GIS Based Analysis of Neighborhood Transit Characteristics: A Case Study of The Vine in Kalamazoo, MI

Shealyn Lach
Western Michigan University, shealynlach@gmail.com

Follow this and additional works at: https://scholarworks.wmich.edu/honors_theses

Part of the Geography Commons

Recommended Citation
https://scholarworks.wmich.edu/honors_theses/3417

This Honors Thesis-Open Access is brought to you for free and open access by the Lee Honors College at ScholarWorks at WMU. It has been accepted for inclusion in Honors Theses by an authorized administrator of ScholarWorks at WMU. For more information, please contact wmu-scholarworks@wmich.edu.
GIS Based Analysis of Neighborhood Transit Characteristics: A Case Study of Vine Neighborhood
2019-2021

Shealyn R. Lach

The Carl and Winifred Lee Honors College

College of Arts and Sciences

Department of Geography, Environment, and Tourism

Western Michigan University
Abstract

This paper introduces an evaluative framework to analyze residential neighborhoods and draw conclusions regarding the safety and convenience of public transit options. Transit quality indicators included elevation, service areas, intersection crash statistics, and bus stop infrastructure. Within this research, a case study of Vine Neighborhood in Kalamazoo, MI was used to test the effectiveness of the framework; neighborhood data was retrieved, analyzed, and spatially modeled with ArcGIS Pro, then discussed to draw conclusions. Ultimately, it was determined that while neighborhood residents may be in close physical proximity to a stop, high elevation changes and pedestrian crash rates indicate Metro transit would be considerably more safe/convenient upon the implementation of more pedestrian amenities or an additional stop. While the framework requires more research prior to real-life application, this research is intended to be the first step in creating a safe, user-oriented transit system that improves the quality of life for residents.
Acknowledgements

Prior to this paper, I would like to extend a few messages of thanks:

First, I would like to thank my thesis advisor, Dr. Dave Lemberg. I am extremely grateful for his guidance and insight during the many challenges experienced while doing my research. I wish you a wonderful retirement filled with lots of travel and relaxation! Additionally, I would like to thank my committee members, Dr. Denise Keele and Dr. Jason Beasley for the time and expertise they have contributed towards my thesis. Thank you for being supportive and flexible through this entire process. Finally, I want to extend a word of thanks to Dr. Kathleen Baker and Dr. Greg Veeck for their patient support as professors. Thank you both for the opportunities you’ve given me to learn and grow as an academic of geography. You provided me with the tools to accomplish this and for that I am extremely grateful.

I would also like to thank my partner Tyler for being endlessly helpful, supportive and kind during all the ups and downs of this project. I could not have completed my thesis without you by my side. Finally, I want to thank my family and friends for being incredibly encouraging and willing to listen to me talk about bus stops for longer than is probably socially appropriate. Love you all!

Dr. Dave Lemberg, Associate Professor Emeritus
Western Michigan University - College of Arts and Science
Department of Geography, Environment, and Tourism

Dr. Denise Keele, Associate Professor
Western Michigan University - College of Arts and Science
Department of Political Science

Dr. W. Jason Beasley, Assistant Professor
Western Michigan University - College of Arts and Science
Department of Economics
# Table of Contents

Abstract 1

Acknowledgements 2

1 Introduction 6
   1.1 History and Background 6
      1.1.1 Metro 7
         1.1.1.1 Metro History 7
         1.1.1.2 Kalamazoo Area Bus Stop Action Plan 8
   1.1.2 Vine Neighborhood 8
      1.1.2.1 Vine History 8
      1.2.2.1 Vine Neighborhood Planning 9
   1.2 Study Area Characteristics 10
      1.2.1 Surrounding Region 10
      1.2.2 Elevation 12
      1.2.3 Sidewalks 13
      1.2.4 Public Transit 14
         1.2.4.1 Bus Routes 15
         1.2.4.2 Bus Stops 16
         1.2.4.3 Stop Spacing 16
      1.2.5 Zoning 17
   1.3 Paper Organization 18

2 Literature Review 18
   2.1 Typical Neighborhood Transit Programs 19
      2.1.1 Flexible Transit Services 19
      2.1.2 Network Planning 20
   2.2 Bus Stops 20
      2.2.1 Placement In Relation to Route 20
      2.2.2 Placement in Relation to Users 21
   2.3 Other Transit Variables 22
      2.3.1 Elevation 22
      2.3.2 Safety 22
      2.3.3 Bus Stop Infrastructure 24

3 Methods 24
   3.1 Data Collection 25
      3.1.1 Ancillary Data Sources 25
      3.1.2 Field Data Sources 26
      3.2.3 Preprocessing 28
   3.2 Data Analysis 28
"If you plan cities for cars and traffic, you get cars and traffic. If you plan for people and places, you get people and places"

-Fred Kent (Founder and president of Project for Public Spaces)
1 Introduction

In 2018, an article by The Atlantic wrote “if the buses are terrible in your city, you may think that buses are terrible in general” (Walker, 2018). In the age of Uber and ride-shares, public attention (and dollars) has been shifting from fixed-route buses in favor of on-demand/door-to-door transit options considered more convenient or safe. However, the truth is that buses can be as good as decision makers and voters want them to be. Particularly in U.S cities, low funding for development and operations is the typical cause of infrequent or poor service, which yields low ridership and public opinion (ibid.). In contrast, Canadian cities with similar population densities to their U.S counterparts have more bus services and significantly more ridership (National Transit Database, 2017 as cited in Walker, 2018). Therefore, mobility limitations and overreliance on individual automobiles, can be the result of ineffective transit, rather than the cause.

