and walking to & from the station are good enough but need to be maintained consistently because of their high importance for the respondents at Agate Station.

The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction. The lower the IS rating, the lesser the importance of an attribute and higher satisfaction rating. (Iseki et al., 2007) Figure 47 shows respondents' IS ratings of attributes associated with the use of Agate Station. This figure is a funnel chart that indicates the improvement priority of attributes at Agate Station according to respondents' importance and satisfaction of attributes. It shows that improvement of protection from wind and cold have a higher priority as compared to other attributes. based to the respondents' ratings.

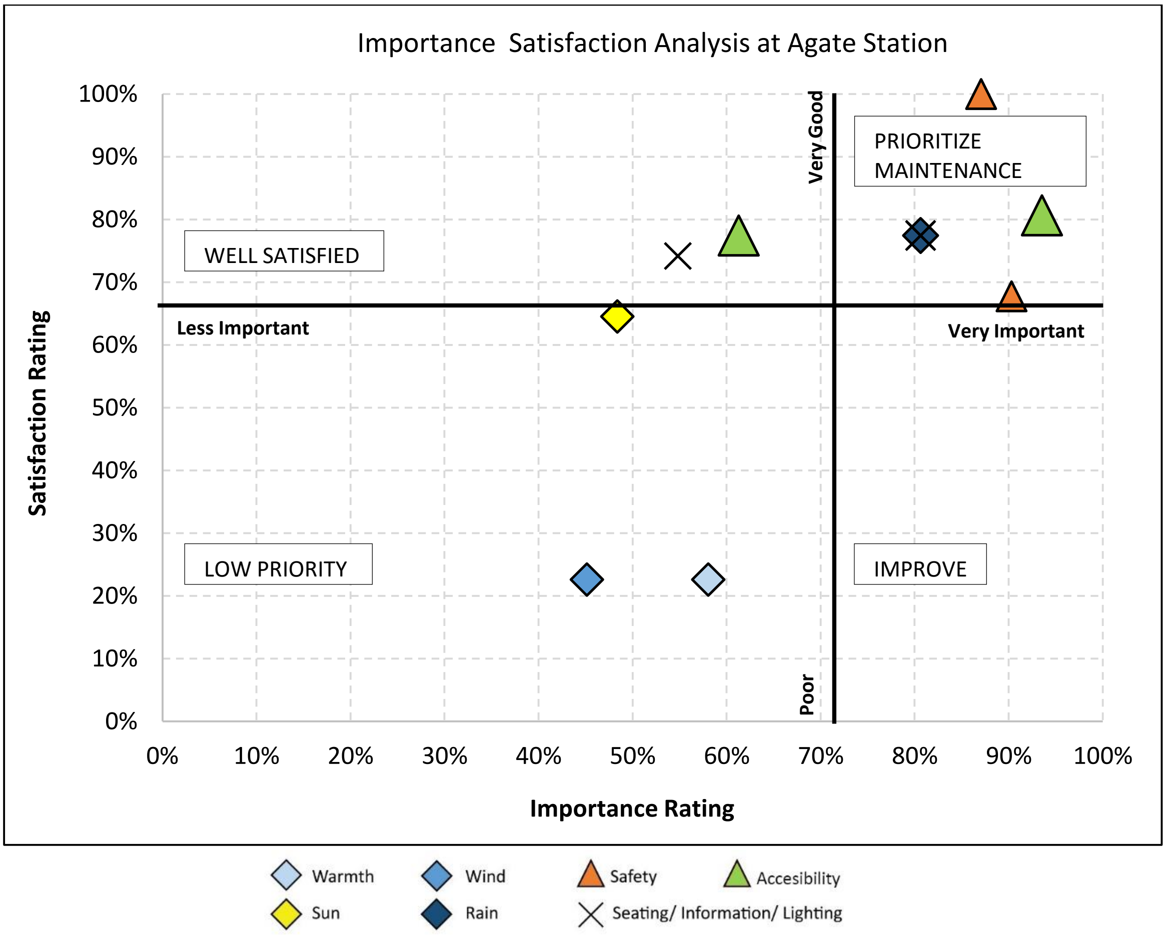


Figure 46: Importance & Satisfaction Ratings of station attributes according to respondents at Agate Station

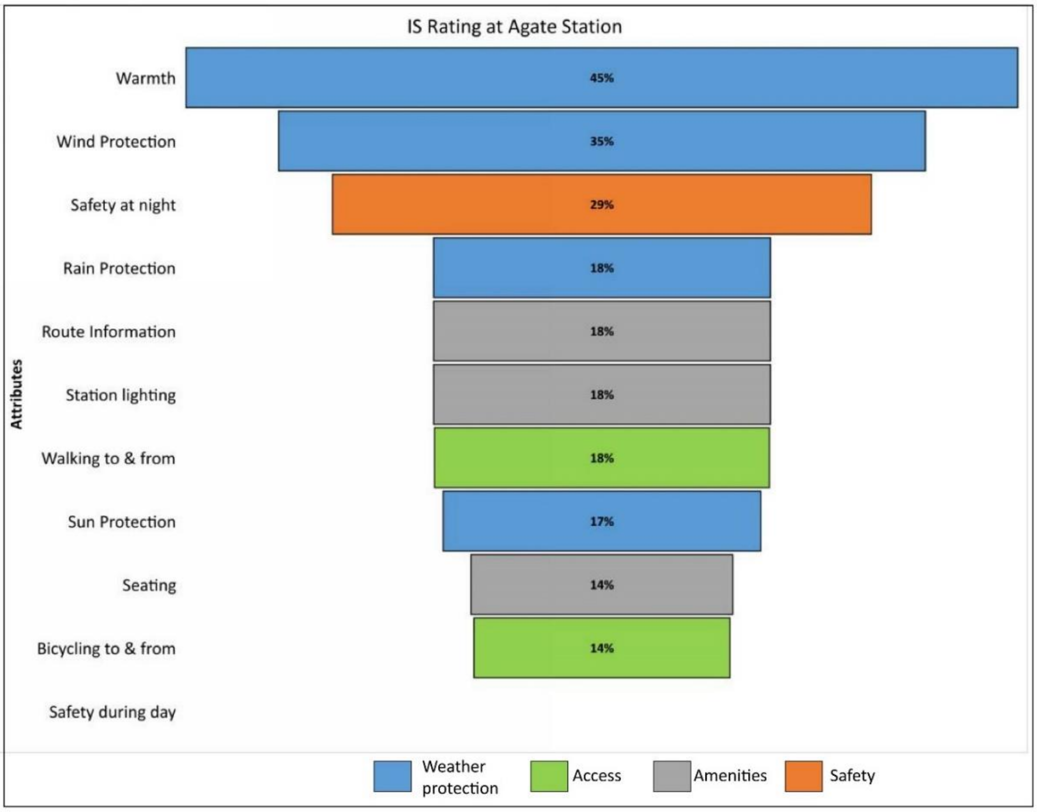


Figure 47: IS Rating at Agate Statio

4.7 Walnut Station

4.7.1 The Station and Built Environment

Street Geometry

Walnut is located on Franklin Boulevard near the intersection of Franklin Boulevard and Walnut Street. There is some vegetation on Franklin Boulevard to the east of the station in the form of a green belt. To the north-west, the station platform faces an approximately 53 feet high motel building called Holiday Inn Express & Suits Eugene and a small drive and walk through coffee shop facility called Dutch Bros. A park is located further to the north-west of the station called Franklin City Park. The south-west platform faces the University of Oregon’s Department of Parking. The height to width ratio at roughly the center of Walnut Station is between

1:7 and 1:28.5 as shown in Figure 49. Sky view factor (SVF) is a measure of shading at Walnut Station which is a result of the station canopy structure and density of the built environment around the station. Here the density of the built environment is a result of the arrangement of buildings, building heights, trees and other structures. The maximum value of SVF can be 1 indicating a sparely built environment with little or no shading. The higher the SVF, the greater the shading. At Walnut Station, the SVF is 0.372.

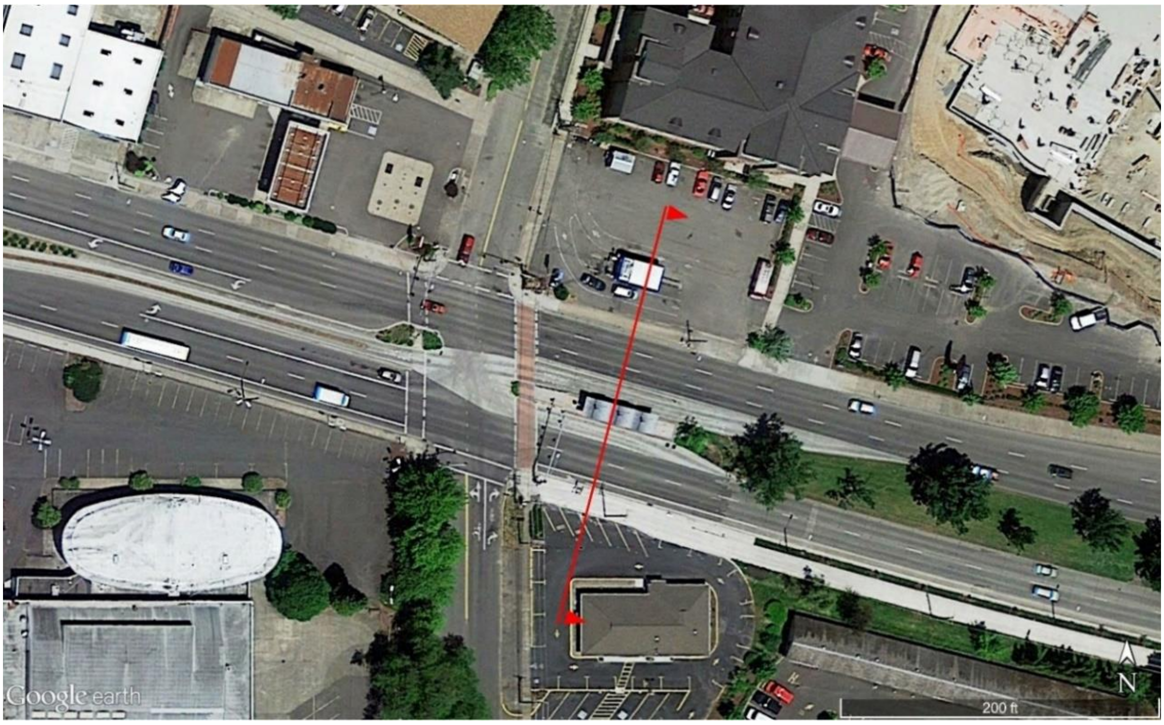


Figure 48: Aerial View of Walnut Station. Source: Google Earth Pro

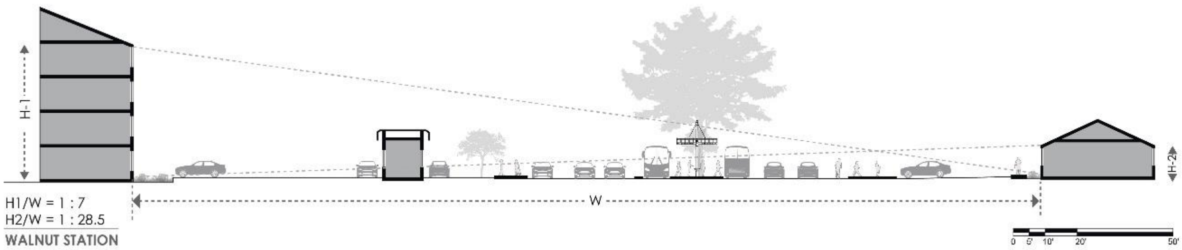


Figure 49: Street Height-to-Width Ratio at EmX Walnut Station

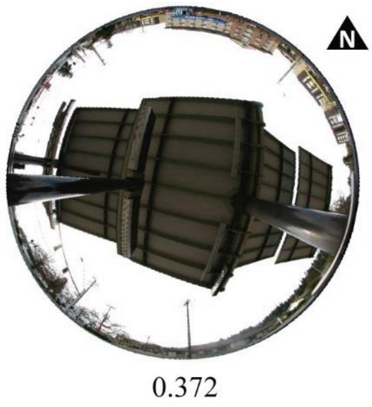


Figure 50: SVF at Walnut Station

Station Description

Walnut station is a center-island station with two boarding platform to serve Eugene and Springfield bound EmX buses each. The station platforms are oriented north-east and south-west. The station is pedestrian accessible from the sidewalks via a crosswalk at the west end. The station canopy structures (46’-0” linear length) cover 53% area of the platform. The station has 7’-4” linear length of seating, real time bus schedule, bike rack, bus route information, trash cans and a ticketing booth.

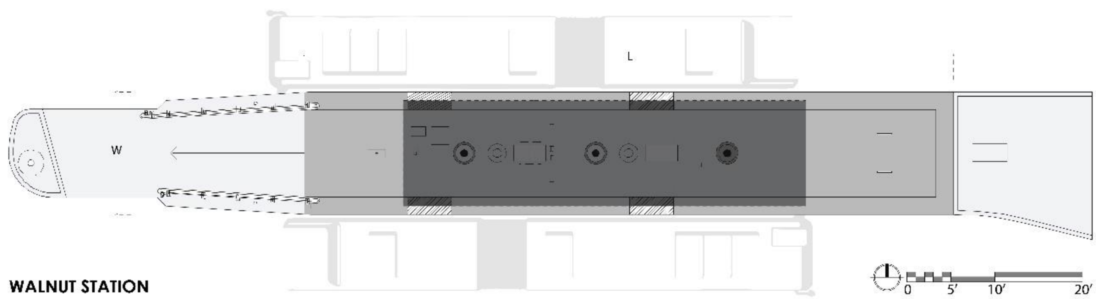


Figure 51: Plan of Walnut Station

Density

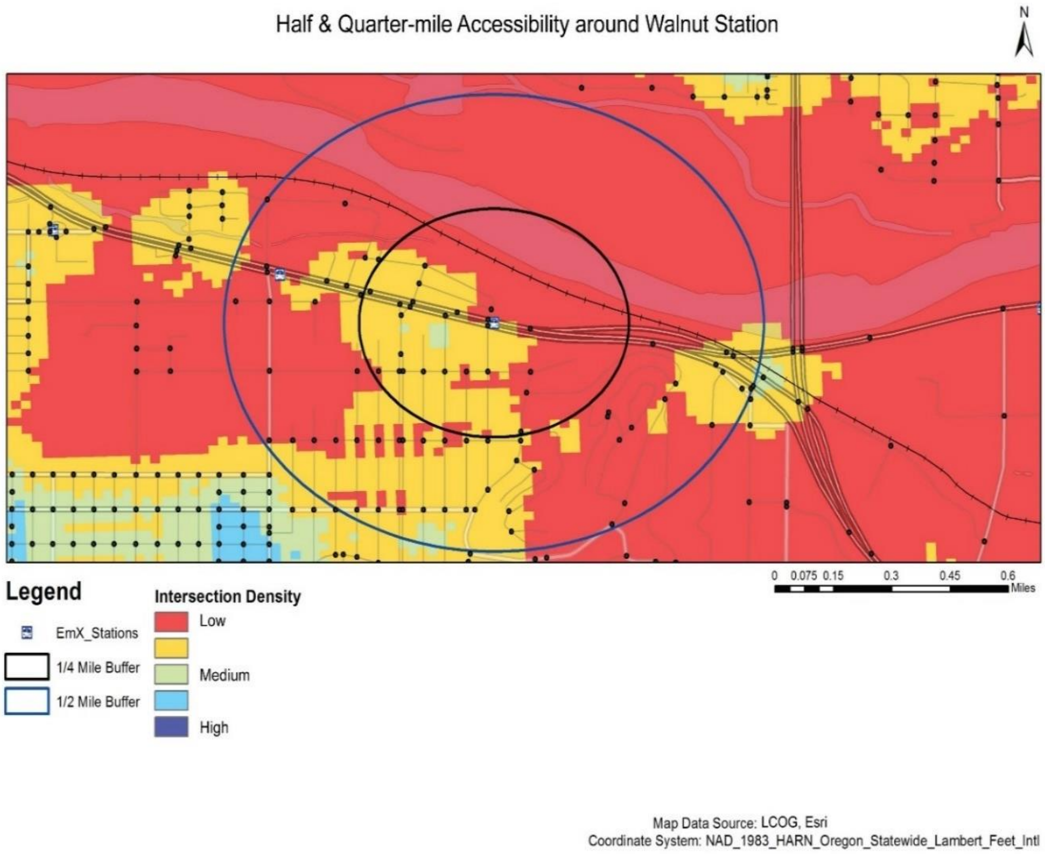
The population density for the block groups around a half-mile radius of Dads' Gates Station varies between 1474 to 10,805 people per square mile (See Appendices, A).

Diversity

The land-use map for a half-mile radius around Walnut Station shows that most of the area to the north of the station across the Willamette River is mostly vacant or street infrastructure. Findings indicate more commercial and multifamily land uses within a quarter mile of the station as compared to for a half-mile. University of Oregon is located to the south of the station. Apartments, a motel and restaurant businesses are located to the north of the station.

Accessibility

The pedestrian catchment zone (PCZ) ratios for a quarter and half-mile radius around the Walnut Station show that the street network around the station is moderate (between poor and good). Higher PCZ ratios indicate better street network for walking (better walkability). Findings show that the PCZ ratios for a quarter mile radius around the station is lower than for a half-mile radius. This indicates a better street network and walkability further away from the station. Map 7 shows that the street intersection density around Walnut Station is generally low, especially to the north of the Willamette River. This indicates poor pedestrian access in these areas (marked red). The pedestrian accessibility is better to the south west of the station but below average.



Map 7: Street Intersection Density around Walnut Station

4.7.2 Thermal Comfort Assessment

Thermal Environment

This thesis measured and recorded climate data at Walnut Station for approximately two hours a day, one day a month for a period of ten months from June 2015 to March 2016 (See Chapter 3, Methods). At Walnut Station, the study recorded climate data (T_A, V_A, T_g & RH) approximately between 9:00 a.m. and 11:00 a.m. for each measurement campaign. Table 7 shows a statistical summary of the recorded seasonal climate data. For a summary of the monthly climate data see Appendix- D.

The highest mean T_A (22.8 ^{o}C) occurred in June 2015 and the lowest (4.97 ^{o}C) occurred in January 2016. Results show that the **mean** MRT was the highest (37.32

^{o}C) for the month of January and the lowest (11.44 ^{o}C) for the month November. Findings indicate that of all the seasons, the highest difference of approximately 10 ^{o}C between the recorded maximum and minimum T_A occurred in fall. The ranges for MRT, Tg, and RH were also the highest in fall with the smallest range for V_A. In summer the range was highest for V_A and lowest for Tg, MRT and RH compared to the other seasons for this study. The study found the highest **mean RH** (90 %) in winter and the lowest (50.81 %) in fall.

Table 7: Seasonal Statistical Summary at Walnut Station

Season	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	Mean	21.15	22.94	27.50	0.98	65.41
	Maximum	22.85	24.65	42.63	3.26	72.63
	Minimum	17.58	18.87	20.80	0.12	58.55
	Range	5.27	5.79	21.84	3.14	14.08
Fall	Mean	14.15	16.26	22.19	0.75	67.79
	Maximum	19.34	30.62	75.78	2.53	89.69
	Minimum	9.53	9.49	5.50	0.13	50.81
	Range	9.81	21.14	70.28	2.40	38.88
Winter	Mean	8.63	12.63	28.67	1.14	78.99
	Maximum	11.76	16.32	64.06	3.21	90.09
	Minimum	4.01	6.48	11.29	0.19	57.14
	Range	7.75	9.84	52.77	3.02	32.95
Spring	Mean	12.90	14.23	20.77	1.49	67.49
	Maximum	15.27	18.03	48.77	2.90	74.95
	Minimum	10.52	10.98	13.30	0.22	59.21
	Range	4.75	7.05	35.47	2.68	15.74

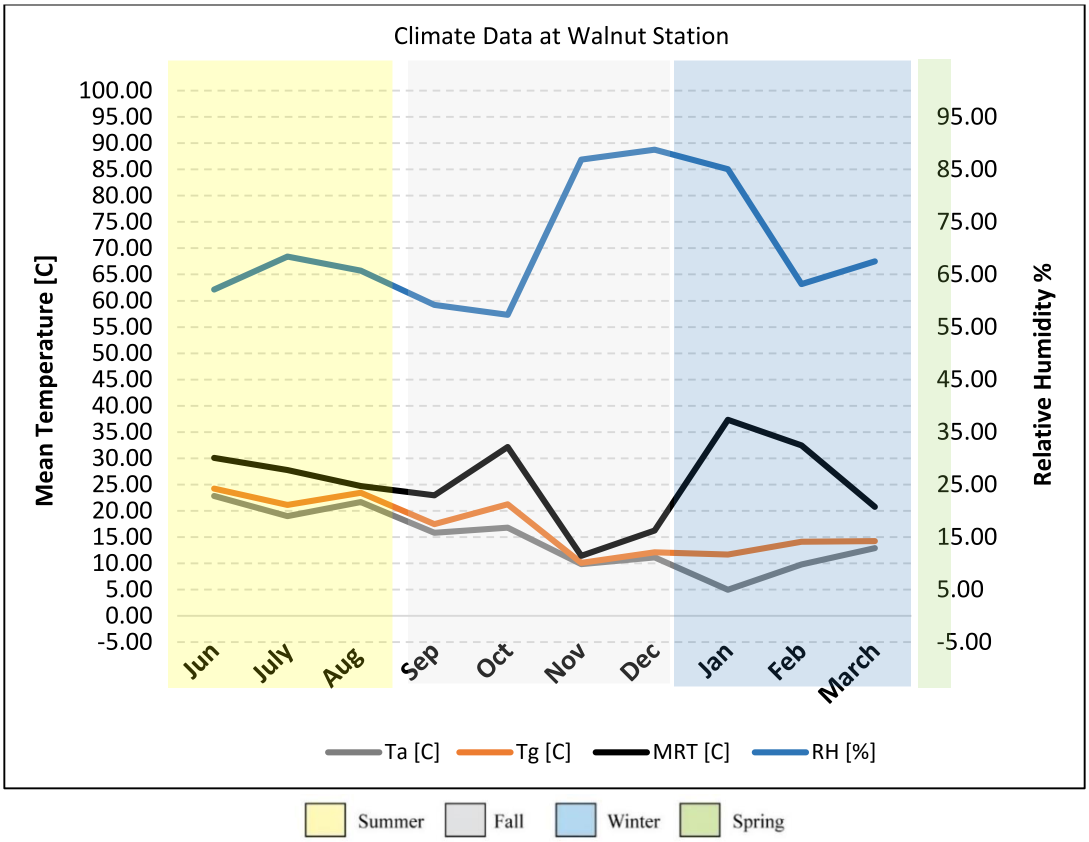


Figure 52: Recorded climate data at Walnut Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at Walnut Station was under thermal stress for three of ten months of the study period. The coldest stress was identified in fall under the 'Moderate Cold Stress' category in the month November. Results show that during winter the environment at Walnut Station was identified under 'Slight Cold Stress' in the month of December. Although in January and February, the environment was thermally comfortable, there was a small difference of 0.07 and 0.4 ºC between 'No Thermal Stress' and 'Slight Cold Stress'.

Although according to the UTCI thermal stress heat map, the environment at Walnut Station was thermally comfortable for the seasonal data measured in this study, results show that the difference between ‘No Thermal Stress’ and ‘Moderate Heat Stress’ for June, July, August and October was relatively small (within 1 to 5 °C).

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Walnut Station	0.34	-0.25	-0.15	-0.91	0.02	-2.60	-1.08	-0.93	-0.68	-2.05

Figure 53: PMV Thermal Stress Heat Map

UTCI (°C) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Walnut Station	24.26	21.73	22.26	17.88	21.46	10.59	12.47	16.00	16.06	13.35

Figure 54: UTCI Thermal Stress Heat Map

4.7.3 Survey Results

Demographic Information

Of the total 25 survey respondents at Walnut Station, a majority of 13 respondents identified themselves as males. The highest number of respondents (15) identified themselves between the age group of 20 -19 and 7 respondents identified themselves in the age group 50-69 years. Results show that the majority of respondents were Anglo/White (48 %) and Asian/Pacific Islander (44%).

Respondents' Travel Behavior

About of 88% respondents at Walnut Station rode EmX frequently between three to seven days. Most of the respondents made the trip for college/school (44%) and for Shopping/Errands (24 %). Among the respondents, the highest number of people walked to and from the station or took the bus. Results show that a greater number of respondents at Walnut Station (68 %) preferred EmX over a car for the trip.

Importance – Satisfaction Analysis

Figure 55 shows the respondents' importance and satisfaction ratings at Walnut Station related to attributes of weather protection (wind, sun, rain and cold), station facilities (seating, route/ schedule information and lighting), pedestrian and bicycle access, and perceptions of safety (during the day and night) at the station.

Results indicate that the users identified all but protection from sun at Walnut Station at importance ratings greater than 50 %. Of these attributes, the respondents at Walnut Station identified protection from rain and safety at night as important attributes that they were not satisfied with. This indicates that these attributes need improvement at Walnut Station. Respondents identified route/ schedule information, pedestrian access of the station, station lighting, and safety at night as important attributes that they were satisfied with. This indicates that these attributes are good enough but need to be maintained consistently because of their high importance for respondents at Walnut Station. Respondents identified protection from sun and seating at Walnut Station at high satisfaction ratings. This indicates that according to the respondents, these attributes do not need improvement at Walnut Station. Findings indicate that respondents identified low satisfaction and importance ratings for protection from wind and cold. This indicates that improving these attributes could improve respondents' satisfaction of these attributes.

The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction. The lower the IS rating, the lesser the importance of an attribute and higher satisfaction rating. (Iseki et al., 2007) Figure 56 shows respondents' IS ratings of attributes associated with the use of Walnut Station. This figure is a funnel chart that indicates the improvement priority of attributes at Walnut Station according to respondents' importance and satisfaction of attributes. It shows that improvement of protection from wind and cold are highest in priority compared to other attributes. This indicates that among the attributes compared, respondents were least satisfied with protection from wind and cold at Walnut Station and most satisfied with pedestrian access of the station.

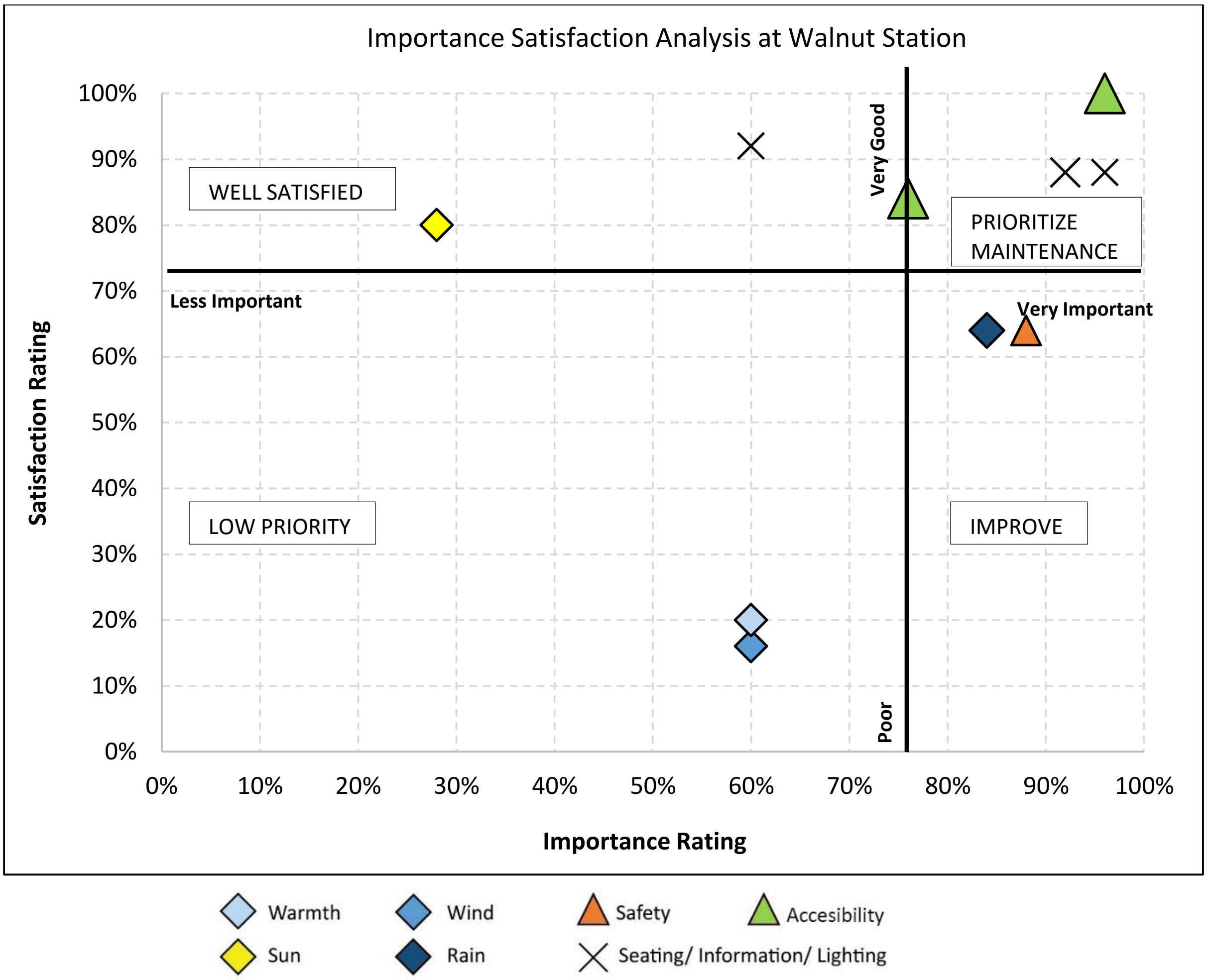


Figure 55: Importance & Satisfaction Ratings of attributes according to respondents at Walnut Station

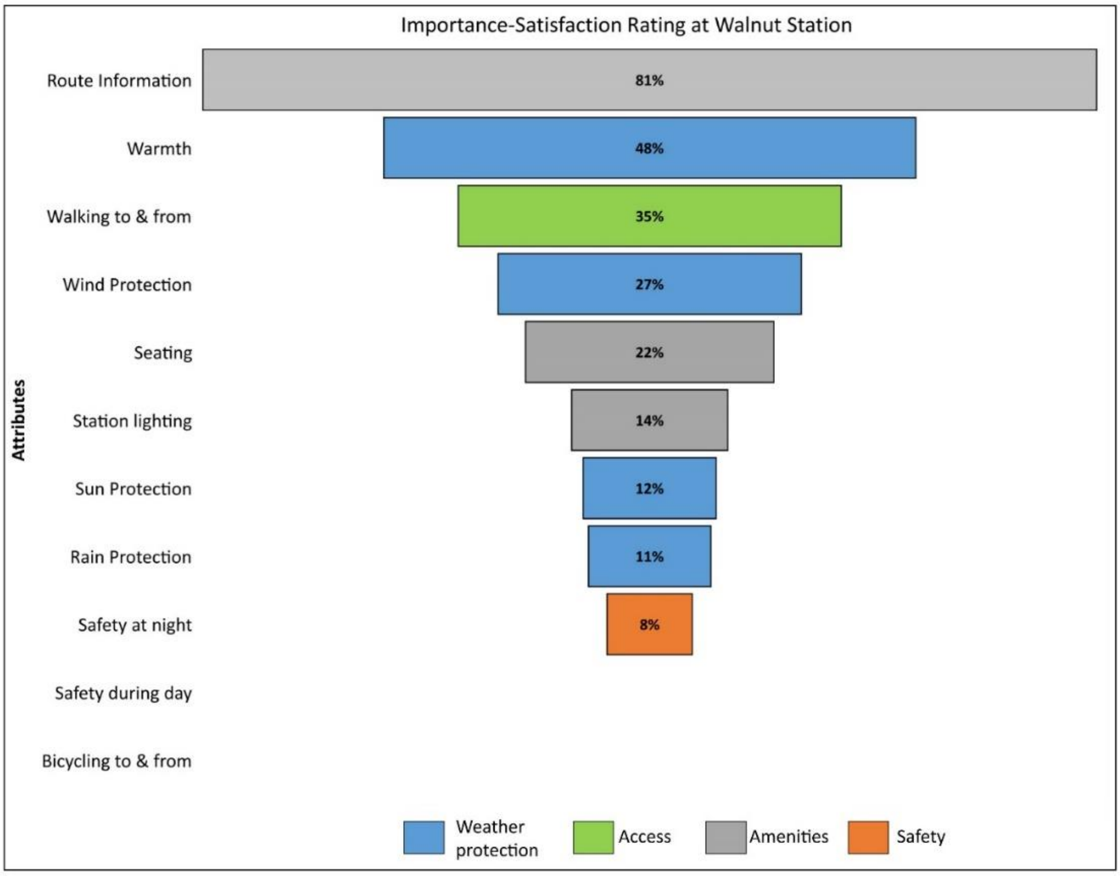


Figure 56: IS Rating at Walnut Station

4.8 Glenwood Station

4.8.1 The Station and Built Environment

Street Geometry

Glenwood Station is located on Franklin Boulevard between Glenwood Boulevard and Henderson Avenue. This is a side station with a single boarding platform that serves Springfield bound EmX buses. The platform faces an auto repair shop to the north. Planned Parenthood, an approximately 30 feet high building is located to the south of the station. The height-to-width ratio of the street at roughly the center of the station is between 1:19.5 and 1:10. Sky view factor (SVF) is a measure of shading at Glenwood Station which is a result of the station canopy structure and density of the built environment around the station. Here the density of the built environment is a result of the arrangement of buildings, building heights, trees and other structures. The maximum value of SVF can be 1 indicating a sparely built environment with little or no shading. The higher the SVF, the greater the shading. The SVF at Glenwood Station is 0.551.

Figure 57: Aerial view of Glenwood Station. Source: Google Earth Pro

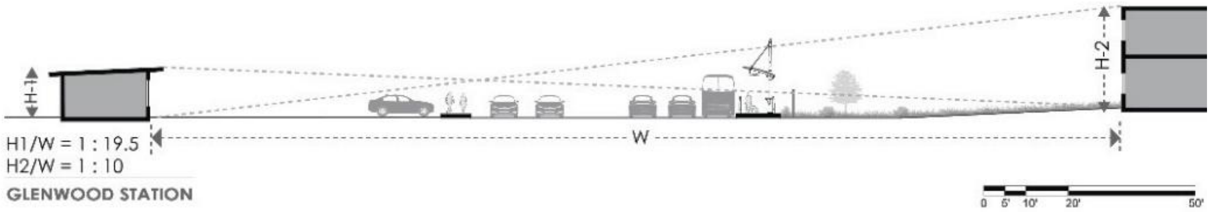


Figure 58: Street Height-to-Width Ratio at EmX Glenwood Station

Figure 59: SVF at Glenwood Station

Station Description

This station is a side station with a single boarding platform that serves Springfield bound EmX buses. The station platform is oriented north, slightly facing the west and south, slightly east. To simply, this study considered the station orientation as north-south with the boarding side facing north. The station canopy structures (15’-0” linear length) cover 28% area of the platform. The platform is 40’-0” long and 10’-0” wide. The station has 3’-8” linear length of seating, bike rack, bus route information, trash can and a ticketing booth.

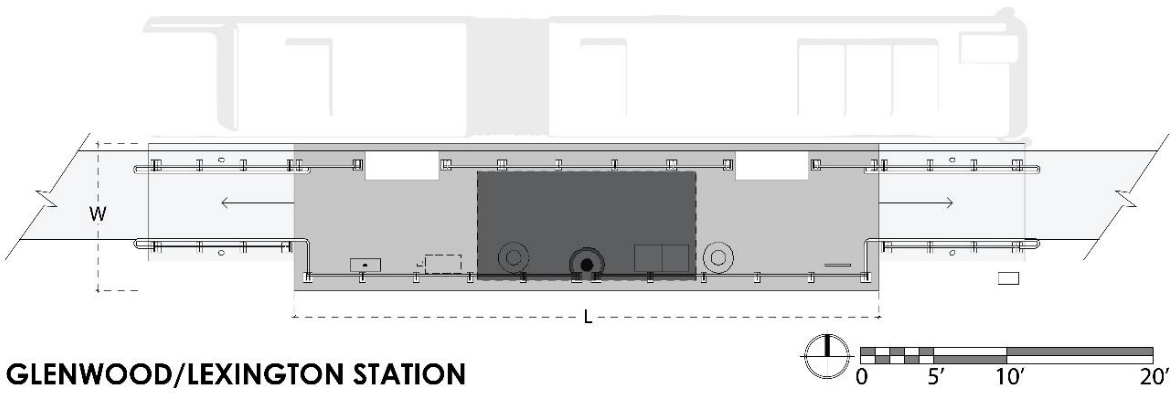


Figure 60: Plan of Glenwood / Lexington Station

Density

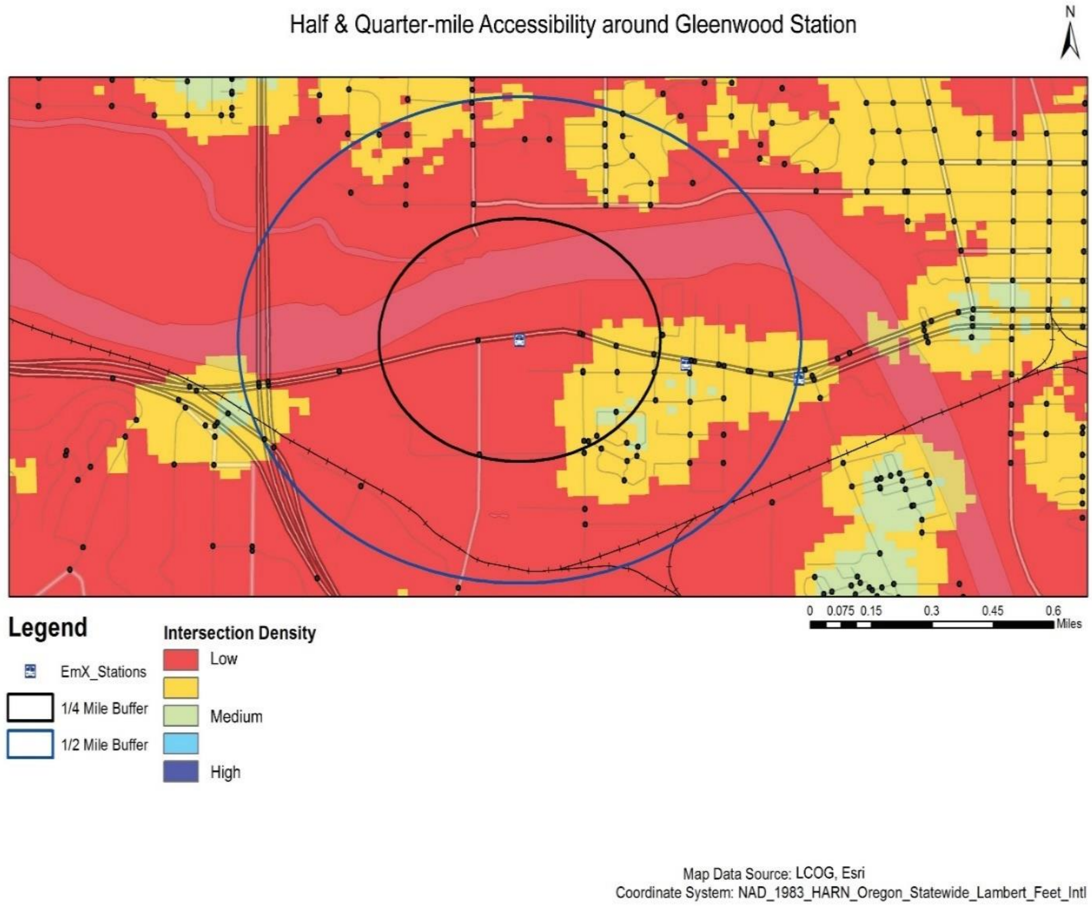
The population density for the block groups around a half-mile radius of Glenwood Station varies between 317 to 1475 people per square mile (See Appendix - A).

Diversity

The land-use maps show that the area within a half-mile of the station is predominantly industrial in use covering up to 26.24 % of the total area around station. Industrial uses are more concentrated within a quarter mile of the station as compared to within a half-mile radius. Within a half-mile radius from the station there are more residential uses than within a quarter mile. There are a couple of car repair shops and a Planned Parenthood building around the Glenwood Station.

Accessibility

The pedestrian catchment zone (PCZ) ratios for a quarter and half-mile radius around Glenwood Station are low. Higher PCZ ratios indicate better street network for walking (i.e. better walkability). Findings indicate that the street network around the Glenwood Station is bad for walking for both a quarter and half-mile radius. Map 8 shows that the street intersection density around Glenwood Station is low overall within a half-mile radius. This indicates poor pedestrian accessibility around Glenwood Station.



Map 8: Street Intersection Density around Glenwood Station

4.8.2 Thermal Comfort Assessment

Thermal Environment

This thesis measured and recorded climate data at Glenwood Station for approximately two hours a day, one day a month for a period of ten months from June 2015 to March 2016 (See Chapter 3, Methods). The study recorded climate data (T_A, V_A, T_g & RH) approximately between 11:15 a.m. and 1:15 p.m. for each measurement campaign. Table 8 shows a statistical summary of the recorded seasonal climate data. For a summary of the monthly climate data see Appendix-D.

The highest mean air temperature (29.23 °C) occurred in June and the lowest occurred in January (8 °C). The difference between the highest and lowest mean T_A indicate an approximate range of air temperatures of 21 °C at Glenwood Station. The recorded mean MRT was highest (63.01 °C) in October and the lowest (24.07 °C) in December. Table 8 shows that the widest ranges for T_A, Tg, MRT and RH occurred in fall and the smallest ranges of T_A, Tg, MRT and RH occurred in spring. The range of air velocity was largest in the summer season and lowest in spring.

Table 8: Seasonal Statistical Summary at Glenwood Station

Season	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	Mean	25.85	31.39	45.48	1.44	51.97
	Maximum	31.05	38.00	84.34	5.10	62.18
	Minimum	21.63	23.50	26.31	0.00	38.90
	Range	9.42	14.51	58.03	5.10	23.28
Fall	Mean	18.10	24.53	47.90	1.23	56.80
	Maximum	24.39	32.85	82.77	3.76	85.53
	Minimum	10.98	12.46	12.49	0.19	38.64
	Range	13.41	20.39	70.28	3.57	46.89
Winter	Mean	12.21	17.74	33.98	0.69	65.02
	Maximum	15.70	23.95	73.88	2.17	83.65
	Minimum	7.22	12.24	16.61	0.18	37.35
	Range	8.48	11.71	57.27	1.99	46.30
Spring	Mean	19.36	29.55	54.33	0.70	49.01
	Maximum	20.84	31.92	83.68	2.53	56.83
	Minimum	17.18	27.95	34.40	0.02	43.13
	Range	3.66	3.97	49.28	2.51	13.71

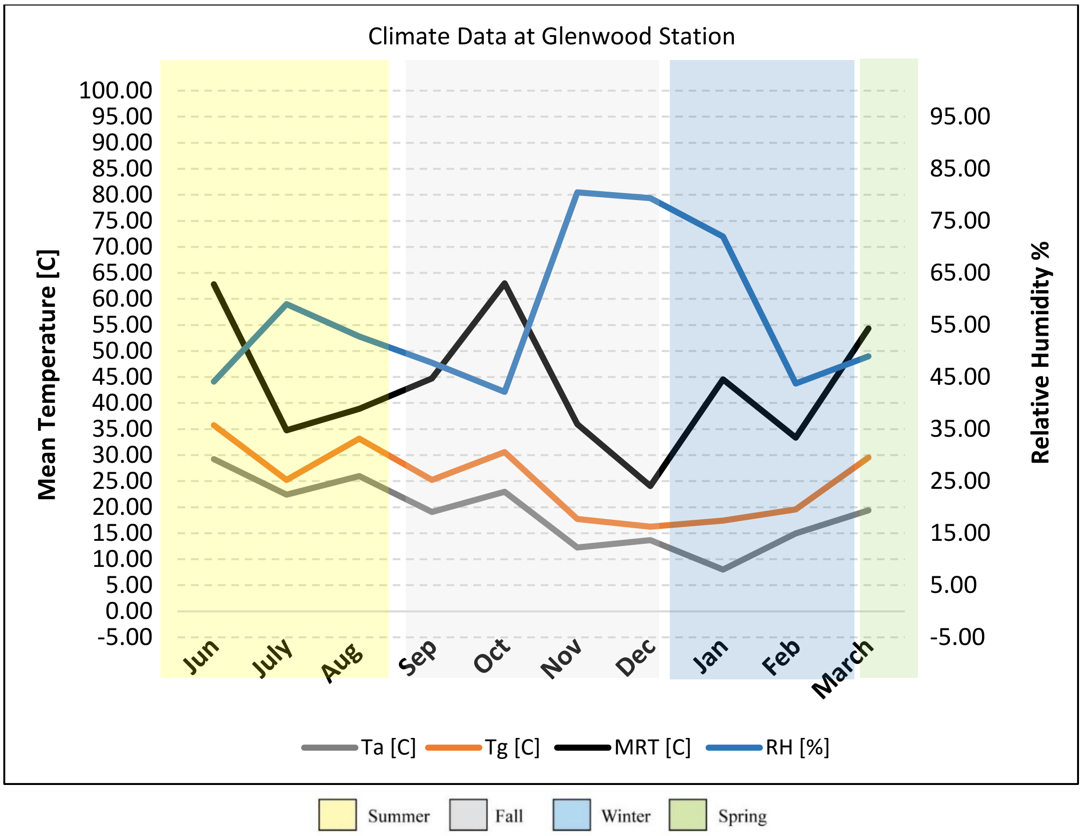


Figure 61: Recorded climate data at Glenwood Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at Glenwood Station was under thermal stress for four out of ten months of the study. The study identified the months of June and August in summers under heat stress categories of 'Strong Heat Stress' and 'Slight Heat Stress'. Results indicate that despite being thermally comfortable, July was close to heat stress. In fall, the study identified the environment at Glenwood Station close to heat stress in September, under 'Moderate Heat Stress' in October and close to cold stress in November. According to PMV thermal stress heat map, winter was thermally comfortable and March was under 'Moderate Thermal Stress'. According to UTCI, the environment at Glenwood Station was under heat stress for the same months identified by PMV. The months of July and September were thermally comfortable but close to heat stress.

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Glenwood Station	3.72	0.65	1.47	0.90	2.29	-0.66	-0.23	0.34	0.29	2.05

Figure 62: PMV Thermal Stress Heat Map

UTCI (°C) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Glenwood Station	36.03	25.33	28.30	25.41	31.55	20.18	17.81	21.21	20.53	29.15

Figure 63: UTCI Thermal Stress Heat Map

4.8.3 Survey Results

Demographic Information

Of the total 11 survey respondents at Glenwood, a majority of seven respondents identified themselves as males. A majority of seven respondents identified themselves in the age group 20-29 years and 3 identified themselves between 50-59 years. Results show that the majority of respondents were Anglo/White (73 %).

Respondents' Travel Behavior

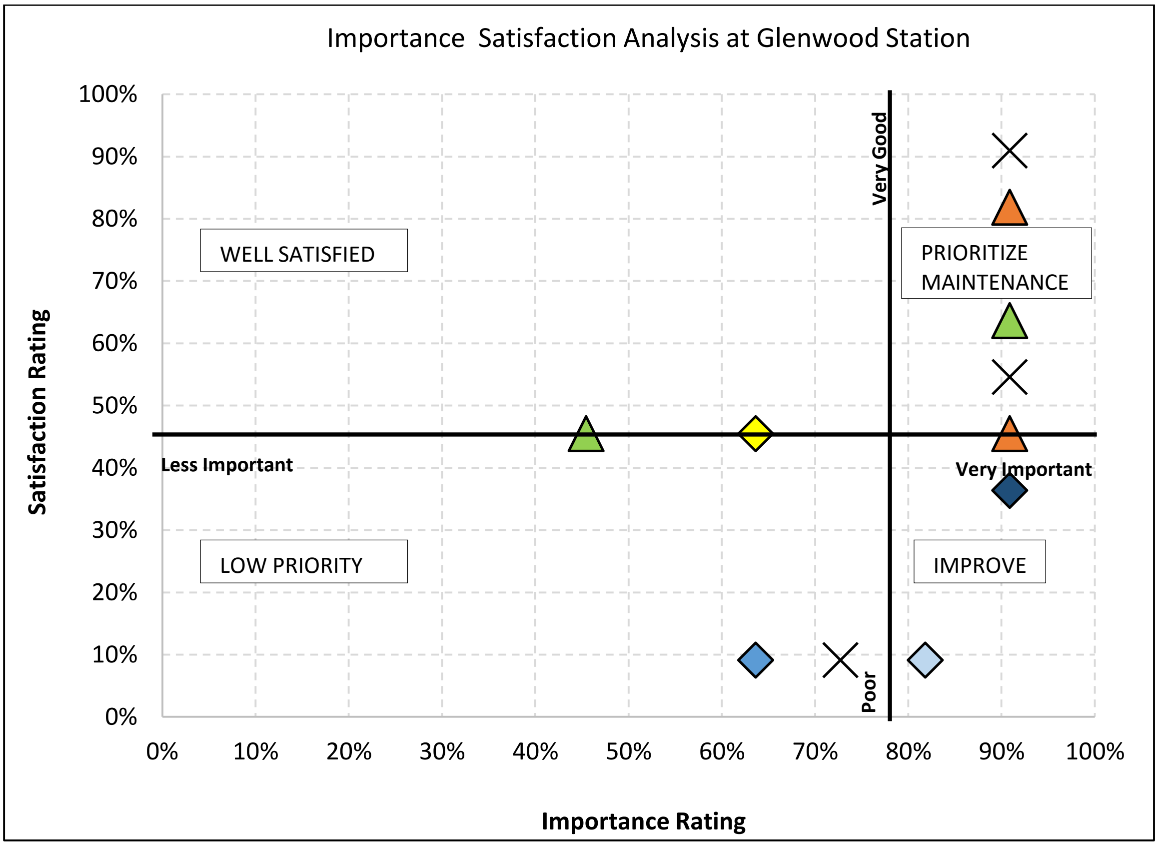
A majority of 82 % respondents at Glenwood Station rode EmX frequently between three to seven days a week. Most of the respondents made the trip for work/job (36 %). Among the respondents, the highest number of people walked to the station but more people took the bus instead of walking to their destinations. Results show that one more respondent preferred a car to those that preferred EmX for the trip.

Importance – Satisfaction Analysis

Figure 64 shows the respondents' importance and satisfaction ratings at Glenwood Station related to attributes of weather protection (wind, sun, rain and cold), station facilities (seating, route/ schedule information and lighting), pedestrian and bicycle access, and perceptions of safety (during the day and night) at the station.

Figure 64 shows that the respondents identified protection from sun, seating, weather protection from the sun, cold, wind & rain, safety during the day, safety at night, station lighting, route/ schedule information, and pedestrian access to the stations at importance rating higher than 50 %. Of these attributes, respondents at Glenwood Station identified protection from rain & cold, and safety at night as important attributes that they were not satisfied with at Glenwood Station. This indicates the need to improve these attributes at Glenwood Station. Findings indicate that safety during the day, route/ schedule information, pedestrian access of the station and station lighting were attributes that respondents identified with high importance and satisfaction. This indicates that these attributes were good but need constant maintenance because of their high importance.

The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction. The lower the IS rating, the lesser the importance of an attribute and higher satisfaction rating. (Iseki et al., 2007) Figure 65 shows respondents' IS ratings of attributes associated with the use of Glenwood Station. This figure is a funnel chart that indicates the improvement priority of attributes at Glenwood Station according to respondents' importance and satisfaction of attributes. It shows the IS ratings of protection from cold, seating, protection from rain, protection from wind and safety at night as 50 % or above. This indicates higher priority of improvement for these attributes compared and low improvement priority for route/ schedule information.



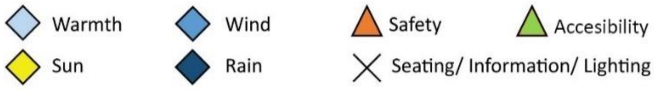


Figure 64: Importance & Satisfaction Ratings of attributes according to respondents at Glenwood Station

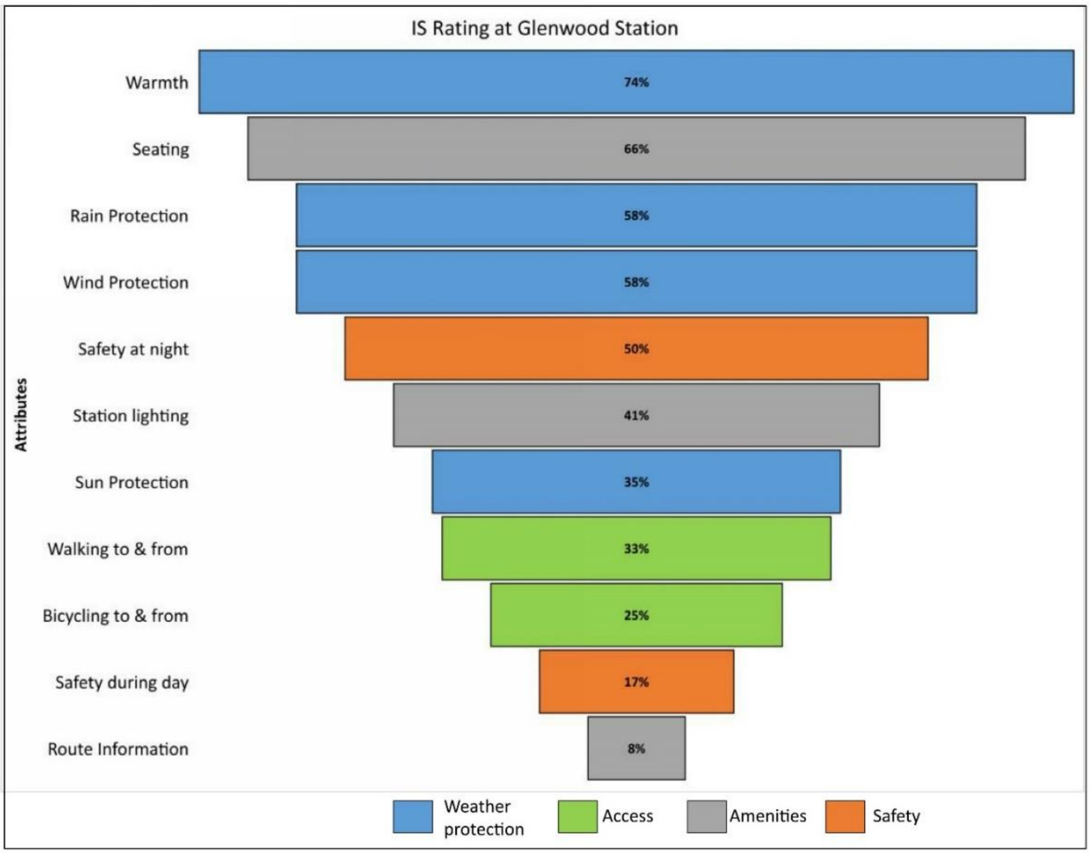


Figure 65: IS Rating at Glenwood Station

4.9 Lexington Station

4.9.1 The Station and Built Environment

Street Geometry

Lexington Station is located on Franklin Boulevard between Lexington Avenue and Mississippi Avenue. To the north, the station platform faces a golf park, pizzeria, construction finishing material supply shop and an action surplus shop that sells military surplus. Auto shop are located to the south of the station. The height-to-width ratio of the street at roughly the center of the station is 1:15.3. Sky view factor (SVF) provides a measure of the shading from the sky. At Lexington Station, SVF is a result of the station canopy structure, density of buildings, trees and other structures around the station. SVF can have a maximum value of 1, indicating sparsely built environment. At Lexington Station, the SVF is 0.541.

Figure 66: Aerial view of Lexington Station. Source: Google Earth Pro

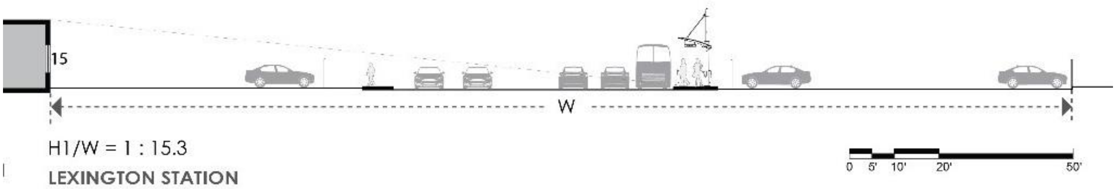


Figure 67: Street Height-to-Width Ratio at Lexington Station

0.541

Figure 68: SVF at Lexington Station

Station Description

Lexington station is a side-station with a single boarding platform that serves Springfield bound EmX buses. The station platform is oriented north, slightly towards the east and south, slightly towards the west, with the boarding side facing northeast. To simply, this study considered the station orientation as north-south with the boarding side facing north. The station canopy structures (15’-0” linear length) cover 28% area of the platform. The platform is 40’-0” long and 10’-0” wide. The station has 3’-8” linear length of seating, bike rack, bus route information, trashcan and a ticketing booth.

Density

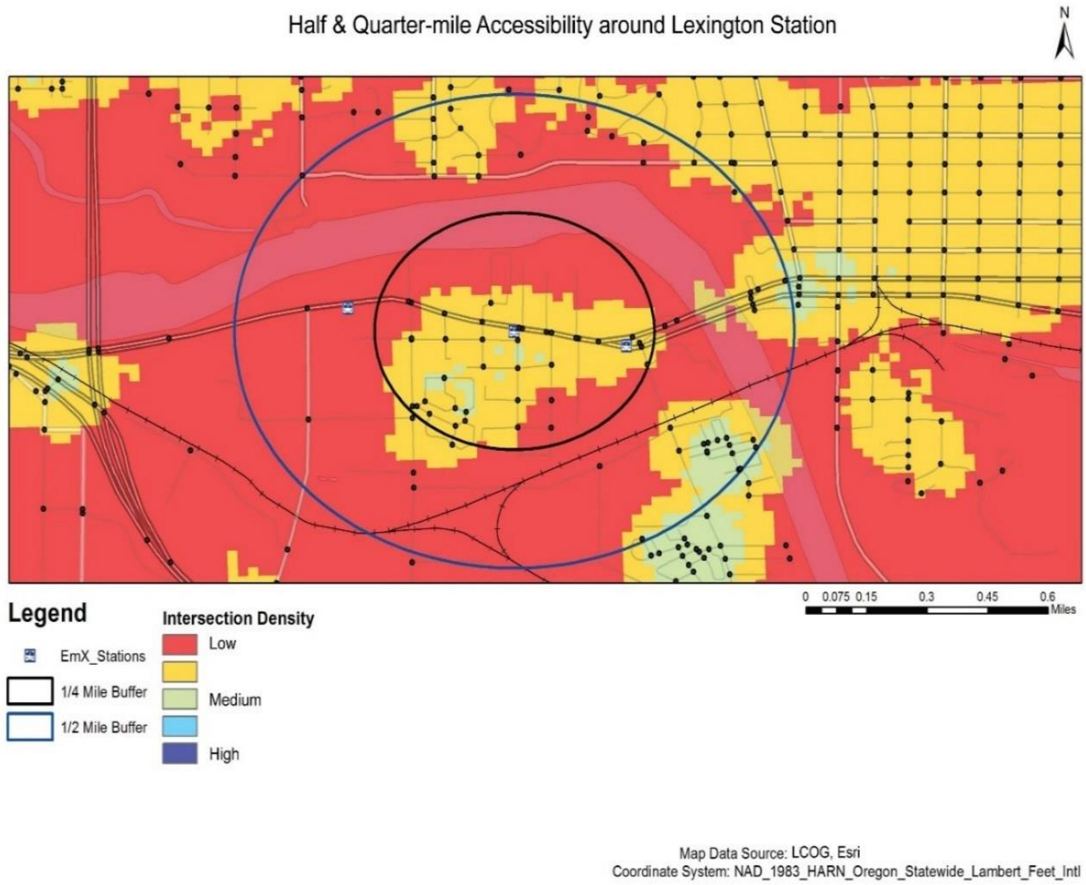
The population density for the block groups around a half-mile radius of Lexington Station varies between 1475 to 6673 people per square mile (See Appendices, A).

Diversity

The land-use maps show that the area within a half-mile of the station is predominantly industrial in use covering up to 24.66 % of the total area around station. Within a quarter mile radius from the station, there are more multifamily and commercial uses as compared to within a half-mile. There are a couple of auto shops and a golf park nearby.