Particularly, in urban neighborhoods where buses are the only public transit option, it is difficult to compete with the appeal of personal automobiles. These types of districts have off-street and on-street parking, are less dense (single and multi family homes only), and rarely have congestion/traffic (Gordon, 2004, Lundergan, 2009). There may be some transit, but it is likely infrequent and with spaced out stops. However, while circumstances of neighborhoods cause them to have different transit needs than dense downtown neighborhoods and entertainment districts, there is still a need for a public transit option that is safe and convenient (Gordon, 2004). This thesis aims to develop evaluative criteria to judge whether neighborhoods are being served by transit in a way that satisfies these two goals (safety and convenience). The research will use the Vine Neighborhood in Kalamazoo, Michigan as a case study to examine; motorist crash statistics, elevation, bus stop infrastructure, and transit service areas, as indicators of the system's quality. Following this analysis, the next section will be devoted to discussing the results and determining possible alternatives to improve safety and convenience of transit options. While this thesis will be focusing on Vine Neighborhood in Kalamazoo, conclusions reached are relevant to other neighborhoods with similar characteristics.

1.1 History and Background

Prior to studying the Vine Neighborhood and Metro system, an understanding of the specific regional history is important. The following section gives a brief summary on both the history and planning strategies employed by Metro, as well as a more in-depth history of the Vine Neighborhood and a description of developments introduced in the Vine Neighborhood Plan of 2018.
1.1.1 Metro

The Vine Neighborhood and the rest of urbanized Kalamazoo are served by Metro, a countywide public transit system with over 600 bus stops for 19 fixed routes, as well as a curb-to-curb paratransit service as federally mandated in the Americans with Disabilities Act of 1990 (ADA) (Metro, 2018). The mission of the Metro System is “to provide the community with public transportation services that are dependable, convenient, safe, cost effective, and accessible for all” (Metro, 2021). While bus routes go all over the county, most routes are concentrated in Kalamazoo City and begin/end at the Kalamazoo Transit Center (KTC) in downtown Kalamazoo. Transit services are provided every day of the week, with shortened hours on Saturday and Sunday. A portion of the Metro bus network specifically serves Western Michigan University and only operates during the Spring and Fall semesters (Metro, 2014, 2021c).

1.1.1.1 Metro History

Kalamazoo County’s public transit program was founded in 1967, when Kalamazoo City residents elected to acquire private ownership of Kalamazoo City Lines, a privately-owned bus service which suffered from increasing operational costs and decreasing riderships (Metro, 2014). In the decade after the service’s acquisition, the city used federal and state funds to revise and expand bus routes/stops and make operational improvements. In part due to these improvements, system ridership began to climb, peaking at 3.5 million riders in 1980 (ibid.). However, beginning in the early 1980s federal policy changes and budget cuts led to reductions of service during off-peak hours and increased fares overall, causing ridership levels to fall to a low of 1.6 million in 1986. To bring stability to the regional transit system, the Kalamazoo City Commission created a Transit Authority Board of Directors, who sought funding solutions. Eventually, a three year, $0.5 million per year millage levy was introduced and passed, establishing a stable financial base for public transit in the Kalamazoo area. This special transit levy led to improved fleet maintenance, data integration, and on-street operations and was renewed favorably through the end of the millennium. To guide future developments, Metro staff created their first short-range transit planning document in 1990, focusing specifically on finances, marketing, and vehicle maintenance. As the millennium came to a close, Metro began developing strategic goals for future operations, including integrating existing public transit, efficient and affordable system management, and redefining public transit as a viable option for residents.

One of the most notable developments that followed was that Metro began servicing the Western Michigan University Campus, as part of a contract between Metro and the university. While initially introduced as a pilot project in 1998, the program was considered an overall success, motivating Metro to provide additional nearby routes for students living in off-campus housing. In 2020, Metro took on operations of all WMU bus routes, including those contained within campus.
Another notable development was the construction of the Kalamazoo Transportation Center (KTC) in 2005 (Metro, 2014). The KTC serves as an intermodal transportation hub in central Kalamazoo and was completed with $2.9 million in federal assistance, as well as local and state contributions. In addition to being the downtown transfer hub for Metro buses, KTC is also served by two Amtrak trains, Blue Water and Wolverine (ibid.).

Kalamazoo’s public transport system also spent much of the past decade on technology improvements, including web and mobile applications for tracking bus location in real-time, and a website with route information, alerts, and fare information (Metro, 2021a, 2021c). These changes are intended to improve the quality of transit, as well as increase ridership. In 2020, the Covid-19 pandemic led to Metro limiting rides to ‘essential only’ with no fares. As of May 2021, this policy remains in place (Metro, 2021c).