Accessibility

The pedestrian catchment zone (PCZ) ratio for a quarter and half-mile radius around the Lexington Station are between medium and high. Higher PCZ ratios indicate better street network for walking (i.e. better walkability). Findings indicate that the walkability around Lexington station is fair. Map 9 shows that the street intersection density for a half-mile around the station is lower than for a quarter mile. This indicates better pedestrian access closer to Lexington Station.



Map 9: Street Intersection Density around Lexington Station

4.9.2 Thermal Comfort Assessment

Thermal Environment

This thesis measured and recorded climate data at Lexington Station for approximately two hours a day, one day a month for a period of ten months from June 2015 to March 2016 (See Chapter 3, Research Methods). The study recorded climate data (T_A, V_A, T_g & RH) approximately between 1:20 p.m. and 3:20 p.m. for each measurement campaign. Table 9 shows a statistical summary of the recorded seasonal climate data. For a summary of the monthly climate data see Appendix-D.

The highest mean air temperature of 32.89 ^{o}C occurred in June 2015 and the lowest occurred in January (8.02 ^{o}C). The recorded mean MRT was the highest (61.77 ^{o}C) in October and the lowest (10.47 ^{o}C) in November. Table 9 shows that the range of Tg, MRT and RH were largest in fall and the smallest range of T_A, Tg, MRT and RH occurred in spring. This study found that of all the seasons, the largest range of air velocity occurred in summer and the lowest occurred in winters.

Table 9: Seasonal Statistical Summary of recorded climate data at Lexington Station

Season	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va[m/s]	RH [%]
Summer	Mean	27.95	32.24	46.44	1.88	47.20
	Maximum	33.76	39.43	81.41	5.19	65.33
	Minimum	22.11	23.83	28.61	0.11	32.47
	Range	11.65	15.60	52.79	5.08	32.86
Fall	Mean	19.41	23.52	40.79	1.35	52.79
	Maximum	28.15	34.65	84.14	4.37	88.38
	Minimum	9.58	9.39	4.78	0.21	32.38
	Range	18.56	25.27	79.36	4.16	56.00
Winter	Mean	11.47	13.34	19.24	0.75	65.60
	Maximum	15.22	16.53	56.04	2.50	86.06
	Minimum	7.44	7.75	8.44	0.19	40.41
	Range	7.78	8.79	47.61	2.31	45.65
Spring	Mean	22.45	28.71	53.40	1.42	40.89
	Maximum	23.26	30.04	70.64	3.34	43.46
	Minimum	21.72	27.26	37.96	0.18	39.50
	Range	1.53	2.78	32.68	3.16	3.97

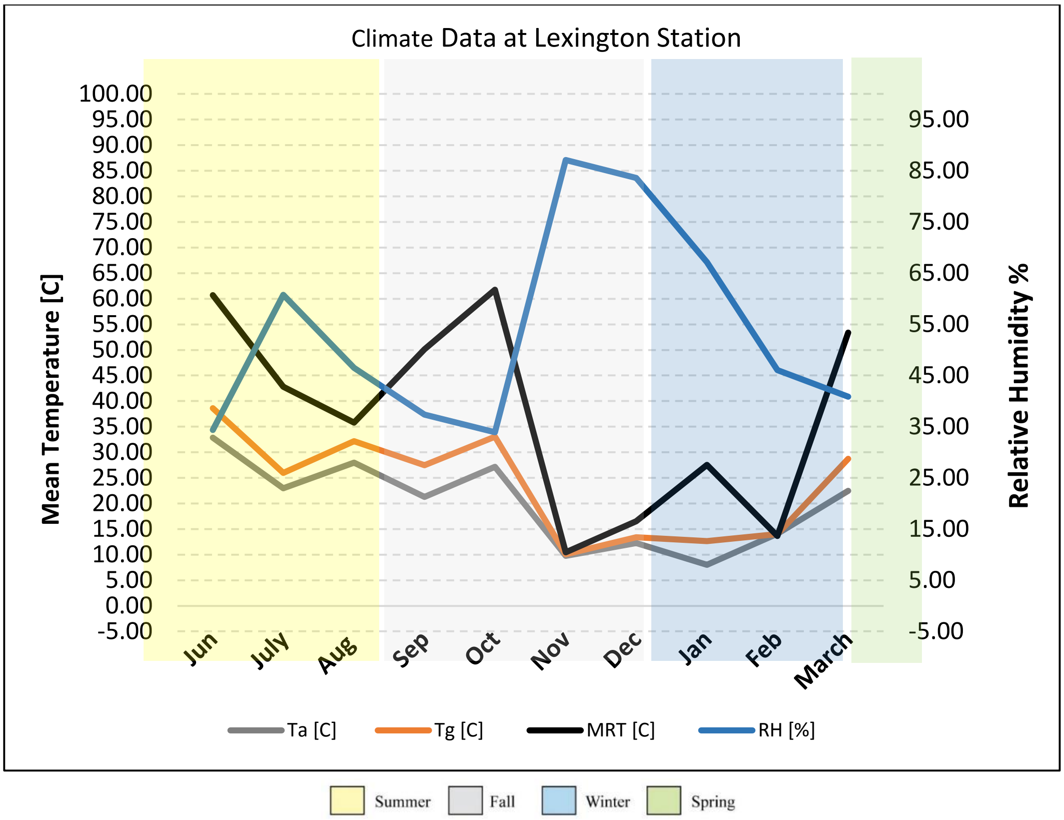


Figure 69: Recorded climate data at Lexington Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at Lexington Station was under thermal stress for seven out of ten months of the study. The study found that in summers, the environment at Lexington Station was under 'Extreme Heat Stress' in June, 'No Thermal Stress' in July and under 'Slight Heat Stress' in August. In the fall, the study found that the environment at Lexington Station was under 'Slight Heat Stress' in September, 'Moderate Heat Stress' in October and 'Moderate Cold Stress' in November. This indicates that the range of thermal stress and perceptions felt by people at the Lexington Station were wide varying between slightly warm, warm and cool. In winters, the study found the environment at Lexington Station under ‘Slight Cold Stress’ in December and close to cold stress in the months of January and February. According to UTCI, the environment at Lexington Station during summers varied between ‘Very Strong Heat Stress’ in June to ‘Moderate Heat Stress in August. In July, the difference between ‘No Thermal Stress’ and ‘Moderate Heat Stress’ was only 0.34 °C so the environment was very close to heat stress in July. In the fall, the environment was under ‘Moderate Heat Stress’ in September, ‘Strong Heat Stress’ in October and under ‘No Thermal Stress’ in November. Winters were thermally comfortable, while spring was under ‘Moderate Heat Stress’ at Lexington Station for the recorded climate.

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Lexington Station	4.38	0.15	1.62	1.39	2.85	-2.40	-1.70	-0.75	-0.76	1.71

Figure 70: PMV Thermal Stress Heat Map

UTCI (°C) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
Lexington Station	38.57	25.66	28.53	27.67	33.29	10.93	14.54	14.89	13.08	29.14

Figure 71: UTCI Thermal Stress Heat Map

4.9.3 Survey Results

Demographic Information

The response rate at Lexington Station was low because of the lack of availability of people at the station during the length of the study. Of the total 6 survey respondents at Lexington Station, a majority of 3 respondents identified themselves as females. The highest number of respondents (3) identified themselves between the age group of 20-29. Results show that the majority of respondents were Asian/Pacific Islander (33 %).

Respondents' Travel Behavior

Half of the respondents at Lexington Station rode EmX frequently between three to seven days per week; the other half rode it for two or fewer days per week. Half of the respondents made the trip for work/job. Among the respondents, the majority walked to get to the station and all of them walked to their destinations. Five out of the total six respondents at Lexington Station preferred using a car to riding EmX for the trip.

Importance – Satisfaction Analysis

Figure 64 shows the respondents' importance and satisfaction ratings at Lexington Station related to attributes of weather protection (wind, sun, rain and cold), station facilities (seating, route/ schedule information and lighting), pedestrian and bicycle access, and perceptions of safety (during the day and night) at the station.

Figure 72 shows that the respondents identified all the attributes at Lexington Station at an importance rating of 50 % or higher. Of these attributes, respondents at Lexington Station identified protection from rain, wind and cold as important attributes that they were not satisfied with. This indicates that these attributes need improvement at Lexington Station. Findings indicate that route/ schedule information and pedestrian access of station are attributes that the respondents identified with high importance and satisfaction. This indicates that these attributes are good enough but need consistent maintenance because of their importance for the respondents at Lexington Station. Respondents identified high satisfaction ratings with safety during the day, seating, and station lighting at Lexington Station. This indicates that these attributes do not need improvement at Lexington Station according to the respondents' ratings. Respondents identified low satisfaction rating for bicycle access of the station and protection from sun at Lexington Station. This suggests that these attributes could also be improved to improve users' satisfaction.

The IS Rating Index indicates how important an attribute is for the respondents and their level of dissatisfaction. The lower the IS rating, the lesser the importance of an attribute and higher satisfaction rating. (Iseki et al., 2007) Figure 73 shows respondents' IS ratings of attributes associated with the use of Lexington Station. This figure is a funnel chart that indicates the improvement priority of attributes at Lexington Station according to respondents' importance and satisfaction of attributes. It shows that improvement of protection from wind is of highest priority at Lexington Station followed by protection from cold, rain and sun. Results show that the station attributes with an IS rating of 50 % or higher are pedestrian access of the station, safety at night, protection from the sun, protection from rain, warmth from cold and protection from wind. Since the sample size at Lexington Station was small (11 surveys), more surveys at this station could improve results of findings and help identify the need for improvement of station attributes according to the respondents.

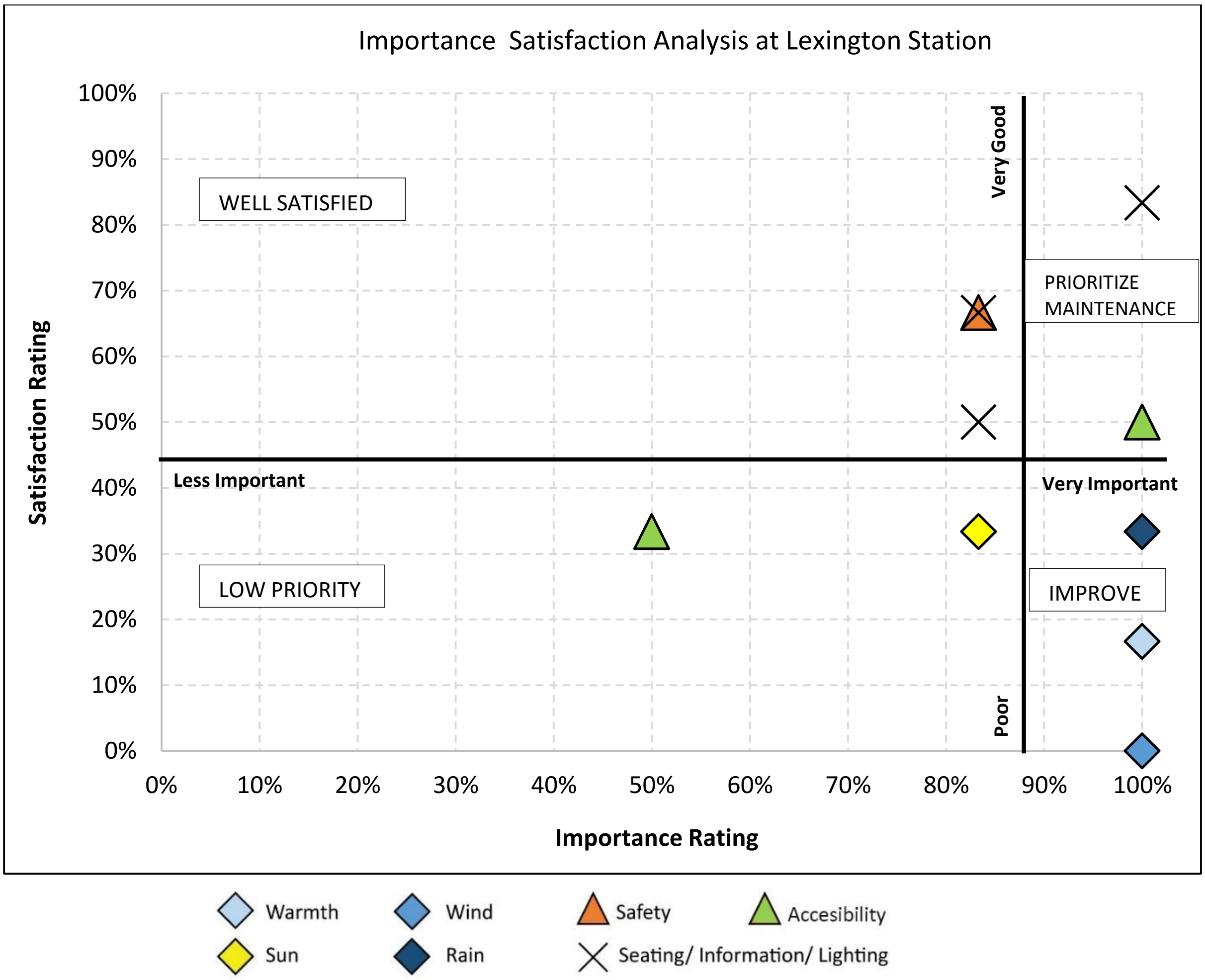


Figure 72: Importance & Satisfaction Ratings of attributes according to respondents at Lexington Station

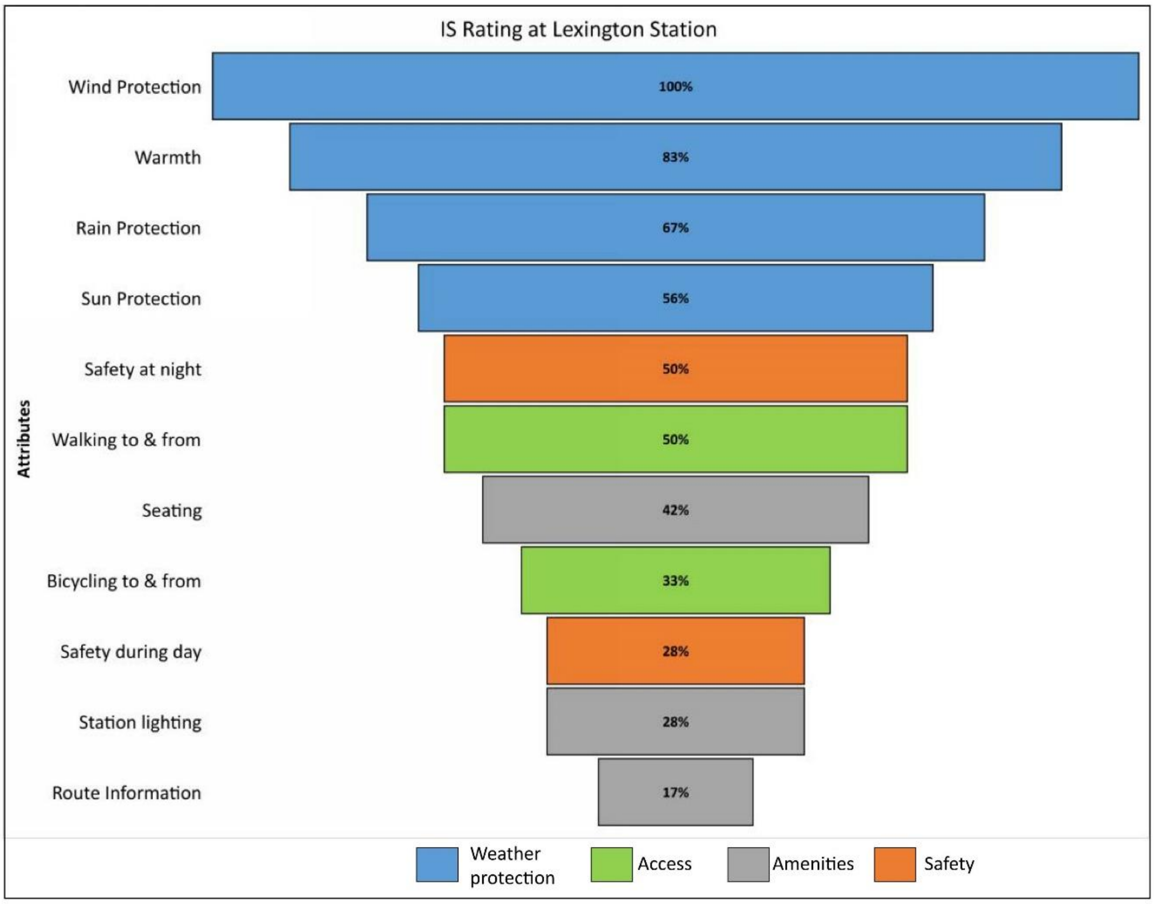


Figure 73: IS Rating at Lexington Station

4.10 McVay Station

4.10.1 The Station and Built Environment

Street Geometry

McVay Station is located on Franklin Boulevard to the west of the Willamette River. This research studied the station platform that serves Springfield bound EmX buses. The boarding platform is south facing. It faces a U-Haul moving and storage facility to the south. To the north, a motorbike shop is located. The area is sparely built. The height-to-width ratio of the street at roughly the center of the station is 1:13.5. Sky view factor (SVF) provides a measure of the shading from the sky. At

McVay Station, SVF is a factor of the station canopy structure, density of buildings, trees or other structures around the station. SVF can have a maximum value of 1, indicating sparsely built environment. At McVay Station, the SVF is 0.656.

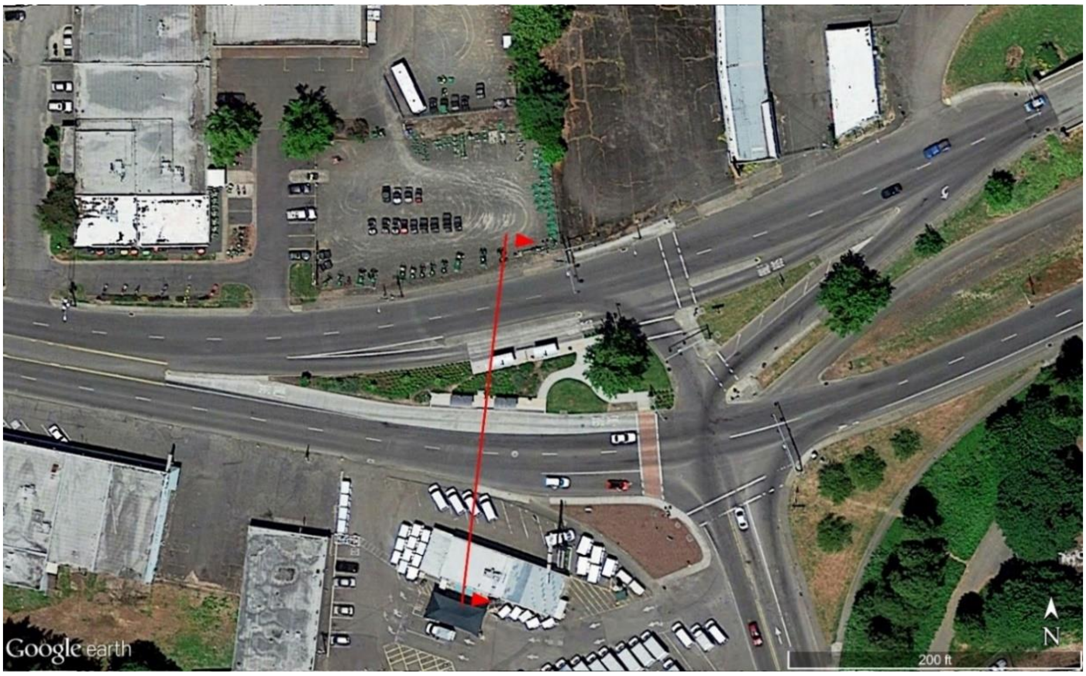


Figure 74: Aerial view of McVay Station. Source: Google Earth Pro

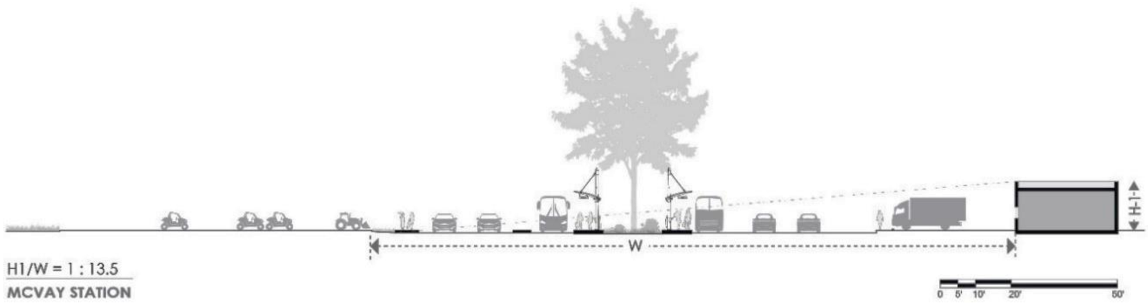


Figure 75: Street Height-to-Width Ratio

0.656

Figure 76: SVF at McVay Station

Station Description

This station is a center-island station with two single boarding platforms each to serve Springfield and Eugene bound EmX buses separately. This research studied the Springfield bound EmX station. This station platform is oriented north, slightly towards east and south slightly towards west, with the Springfield bound boarding side facing south slightly west. To simply, this study considered the platform's orientation as north-south with the boarding side facing south. The station canopy structures (30'-0" linear length) cover 27.4% area of the platform. The platform measures to be 78'-0" long and 10'-6" wide. The station has 7'-4" linear length of seating, bike rack, bus route information, real time schedule, trash cans and a ticketing booth.

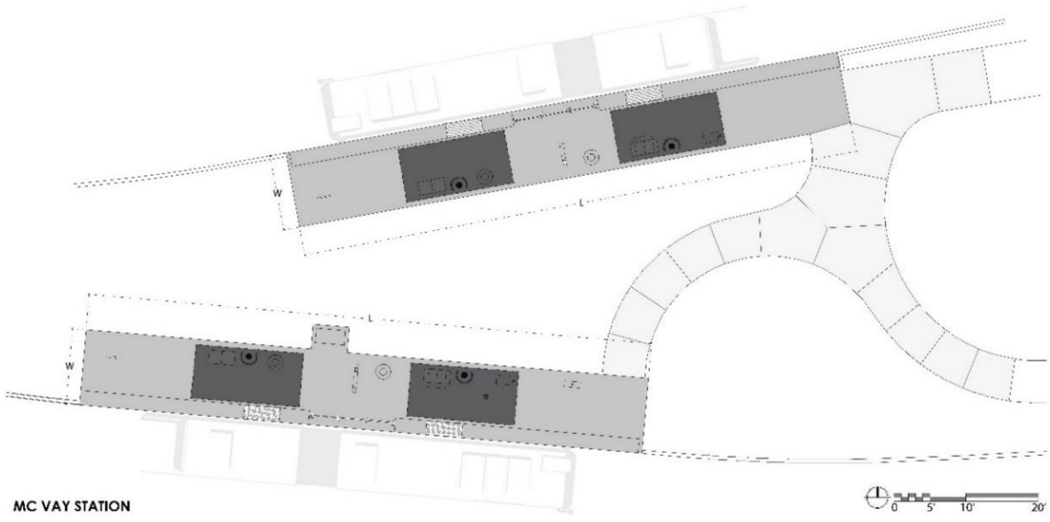


Figure 77: Plan of McVay Station

Density

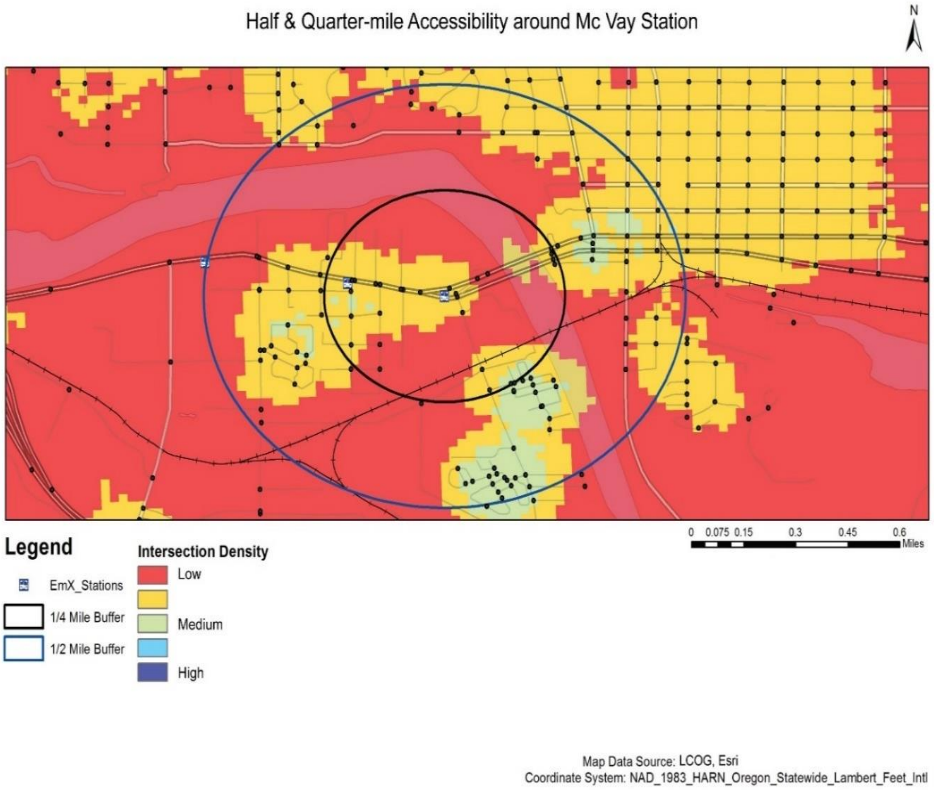
The population density for the block groups around a half-mile radius of Lexington Station varies between 1475 to 6673 people per square mile (See Appendix, A).

Diversity

The land use maps show that a majority of 18.77% of the total area for a half-mile radius around McVay Station is industrial. In comparison to the area of a quarter mile radius around the station, industrial uses, multi-family and residential uses are more concentrated within a half-mile radius of the station. Commercial uses are more concentrated within a quarter mile radius in comparison to a half-mile radius.

Accessibility

The pedestrian catchment zone (PCZ) for a quarter and half-mile radius around McVay Station are between medium and high. Higher PCZ ratios indicate better street network for walking (i.e. better walkability). Findings indicate that the walkability around McVay Station is fair. Map 10 shows that the street intersection density around McVay station is generally low but higher in some areas around the station. This indicates poor pedestrian access in the areas marked red and better pedestrian access in the areas marked in yellow and blue.



Map 10: Street Intersection Density around McVay Station

4.10.2 Thermal Comfort Assessment

Thermal Environment

This thesis measured and recorded climate data at McVay Station for approximately two hours a day, one day a month for a period of ten months from June 2015 to March 2016 The study recorded climate data (T_A, V_A, T_g & RH) approximately between 3:30 p.m. and 5:30 p.m. for each measurement campaign. (See Chapter 3, Methods)

Table 10 shows a statistical summary of the recorded seasonal climate data. For a summary of the monthly climate data see Appendix-D.

The highest mean air temperature (34.15 ^{o}C) occurred in June 2015 and the lowest (7.77 ^{o}C) occurred in January. Results show that the recorded mean MRT was the highest (43.77 ^{o}C) for the month of October and the lowest (6.44 ^{o}C) for the month January. Table 10 shows that of all the seasons in this study, the largest ranges of T_A, Tg, MRT and RH were also the widest in the fall. Findings show that the largest range of air velocity occurred in summer and the lowest in spring.

Table 10: Seasonal Statistical Summary at McVay Station

Season	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	Mean	28.25	29.44	31.61	0.96	43.73
	Maximum	34.31	34.84	45.70	4.74	63.79
	Minimum	21.94	23.47	25.55	0.11	29.62
	Range	12.37	11.36	20.15	4.63	34.17
Fall	Mean	19.91	21.69	27.73	0.99	53.57
	Maximum	28.84	33.26	67.26	4.09	92.73
	Minimum	9.26	8.89	6.59	0.00	31.90
	Range	19.58	24.37	60.68	4.09	60.83
Winter	Mean	11.97	11.68	10.81	0.60	64.16
	Maximum	14.79	15.03	28.75	3.17	82.90
	Minimum	6.81	5.44	-2.60	0.14	44.66
	Range	7.98	9.59	31.35	3.03	38.25
Spring	Mean	22.93	28.93	43.26	0.62	41.47
	Maximum	23.14	29.87	59.72	2.72	44.14
	Minimum	22.71	27.78	33.04	0.04	35.74
	Range	0.43	2.09	26.68	2.68	8.39

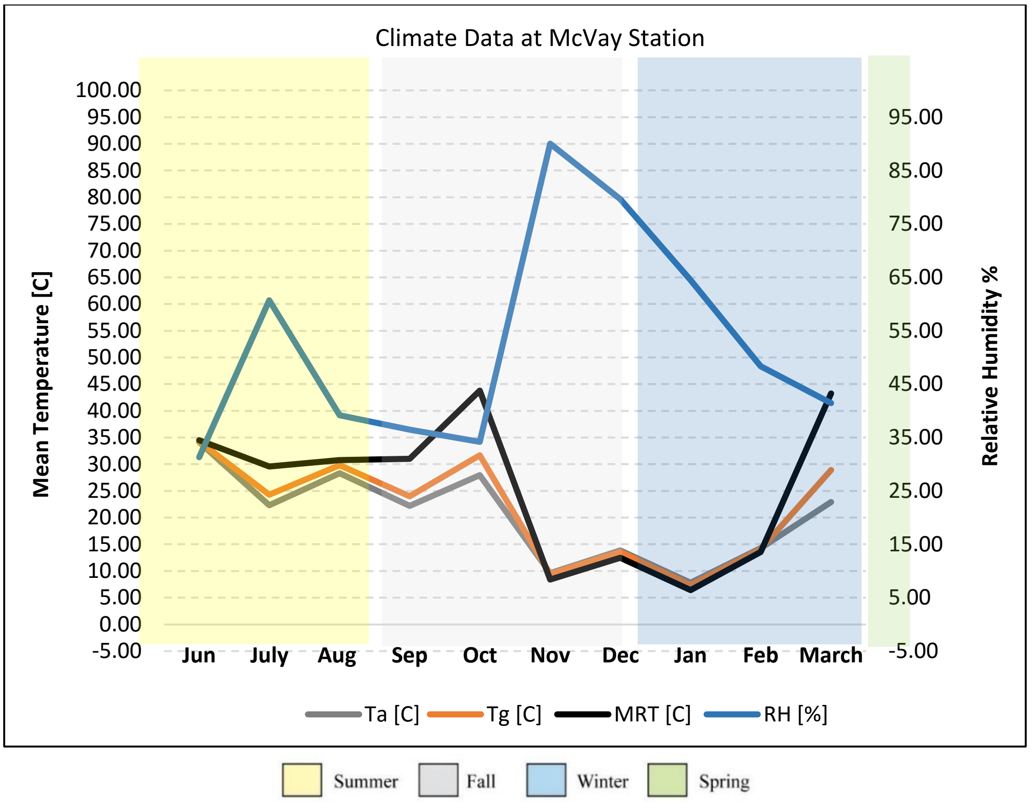


Figure 78: Recorded climate data at McVay Station

Assessment of Thermal Comfort Conditions using Thermal Indices

This thesis identified conditions of thermal comfort by calculating assessment indices PMV and UTCI. These thermal indices identified categories of thermal stress for the recorded climate data according to the assessment scales shown here above the heat maps.

Results show that according to PMV the environment at McVay Station was under thermal stress for seven out of ten months of the study period. In summers, the environment at McVay Station was under 'Moderate Heat Stress' and 'Slight Heat Stress' for the months of June and August. The difference between 'No Thermal Stress' and 'Slight Heat Stress' in July was very small (0.5 ^{o}C). In the fall season, the environment was under thermal stress varying from 'Moderate Heat Stress' in October and 'Moderate Cold Stress' in November. In winter, the month of December and January were under ‘Slight Cold Stress’. Although February was thermally comfortable, the difference between ‘No Thermal Stress’ and ‘Slight Cold Stress’ was very small (0.3 ^oC). This indicates that the environment was very close to cold stress. According to UTCI, the environment during summers was under ‘Moderate Heat Stress’ in August. In June and July, the difference from heat stress was small, (approximately 1.5 ^oC for June and July). In Fall, the environment was under ‘Moderate Heat Stress’ in October and in March in spring. In winters, the environment was under ‘Slight Cold Stress’ in the month of January.

PMV (C)	+ 4	+ 3	+ 2	+ 1	0	- 1	- 2	- 3	- 4
Thermal Perception	VERY HOT	HOT	WARM	SLIGHTLY WARM	COMFORTABLE	SLIGHTLY COOL	COOL	COLD	VERY COLD
STRESS CATEGORY	EXTREME HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	SLIGHT HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
McVay Station	2.76	0.49	1.41	0.35	2.25	-2.82	-1.70	-1.37	-0.73	1.67

Figure 79: PMV Thermal Stress Heat Map

UTCI (^oC) RANGE	above +46	+38 to +46	+32 to +38	+26 to +32	+9 to +26	+9 to 0	0 to -13	-13 to -27	-27 to -40	below -40
STRESS CATEGORY	EXTREME HEAT STRESS	VERY STRONG HEAT STRESS	STRONG HEAT STRESS	MODERATE HEAT STRESS	NO THERMAL STRESS	SLIGHT COLD STRESS	MODERATE COLD STRESS	STRONG COLD STRESS	VERY STRONG COLD STRESS	EXTREME COLD STRESS

	Summer			Fall			Winter			Spring
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March
McVay Station	24.51	24.51	27.75	22.86	30.71	9.57	14.12	8.02	13.38	27.89

Figure 80: UTCI Thermal Stress Heat Map

4.11 Discussions

This section presents a discussion of the findings of analyses in response to the research questions mentioned in Chapter 1. The research incorporates discussions specific to each case study station under station names in this chapter and a comparison across stations in this discussions section.

1. How do transit users' out of vehicle experience correlate to the built environment at semi-outdoor Emerald Express bus rapid transit stations?
    a. How do users' satisfaction with accessibility of stations correlate to pedestrian accessibility as measured by pedestrian catchment zone ratios around EmX stations?

This research studied the correlations between users' satisfaction ratings of accessibility at the EmX stations and the recorded pedestrian catchment zone (PCZ) ratios across the stations. Theoretically, PCZ ratios are a measure of the density of street network and the higher the PCZ ratios, the better the street network for walking. Figure 81 shows a general trend of a positive relationship between PCZ ratios and satisfaction ratings of accessibility. The linear regression line fitted for respondents' satisfaction ratings had a small value of 0.17 for R^2 coefficient which indicates a very weak relationship between satisfaction ratings of pedestrian access and PCZ ratios.

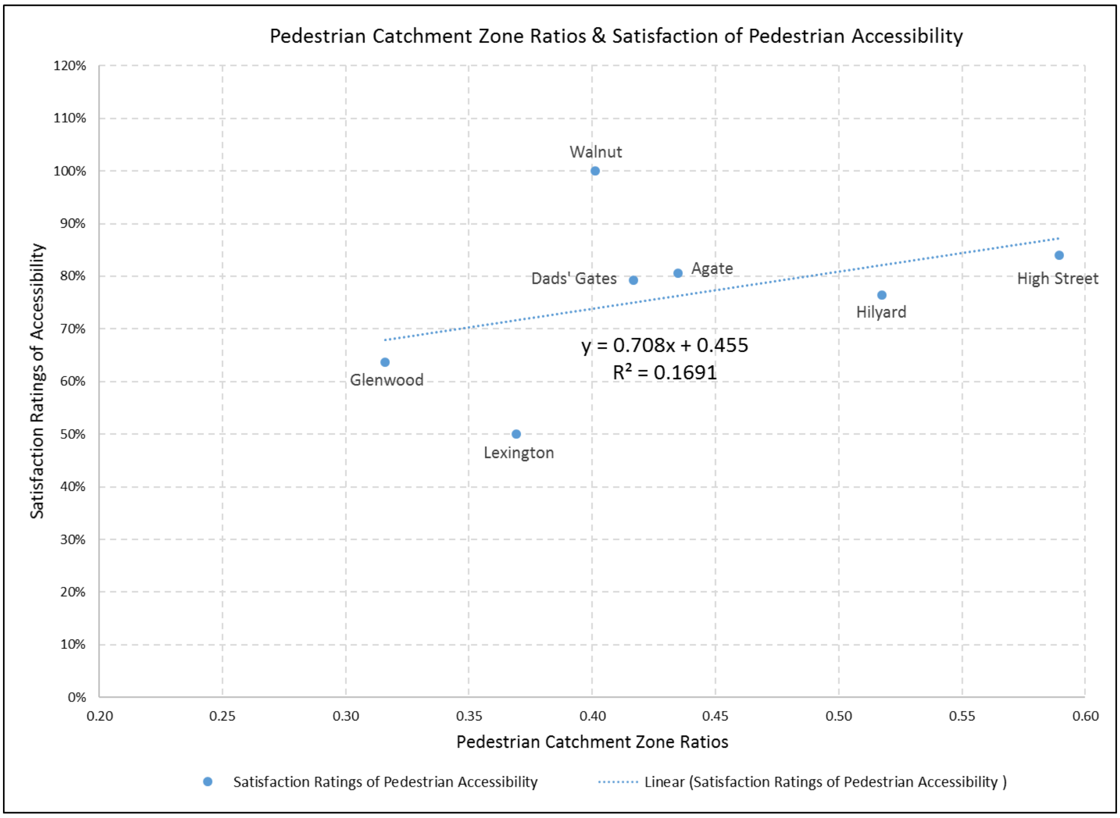


Figure 81: PCZ ratios & Users' Satisfaction Ratings of Pedestrian Accessibility

b. How do users' satisfaction with safety at the stations correlate to design attributes of street shading as measured by sky view factor and proportion of commercial land-use around EmX stations?

This research studied correlations between users' satisfaction ratings of safety at the stations during the day, night and the mean of day and night satisfaction ratings with sky view factor (SVF) across the stations. Sky view factor is a design attribute of the built environment. It is a measure of street shading which is a result of the street geometry and urban form. Figure 82 shows a general trend of decreasing satisfaction ratings with an increase in sky view factor across the stations. The linear regression line fitted to the satisfaction ratings of safety during the day indicates a weak relationship; R^2 coefficient of 0.58. The linear regression line fitted to satisfaction ratings of safety at night indicates a strong relationship; R^2 coefficient of 0.93. The linear regression line for mean satisfaction ratings of safety also indicates a strong relationship between the SVF and satisfaction of safety; R^2 coefficient of 0.82. The gradient coefficient of the respondents' mean satisfaction ratings was -0.85 which shows that mean satisfaction rating of safety at EmX stations will decrease by 8.5 % for every 0.1 increase in the value of SVF.

Figure 83 shows a strong positive relationship between users' satisfaction ratings of safety and the percentage of commercial land-use around a half mile radius of the stations (R^2 coefficient of 0.76). Results show a strong negative relationship between users' satisfactions with safety and non-commercial land uses.

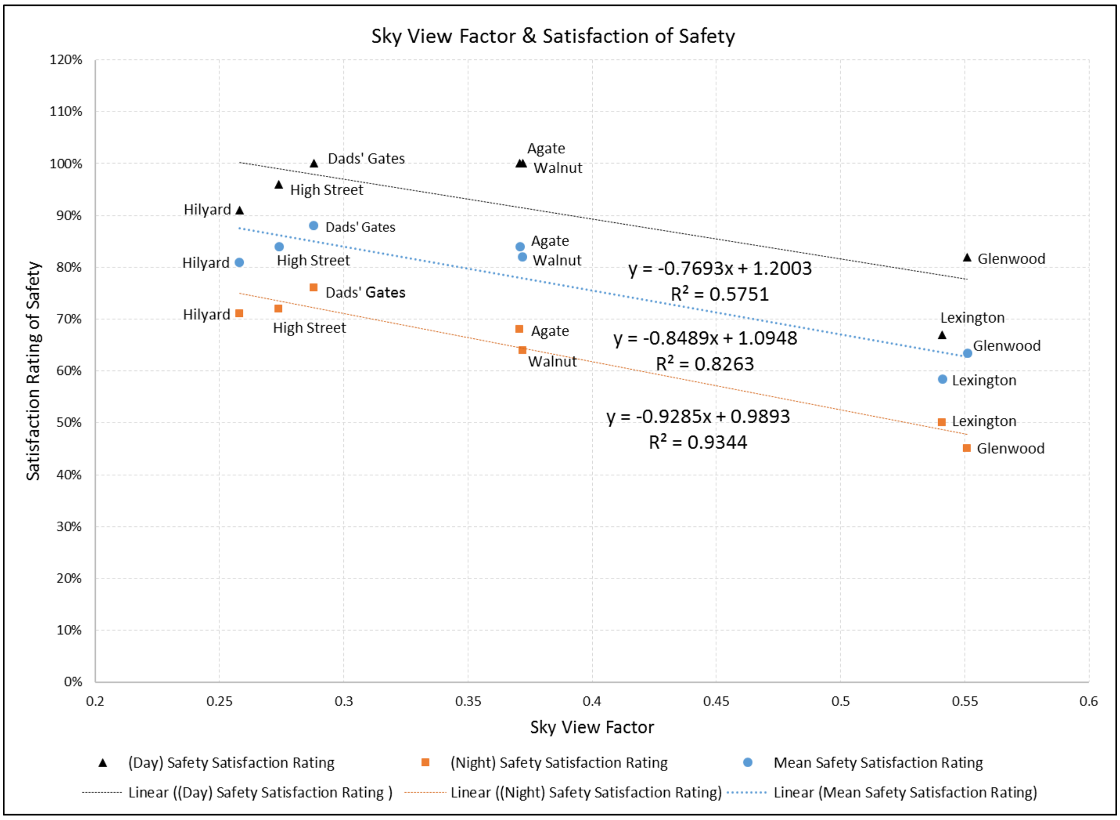


Figure 82: Sky View Factor & Satisfaction Ratings of Safety at stations

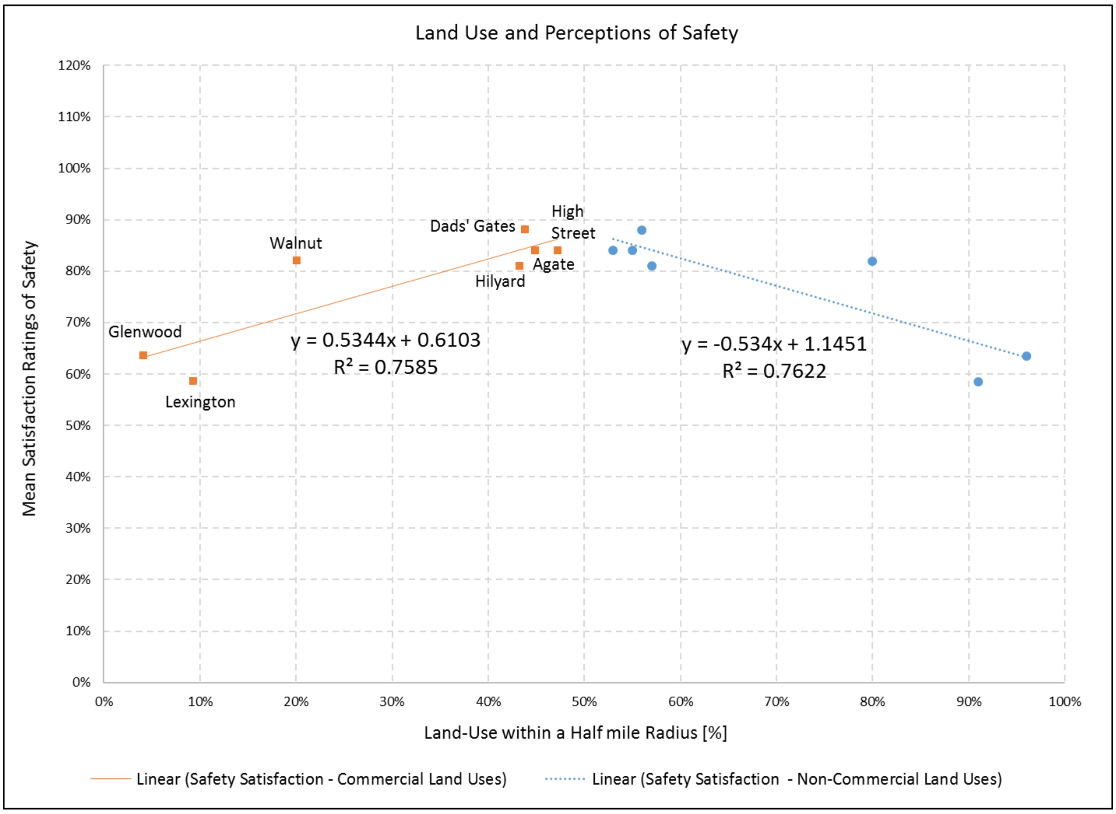


Figure 83: Land Use & Satisfaction Ratings of Safety at stations

c. How do users' satisfaction with weather protection at the stations correlate to design attributes of street shading as measured by sky view factor and percentage of canopy shade at EmX stations?

This research studied correlations between respondents' satisfaction ratings of weather protection and the design attributes of the built environment as measured by sky view factor and percentage of canopy shade at EmX stations. Sky view factor measures the amount of street shading which is the result of surrounding structures like buildings and trees. Figure 84 shows that there is a strong negative relationship between satisfaction ratings of weather protection and sky view factor, indicated by R^2 coefficient of 0.94. Results indicate that respondents were less satisfied with weather protection at stations in sparely built environments with lower street shading and more satisfied in environments with higher street shading. Figure 85 shows a general positive trend between users' satisfaction of weather protection and percentage of canopy shade at the stations but a small value of 0.25 for R^2 coefficient indicates a very weak relationship. Results show that for High Street Station with a low percentage of canopy shade but higher street shading (small value of SVF), respondents' satisfaction rating of weather protection was high.

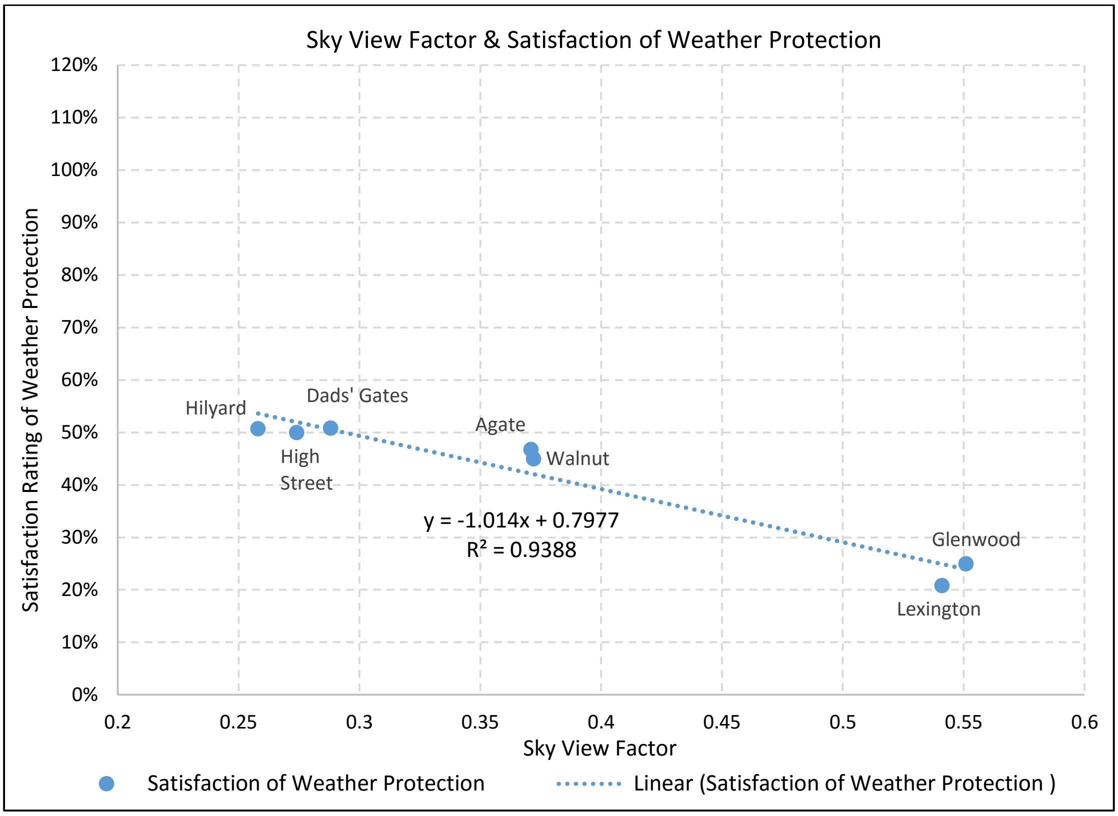


Figure 84: Sky View Factor & Satisfaction Ratings of Weather Protection at stations

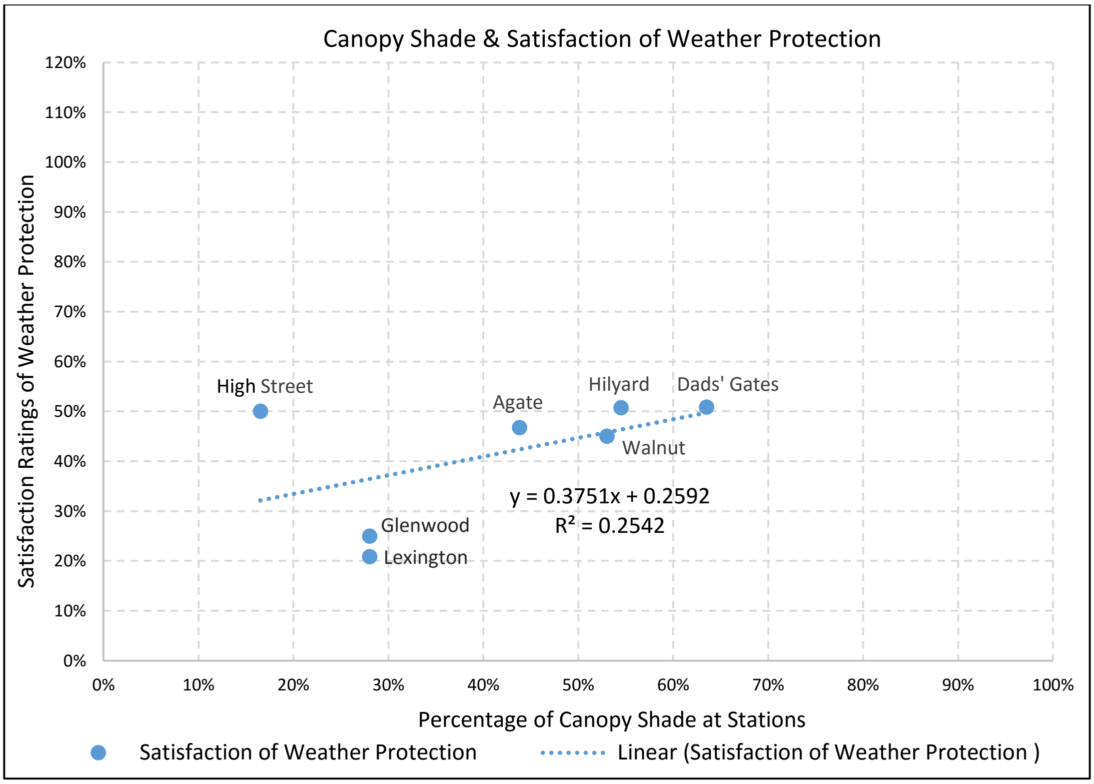


Figure 85: Canopy shade & Satisfaction of Weather Protection at EmX stations

2. How do users' satisfaction with accessibility, safety, weather protection and amenities at EmX stations correlate to their preference of EmX?

This research calculated respondents' satisfaction ratings at each station by calculating the arithmetic mean of satisfaction ratings of station attributes recorded for this study. The study asked respondents 'Would you have preferred to make this trip by car instead?' and determined the proportion of respondents who identified a preference of EmX. Results show general positive relationship trends between respondents' satisfaction ratings of accessibility, safety, weather protection, amenities, and their preference of EmX. Figure 86 shows that the relationship between mean satisfaction ratings and preference of EmX was not very strong; R2 coefficient of 0.53. Figure 87 shows a strong positive relationship between satisfaction ratings of pedestrian accessibility and respondents' preference of EmX as indicated by R^2 coefficient of 0.86 and a positive gradient of the linear regression line. Figure 88 shows that the relationship between mean satisfaction of safety and preference of EmX is not very strong as indicated by R^2 coefficient of 0.50. Figure 89 and Figure 90 show that the relationships between satisfaction of weather protection & amenities, and respondents' preference of EmX are weak relations as indicated by R^2 coefficients of 0.43 and 0.26.