1.1.1.2 Kalamazoo Area Bus Stop Action Plan

Kalamazoo Area Bus Stop Action Plan is a planning document written in 2018 to assess the condition of the Metro System and propose solutions, including bus stop location changes, improved stop amenities and signage, accessibility upgrades, and guidelines for future stops. These recommendations were centrally based on current ridership, stop spacing, stop amenities, and passenger safety factors. The ultimate goal of the action plan was to improve rider experience, operational efficiency and passenger safety. While not all recommendations were implemented, this plan gives a general summary of the factors affecting Metro transit planning and usage, as well as the general priorities of Metro’s transit planners.

1.1.2 Vine Neighborhood

1.1.2.1 Vine History

Being the oldest neighborhood in the city, Vine in Kalamazoo, MI has experienced significant changes over the past 150+ years. Originally, it was the location of the earliest homes in the city, built as early as the 1840s, many of them being large single-family dwellings for Dutch Immigrants (The City of Kalamazoo & Vine Neighborhood Association, 2018, p. 4-5). However, during the Depression era (1929-1941), economic factors caused many of these larger homes to be divided up into apartments and rented out to borders, many of them students and professors of the recently established college: Western Normal School. In the Post-War period (1942-1960), Vine lost a significant portion of their stable population, as suburbanization led to many local residents moving to the outskirts of Kalamazoo, and being replaced by even more students of the now Western Michigan University (WMU), who affectionately called the
neighborhood “the student ghetto” (ibid. p. 5, 26). College students reigned over the neighborhood until WMU expanded its campus to include new apartments and residence halls, motivating students to move from off-campus housing to on-campus (ibid. p. 5). It was around this time (1970-1980) that remaining residents began to come together and form the Vine Neighborhood Association, hoping to keep the neighborhood vibrant, while also restoring it from a “student ghetto” to a community open to families, retirees, students, and people of all backgrounds. p. 5). See figure one for an in-depth timeline.

![Figure 1: Vine Neighborhood Historical Timeline (Kalamazoo & Vine Neighborhood Association, 2018)](image-url)

1.2.2.1 Vine Neighborhood Planning

While the Vine Neighborhood Association has been greatly successful in improving the area, some issues within the neighborhoods could not be addressed by a neighborhood association alone. In these situations, a neighborhood plan can be developed to address more systematic issues (City of Kalamazoo & Vine Neighborhood Association, 2018). A neighborhood plan is a cooperation project
between a city’s planning office and residents to determine the neighborhood’s goals and priorities for the future (ibid.). In 2018, nearly 200 people throughout Kalamazoo contributed to developing such a plan for Vine, called the *Imagine Vine Neighborhood Plan* to complement the master plan for Kalamazoo City--*Imagine Kalamazoo 2025*. This 30 page plan aimed to develop a guide for strategic, resident-driven improvements which addressed issues within the neighborhood while still preserving its unique culture and values (ibid.). *Imagine Vine Neighborhood* outlined goals for the neighborhood spanning across five categories: housing, community, connectivity, commercial, and environment, parks, and food access (Table 1). The developed goals within these categories were also connected to the overall city's 10 strategic vision goals, ensuring that the neighborhood plan would coincide with strategic city-wide planning (ibid.).

<table>
<thead>
<tr>
<th>Imagine Vine Goal</th>
<th>Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>Develop housing opportunities that meet the needs of Vine’s diverse population.</td>
</tr>
<tr>
<td>Community</td>
<td>Vine offers unique opportunities for all ages to feel a part of the Vine community. Residents are aware of all community news and events</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Vine has clear and safe infrastructure for all users to navigate Vine with ease</td>
</tr>
<tr>
<td>Environment, Parks, &amp; Food Access</td>
<td>Vine is a sustainable, biodiverse area with spaces and programming that meet the needs and interests of residents, while ensuring residents have access to fresh food.</td>
</tr>
<tr>
<td>Commercial</td>
<td>Vine has thriving businesses and a strong sense of place</td>
</tr>
</tbody>
</table>

*Table 1: Vine Neighborhood Plan Goals and Visions (The City of Kalamazoo & Vine Neighborhood Association, 2018)*

1.2 Study Area Characteristics

Having given a brief description of history and planning methods for both Metro and the Vine Neighborhood, the following section will describe the characteristics of both the specific study area and the surrounding region.

1.2.1 Surrounding Region

The transit study area (i.e. The Vine Neighborhood) is located in Kalamazoo, MI (figure two). This city is located in the southeastern corner of Michigan’s Lower Peninsula at the intersection of Interstate 94 (I-94) and U.S. Route 131 (US 131), equidistant from Chicago and Detroit and approximately 40 miles north of the Indiana Border. The city is majorly located within the Kalamazoo Valley on the southwest bank of a large bend within the Kalamazoo River and contains several of the river's tributaries. Kalamazoo is home to three institutions of higher learning: Western Michigan
University, Kalamazoo College, and Kalamazoo Valley Community College, and is generally considered a ‘college town’ as a result (The City of Kalamazoo, n.d.). The city is also known for being home to many industries, ranging from medical science to craft beer; notably, the multinational pharmaceutical company Pfizer recently manufactured the Pfizer-BioNTech Covid-19 vaccine is just south of Kalamazoo’s municipal boundary (Gardner, 2020).