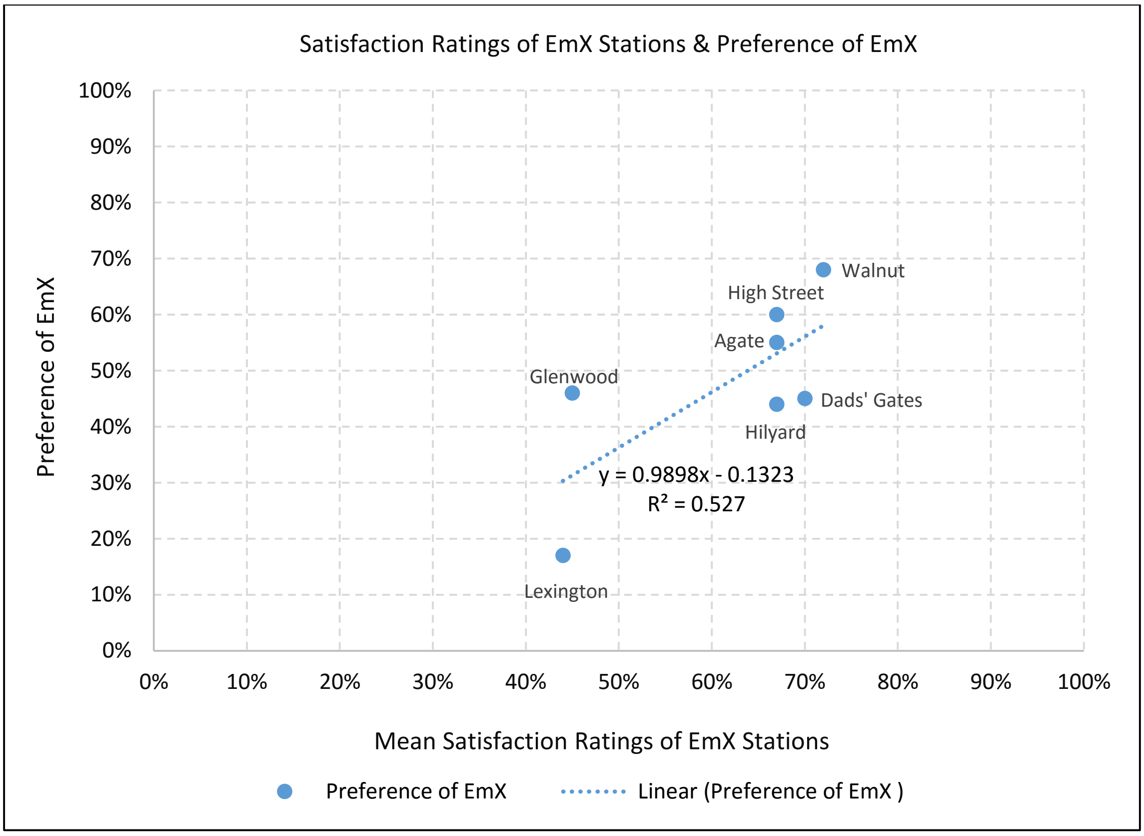


Figure 86: Satisfaction ratings & Preference of EmX at stations

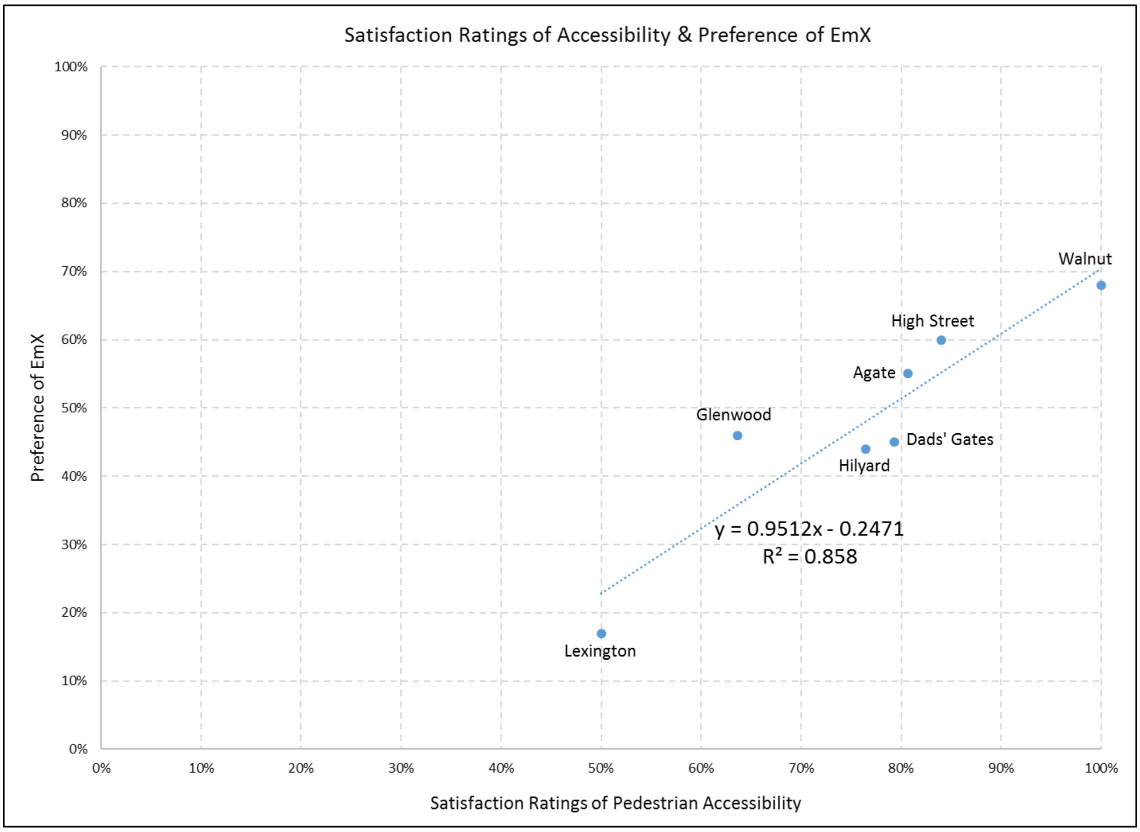


Figure 87: Satisfaction ratings of Pedestrian Accessibility & Preference of EmX

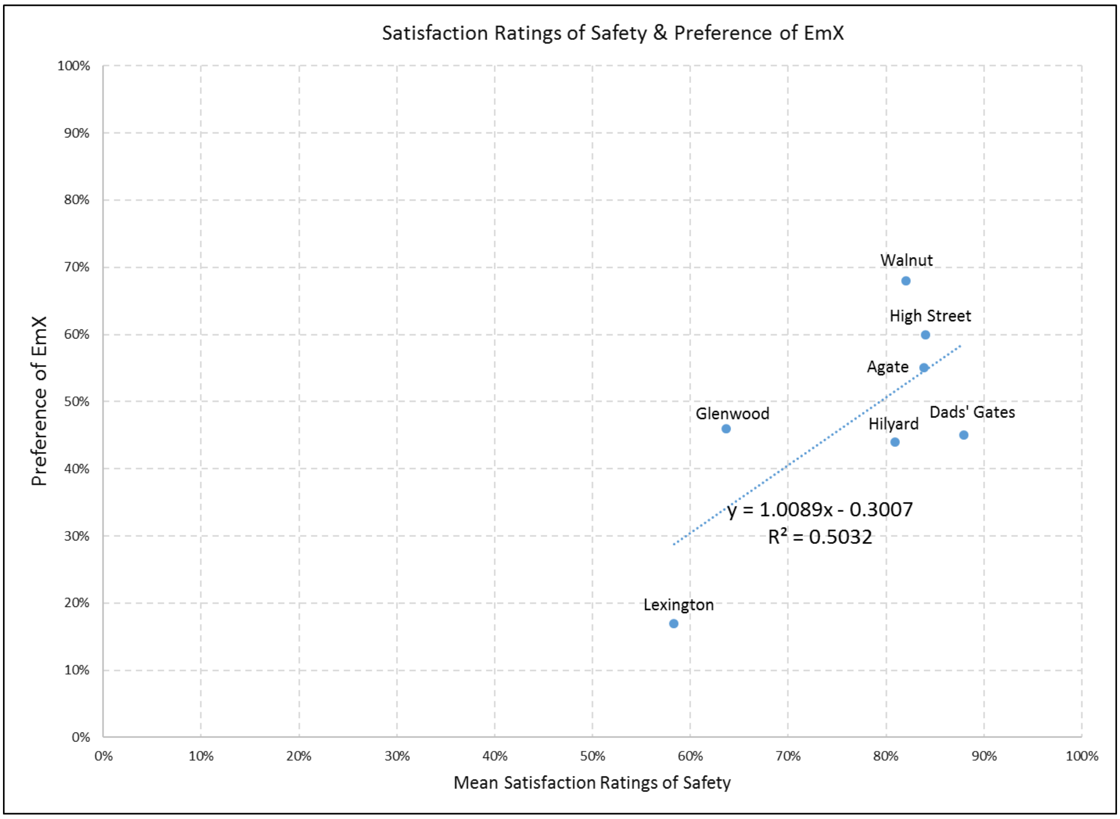


Figure 88: Satisfaction ratings of Safety & Preference of EmX

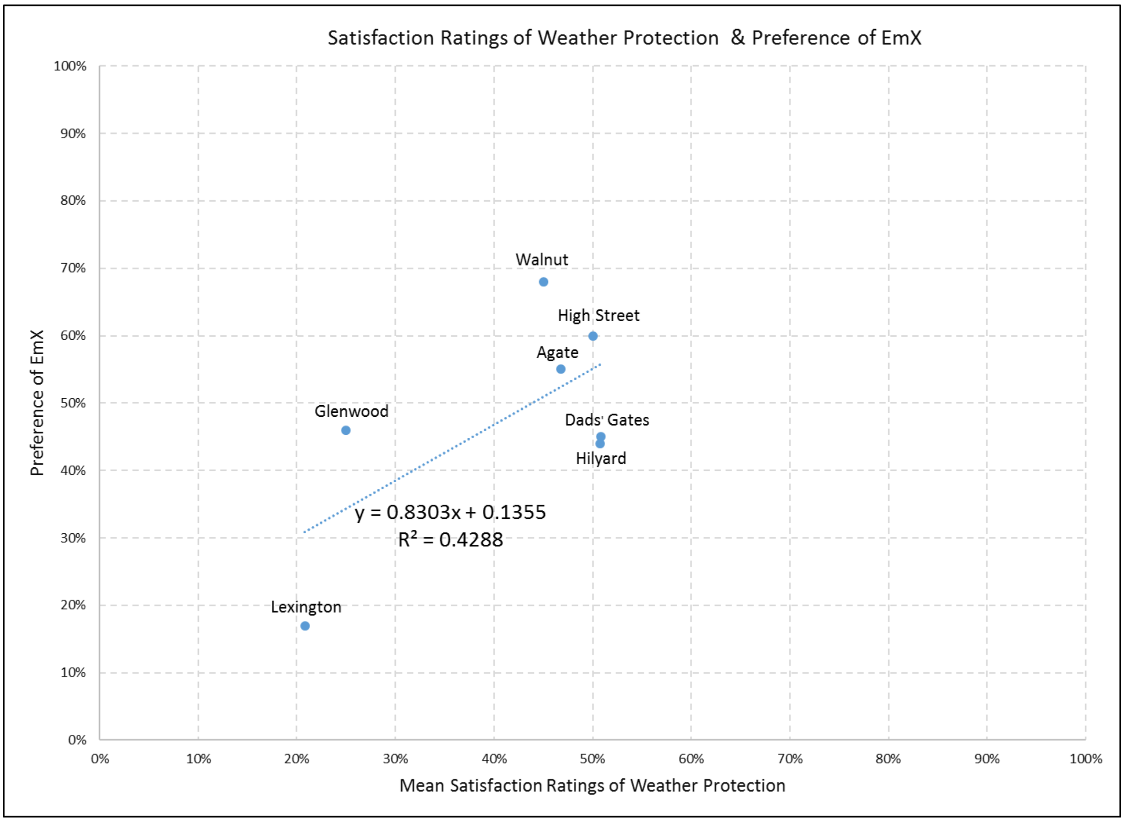


Figure 89: Satisfaction ratings of Weather Protection & Preference of EmX

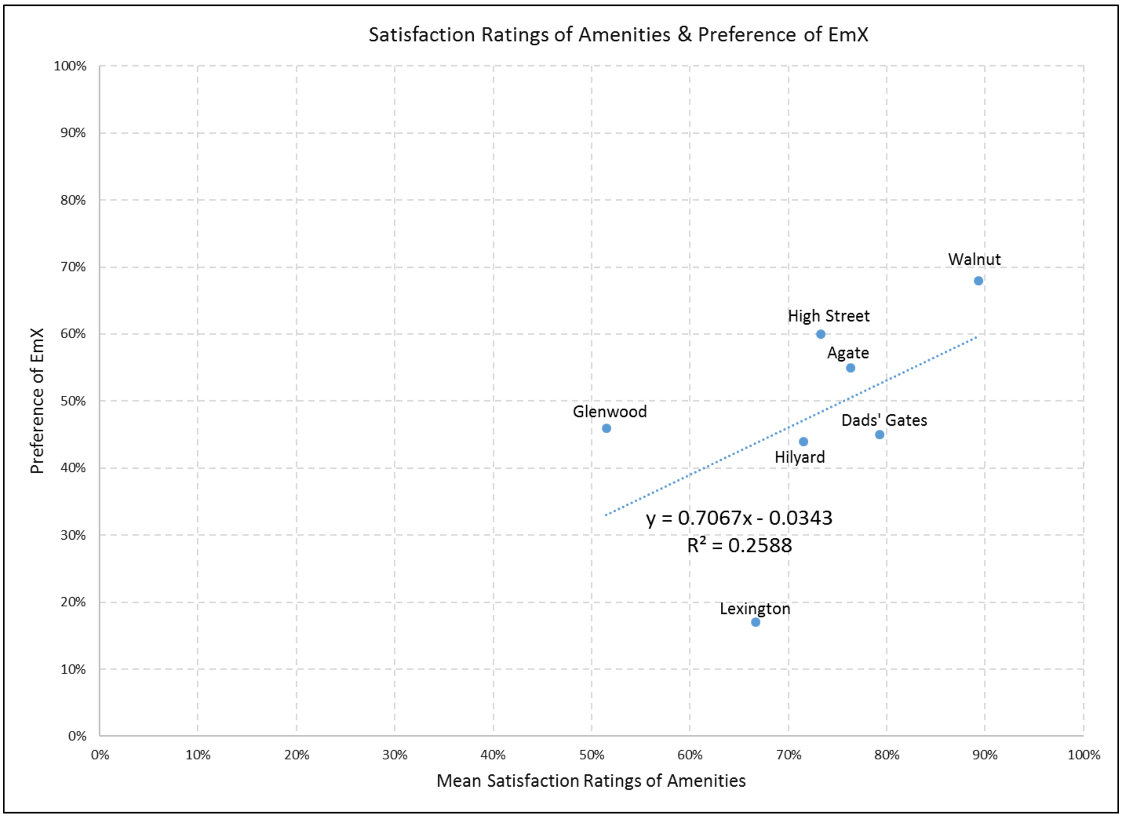


Figure 90: Satisfaction ratings of Amenities & Preference of EmX

3. How do users' perceptions of importance and satisfaction identify the priority and need for improvement among station attributes?

This study analyzed users' importance and satisfaction ratings using Importance-Satisfaction analysis to identify priorities and improvement needs of attributes at the stations. The importance-satisfaction analysis quadrant plots identify attributes that need to be improved, those that should be prioritized for constant maintenance, those that are less important for users and those with which users are well satisfied. The IS rating identifies the rankings of station attributes according to their need for improvement. IS rating can be used to prioritize attributes for improvement.

According to the analysis, the study did not identify any attributes that needed improvement at High Street Station. Protection from wind, cold and rain ranked as the top three attributes at High Street Station for their improvement need. Pedestrian access, route/schedule information, station lighting and safety during the day and night were station attributes that should be prioritized for consistent maintenance. This study did not identify any attributes that needed to be improved at Hilyard Station, but among the surveyed attributes, protection from cold temperatures and wind ranked as the top two attributes according to their improvement need. Safety during the day and night, protection from rain, station lighting, route/schedule information and pedestrian access of Hilyard Station were identified as attributes that should be prioritized for consistent maintenance. The study did not identify any attributes that needed improvement at Dads' Gates Station. However, according to the improvement need, protection from wind and cold temperatures ranked as the top two attributes. Safety during the day and night, pedestrian access, protection from rain, route/schedule information and station lighting were identified as station attributes that should be prioritized for consistent maintenance at Dads' Gates Station. At Agate

Station, the study did not identify attributes that needed immediate improvement, but according to their improvement need (indicated by IS ratings), protection from cold temperatures and wind ranked as the top two attributes. Safety during the day and night, pedestrian access, protection from rain and station lighting were identified as station attributes that should be prioritized for consistent maintenance for users. The study identified protection from rain and safety at night as attributes that needed improvement at Walnut Station. Pedestrian access, safety during the day, route/schedule information and lighting were identified as attributes that should be prioritized for consistent maintenance at Walnut Station. Among the attributes, protection from wind, cold temperatures, safety at night and protection from rain ranked as the top four attributes according to the improvement needs as indicated by IS ratings. This study identified that protection from cold temperatures, rain and safety at night needed improvement at Glenwood Station. Safety during the day, pedestrian access, route/schedule information and lighting were identified as attributes that should be prioritized for consistent maintenance at Glenwood Station. Protection from cold temperatures, seating, protection from rain, protection from wind and safety at night ranked as the top five attributes according to the improvement need as indicated by IS ratings. Lexington Station needed improvement of protection from rain, wind and cold temperatures. According to the improvement need (as indicated by IS ratings), weather protection from wind, cold temperatures, rain and sun ranked as the top four attributes at Lexington Station. The study identified pedestrian access and route/schedule information as attributes that should be prioritized for consistent maintained at Lexington Station for the users.

4. How do the thermal assessment indices Universal Thermal Climate Index (UTCI) and Predicted Mean Votes (PMV) identify categories of users' thermal stress across semi-outdoor EmX BRT stations?

This research recorded thermal climate data at each case study semi-outdoor Emerald Express bus rapid transit station and identified thermal stress categories at the stations using assessment indices UTCI and PMV. For a comparison of the results of PMV and UTCI, the study divided thermal stress into three categories 'No Thermal Stress', 'Thermal Heat Stress' and 'Thermal Cold Stress'. The study calculated the proportion of months for which both indices identified the same stress categories as 'Agree' and the proportion of months for which the indices identified different stress categories as 'Disagree'. Figure 91 shows that on average, the thermal assessment indices were 75 % in agreement with identifying the thermal stress categories at the stations.

Figure 92 shows that the percentage frequency of the times both indices identified the same thermal stress categories across stations. At Glenwood station, both indices were in complete agreement in the identification of stress categories. It should be noted that for the climate data recorded at Glenwood Station, no months were found with cold stress. Figure 93 shows that both the indices were in most agreement for the category of 'No Thermal Stress' followed by 'Heat Stress' and least in agreement with 'Cold Stress'.

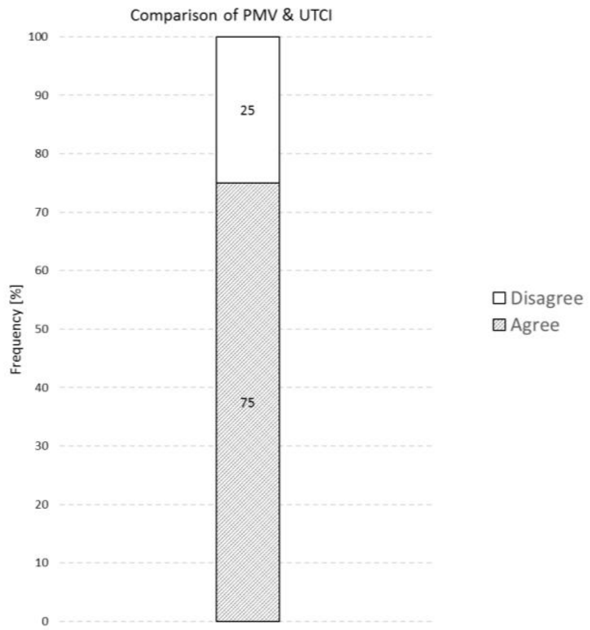


Figure 91: Agreement & Disagreement of PMV & UTCI

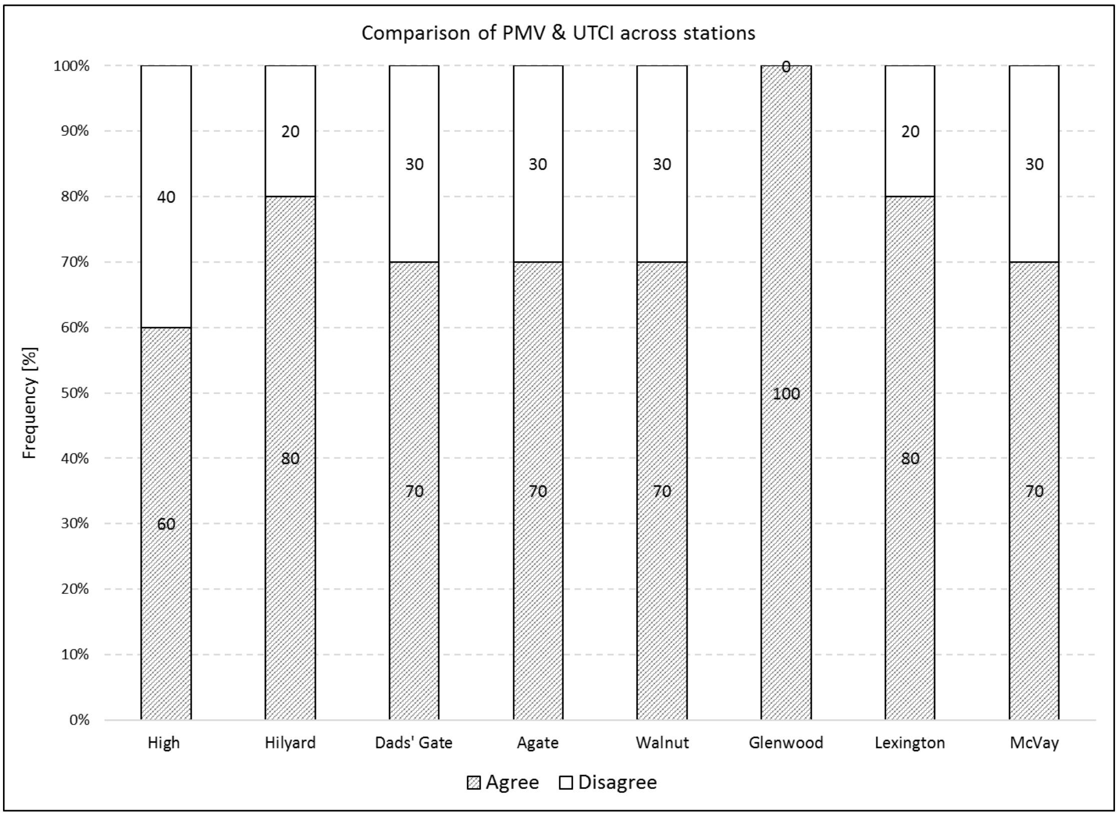


Figure 92: Agreement of PMV & UTCI in identifying categories of thermal stress

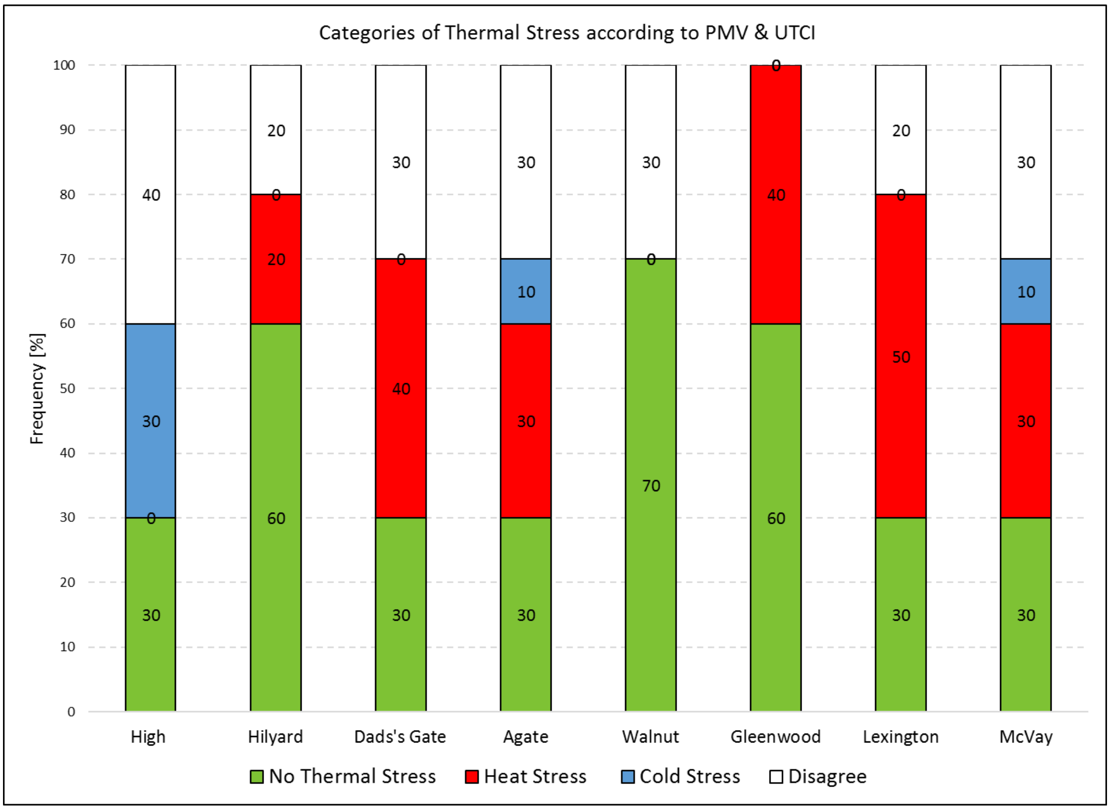


Figure 93: Categories of thermal stress according to PMV & UTCI across stations

Summary

Findings of this research show that mean of user satisfaction ratings at all center island stations (High Street to Walnut) were higher than 60%, while ratings at side stations (Glenwood and Lexington) were lower than 50%. The stations with low satisfaction ratings also had street geometries (H: W) wider than 1:12 and the two highest values of SVF recorded in this study. Vehicular speed did not seem to have a strong relation to user satisfaction ratings at the stations in this research. For instance, Agate Station, Walnut, Lexington and Gleenwood stations were all located on Franklin Boulevard with vehicular speeds of ?? mph but user satisfaction ratings at Agate and Walnut were much higher than at Glenwood and Lexington. This suggests that center island stations were popular among users. (See Appendix – E)

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS & FUTURE WORK

This chapter presents conclusions of the study's research concerns, recommendations and suggestions for future work.

5.1 Conclusions

How do users' satisfaction with accessibility, safety, weather protection and amenities at EmX stations correlate to their preference of EmX?

One of the most important conclusions of this research is that of the attributes studied, transit users' satisfaction with pedestrian accessibility of stations is most strongly correlated to their preference of using Emerald Express (EmX) bus rapid transit (BRT) over a car. Perceptions of satisfaction with safety, weather protection and amenities have weak correlations with users' preference of EmX. This suggests that improving people's satisfaction with pedestrian accessibility of stations is most likely to increase their preference of using EmX BRT. This conclusion is important for urban planners, architects and transit planners for improving the built environment of bus rapid transit stations and increasing preference of BRT.

The following are conclusions to research questions addressed in this study:

How do transit users' out of vehicle experience correlate to the built environment at semi-outdoor Emerald Express bus rapid transit stations?

Transit users' satisfaction with pedestrian accessibility of EmX BRT stations had weak but positive correlations with accessibility of the built environment as measured by pedestrian catchment zone ratios (PCZ ratios). This suggest that users' satisfaction with accessibility may not be improved too much by increasing the density of the street network alone (higher PCZ ratios).

Transit users' satisfaction ratings of safety at night had strong correlations with design of the built environment as measured by sky view factor at the stations and weak relations during the day. Users perceived stations with built environments consisting of fewer buildings and trees (indicated by higher sky view factor) as less safe. They generally felt more safe at stations during the day as compared to the night and their perceptions of safety were more strongly related to the built environment at night.

The study found strong positive correlations between commercial land-uses and users' safety at the stations. These findings suggest that users perceive stations in sparsely built environments with low proportions of commercial land-uses as less safe and that transit authorities, urban planners and architects should consider design interventions to improve perceptions of safety among users in such environments especially at night.

Transit users' satisfaction ratings of weather protection had strong correlations with design of the built environment as measured by sky view factor and weak correlations with percentage of canopy shade. Findings suggest that architects should pay more attention to design interventions for weather protection in sparsely built environments with lower street shading as compared to those in denser environments with higher street shading.

<u>How do users' perceptions of importance and satisfaction identify the priority and need for improvement among station attributes?</u>

An analysis of user's importance and satisfaction ratings of attributes at the stations identify that none of the attributes needed improvement at High Street Station, Hilyard Station, Dads' Gate Station and Agate Station. At Walnut Station attributes of weather protection from rain and safety at night needed improvement. At

Glenwood Station attributes of weather protection from cold temperatures, rain and safety at night needed improvement.

At Lexington Station, attributes of weather protection from cold temperatures, rain and wind needed improvement. Findings suggest that people were less satisfied with weather protection and safety at night at stations in environments that had few buildings and trees around, as indicated by a higher value of sky view factor.

<u>How do the thermal assessment indices Universal Thermal Climate Index (UTCI) and Predicted Mean Votes (PMV) identify categories of users' thermal stress across semi-outdoor EmX BRT stations?</u>

Findings show that the thermal assessment indices UTCI and PMV identified the same categories of thermal stress 75 % of the time in this study. This study found that the indices were most in agreement when identifying the absence of thermal stress followed by thermal heat stress and least agreed on identifying conditions of cold stress. This conclusion adds to the limited existing literature on thermal comfort research with UTCI and PMV at semi-outdoor environments. This conclusion is important for the design of semi-outdoor bus stations and transitional environments.

5.2 Recommendations

Based on the results, this research developed a rating system for semi-outdoor bus stations to determine the performance of stations based on quantitative attributes of the built environment studied. The attributes in the rating system include Sky View Factor, Street Height-to-width ratio, Pedestrian Catchment Zone Ratios, Commercial land-use, Station Canopy shade and Station Type. The research first determined ranges for each attribute. SVF, PCZ ratios can have a maximum value of 1.0 and a minimum value of 0.0. Since this research calculated land use and canopy shade as percentages, they also have a maximum value of 1.0 and a minimum value of 0.0. The study identified stations types as either center-island or side stations and assigned a rank 1 to center-island stations and 0 to side stations, based on the findings that center-island stations had higher satisfaction ratings. With regards to the range of Height-to-width ratios, previous research suggests H/W ratios between 0.25 and 7.0 as good for comfort and safety (Alkhresheh, 2007).

The research then ranked attributes from 0 to 8 based on the correlations in this study, a higher value corresponding to a better performance. Table 11 shows the ranges and rankings of the attributes. For negative correlations in this study, an attribute's value between the range 0.0-0.1 is ranked highest as 8, in decreasing order for increasing value of the attribute. For positive correlations, the study ranked values between the range 0-0.1 as 0 and 0.91-1.0 as 8. The maximum ranking score is the sum of all rankings and equals 41. The research then determined ratings for each station by calculating the total ranking score and dividing that by the maximum ranking. The calculated station rating can have a minimum value of 0, indicating poor performance and a maximum value of 1, indicating the best station performance. Figure 94 shows ratings for the eight case study stations in this research.

Table 11: Attribute ranges and rankings scale

SVF Range	Ranking	H/W Range	Ranking	PCZ ratio Range	Rankin g	Commercial Landuse Range	Ranking	Canopy shade Range	Ranking	Station Type	Ranking
0.0-0.1	8	0.0-0.1	0	0.0-0.1	0	0.0-0.1	0	0.0-0.1	0	Center-Island	1
0.11-0.2	7	0.11-0.2	1	0.11-0.2	1	0.11-0.2	1	0.11-0.2	1	Side station	0
0.21-0.3	6	0.21-0.3	2	0.21-0.3	2	0.21-0.3	2	0.21-0.3	2		
0.31-0.4	5	0.31-0.4	3	0.31-0.4	3	0.31-0.4	3	0.31-0.4	3		
0.41-0.5	4	0.41-0.5	4	0.41-0.5	4	0.41-0.5	4	0.41-0.5	4		
0.51-0.6	3	0.51-0.6	5	0.51-0.6	5	0.51-0.6	5	0.51-0.6	5		
0.61-0.7	2	0.61-0.7	6	0.61-0.7	6	0.61-0.7	6	0.61-0.7	6		
0.71-0.8	1	0.71-0.8	7	0.71-0.8	7	0.71-0.8	7	0.71-0.8	7		
0.91-1.0	0	0.91-1.0	8	0.91-1.0	8	0.91-1.0	8	0.91-1.0	8		

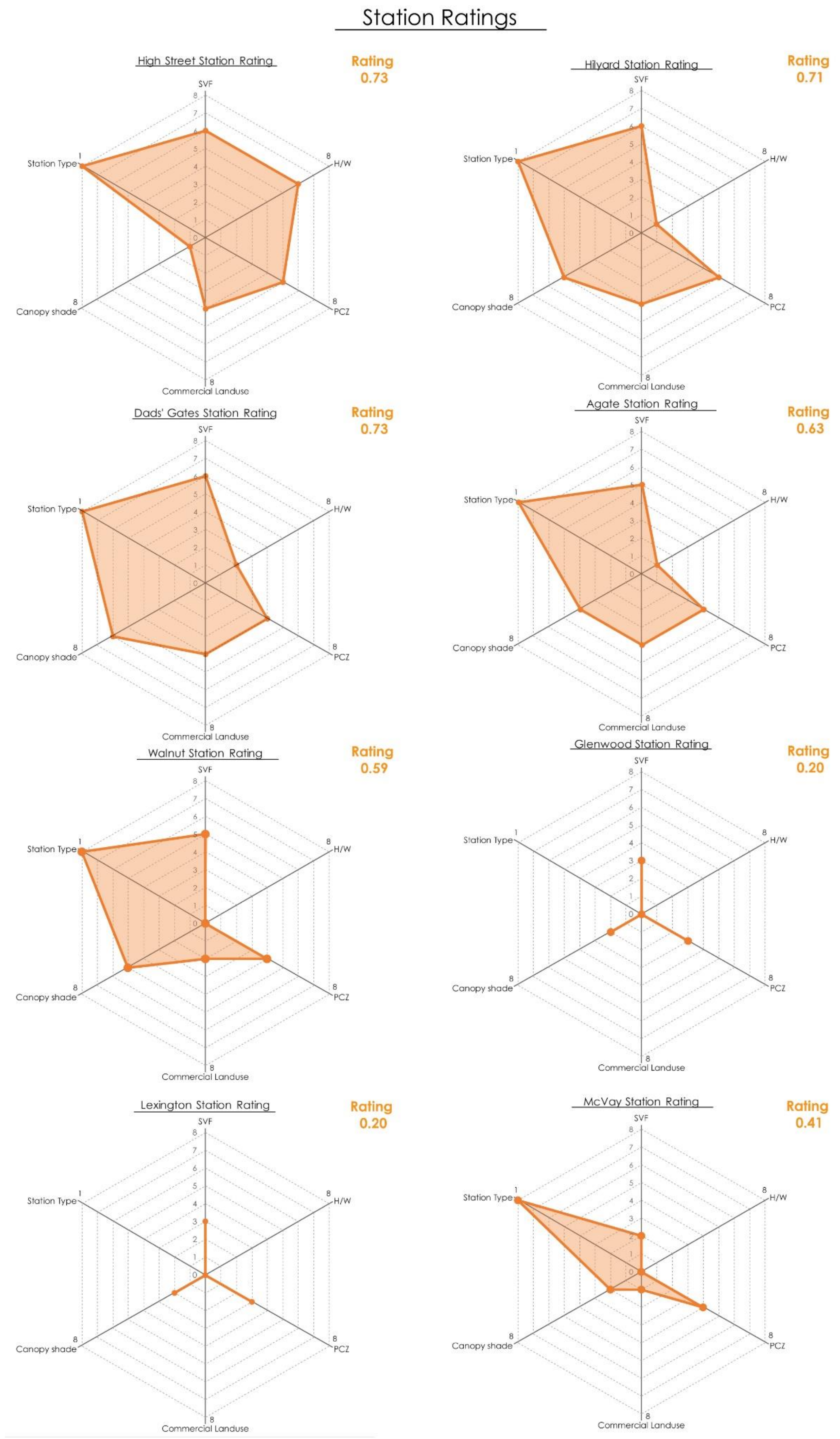


Figure 94: Station Ratings

Based on the station ratings, this research suggests short and long term improvements for the stations. The research found higher satisfaction ratings for safety at center-island stations. This can be explained by William Whyte's (1980) theory that people are attracted to places with other people. Center-island stations with two boarding platform serve two buses and tend to have relatively more people waiting at the stations compared to side stations. This research suggests center-island stations with two boarding platform instead of side stations as better for user satisfactions. For immediate, short term improvements at stations with lower ratings for H/W ratio and SVF, the study suggests design interventions such as increasing the canopy shade and providing vertical obstructions for wind can improve weather protection at the stations. Planting street trees can improve the SVF and H/W and improve people's perceptions of safety at the stations by creating a feeling of enclosure. Safety upgrades like installing surveillance cameras and an emergency phone for people to call for help in need can also improve their perceptions of safety at the stations. Another short term improvement measure is to locate food trucks and coffee shops near the stations to increase diversity of uses and the activity of people coming and going, creating indirect surveillance at the stations referred to as 'eyes on the street' by Jane Jacobs (1961, p. 36).

For long term improvements at the stations with low ratings for H/W ratios and SVF, the building density in the surrounding should be increased and buildings should be brought closer to the stations by reducing setbacks, to create a sense of enclosure on the streets. Alexander (1977) suggested that the street width smaller than the building heights is most comfortable for people. To improve walkability around stations with low ratings for PCZ ratios, the density of the street network should be increased. For stations with low ratings for commercial land uses around, land use policies to increase diversity with more commercial land uses at the ground floor and residential above should be implemented. A mix of commercial and residential land uses ensures the presence of people at different times of the day coming and going for commerce and residence the concept of ‘eyes on the streets’ (Jacobs, 1961, p. 36) which can improve perceptions of safety at the stations and streets. In this research, Glenwood and Lexington station had the same and lowest station ratings. The following renders show what the stations look like before and after the suggested improvements.

Figure 95: Before Improvements at Lexington Station

Figure 96: After Phase 1 of short term improvements; center-island station, sliding doors, street trees and crosswalk

Figure 97: After Phase 2 of short term improvements; install food carts

5.3 Future Work

This thesis adds to limited existing research on the relationship between transit users' out of vehicle experience of a journey and attributes of the built environment, but was limited in its scope regarding the perceptions and attributes of the built environment being studied. Future research could include many other factors related to users' perceptions and attributes of the built environment to study this relationship further.

This research was limited by the sample size of paper surveys and the lack of consistent survey sample sizes across the stations due to different response rates. Future research could increase these sample sizes to represent population trends more accurately and keep the number of surveys consistent for comparisons.

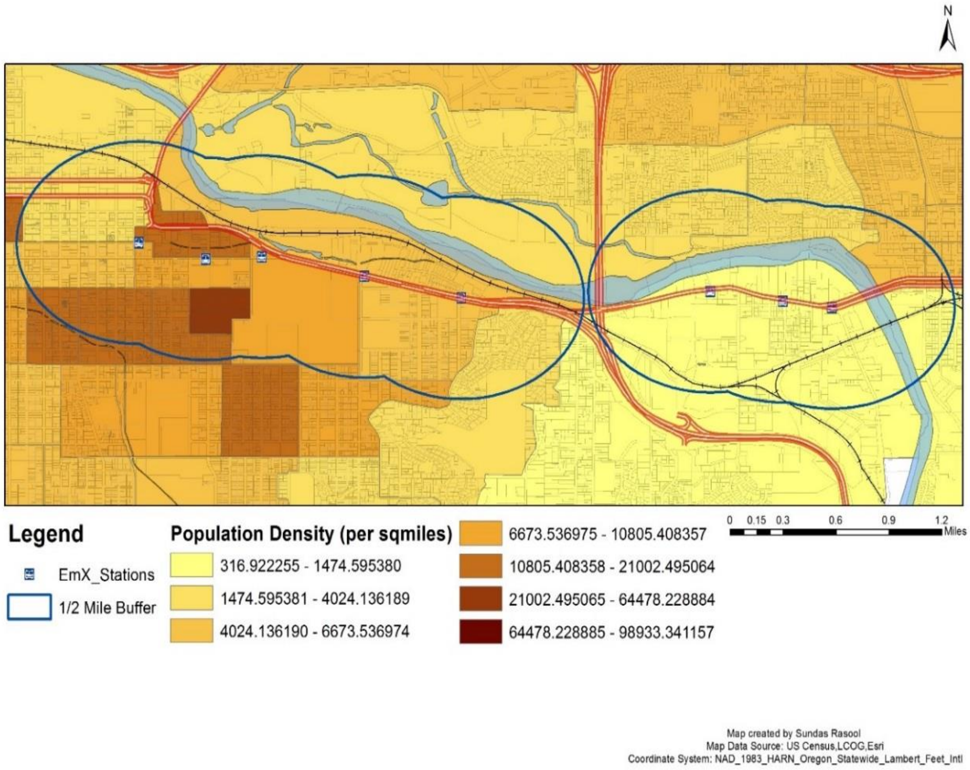
For an assessment of transit users' thermal comfort at semi-outdoor EmX stations, this research recorded climate data for two consecutive hours at each station, distributed over two days a month. Future research could make simultaneous measurements at different stations to compare thermal comfort conditions across different built environments.

This research was unable to record users' perceptions of thermal sensations via thermal comfort surveys, simultaneous to climate measurements at the stations due to limited availability of respondents at the stations. Future research could record users' thermal perceptions through surveys to study how well the thermal assessment indices UTCI and PMV predict users' thermal comfort conditions at the semi-outdoor environments. This could also unfold trends between users' satisfaction of weather protection and thermal stress conditions at the stations.

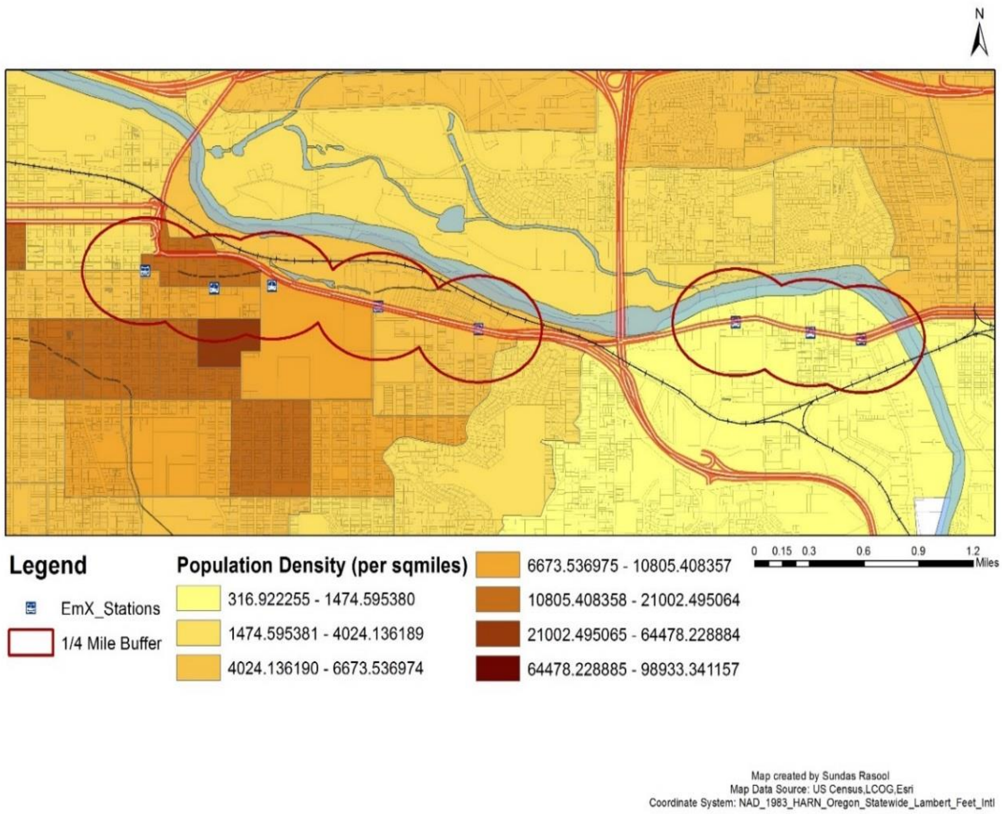
Finally, this research studied the correlations of users' modal preference between a car and EmX bus rapid transit and their satisfactions with limited attributes of pedestrian accessibility, weather protection, safety and amenities at the stations. Future research should include other factors that have not been studied in this research and may influence modal preference of bus rapid transit.

APPENDICES

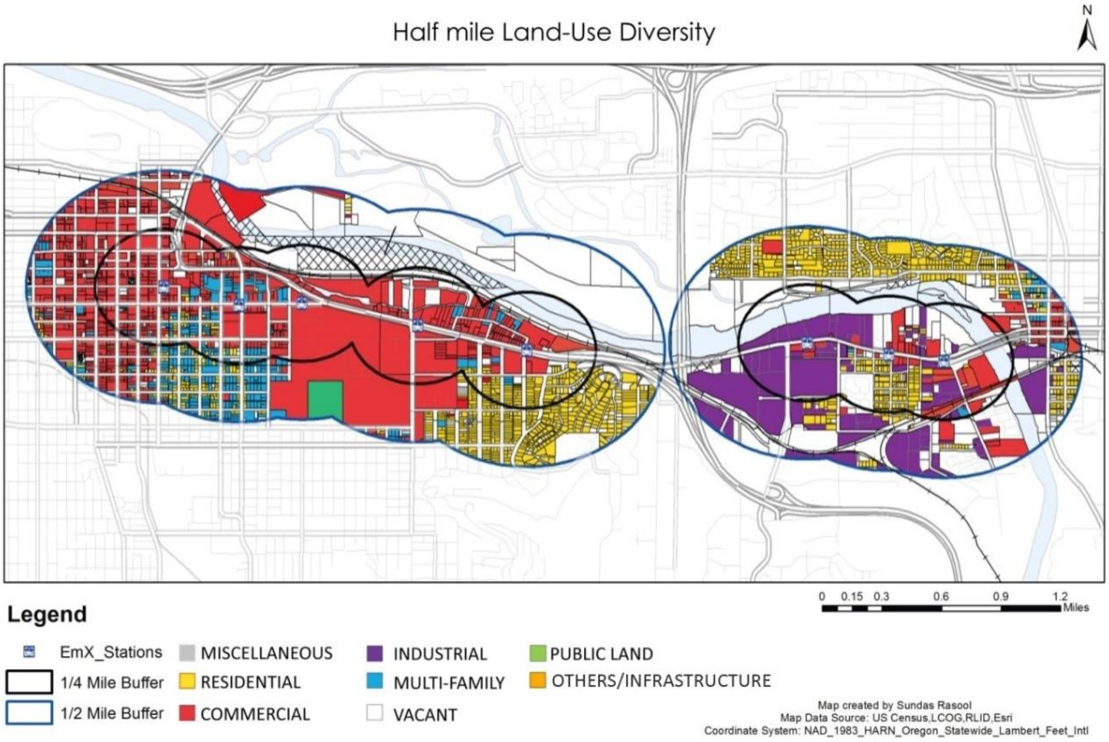
A. MAPS

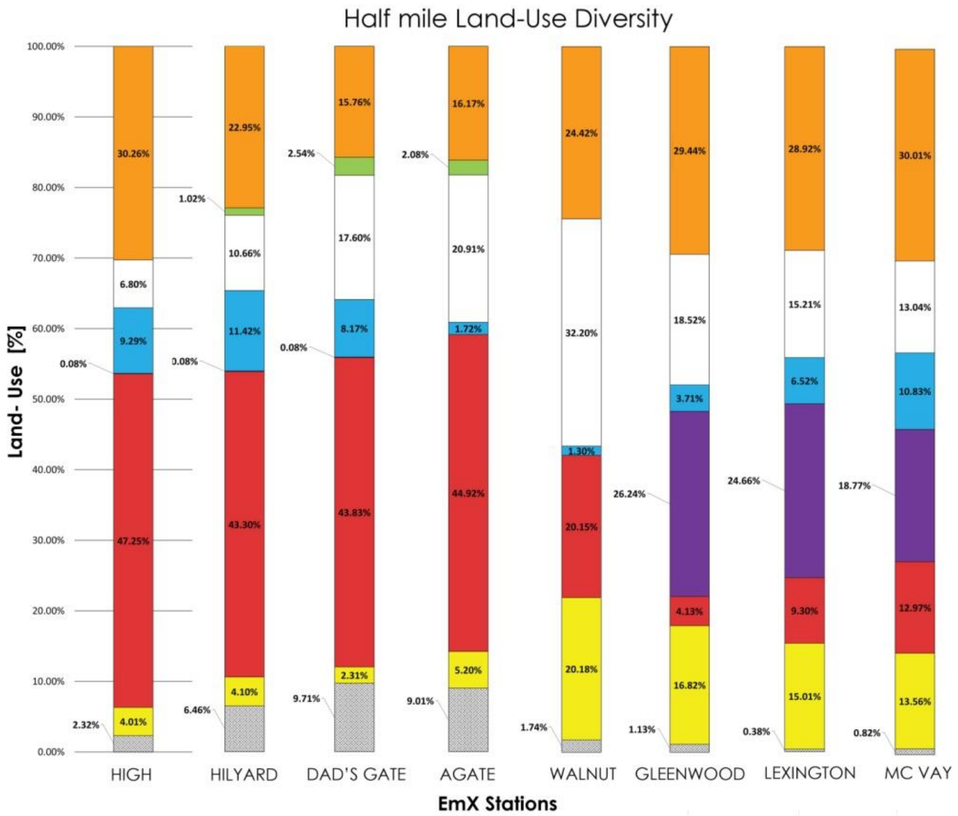


Map of distribution of population density for half-mile radii around EmX stations.

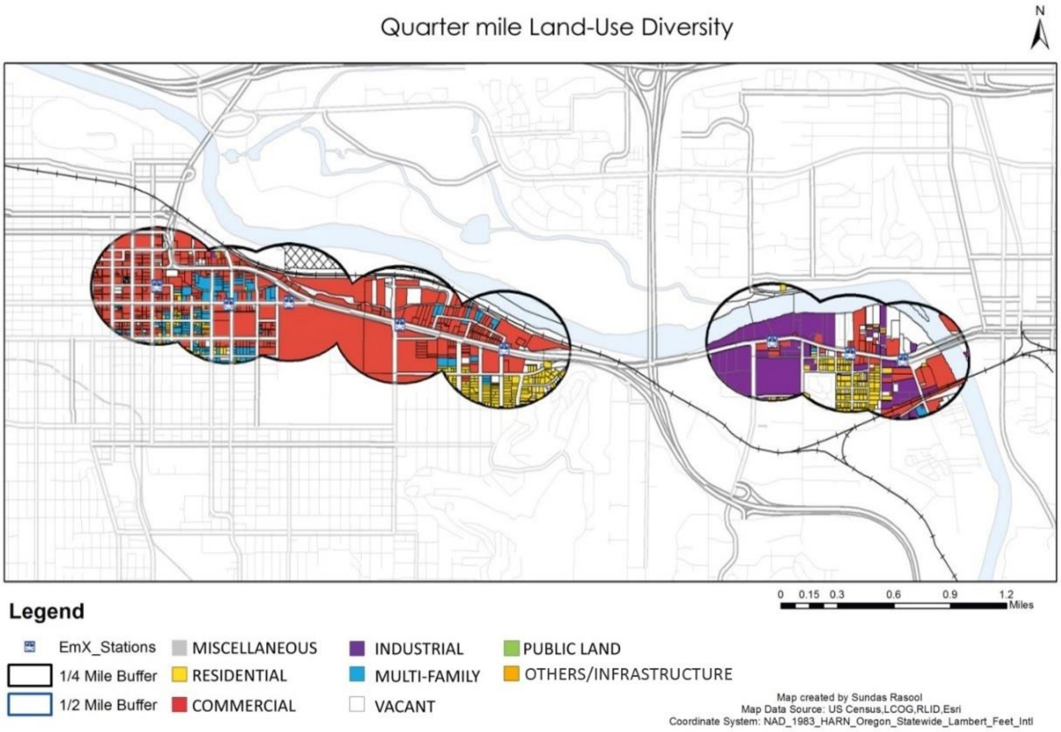


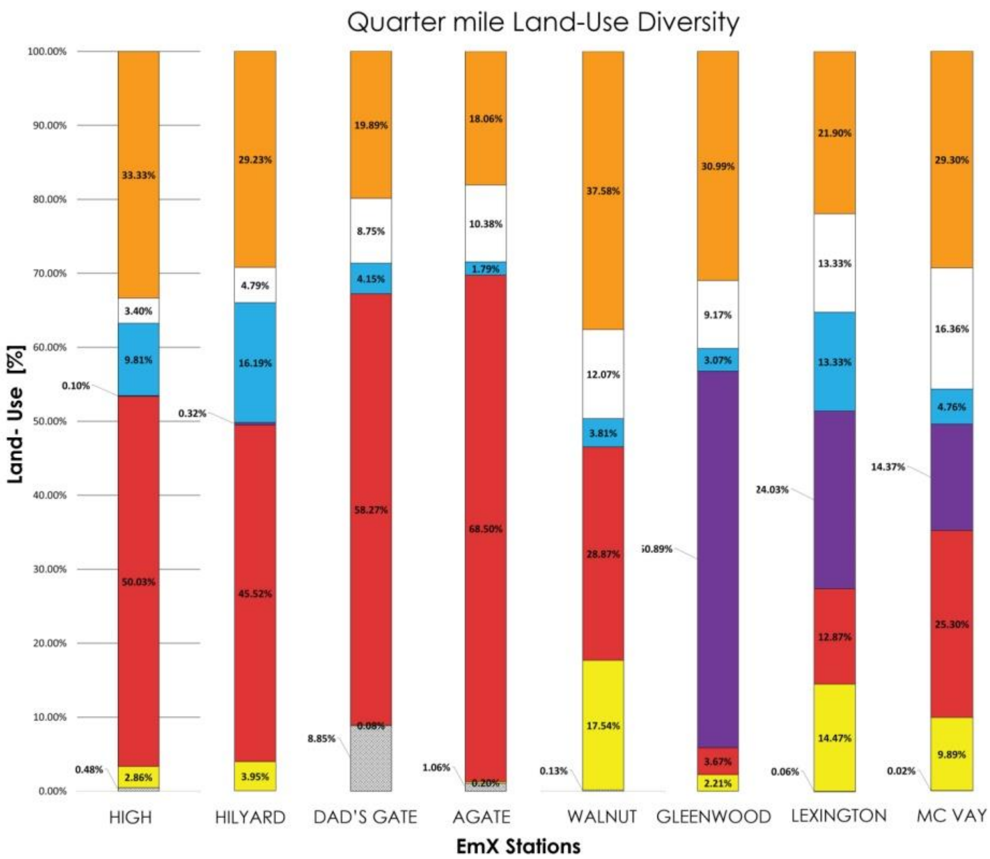
Map of distribution of population density for quarter mile radii around EmX stations.



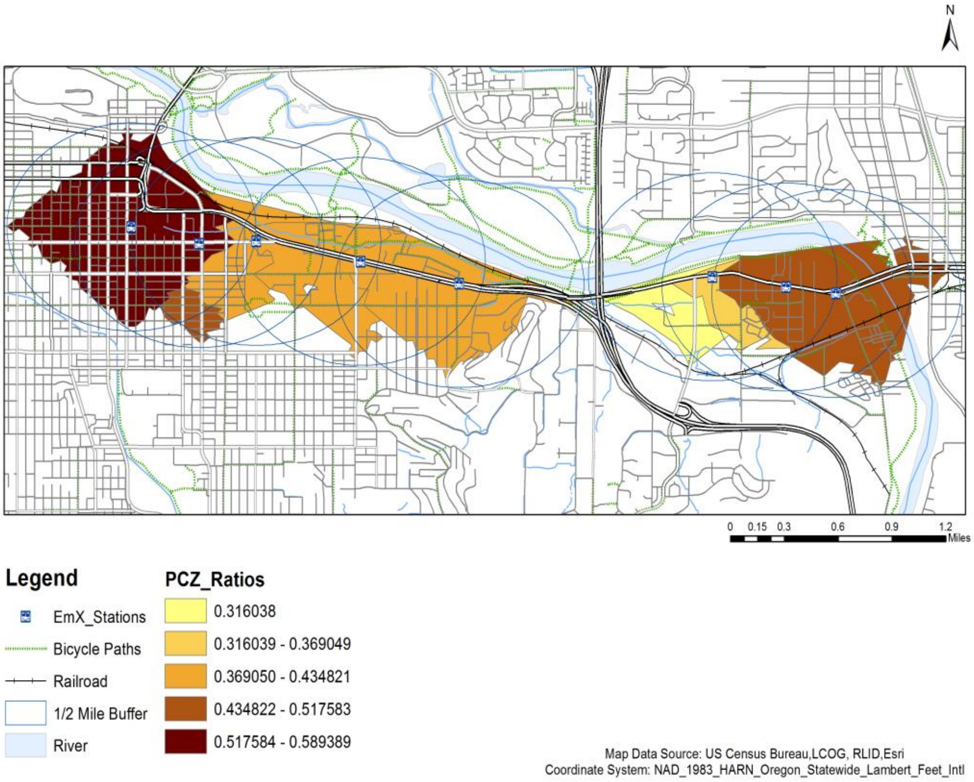


Distribution of land uses for half-mile radii around EmX stations.

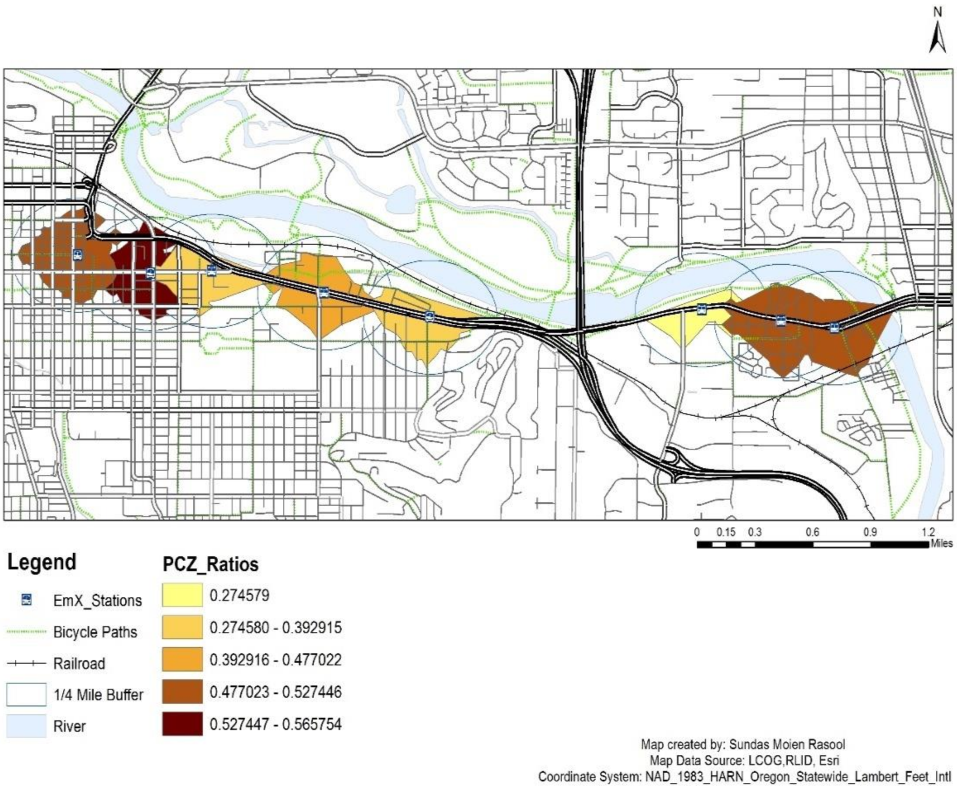




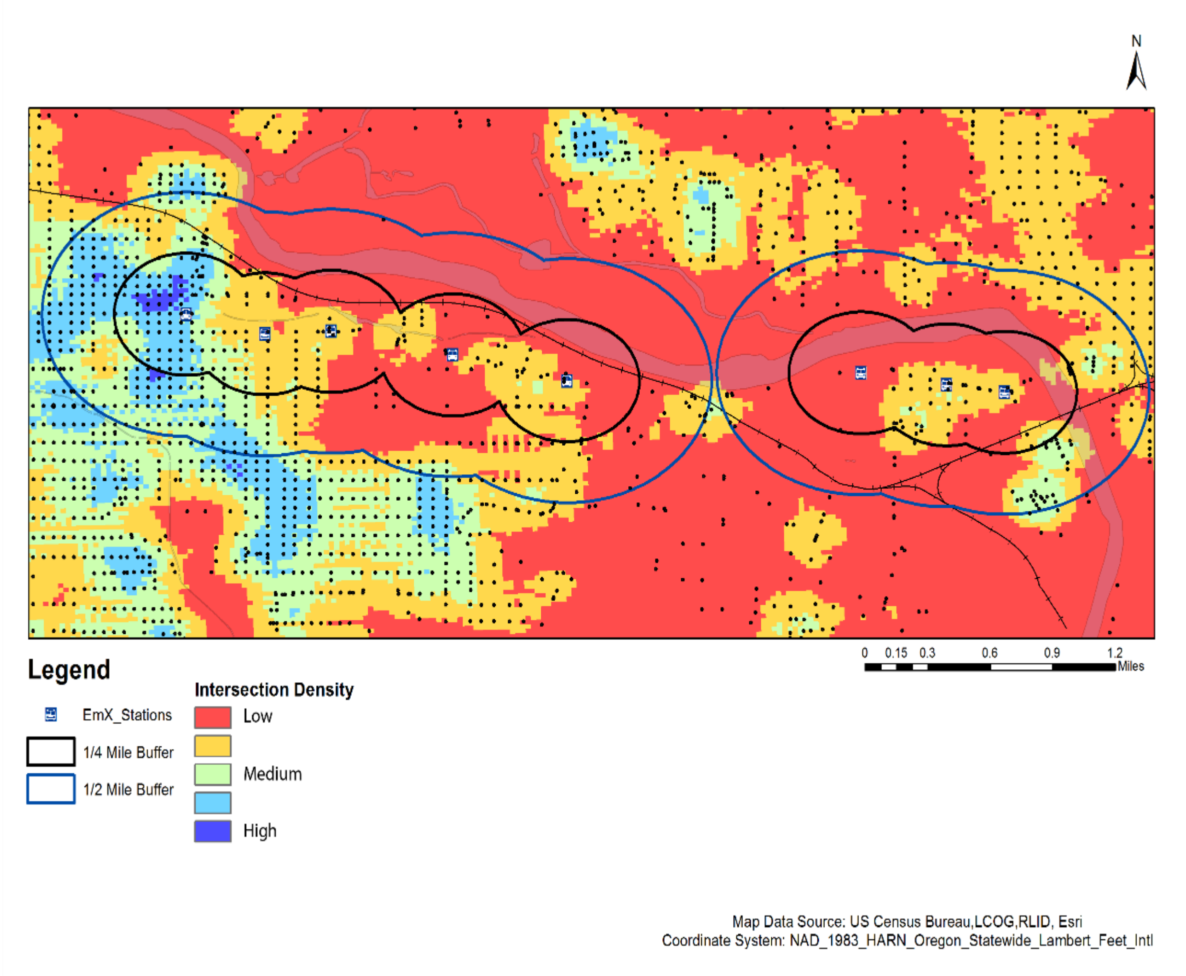
Distribution of land uses for quarter mile radii around EmX stations.