Figure 2: Kalamazoo and Vine Reference (W.E. Upjohn Center for the Study of Geographical Change, n.d.)

The Vine Neighborhood is centrally located within Kalamazoo just south of Downtown and west of Western Michigan University’s East Campus (see figure 3). This area is approximately one square mile with a population of 5,572, making it one of the densest neighborhoods in the region. The area also contains five parks, a historic district, and a variety of local businesses (City of Kalamazoo & Vine Neighborhood Association, 2018). Residents are mostly college students, long-term renters, or homeowners, although the overall number of students has decreased within the past 20 years due to new developments to the west of the area. The area has a median income of $22,359 and an average age of 25 (ibid.).
1.2.2 Elevation

The overall majority of the transit study area is flat or level, excluding a large portion of the west side of the neighborhood which is located on top of a hill (Figure 4). The roads Merrill St and Davis St. are approximate N/S borders to this elevation change.
1.2.3 Sidewalks

The Vine neighborhood is nearly covered in sidewalks, with very few roads unaccompanied by a pathway on both sides (City of Kalamazoo & Vine Neighborhood Association, 2018). Despite this, a sidewalk audit performed by the City of Kalamazoo and volunteers in 2017 found that many of these sidewalks are in disrepair and difficult to pass over, especially for those with strollers or wheelchairs. A considerable number of sidewalk squares were shown to need repair, with many of these damaged squares falling along popular pedestrian routes (Figure 5). This being said, according to the website Walk Score, the Vine Neighborhood achieves a walk score of 75/100 based on the distance to nearby places and overall pedestrian friendliness (Figure 6) (Walk Score, 2018). While the Vine has the space for wide pedestrian friendly sidewalks, without consistent maintenance these pathways have suffered the consequences of heavy use and require repairs (City of Kalamazoo & Vine Neighborhood Association, 2018).
1.2.4 Public Transit
1.2.4.1 Bus Routes

There are three bus routes that go near or border the Vine Neighborhood, route 1-Westnedge, 4-Oakland, and 16-Lovell (Figure 7,8).

Route 1 begins at the KTC in downtown Kalamazoo and then continues south along S Westnedge Ave until it reaches the mall in the neighboring town of Portage. At this point, the Westnedge route turns around and begins to head north along Westnedge Ave until the one-way pair splits, at which point it follows Park Street north to the KTC (Metro, 2021). Route 4 also begins at the KTC, then follows Oakland Road south until slightly past I-94, where it begins to go west on Milham Ave. past US 131. The Oakland route then stops by several apartment complexes before heading back north up Oakland to return to KTC (ibid.). Route 16 begins at KTC and continues south until Lovell, which continues west towards Western Michigan Universities’ campus. The Lovell route stops on campus and then continues onto Michigan Ave slightly past U.S. 131 before turning around and repeating this path back to KTC (except taking South Street east instead of Lovell) (ibid.).
Prior to 2021 there was an additional route in the neighborhood, Route 12-Duke. This bus went N/S on Duke St. west of the other routes, but has not run since January 18, 2021 according to the Metro website (Metro, 2018, 2021).

1.2.4.2 Bus Stops

There are over 20 bus stops located within or on the boundaries of the Vine Neighborhood most of them located along Oakland, S Westnedge, Lovell, and Park Street (Figure 7) (Metro, 2021b). At the very least, each stop includes a sign designating it a bus stop (Metro, 2018). Other stops have route information, shelters, or trash cans.

1.2.4.3 Stop Spacing

Average stop spacing for Metro is 1600 feet, with most (79%) of routes having stops 1000-1600 feet, including stops on routes Westnedge and Oakland (Metro, 2018). The third route- Lovell, is above average with an approximate spacing of 1,700 feet on average, meaning stops are more spaced out and more efficient, but farther away from potential users (Table 2) (ibid.).

<table>
<thead>
<tr>
<th>Route Name</th>
<th>Approximate Average Spot Spacing (ft)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westnedge</td>
<td>1,200</td>
<td>Low</td>
</tr>
<tr>
<td>Oakland</td>
<td>1,550</td>
<td>Average</td>
</tr>
<tr>
<td>Lovell</td>
<td>1,700</td>
<td>Average</td>
</tr>
</tbody>
</table>

*Table 2: Vine Bus Route Spacing (Metro, 2018)*
1.2.5 Zoning

The Vine Neighborhood is mostly residential, however there are other zones present. Most of the residential areas are classified as R2-Medium Density, except for a small section on the north border of Howard St. which is R1-Low Density and a small area east of that and another area in the north west corner near Burdick and Vine which is R3-High Density (The City of Kalamazoo, 2017). Apart from residential, Vine zoning gets progressively more urban in the northeast direction, first Neighborhood Edge, then Urban Edge, then the most northeastern corner of the neighborhood is zoned as Downtown. Near central Vine, there is a cluster of commercial areas which The City of Kalamazoo calls a
neighborhood node; south of this, there is a larger commercial section called a commercial node. There are a few areas throughout the neighborhood zoned as parks and natural features, and starting just east of Oakland Dr., the west side of the neighborhood is zoned campus (ibid.) See figure 9 for a map of these designations.