Pedestrian Catchment Zones for half-mile radii around EmX stations



Pedestrian Catchment Zones for quarter mile radii around EmX stations



Map showing the street intersection densities around EmX stations

B. SURVEY TOOL

I am a graduate student of architecture at the University of Oregon, conducting my masters thesis research on improving user comfort & satisfaction at EmX stations. This involves asking people's opinions at the stations. The survey should take about 1-2 minute, is voluntary, anonymous and you are not obligated to take or complete it. You can request a leaflet with consent information for your reference. Please note that You MUST BE 18YEARS or OLDER to participate and that you will not receive any benefits. Please verify; **Are you 18 yrs old or older? Yes** _______ **NO** ______**Are you willing to participate? Yes** ______ **NO** _______

Contact for further information: Sundas Rasool (srasool@uoregon.edu) or Prof. Mark.L Gillem (mark@uoregon.edu)

Station Name: ____

Date & Time: ____________________________________

1. How many days in a typical week do you ride EmX?

__________days a week

☐ less than once a week

2. What is the purpose of your trip today?

☐ work or job ☐ college or school

☐ shopping or errands ☐ visiting family or friends

other: ________________

3. How often do you make this trip?

☐ regularly ☐ not often

☐ sometimes ☐ never before

4. How did you get to the station today?

☐ by bus ☐ walked ______ minutes

☐ drove in a car myself ☐ Biked ______ minutes

☐ got a ride

5. How will you get to your destination from the station?

☐ by bus ☐ walk ______ minutes

☐ drive in a car myself ☐ Bike ______ minutes

☐ get a ride

6. Would you have preferred to make this trip by car instead?

☐ Strongly prefer car ☐ Strongly prefer EmX

☐ Usually prefer car ☐ Usually prefer EmX

7. Are you: ☐ Male ☐ Female ☐ Other

8. What is your our background? (*choose all that apply*)

☐ Ameican Indian ☐ Hispanic/ Latino

☐ Asian/ Pacific Islander ☐ Anglo/White

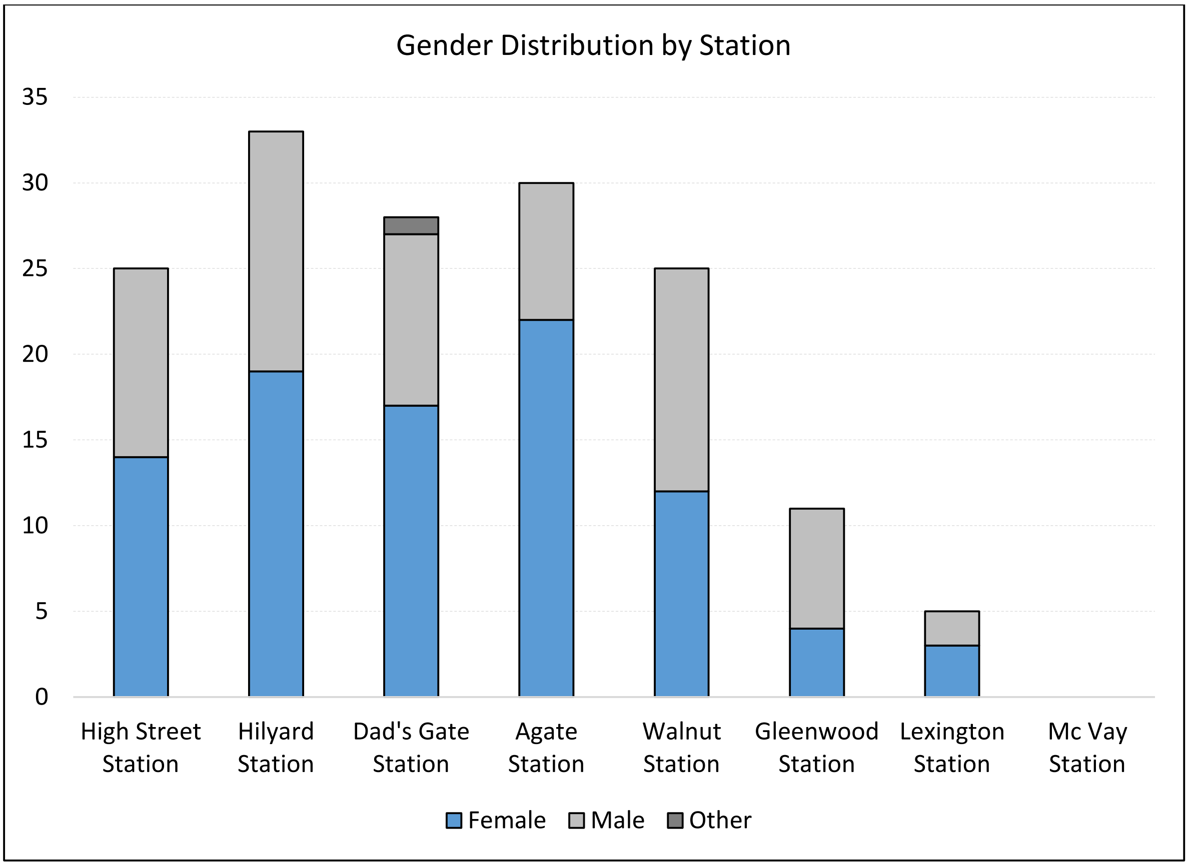
☐ African- American/ Black ☐ Other: ______________

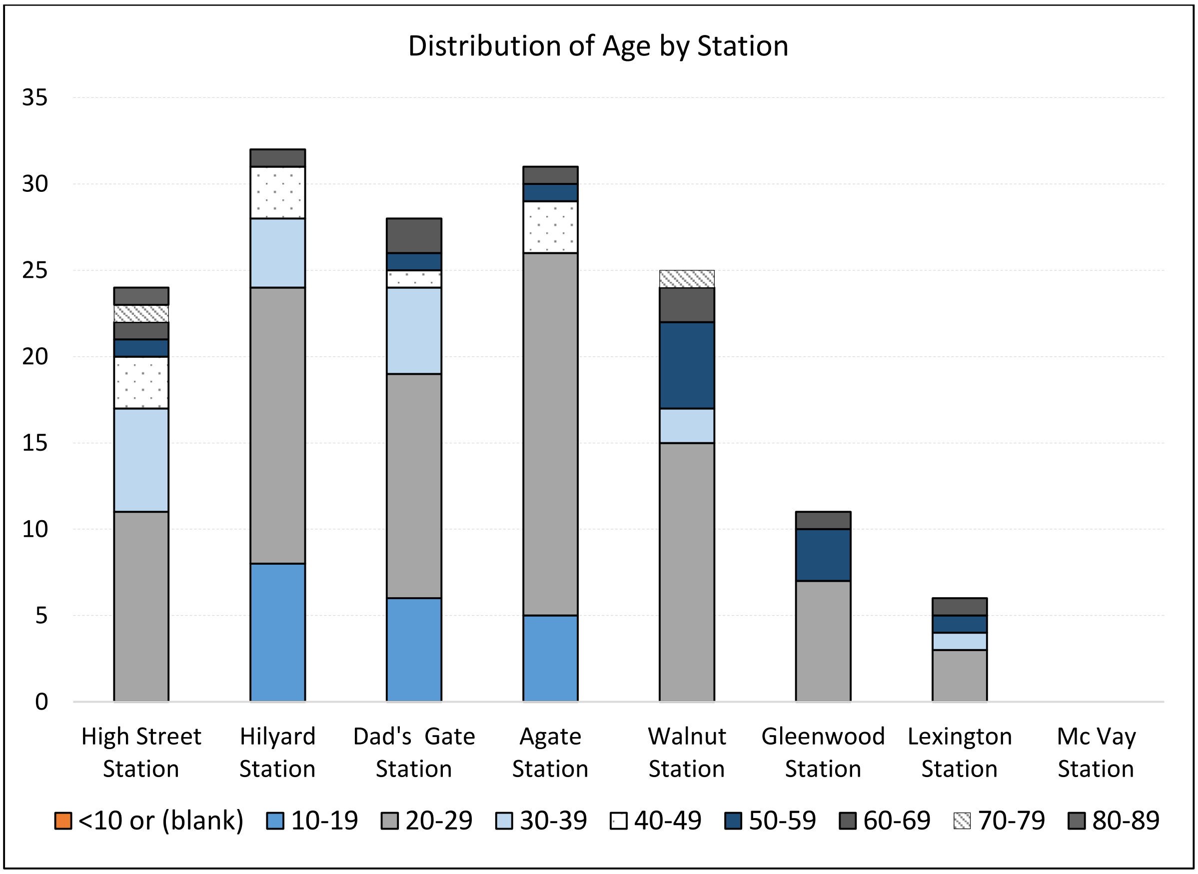
9. In what year were you born? 19__ __

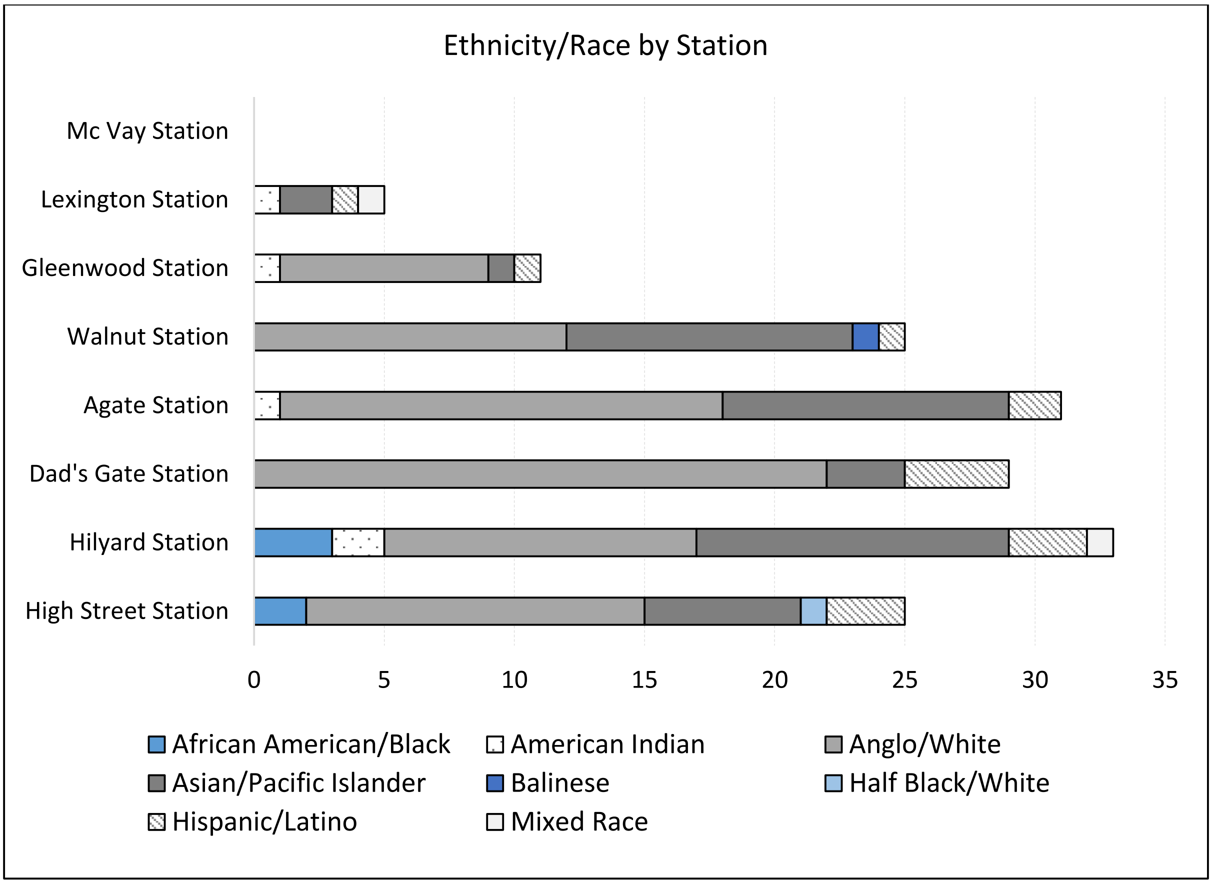
10.		**Do you agree or disagree?**				**How important is it to you?**			
		Strongly Agree 4	Agree somewhat 3	Disagree somewhat 2	Strongly disagree 1	Very important 4	Important 3	Somewhat Important 2	Not important 1
A.	There are enough places to sit								
B.	The shelter here protects from the sun well								
C.	The shelter here protects from rain well.								
D.	The shelter here protects from wind well.								
E.	The shelter is relatively warm in cold temperatures compared to the surroundings.								
F.	Information on route and schedule is easily available.								
G.	I feel safe here during the day.								
H.	I feel safe here at night.								
I.	The station is well lit at night.								
J.	Walking to and from the station is easy and safe.								
K.	Bicycling from here to my destination is easy and safe.								

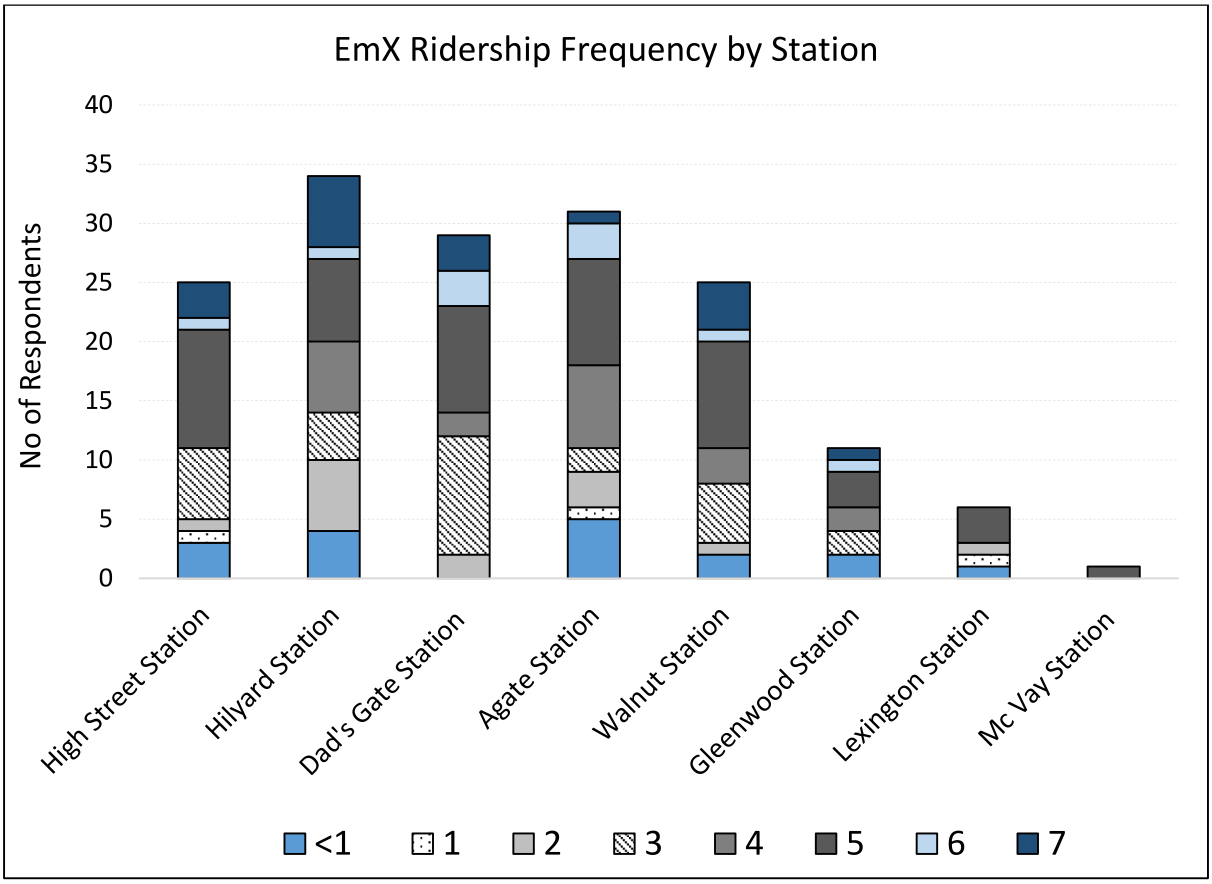
Thank you for your cooperation!

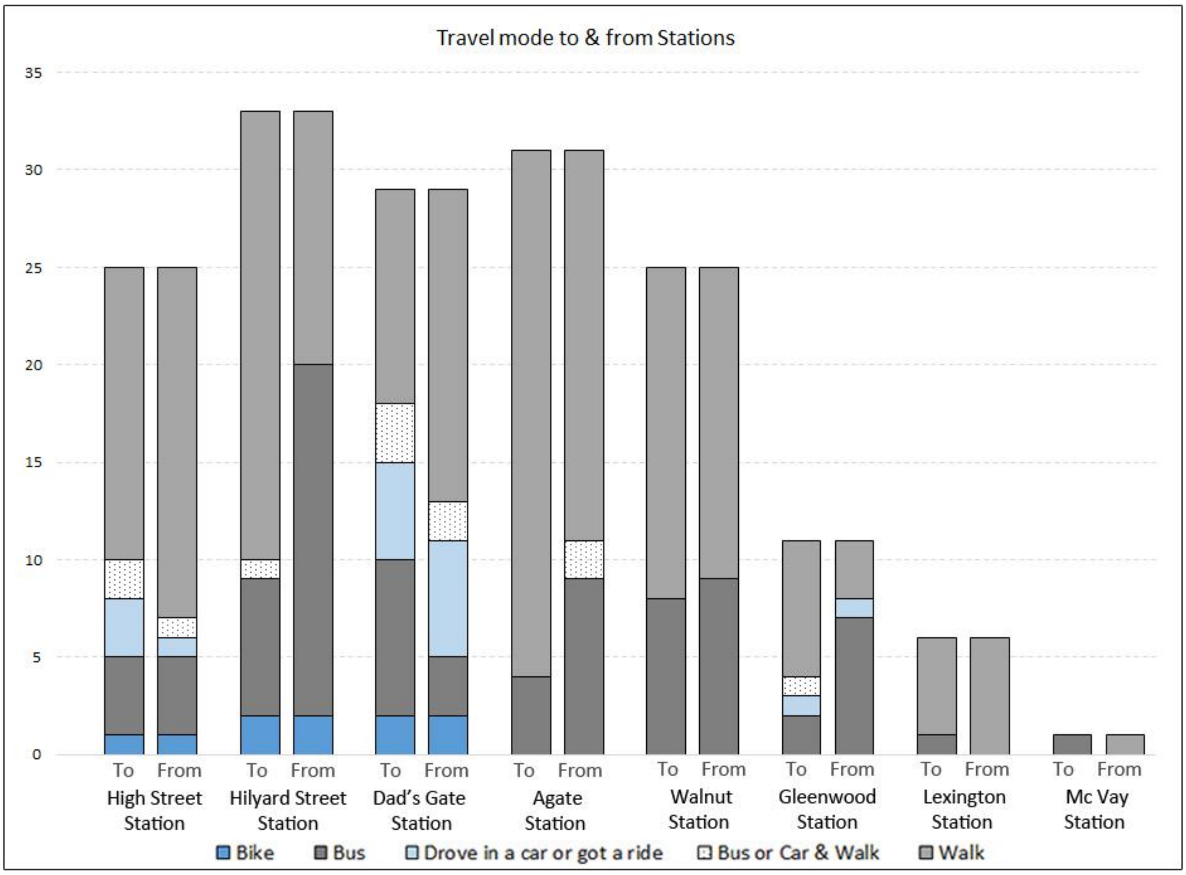
C. SURVEY RESULTS

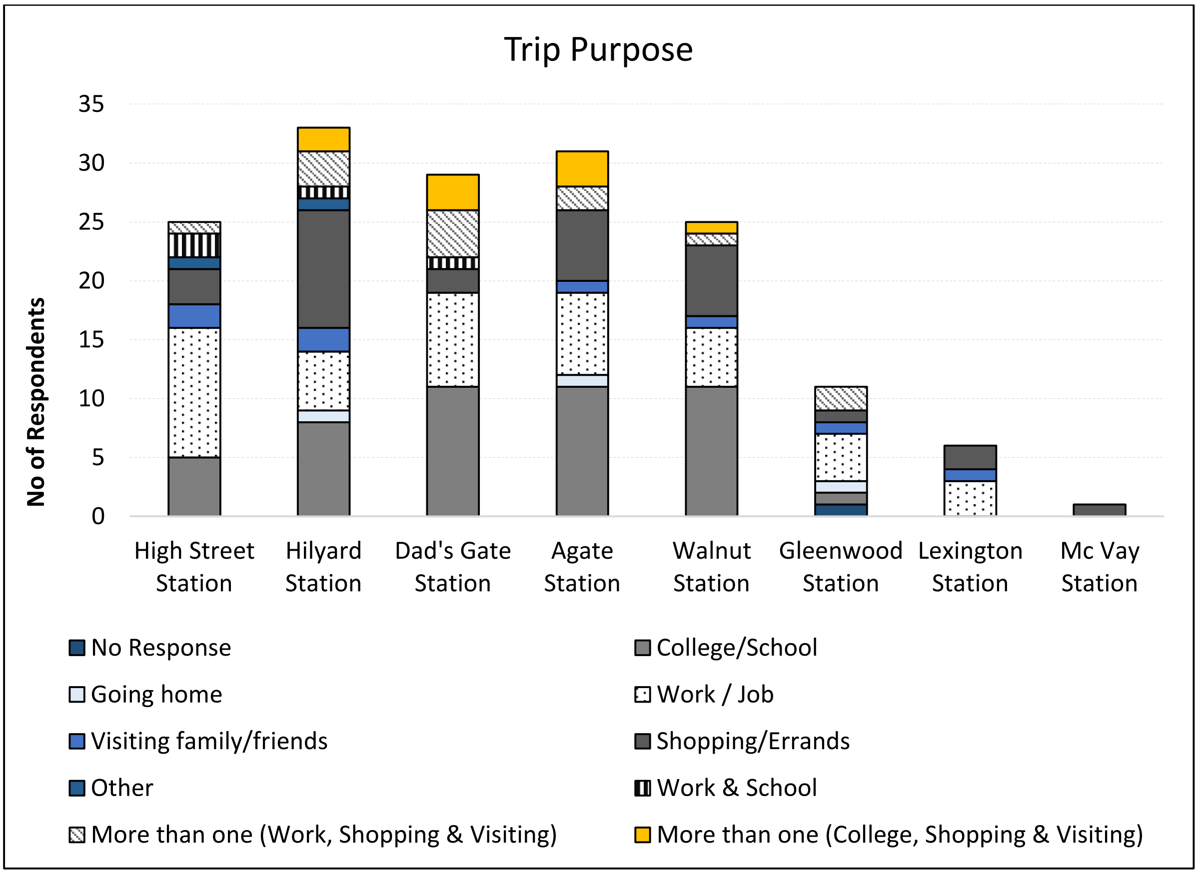

Gender Distribution by Station
35
30
25
20
15
10
5
0
High Street Station
Hilyard Station
Dad's Gate Station
Agate Station
Walnut Station
Gleenwood Station
Lexington Station
Mc Vay Station
Female
Male
Other

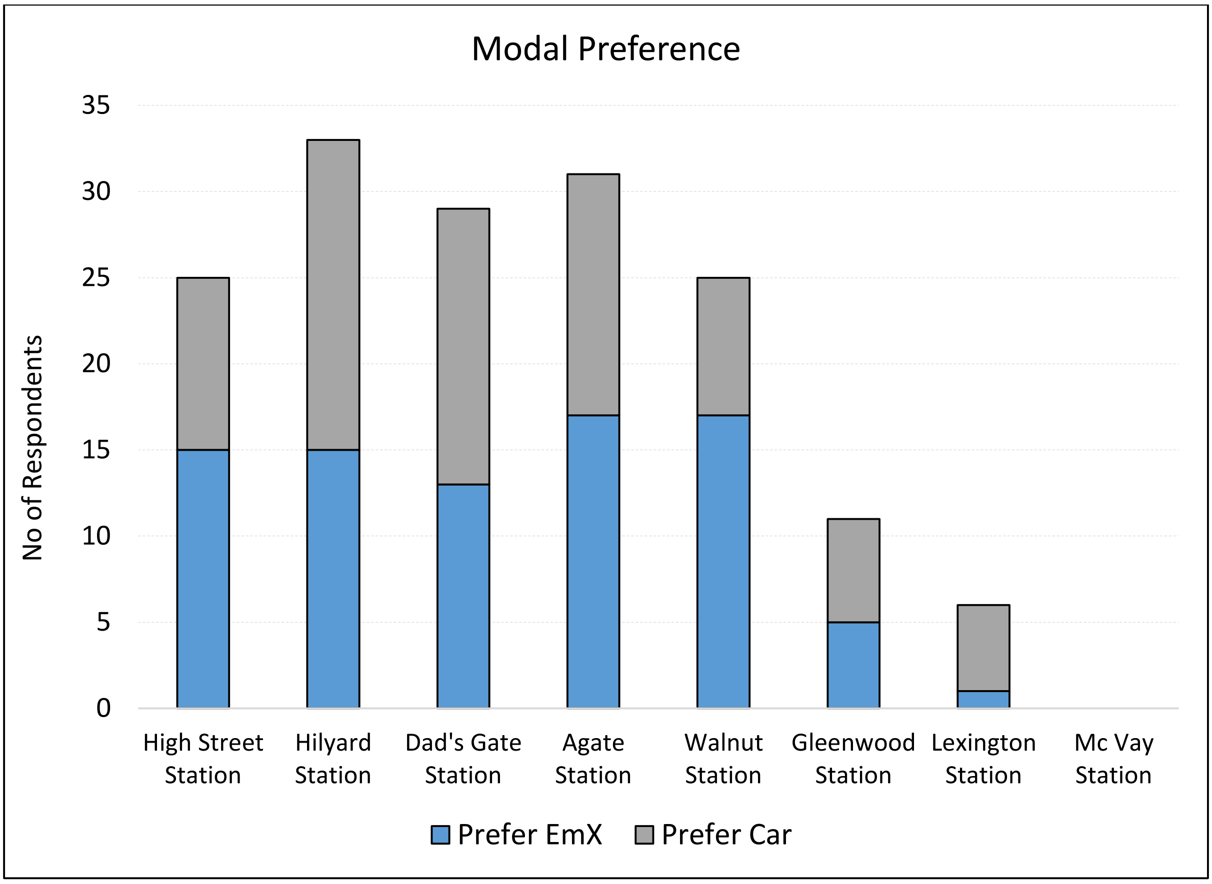

Distribution of Age by Station
35
30
25
20
15
10
5
0
High Street Station
Hilyard Station
Dad's Gate Station
Agate Station
Walnut Station
Gleenwood Station
Lexington Station
Mc Vay Station
<10 or (blank)
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-89


Ethnicity/Race by Station
Mc Vay Station
Lexington Station
Gleenwood Station
Walnut Station
Agate Station
Dad's Gate Station
Hilyard Station
High Street Station
0
5
10
15
20
25
30
35
African American/Black
American Indian
Anglo/White
Asian/Pacific Islander
Balinese
Half Black/White
Hispanic/Latino
Mixed Race


EmX Ridership Frequency by Station
No of Respondents
40
35
30
25
20
15
10
5
0
High Street Station
Hilyard Station
Dad's Gate Station
Agate Station
Walnut Station
Gleenwood Station
Lexington Station
Mc Vay Station
<1
1
2
3
4
5
6
7


Travel mode to & from Stations
35
30
25
20
15
10
5
0
To From
High Street Station
To From
Hilyard Street Station
To From
Dad's Gate Station
To From
Agate Station
To From
Walnut Station
To From
Gleenwood Station
To From
Lexington Station
To From
Mc Vay Station
Bike
Bus
Drove in a car or got a ride
Bus or Car & Walk
Walk


Trip Purpose
No of Respondents
35
30
25
20
15
10
5
0
High Street Station
Hilyard Station
Dad's Gate Station
Agate Station
Walnut Station
Gleenwood Station
Lexington Station
Mc Vay Station
No Response
College/School
Going home
Work / Job
Visiting family/friends
Shopping/Errands
Other
Work & School
More than one (Work, Shopping & Visiting)
More than one (College, Shopping & Visiting)



Modal Preference
35
30
25
20
15
10
5
0
No of Respondents
High Street Station
Hilyard Station
Dad's Gate Station
Agate Station
Walnut Station
Gleenwood Station
Lexington Station
Mc Vay Station
Prefer EmX
Prefer Car

D. THERMAL MEASUREMENTS

Metabolic activity and seasonal clothing levels

Month	Season	Clothing Insulation (Clo)
December January February	Winter	1.0 Typical winter indoor clothing
March April May	Spring	0.57 Trousers, short sleeve shirt
June July August	Summer	0.5 Typical summer indoor clothing
September October November	Fall	0.61 Trouser, long sleeve shirt

Seasons	Month	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	June '15	Mean	20.12	24.90	36.57	0.68	63.75
		Median	20.09	24.67	33.60	0.52	63.57
		Mode	#N/A	20.37	#N/A	0.57	#N/A
		Standard Deviation	0.73	3.67	12.79	0.52	2.09
		Maximum	21.18	29.46	59.68	2.35	66.49
		Minimum	19.22	20.08	21.45	0.12	60.64
		Range	1.95	9.39	38.23	2.23	5.86
	July '15	Mean	20.20	25.31	39.06	0.70	53.37
		Median	20.08	24.63	36.25	0.65	53.69
		Mode	19.29	23.11	#N/A	0.41	55.70
		Standard Deviation	0.69	3.41	12.98	0.44	1.90
		Maximum	21.32	30.72	71.53	1.89	56.26
		Minimum	19.27	19.70	20.52	0.08	49.85
		Range	2.05	11.02	51.01	1.81	6.41
	August '15	Mean	18.60	20.69	26.54	0.76	66.77
		Median	18.40	20.16	24.54	0.74	66.93
		Mode	17.61	18.39	#N/A	0.82	68.39
		Standard Deviation	1.01	2.57	5.96	0.37	1.43
		Maximum	20.37	28.74	47.63	1.81	69.01
		Minimum	17.32	18.11	20.33	0.16	64.36
		Range	3.05	10.64	27.30	1.65	4.65
Fall	September '15	Mean	13.16	14.41	19.02	0.89	76.00
		Median	13.21	14.55	18.81	0.74	75.80
		Mode	12.61	14.63	#N/A	0.28	78.06
		Standard Deviation	0.52	0.61	2.11	0.60	1.51
		Maximum	14.12	15.94	25.47	2.50	78.69
		Minimum	12.29	13.26	15.36	0.20	72.46
		Range	1.83	2.68	10.11	2.30	6.22
	October '15	Mean	13.83	14.22	15.32	0.63	73.54
		Median	13.69	14.27	14.78	0.55	73.80
		Mode	13.21	14.27	#N/A	0.26	#N/A
		Standard Deviation	0.59	0.60	1.84	0.40	1.57
		Maximum	15.10	15.61	22.14	2.03	75.82
		Minimum	13.16	13.35	13.55	0.17	69.51
		Range	1.94	2.25	8.59	1.86	6.32
	November '15	Mean	10.81	11.58	15.11	1.13	70.45
		Median	10.61	11.41	15.10	1.19	70.75
		Mode	10.30	10.96	#N/A	1.21	71.81
		Standard Deviation	0.54	0.74	2.48	0.46	1.20
		Maximum	11.90	12.97	19.25	2.16	71.90
		Minimum	10.25	10.35	9.46	0.22	68.04
		Range	1.66	2.62	9.79	1.94	3.86
Winter	December '15	Mean	4.64	5.24	7.06	0.48	72.38
		Median	4.48	5.21	7.67	0.46	73.30
		Mode	4.01	4.17	#N/A	0.61	71.04
		Standard Deviation	0.58	0.92	2.35	0.20	2.54
		Maximum	5.82	6.86	11.79	1.14	75.22
		Minimum	3.99	3.93	1.98	0.14	65.88
		Range	1.84	2.93	9.80	1.00	9.34
	January '16	Mean	5.17	5.97	8.64	0.58	87.23
		Median	5.05	5.76	8.22	0.55	87.19
		Mode	5.02	5.57	#N/A	0.43	86.56
		Standard Deviation	0.27	0.62	2.31	0.30	1.28
		Maximum	5.77	7.22	14.50	1.24	89.95
		Minimum	4.84	5.15	5.44	0.16	84.59
		Range	0.93	2.06	9.06	1.08	5.36
	February '16	Mean	10.87	10.95	11.00	1.57	78.74
		Median	10.86	11.10	12.06	1.38	79.20
		Mode	11.25	9.83	#N/A	0.81	80.18
		Standard Deviation	0.42	0.74	4.03	0.98	2.11
		Maximum	11.47	12.20	19.60	4.72	82.44
		Minimum	10.27	9.78	-1.54	0.39	72.77
		Range	1.20	2.42	21.14	4.33	9.66
Spring	March '16	Mean	10.30	14.07	27.04	0.79	70.45
		Median	10.39	14.48	26.44	0.71	70.95
		Mode	11.47	14.55	#N/A	0.64	71.83
		Standard Deviation	1.03	1.43	6.07	0.44	3.51
		Maximum	11.59	16.08	42.12	1.77	75.85
		Minimum	8.47	10.25	16.08	0.13	64.83
		Range	3.12	5.84	26.03	1.64	11.02

Statistical Summary of monthly climate data at High Street Station

Jun-15	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Mean	24.23	26.63	34.06	0.79	55.81
Median	23.93	26.35	34.45	0.68	55.78
Mode	23.33	#N/A	#N/A	0.82	#N/A
Standard Deviation	1.54	1.59	3.34	0.51	2.14
Maximum	27.11	29.41	39.93	2.40	59.43
Minimum	22.03	24.15	28.12	0.11	52.32
Jul-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	24.11	26.37	31.59	0.52	42.87
Median	23.76	26.01	31.21	0.41	42.82
Mode	23.71	27.51	#N/A	0.44	42.82
Standard Deviation	0.96	1.02	2.58	0.36	2.08
Maximum	25.53	28.12	39.24	1.57	47.57
Minimum	22.32	24.10	26.42	0.00	39.99
Aug-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	25.42	26.74	27.41	0.76	54.29
Median	25.84	26.87	27.43	0.52	53.35
Mode	25.84	24.77	#N/A	0.31	52.79
Standard Deviation	0.94	1.31	1.76	0.57	2.66
Maximum	26.70	28.79	30.88	2.88	60.81
Minimum	23.18	24.77	24.67	0.16	50.47
Sep-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	17.32	20.13	28.59	0.69	57.69
Median	17.27	19.88	28.14	0.64	58.87
Mode	17.32	19.56	#N/A	0.42	65.52
Standard Deviation	1.00	0.68	2.96	0.37	5.59
Maximum	18.91	21.51	39.04	1.88	66.87
Minimum	15.53	18.96	23.08	0.21	49.30
Oct-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	20.20	30.67	60.88	0.93	54.74
Median	20.03	30.48	60.18	0.79	54.86
Mode	19.98	31.79	#N/A	0.31	55.00
Standard Deviation	1.71	1.94	10.95	0.58	5.04
Maximum	23.14	34.07	88.75	2.67	63.30
Minimum	17.46	26.82	31.49	0.00	45.59
Nov-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	13.33	13.93	16.07	0.84	68.27
Median	13.50	13.93	16.19	0.82	68.97
Mode	13.50	13.47	#N/A	0.70	69.10
Standard Deviation	0.40	0.32	1.65	0.37	3.41
Maximum	13.76	14.53	20.52	1.99	74.06
Minimum	12.44	13.43	12.89	0.20	62.81
Dec-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	8.42	13.48	27.13	0.54	67.42
Median	8.39	13.14	25.80	0.45	67.85
Mode	7.37	12.34	#N/A	0.23	69.05
Standard Deviation	0.84	1.41	7.80	0.30	1.64
Maximum	9.78	17.20	55.82	1.64	69.77
Minimum	7.32	11.44	14.87	0.20	64.33
Jan-16	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	5.84	8.26	15.08	0.41	87.24
Median	5.45	7.22	9.59	0.37	88.26
Mode	5.23	5.51	6.18	0.20	88.47
Standard Deviation	0.69	3.18	11.44	0.23	2.30
Maximum	7.04	16.56	47.54	1.29	90.00
Minimum	5.21	5.41	5.70	0.15	81.56
Feb-16	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	12.32	14.42	22.73	0.93	68.26
Median	12.28	14.51	21.92	0.84	67.56
Mode	12.24	14.79	#N/A	1.85	66.71
Standard Deviation	0.40	1.43	7.29	0.59	2.08
Maximum	12.92	16.94	45.22	3.64	73.16
Minimum	11.66	11.98	12.27	0.26	63.67
Mar-16	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	14.88	18.58	28.92	0.72	55.31
Median	14.96	17.50	24.97	0.59	55.16
Mode	15.61	16.94	#N/A	0.28	54.45
Standard Deviation	0.83	2.37	9.83	0.51	1.30
Maximum	16.23	24.32	63.01	2.44	58.43
Minimum	13.38	16.73	19.61	0.17	52.82

Statistical Summary of monthly climate data at Hilyard Station

Seasons	Month	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	June '15	Mean	29.03	31.00	35.68	0.57	48.24
		Median	29.05	30.99	35.04	0.42	47.74
		Mode	30.50	32.07	#N/A	0.13	#N/A
		Standard Deviation	1.01	0.89	2.86	0.50	2.47
		Maximum	30.50	32.64	41.53	2.11	52.36
		Minimum	27.48	29.59	31.65	0.00	44.12
		Range					
	July '15	Mean	27.29	28.89	33.17	0.67	39.73
		Median	27.31	28.84	32.81	0.52	39.68
		Mode	27.36	28.07	#N/A	0.44	39.68
		Standard Deviation	0.85	0.72	2.11	0.47	1.00
		Maximum	28.67	30.02	38.68	2.29	41.54
		Minimum	26.06	27.51	27.53	0.00	37.65
		Range					
	Aug '15	Mean	27.76	28.76	29.24	0.78	47.13
		Median	27.80	28.78	29.34	0.60	46.76
		Mode	27.63	28.20	#N/A	0.32	49.27
		Standard Deviation	0.50	0.54	0.88	0.59	1.38
		Maximum	28.59	30.19	31.49	2.92	50.43
		Minimum	26.65	27.43	27.18	0.15	44.26
		Range					
Fall	Sep '15	Mean	19.02	20.73	27.95	1.21	49.02
		Median	19.08	20.89	27.23	1.05	48.64
		Mode	19.72	19.48	#N/A	1.19	46.45
		Standard Deviation	0.52	0.90	3.56	0.70	2.49
		Maximum	19.79	22.13	38.51	2.97	53.09
		Minimum	18.18	19.39	21.93	0.26	45.23
		Range					
	Oct '15	Mean	26.13	33.79	58.75	1.18	37.66
		Median	26.55	34.08	55.87	0.92	37.03
		Mode	26.79	34.73	#N/A	0.61	41.01
		Standard Deviation	0.72	1.23	11.62	0.90	1.66
		Maximum	26.87	35.58	96.87	4.75	41.46
		Minimum	24.77	30.34	39.67	0.15	35.63
		Range					
	Nov '15	Mean	13.00	13.02	12.93	0.62	80.72
		Median	12.99	13.04	13.08	0.55	81.22
		Mode	12.82	13.06	12.67	0.23	82.20
		Standard Deviation	0.14	0.19	0.73	0.34	1.35
		Maximum	13.33	13.38	14.10	1.52	82.45
		Minimum	12.82	12.58	10.14	0.20	77.08
		Range					
Winter	Dec '15	Mean	9.87	10.43	11.88	0.51	65.97
		Median	10.00	10.36	11.15	0.49	65.44
		Mode	10.25	10.44	#N/A	0.26	#N/A
		Standard Deviation	0.39	0.84	2.41	0.25	1.64
		Maximum	10.32	12.58	22.06	1.26	68.93
		Minimum	9.11	9.31	9.59	0.18	63.69
		Range					
	Jan '16	Mean	6.81	7.96	11.48	0.49	84.30
		Median	6.74	7.59	10.15	0.44	84.49
		Mode	6.74	7.22	9.08	0.27	86.02
		Standard Deviation	0.21	1.02	4.18	0.25	1.93
		Maximum	7.32	10.96	30.18	1.86	88.21
		Minimum	6.59	6.97	7.78	0.18	79.99
		Range					
	February '16	Mean	12.98	14.62	20.92	0.85	57.16
		Median	13.11	14.58	19.79	0.77	56.53
		Mode	13.11	15.84	#N/A	0.48	56.56
		Standard Deviation	0.35	0.91	4.74	0.48	3.68
		Maximum	13.28	16.13	35.47	2.71	66.58
		Minimum	12.05	12.61	12.52	0.24	51.44
		Range					
Spring	Mar '16	Mean	18.00	23.16	40.21	0.97	52.39
		Median	17.87	23.10	36.90	0.81	52.88
		Mode	17.80	19.77	#N/A	0.73	53.45
		Standard Deviation	0.77	3.22	12.83	0.64	2.72
		Maximum	19.22	28.07	74.05	3.12	56.93
		Minimum	16.56	18.25	22.28	0.16	46.25
		Range					

Statistical Summary of monthly climate data at Dads' Gates Station

Seasons	Month	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	June '15	Mean	31.41	32.51	36.19	1.05	43.19
		Median	31.46	32.46	36.40	1.11	43.08
		Mode	31.64	32.23	#N/A	0.11	#N/A
		Standard Deviation	0.28	0.26	2.21	0.71	0.84
		Maximum	31.84	33.05	40.84	2.68	44.84
		Minimum	30.85	32.02	33.00	0.11	42.18
		Range	0.99	1.03	7.84	2.57	2.66
	July '15	Mean	28.86	29.73	32.97	1.24	38.27
		Median	28.87	29.74	33.08	1.19	38.21
		Mode	28.77	29.79	#N/A	0.30	38.67
		Standard Deviation	0.18	0.20	1.47	0.80	0.53
		Maximum	29.24	30.24	37.17	3.67	39.77
		Minimum	28.47	29.19	30.47	0.19	37.24
		Range	0.77	1.05	6.70	3.48	2.53
	Aug '15	Mean	28.36	27.23	25.83	1.90	40.19
		Median	28.30	26.89	24.93	1.84	39.43
		Mode	28.27	26.57	#N/A	0.70	38.18
		Standard Deviation	0.24	1.10	2.44	0.92	2.46
		Maximum	28.99	29.52	31.59	4.56	46.07
		Minimum	28.05	25.14	20.87	0.28	36.70
		Range	0.94	4.38	10.72	4.28	9.37
Fall	Sep '15	Mean	17.96	19.54	26.75	1.21	52.43
		Median	17.83	18.50	21.63	1.05	52.67
		Mode	17.13	16.58	#N/A	0.50	#N/A
		Standard Deviation	1.04	2.56	10.59	0.79	3.50
		Maximum	19.84	25.38	60.13	3.57	60.03
		Minimum	16.27	16.51	16.83	0.17	46.08
		Range	3.57	8.87	43.30	3.40	13.95
	Oct '15	Mean	26.82	28.49	33.49	0.92	34.34
		Median	26.92	28.22	32.48	0.57	34.26
		Mode	26.94	26.40	26.25	0.26	34.98
		Standard Deviation	0.25	1.70	6.84	0.79	0.43
		Maximum	27.14	32.20	54.64	4.18	35.35
		Minimum	26.28	26.16	25.40	0.00	33.67
		Range	0.86	6.04	29.24	4.18	1.68
	Nov '15	Mean	12.63	12.30	11.00	0.68	82.29
		Median	12.45	12.17	11.01	0.61	83.05
		Mode	12.44	12.05	#N/A	0.36	84.76
		Standard Deviation	0.50	0.47	0.65	0.37	3.20
		Maximum	13.59	13.35	12.44	1.70	86.34
		Minimum	11.98	11.71	9.10	0.17	75.35
		Range	1.62	1.64	3.35	1.53	10.99
Winter	Dec '15	Mean	8.63	8.57	8.26	0.30	73.95
		Median	8.67	8.57	8.20	0.24	73.00
		Mode	7.97	7.92	7.82	0.20	72.18
		Standard Deviation	0.58	0.64	0.79	0.13	3.46
		Maximum	9.58	9.71	10.07	0.90	80.79
		Minimum	7.67	7.49	6.89	0.15	68.90
		Range	1.91	2.21	3.18	0.76	11.89
	Jan '16	Mean	7.03	7.40	8.43	0.42	78.67
		Median	7.02	7.02	7.09	0.38	78.60
		Mode	6.99	6.23	7.02	0.21	79.82
		Standard Deviation	0.26	1.09	3.39	0.19	1.66
		Maximum	7.49	10.49	20.84	1.08	82.34
		Minimum	6.56	6.23	4.72	0.18	74.58
		Range	0.93	4.26	16.12	0.90	7.77
	February '16	Mean	12.68	14.07	20.13	1.10	54.61
		Median	12.63	13.98	19.25	1.14	54.43
		Mode	12.61	13.79	#N/A	1.14	54.28
		Standard Deviation	0.11	0.72	3.79	0.51	1.45
		Maximum	12.90	16.49	35.24	2.51	57.02
		Minimum	12.49	13.23	14.80	0.24	51.39
		Range	0.41	3.25	20.44	2.27	5.63
Spring	Mar '16	Mean	20.44	22.27	27.53	0.67	36.58
		Median	20.51	21.99	25.95	0.51	35.88
		Mode	20.34	21.82	#N/A	0.15	41.67
		Standard Deviation	0.35	0.73	4.52	0.47	3.07
		Maximum	20.89	24.32	43.93	2.33	42.95
		Minimum	19.75	21.32	22.65	0.06	32.20
		Range	1.14	3.00	21.28	2.27	10.75

Statistical Summary of monthly climate data at Agate Station

Seasons	Month	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	June '15	Mean	22.80	24.25	30.06	1.16	62.14
		Median	22.85	23.91	28.30	1.10	62.36
		Mode	22.90	23.55	#N/A	0.27	62.85
		Standard Deviation	0.76	1.08	7.11	0.74	1.39
		Maximum	24.34	28.07	64.41	3.24	64.51
		Minimum	21.56	22.94	23.89	0.12	58.55
		Range	2.78	5.13	40.52	3.12	5.96
	July '15	Mean	18.97	21.10	27.76	0.77	68.40
		Median	18.68	21.25	26.66	0.61	69.12
		Mode	18.22	19.41	#N/A	0.18	70.53
		Standard Deviation	0.87	1.40	5.15	0.62	2.55
		Maximum	20.56	23.28	42.63	2.47	72.63
		Minimum	17.58	18.87	20.80	0.12	63.41
		Range	2.97	4.41	21.84	2.35	9.22
	Aug '15	Mean	21.67	23.46	24.69	1.02	65.70
		Median	21.57	23.28	24.55	0.85	66.17
		Mode	22.01	23.04	#N/A	0.26	68.02
		Standard Deviation	0.65	0.52	0.80	0.68	2.14
		Maximum	22.85	24.65	27.19	3.26	69.01
		Minimum	20.77	22.82	23.53	0.19	61.18
		Range	2.08	1.83	3.66	3.07	7.83
Fall	Sep '15	Mean	15.82	17.45	22.97	0.75	59.20
		Median	15.75	17.46	22.77	0.61	58.78
		Mode	16.80	17.23	#N/A	0.29	63.83
		Standard Deviation	0.76	1.04	3.51	0.52	3.26
		Maximum	17.23	19.22	31.83	2.53	64.53
		Minimum	14.77	15.58	17.14	0.21	53.89
		Range	2.46	3.64	14.69	2.32	10.64
	Oct '15	Mean	16.81	21.26	32.16	0.64	57.30
		Median	17.13	18.33	22.42	0.57	55.14
		Mode	17.13	15.89	#N/A	0.39	#N/A
		Standard Deviation	1.50	5.54	15.84	0.35	4.71
		Maximum	19.34	30.62	75.78	2.00	64.95
		Minimum	14.34	14.98	16.64	0.13	50.81
		Range	5.00	15.64	59.14	1.87	14.14
	Nov '15	Mean	9.82	10.07	11.44	0.84	86.86
		Median	9.71	9.69	9.39	0.77	86.53
		Mode	9.61	9.61	9.26	0.63	86.27
		Standard Deviation	0.30	0.62	3.97	0.49	1.47
		Maximum	10.76	11.61	21.61	2.11	89.69
		Minimum	9.53	9.49	5.50	0.20	82.30
		Range	1.23	2.13	16.11	1.91	7.39
Winter	Dec '15	Mean	11.14	12.09	16.26	1.12	88.76
		Median	11.13	12.00	15.88	1.09	89.11
		Mode	10.69	11.44	#N/A	1.84	88.39
		Standard Deviation	0.37	0.79	3.24	0.55	1.11
		Maximum	11.76	13.69	24.21	2.12	90.09
		Minimum	10.59	10.71	11.29	0.24	85.77
		Range	1.17	2.98	12.93	1.88	4.32
	Jan '16	Mean	4.97	11.68	37.32	1.05	85.06
		Median	4.92	12.15	35.81	1.08	85.10
		Mode	4.66	9.34	#N/A	1.13	83.58
		Standard Deviation	0.49	2.50	11.33	0.46	1.58
		Maximum	5.80	15.53	64.06	1.93	88.35
		Minimum	4.01	6.48	14.60	0.19	82.40
		Range	1.79	9.05	49.46	1.74	5.95
	February '16	Mean	9.78	14.13	32.44	1.24	63.15
		Median	9.98	13.95	32.05	1.04	63.08
		Mode	8.62	13.91	#N/A	1.04	#N/A
		Standard Deviation	0.92	0.97	5.96	0.75	3.58
		Maximum	11.39	16.32	47.37	3.21	69.13
		Minimum	8.22	12.29	22.29	0.26	57.14
		Range	3.17	4.03	25.08	2.95	11.99
Spring	Mar '16	Mean	12.90	14.23	20.77	1.49	67.49
		Median	12.87	14.79	19.14	1.45	67.47
		Mode	12.61	11.93	#N/A	2.26	68.27
		Standard Deviation	1.48	2.02	6.87	0.69	4.68
		Maximum	15.27	18.03	48.77	2.90	74.95
		Minimum	10.52	10.98	13.30	0.22	59.21
		Range	4.75	7.05	35.47	2.68	15.74

Statistical Summary of monthly climate data at Walnut Station

Seasons	Month	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	June '15	Mean	29.23	35.76	62.82	1.86	44.10
		Median	29.35	35.76	63.60	1.76	43.03
		Mode	28.82	36.44	#N/A	0.46	43.27
		Standard Deviation	1.28	1.08	11.07	1.28	4.27
		Maximum	31.05	38.00	84.34	5.10	53.90
		Minimum	26.35	33.47	43.60	0.21	38.90
		Range	4.70	4.54	40.74	4.89	15.00
	July '15	Mean	22.39	25.26	34.75	1.03	59.00
		Median	22.32	24.97	33.93	1.03	59.18
		Mode	22.27	25.23	#N/A	0.93	58.15
		Standard Deviation	0.31	1.43	5.89	0.67	1.28
		Maximum	23.04	29.99	56.84	2.78	62.18
		Minimum	21.63	23.50	26.31	0.07	56.38
		Range	1.41	6.49	30.53	2.71	5.80
	Aug '15	Mean	25.94	33.16	38.88	1.42	52.82
		Median	25.98	33.26	38.53	1.18	52.78
		Mode	25.84	33.26	#N/A	0.34	50.50
		Standard Deviation	0.67	1.29	3.63	0.98	1.99
		Maximum	26.97	35.64	50.06	4.49	57.53
		Minimum	24.61	29.82	32.59	0.00	49.41
		Range	2.36	5.82	17.47	4.49	8.12
Fall	Sep '15	Mean	19.10	25.24	44.74	1.05	47.78
		Median	18.75	25.19	44.44	0.83	49.41
		Mode	18.13	19.60	#N/A	0.42	49.86
		Standard Deviation	1.05	4.60	16.93	0.70	3.58
		Maximum	21.03	31.08	82.77	3.38	53.23
		Minimum	17.99	19.37	22.29	0.19	38.97
		Range	3.05	11.71	60.48	3.19	14.26
	Oct '15	Mean	22.94	30.59	63.01	1.72	42.12
		Median	23.17	30.65	64.22	1.69	41.20
		Mode	22.27	29.49	#N/A	2.60	40.05
		Standard Deviation	0.98	0.97	8.44	0.76	2.29
		Maximum	24.39	32.85	79.50	3.76	46.84
		Minimum	21.27	29.17	41.88	0.23	38.64
		Range	3.12	3.68	37.62	3.53	8.20
	Nov '15	Mean	12.26	17.75	35.95	0.94	80.51
		Median	12.29	18.65	38.14	0.85	81.48
		Mode	11.03	13.04	#N/A	0.89	84.78
		Standard Deviation	0.86	3.50	14.12	0.56	4.20
		Maximum	13.59	23.21	63.54	2.69	85.53
		Minimum	10.98	12.46	12.49	0.25	70.18
		Range	2.61	10.75	51.05	2.44	15.35
Winter	Dec '15	Mean	13.68	16.22	24.07	0.69	79.35
		Median	13.75	16.14	22.42	0.55	79.87
		Mode	14.51	14.07	#N/A	0.57	82.28
		Standard Deviation	0.83	1.75	6.59	0.39	2.79
		Maximum	14.55	21.56	54.27	1.70	83.65
		Minimum	12.41	13.83	16.61	0.20	74.94
		Range	2.14	7.72	37.66	1.50	8.71
	Jan '16	Mean	8.00	17.41	44.54	0.74	71.98
		Median	7.85	18.00	43.66	0.61	71.65
		Mode	7.70	16.94	#N/A	0.28	74.26
		Standard Deviation	0.51	1.78	10.03	0.43	3.81
		Maximum	8.72	20.27	73.88	2.17	78.79
		Minimum	7.22	12.24	27.35	0.20	64.99
		Range	1.50	8.03	46.53	1.97	13.80
	February '16	Mean	14.94	19.58	33.34	0.66	43.73
		Median	15.25	20.15	33.84	0.57	41.76
		Mode	15.27	21.10	#N/A	0.48	39.66
		Standard Deviation	0.71	2.50	12.22	0.35	5.29
		Maximum	15.70	23.95	55.09	1.56	54.78
		Minimum	13.02	15.89	17.24	0.18	37.35
		Range	2.68	8.06	37.85	1.38	17.43
Spring	Mar '16	Mean	19.36	29.55	54.33	0.70	49.01
		Median	19.15	29.34	51.60	0.53	49.21
		Mode	19.08	28.44	#N/A	0.27	44.43
		Standard Deviation	0.97	1.06	11.44	0.56	3.72
		Maximum	20.84	31.92	83.68	2.53	56.83
		Minimum	17.18	27.95	34.40	0.02	43.13
		Range	3.66	3.97	49.28	2.51	13.71

Statistical Summary of monthly climate data at Glenwood Station

Seasons	Month	Descriptive Analysis	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Summer	June '15	Mean	32.89	38.61	60.71	1.62	34.37
		Median	33.07	38.77	58.91	1.20	33.95
		Mode	32.12	38.98	#N/A	0.83	36.52
		Standard Deviation	0.60	0.68	9.21	1.16	1.46
		Maximum	33.76	39.43	81.41	5.19	37.99
		Minimum	31.61	35.32	41.50	0.11	32.47
		Range	2.15	4.12	39.91	5.08	5.52
	July '15	Mean	22.99	25.96	42.79	2.37	60.76
		Median	23.09	25.45	40.58	2.39	60.71
		Mode	23.09	27.41	#N/A	1.74	60.97
		Standard Deviation	0.57	1.71	8.94	1.03	2.72
		Maximum	24.07	30.34	78.93	5.05	65.33
		Minimum	22.11	23.83	28.61	0.25	54.45
		Range	1.97	6.51	50.32	4.81	10.88
	Aug '15	Mean	27.98	32.15	35.81	1.66	46.48
		Median	28.02	32.18	35.91	1.50	46.48
		Mode	27.63	32.69	#N/A	0.99	47.56
		Standard Deviation	0.43	1.35	2.89	1.14	1.34
		Maximum	28.72	36.07	43.33	4.83	49.07
		Minimum	27.01	29.29	30.05	0.15	43.98
		Range	1.70	6.78	13.28	4.68	5.08
Fall	Sep '15	Mean	21.26	27.48	50.12	1.25	37.36
		Median	21.14	28.38	49.67	1.13	38.11
		Mode	20.98	28.74	#N/A	0.64	39.07
		Standard Deviation	0.48	2.32	12.26	0.79	1.74
		Maximum	22.20	30.87	84.14	3.50	39.87
		Minimum	20.39	21.68	23.77	0.22	33.56
		Range	1.81	9.20	60.37	3.28	6.31
	Oct '15	Mean	27.17	33.04	61.77	2.17	33.93
		Median	27.41	32.99	61.55	1.99	33.39
		Mode	27.60	32.64	#N/A	1.59	32.89
		Standard Deviation	0.67	0.68	7.66	0.92	1.29
		Maximum	28.15	34.65	78.18	4.37	37.20
		Minimum	25.74	31.41	43.57	0.49	32.38
		Range	2.40	3.24	34.60	3.88	4.82
	Nov '15	Mean	9.79	10.05	10.47	0.63	87.08
		Median	9.78	10.00	10.85	0.60	87.35
		Mode	9.83	9.46	12.63	0.31	86.90
		Standard Deviation	0.13	0.48	2.35	0.32	0.72
		Maximum	10.27	10.88	15.39	1.43	88.38
		Minimum	9.58	9.39	4.78	0.21	85.26
		Range	0.69	1.50	10.60	1.22	3.12
Winter	Dec '15	Mean	12.29	13.40	16.56	0.65	83.63
		Median	11.86	13.11	16.06	0.52	84.52
		Mode	11.39	12.15	#N/A	0.34	85.02
		Standard Deviation	0.96	1.26	2.62	0.40	2.18
		Maximum	14.41	15.15	23.68	1.91	86.06
		Minimum	11.37	11.86	12.95	0.19	77.26
		Range	3.04	3.30	10.73	1.72	8.81
	Jan '16	Mean	8.02	12.63	27.54	0.79	67.14
		Median	8.11	14.06	28.54	0.68	66.59
		Mode	8.22	7.75	#N/A	0.76	68.06
		Standard Deviation	0.32	3.01	13.54	0.48	3.09
		Maximum	8.72	16.53	56.04	2.05	73.88
		Minimum	7.44	7.75	8.44	0.22	60.14
		Range	1.27	8.79	47.61	1.83	13.75
	February '16	Mean	14.10	14.01	13.63	0.81	46.04
		Median	13.77	13.92	13.75	0.70	48.07
		Mode	13.50	13.59	#N/A	0.55	48.07
		Standard Deviation	0.60	0.42	0.97	0.51	3.41
		Maximum	15.22	14.98	15.52	2.50	49.71
		Minimum	13.50	13.40	11.17	0.20	40.41
		Range	1.73	1.58	4.35	2.30	9.30
Spring	Mar '16	Mean	22.45	28.71	53.40	1.42	40.89
		Median	22.59	28.72	51.88	1.30	40.75
		Mode	22.66	29.02	#N/A	0.86	40.09
		Standard Deviation	0.47	0.77	8.88	0.78	0.86
		Maximum	23.26	30.04	70.64	3.34	43.46
		Minimum	21.72	27.26	37.96	0.18	39.50
		Range	1.53	2.78	32.68	3.16	3.97

Statistical Summary of monthly climate data at Lexington Station

Jun-15	Ta [C]	Tg [C]	MRT [C]	Va [m/s]	RH [%]
Mean	34.15	34.23	34.50	1.18	31.29
Median	34.18	34.18	34.16	0.88	31.21
Mode	34.20	34.15	#N/A	0.41	31.25
Standard Deviation	0.12	0.28	1.40	0.99	0.82
Maximum	34.31	34.84	39.65	4.74	33.10
Minimum	33.89	33.55	32.43	0.11	29.62
Jul-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	22.29	24.29	29.55	0.62	60.73
Median	22.20	24.00	28.31	0.42	61.30
Mode	22.15	24.10	#N/A	0.37	61.87
Standard Deviation	0.24	0.88	3.25	0.51	2.17
Maximum	22.85	26.94	45.70	3.23	63.79
Minimum	21.94	23.47	25.55	0.18	56.08
Aug-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	28.32	29.81	30.78	1.08	39.16
Median	28.30	29.94	30.76	0.89	38.76
Mode	28.27	30.17	#N/A	0.40	38.18
Standard Deviation	0.31	0.97	1.62	0.73	1.86
Maximum	28.99	31.54	34.53	3.37	44.18
Minimum	27.48	27.43	27.23	0.23	36.59
Sep-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	22.21	24.02	30.98	1.16	36.48
Median	22.18	23.69	29.07	1.05	36.38
Mode	22.13	23.81	#N/A	0.77	35.26
Standard Deviation	0.18	1.18	5.90	0.63	1.46
Maximum	22.51	27.04	51.72	2.82	39.59
Minimum	21.87	22.82	23.92	0.22	33.63
Oct-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	27.95	31.66	43.77	0.98	34.20
Median	27.94	32.02	42.89	0.87	34.33
Mode	27.51	30.12	#N/A	1.49	33.78
Standard Deviation	0.48	1.05	6.81	0.68	0.77
Maximum	28.84	33.26	67.26	4.09	35.82
Minimum	26.97	29.64	29.94	0.00	31.90
Nov-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	9.58	9.39	8.43	0.81	90.02
Median	9.53	9.29	8.27	0.75	90.72
Mode	9.31	9.04	7.27	0.82	92.02
Standard Deviation	0.25	0.38	1.00	0.33	2.06
Maximum	10.03	10.22	11.03	1.69	92.73
Minimum	9.26	8.89	6.59	0.20	86.76
Dec-15	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	13.85	13.54	12.47	0.61	79.67
Median	13.58	13.31	12.50	0.58	79.75
Mode	13.47	12.53	#N/A	0.43	82.37
Standard Deviation	0.59	0.75	1.48	0.30	2.10
Maximum	14.79	15.03	15.68	1.50	82.90
Minimum	13.04	12.49	9.53	0.17	76.01
Jan-16	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	7.77	7.37	6.44	0.43	64.47
Median	7.67	6.84	5.56	0.16	64.65
Mode	8.27	6.31	4.77	0.15	60.36
Standard Deviation	0.65	1.55	4.41	0.53	3.81
Maximum	9.04	12.05	28.75	2.05	72.12
Minimum	6.81	5.44	-2.60	0.14	59.08
Feb-16	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	14.28	14.12	13.53	0.75	48.34
Median	14.27	14.23	13.90	0.65	48.02
Mode	14.27	14.27	14.27	0.69	48.61
Standard Deviation	0.12	0.57	2.58	0.46	2.25
Maximum	14.51	14.89	18.35	3.17	55.85
Minimum	13.93	12.22	6.62	0.22	44.66
Mar-16	**Ta [C]**	**Tg [C]**	**MRT [C]**	**Va [m/s]**	**RH [%]**
Mean	22.93	28.93	43.26	0.62	41.47
Median	22.92	28.99	41.21	0.39	41.49
Mode	22.99	28.99	#N/A	0.30	43.64
Standard Deviation	0.11	0.52	6.56	0.53	1.56
Maximum	23.14	29.87	59.72	2.72	44.14
Minimum	22.71	27.78	33.04	0.04	35.74

Statistical Summary of monthly climate data at McVay Station

E. STATIONS DATA

Station Name	Station Type	Photograph	Orientation	Ariel View	Fisheye Photographs	Sky View Factor
High Street Station	Center Station One Platform		N-S			0.274
Hilyard Station	Center Station Two Platforms		N-S			0.258
Dads' Gates Station	Center Station Two Platforms		N-S			0.288
Agate Station	Center Station Two Platforms		NE-SW			0.371
Walnut Station	Center Station Two Platforms		NE-SW			0.372
Glenwood Station	Side Station One Platform		N-S			0.551
Lexington Station	Side Station One Platform		N-S			0.541
McVay Station	Center Station One Platform		N-S			0.656

Summary of Stations' Built Environments

STATION	H: W	Mean H/W	SVF	TYPE	Posted Speed Limit (MPH)	Mean. Satisfaction Ratings (%)
High Street	1:3, 1:1	0.67	0.27	Center island Single boarding platform	25	67
Hilyard	1:4.8, 1:7.5	0.17	0.258	Center island Double boarding platform	25	67
Dads' Gates	1:4, 1:5.2	0.22	0.288	Center island Double boarding platform	25	70
Agate	1:8.4, 1:4.6	0.17	0.371	Center island Double boarding platform	35	67
Walnut	1:7, 1:28.5	0.09	0.372	Center island Double boarding platform	45	72
Glenwood	1:19.5, 1:10	0.08	0.551	Side Station Single boarding platform	35	45
Lexington	1:15.3	0.07	0.541	Side Station Single boarding platform	35	44
McVay	1:13.5	0.07		Center island Double boarding platform	35	excluded

Summary of Stations' Built Environment

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