1.3 Paper Organization

Within the Vine Plan, it was indicated that further research was necessary for some goals prior to addressing them. As Imagine Vine Neighborhood relied heavily on qualitative feedback from residents and community partners as means to evaluation, there was a need for quantitative data analysis and spatial modeling to inform the city and neighborhood association where particularly improvements should be focused, especially regarding pedestrian and public transit infrastructure (The City of Kalamazoo, 2017, p. 21). Therefore, the goal of this study is to contribute to existing literature regarding public transit in neighborhoods, as well as assist Vine neighborhood in achieving their goals through data analysis. The following section of this paper will be a review of literature regarding transit planning, bus stop placement, and other transit variables useful for evaluation. The next section will be devoted to the case study of Kalamazoo City’s Vine Neighborhood and the analysis methods used to model indicators of transit quality, this section will be followed with the results of analysis. The final sections will be devoted to discussing results and their implications for future transit planning. Finally, findings from this research will be used to propose alternatives to improve transit ridership through safety and convenience improvements.

2 Literature Review

The phrase ‘public transit’ can refer to subways, light rail, or massive bus systems operated in major urban areas (Lundergan, 2009). However, many smaller urban cities throughout the world also benefit from the utilization of smaller mass transit in their region. For example, Metro in the city of Kalamazoo, MI has operated buses for over 100 years in order to increase mobility for its residents (Metro, 2014). Of course, the areas served by the Kalamazoo Metro have not necessarily been consistent. Routes and stops have been fluid with changing demographics and population shifts in order to meet the maximum potential of the region. How bus routes are determined is typically the job of a transportation planner, a professional whose general goal is to increase ridership while still retaining current riders (Thompson et al., 2002). Planners rely on academic research to guide many aspects of planning, such as bus stop routing and placement, therefore, the next section will be devoted to discussing relevant transit research.
This section will begin with literature on types of small-urban bus systems and research into their efficiency and accessibility. Next, a section will be devoted to bus stop literature, analyzing research on ideal locations of bus stops and discussions optimal on bus stop infrastructure. Finally, it will conclude by discussing the infrastructure used to get to and from the stop. In order to analyze neighborhood public transit, we must first look at transit planning in similar cities and bus systems. By looking at literature and other case studies, we can determine what tends to work and what does not, the general standards for bus transit. This literature review is intended to give context to the overarching knowledge transportation planners depend on when developing and modifying transit networks near neighborhoods, as well as explain how this thesis fits into existing planning literature.

2.1 Typical Neighborhood Transit Programs

During the mid-20th century, many Western countries experienced similar population shifts as lower density regions began to grow on the borders of cities (Mees, 2010). Jobs too shifted from central locations within Central Business Districts to being more dispersed throughout the region (ibid.). For public transportation, this density structure offered several challenges to traditional models; while a dense urban area can be served by frequent bus stops in residential areas, outlying lower density neighborhoods have dispersed trip origins and trip destinations, meaning bus routes must be more spread out and infrequent (ibid.). Additionally, small urban transportation systems traditionally lack the framework to have a strategic planning process, rather bus route planning is typically short-term and reactive (Gordon, 2004)

2.1.1 Flexible Transit Services

A common response to the issues of low-density transit, particularly in rural areas, is ‘flexible transit services’, a range of personal transport services which may be flexible in their route, vehicle allocation, passenger type or other dimension. The US has a history of implementing a flexible transport service more commonly known by the term ‘dial-a-ride’ services. These are typically used in rural or very suburban regions not dense enough for a full public transit route or in larger cities as part of ‘paratransit’, creating transportation for those transportation disadvantaged, primarily the disabled and the elderly. Researchers Mulley and Daniels (2009) found that flexible transport services like dial-a-ride or public taxis should be opened to the public for a subsidized fare, as they can expand the range of public transit and lower costs. This finding rested in the assumption that buses in low density regions are wasteful and likely to be constantly underutilized.
2.1.2 Network Planning

Mees (2010) disagrees with claims like these, asserting that a resistance to buses is due to the persistent false belief of “density as destiny”, which assumes that transportation patterns are simply outcomes of urban form. Density as destiny believes that the only way to achieve efficient public transportation is by designing compact cities which employ smart growth; therefore, areas like the suburbs are doomed to the domination of massive highways to serve the needs of personal automobiles. In his work, Mees argues that density is not destiny, offering a solution through ‘network planning’ which allows efficiency and ridership to rise together (ibid.). Under this concept, instead of designing direct bus routes from destination to end, bus networks would rely on easy transfers to bring distant users to their intended destination. This network would use centralized planning-- if busing is left to the free market, private buses will only wish to operate singular popular routes, but if network planning is used, the less popular routes will still connect users with the whole network, offering ease to users in low density users (ibid.). Despite the common belief that a network which relies on transfers will be unpopular and underutilized, Mees gives examples of several cities which have replicated this model to great success, making the claim that transit services which provide door-to-door transit wholly mistake the nature of public transit and its environmental, social and economic advantages (ibid).

2.2 Bus Stops

While it is important to have efficient bus routing, it is also important to have well placed and structured bus stops. Bus stops are the first and last place a rider experiences while taking public transportation, therefore several qualities must be examined in order to ensure riders are able to use them to their fullest. Key factors to consider are the location of the bus stop on the route and the safety and convenience of the stop itself. While some of these traits may sound trivial, bus stop features can be essential to ensure riders are able to access and navigate public transportation to get to their intended destination. This next section will examine existing literature concerning ideal bus stops, and how bus stops should reflect the wants and needs of riders.

2.2.1 Placement in Relation to Route

Determining the location and amount of bus stops on the overall network can be difficult, as several questions are likely to quickly arise. Many larger transit services have standard guidelines for bus stops based on the Transit Cooperative Research Program (TCRP) Report 19, a report sponsored by the Federal Transit Administration in 1996 which sought standards for bus systems across the country (Transportation Research Board, 1996) As this guide is over 20 years old, many transit services have updated it through individual reports, but the essential information within the guide is still relevant.
Concerning spacing, Murray and Wu (2003) agrees with the TCRP report by saying that planners need to reconcile the contrast between transit accessibility and system efficiency—bus stops should be close enough to each other to ensure that users along the network can reach spots within a reasonable walking distance; on the other hand, if bus stops are placed too close to each other, then the bus will spend excessive time idling while passengers board and disembark. However, there are some disagreements on how to reconcile this difference. Murray and Wu’s (2003) study proved that as the number of stops goes up, accessibility rises at a decreasing rate, indicating that more bus stops do not necessarily mean a corresponding amount of people are connected to the transit route. The TCRP report has quite large ranges regarding acceptable bus spacing: 300 to 1000 ft. in central core areas of central business districts, 500 to 1200 ft. in urban areas, 600 to 2500 feet in suburban areas, and 650 to 2640 ft. in rural areas (Transportation Research Board, 1996). These large ranges likely have to do with the reconciliation mentioned earlier; each transit service is responsible in determining their own priorities when creating their routes; whether they prefer a slow service with high accessibility or vice versa. In Columbus, Ohio, where Murray and Wu did their research, they determined that the most effective bus spacing would be approximately 890 and 1200 feet apart (Murray & Wu, 2003). As much of Columbus could be considered an urban region, Murray and Wu’s findings agree with the TCRP report.

2.2.2 Placement in Relation to Users

In addition to determining bus stop placement in relation to other stops, it is also important to discuss bus placement in relation to the system’s users. The percentage of a population that is served by public transit is one performance measure to evaluate a transit system. Broadly defined, in order for an area to be considered ‘served’ it has to fall within a certain area of a transit station or stop (El-Geneidy et al., 2013). Within the planning community a buffer or service area analysis is typically used to designate accessibility to transit and a willingness to travel by foot. Generally, this service area should be 400m (1312 feet or .25 miles) away from a bus stop, meaning any user whose residence or place of work that is over 400m away from a stop is considered not served by the transit network and considered unlikely to use the service (El-Geneidy et al., 2013; Tao et al., 2018). Despite this, a survey conducted in the Montreal region of Quebec concluded that the 400m (1312 ft) rule of thumb ought to be raised even further, as many North American transit users are shown to be willing to walk 500-600 m. (1640-1969 ft.) for bus transit, dependent on other factors such as bus stop facilities and transit service (El-Geneidy et al., 2013). The Murray and Wu (2003) study also supports this point, as its ideal transit system has users 626-642 m. (2054-2106 ft.) away from the nearest stop.
2.3 Other Transit Variables

There are other variables that affect transit usage other than stop location. Walkability and bus stop infrastructure are both key transit factors shown to affect usage and perceptions of public transit (ibid.). People are more likely to walk far to a transit stop if they are male, young, walking in a safe and maintained area, or if walking more will lead to faster service or less transfers. Therefore, Tao et al. (2020) suggests that if planners want to increase ridership, they should first make steps to improve walkability or improve the transit service itself, rather than bring bus stops closer to residents.

2.3.1 Elevation

Elevation change, or slope, has a significant effect on transit users and buses themselves. Eldeeb Et Al. (2015) made the claim that areas with a slope of 4% or higher are generally unsuitable, due to excessive noise, sliding risk and general stress on buses caused by stopping. The TCRP report indicated a higher number of 6-8% should be considered the maximum road grade for bus stops but agreed that bus stops should not be located on an upgrade in a residential area, as the noise is likely to cause resident complaints (Transportation Research Board, 1996).

It is also important to consider the slope preferred by bus users who will walk to stops. Meeder et al. (2017) found that walking attractiveness in general was significantly negatively influenced by sidewalk slope (which typically follows the running slope of adjacent roads), their research indicating that each 1% of slope roughly correlated with a 10% less likelihood of walking. Therefore, Meeder et al. suggests bus stops are generally most convenient to both riders and transit systems when located along flat/level intersections.

2.3.2 Safety

Tao, et al. (2020) also emphasized that the physical surroundings of bus stops must also be considered, including nearby buildings or street lighting. Many of these surroundings affect the safety or perceived safety of bus stops, as Abenoza, et al. (2018) showed that perceived safety is more important than actual safety, regarding its ability to affect travel behavior. This research study proved that natural surveillance provided by transparent bus structures, sufficient lighting, and a clear view of the users surroundings positively influenced the users perception of safety more than anything else, thus indicating that users who experienced bus stops with these features are likely to ride again.

While Abenoza et al. (2018) provided concrete steps a transportation planner can implement to make bus stops perceived as safer and improve ridership, their research mainly defined safety as the ability to avoid being a victim of a crime. There are more aspects to bus stop safety which would be irresponsible to not examine, particularly traffic safety. A Norwegian study in 1993 found that 87% of
transit-related injuries happen while a person is walking to and from the bus, compared to the 13% injured onboard the bus. Because there is a strong positive correlation between pedestrian-vehicle crashes and pedestrian generators like bus stops (Truong, 2011), some of this risk is expected, however planners can lessen danger by focusing on bus stop placement. The study by Truong & Somenahalli did this by identifying pedestrian-vehicle crash hot spots by means of GIS analysis (2011). By adding an element of spatial analysis this research pinpointed popular crash areas to avoid when placing bus stops (ibid).

Additionally, where bus stops are placed along roads can affect pedestrian safety. The TCRP report considers three possible locations for a bus stop, prior to the intersection, after the intersection, and mid-block (1993) (Figure 10).

![Figure 10: Possible Bus Stops (Source: TCRP, 1996, p. 20)](image)

Generally, it appears that far-side stops are preferred as they minimize traffic congestion and are generally safer than near-side and mid-block bus stops (IDOT, 2006). Truong & Somenahalli’s GIS hot spot analysis determined that severe pedestrian-vehicle crashes are more likely to occur at mid-block locations than at intersections. This statistic is likely due to the lack of pedestrian facilities like crosswalks in the middle of roads-- it is much more common to place these at intersections (Truong & Somenahalli, 2011). If bus stops are placed in the middle of a road without appropriate crossing facilities, it can lead to jaywalking and failure to yield which may result in a crash. However, it should be noted that vehicle-vehicle crashes are actually more common at intersections with bus stops, as a stopping bus can cause drivers behind the bus to switch lanes quickly to avoid also stopping, a quick traffic maneuver which can put them at risk on a busy intersection (Wan, et al., 2012).
2.3.3 Bus Stop Infrastructure

After ensuring that a bus stop is safe, it is also important to consider how users get to, and use a bus stop. Part of this discussion involves how close bus stops are to users, which was mentioned previously, but it also must consider the infrastructure of the path to the stop and the stop itself. At minimum, it is important for a stop to be connected to the pedestrian and bicyclist networks and have a street sign which designates where the bus will be stopping (Transportation Research Board, 1996). However, additional details like nearby pedestrian crosswalks, bike racks, bus shelters, benches, and route information can affect the ease in which users use the bus system in their area (Transportation Research Board, 1996; Tavares et al., 2015; Abenoza et al., 2018).

A bus shelter is especially important in regions with high levels of precipitation or other elements which would make waiting for a bus otherwise uncomfortable. The TCRP recommends that shelters be given to bus stops based on the number of passengers per day, specifically recommending rural stops have shelters if there are 10 passengers per day, suburban stops with 25 per day, and urban stops with 50 to 100 passengers per day (1996). However other factors such as proximity to elderly living communities and availability of land may denote which stops ought to be given priority. A bus stop bench may be located whether or not there is a bus stop, but it is suggested that benches are prioritized for bus stops which are frequently used by elderly or the disabled (TCRP, 1996). Within a shelter, a transit provider can choose to have transparent walls to ensure safety, or advertisements to provide additional funding to the system, or route information (Abenoza et al., 2018). Tavares et al. argued that having information on bus routes located at bus stops is essential to using public transit with ease and efficiency (2015). Information featured may include bus stop identification, tips for transit use, maps of the area, bus fare information, and a full itinerary of the line (ibid.) A study by the University of Utah found bus stop improvements (shelters, signage, seating, and sidewalks) led to a statistically significant increase in ridership (92% higher) and decrease in paratransit demand (94% lower) (Kim et al., 2018). Improvements were relatively inexpensive and popular among riders and local officials (ibid.). Generally speaking, more transit infrastructure is generally preferable, so long as it is maintained and benefits transit users.

3 Methods

As discussed in the previous sections, there are many different factors a transportation planner ought to consider when designing or making changes to transit services; bus stops spacing along the route and service areas in relation to other users, but also bus stop safety, pedestrian infrastructure, and stop amenities. The next sections of the paper will be devoted to a case study that analyzes these factors to
draw conclusions about neighborhood transit characteristics. The first section will be focused on explaining the process of data collection used for research. The second section will be devoted to explaining the data analysis process used. The main factors used to evaluate the convenience and safety of public transit were derived from existing research methods (mentioned in the literature review) and topics identified in the *Kalamazoo Area Bus Stop Action Plan* and *Imagine Vine Neighborhood Plan*.

### 3.1 Data Collection

Two methods of data collection were used in research, ancillary data collection and field collection. Ancillary data was retrieved from pre-existing sources, and processed to suit the extent of the data analysis. Due to the Covid-19 pandemic, most field data were retrieved using Metro’s ‘Track My Bus’ web application and ‘Google Maps Street View’, a technology feature from Google using interactive panoramic photos to allow a user to “drive” down a road and view physical conditions of the area. The most recent Google Street View panoramas within Vine were taken in September 2019, meaning any information gathered from this source reflected the state of the neighborhood at that time, not necessarily current conditions. In situations where information on Google differed from information on Metro’s website, data was modified to reflect that of Metro, as it was generally more recent.

#### 3.1.1 Ancillary Data Sources

The following layers were downloaded from various public sources to aid data analysis.

- **Terrain (ESRI, 2021)** - Retrieved as a dynamic World Elevation layer, this layer file (.lyrx) represented ground service heights, as based on a digital terrain model (DTM). The layer was created using a mosaic method, which pulled data from several different data sources and resampled the data to fit projection, extent, and cell size. Unlike other similar layers from ArcGIS online which scale slope variables to aid visualization, this layer represents slope percent as floating-point elevation values, making it ideal for analysis. The layer file was published 2013, however, ESRI regularly updates the elevation to match changes made to source data, the last update being Mar 24, 2021.

- **All Roads (State of Michigan, 2021)** - This dataset was retrieved from the State of Michigan’s GIS Open Data website as a shapefile. It represents all roads from the Michigan Geographic Framework, a digital base map for the State of Michigan government. For this map, features and attributes were based on current TIGER/Line Files from 1997-2014 and updated to reconcile differences between municipal and state defined boundaries.

- **Kalamazoo City and Neighborhood Boundaries (W.E. Upjohn Center for the Study of Geographical Change, n.d.)** - These layers were retrieved from W.E. Upjohn Center for the
Study of Geographical Change as a shapefiles with little information regarding their source or metadata.

- **Crash data (Michigan Office of Highway Safety Planning, 2020)**- Data about car crashes within the vicinity of the Vine neighborhood was retrieved from the Michigan Traffic Crash Faces (MTCF) website through the Data Query Tool. First, a search extent was defined that was slightly larger than the boundaries of the neighborhood. Next, the top 20 intersections in pedestrian crashes, bicyclist crashes, bus related crashes and total crashes was retrieved as tabular data in a .csv file and organized by number. Each record was a different intersection, with attributes based on MDOT available data, although many intersections were in the top 20 for multiple fields, meaning there were only 32 total intersections. The fields were: ID, intersection, pedestrian crashes, bus crashes, bicycle crashes, and total crashes.

- **Kalamazoo Metro Bus Routes (W.E. Upjohn Center for the Study of Geographical Change, n.d.)**- Data regarding bus routes was retrieved from the W.E. Upjohn Center as a shapefile with little information regarding its source or metadata.

### 3.1.2 Field Data Sources

The following data was manually created to aid analysis.

- **Bus Stops (Metro, 2021)**- CSV table was manually created in Microsoft Excel. To create the initial table, a record was made for each bus stop within the neighborhood or less than 400m from the border. Fields used were x,y coordinates, route name, intersection, stop ID, and stop infrastructure. The “Track My Bus” application provided by Metro Services and Google Maps was used as a reference to create fields for each stop (see table).

<table>
<thead>
<tr>
<th>Field</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>X,Y Coordinates</td>
<td>Google Maps and Metro Services</td>
</tr>
<tr>
<td>Route Name</td>
<td>Google Maps and Metro Services</td>
</tr>
<tr>
<td>Intersection/Stop Name</td>
<td>Metro Services</td>
</tr>
<tr>
<td>Stop ID</td>
<td>Google Maps</td>
</tr>
<tr>
<td>Route Information</td>
<td>Google Maps (Street View)</td>
</tr>
<tr>
<td>Shelter Present</td>
<td>Google Maps (Street View)</td>
</tr>
<tr>
<td>Bench Present</td>
<td>Google Maps (Street View)</td>
</tr>
</tbody>
</table>

*Table 3: Sources for Bus Stop data fields*
As bus stops serve as gathering hubs for transit users, this dataset was essential for determining the service area of transit. Additionally, information about stop infrastructure would be used to draw conclusions regarding the convenience of transit. This information was gathered by going to the location of the bus stop in Google Street View and looking at the stop to determine available amenities. During the street view search, bus stop signs were not found at all for the stops Lovell and Davis, and Oakland &, although it is unknown if this is a recent issue, due to discontinued stops, or incorrect original placement on Google maps.

<table>
<thead>
<tr>
<th>Route</th>
<th>Intersection</th>
<th>Detail</th>
<th>StopID</th>
<th>Route Information</th>
<th>Shelter</th>
<th>Bench</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westnedge</td>
<td>Westnedge at Lovell</td>
<td>SW Side</td>
<td>5</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Westnedge at Walnut</td>
<td>NW Corner</td>
<td>6</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Westnedge at Vine</td>
<td>NW Corner</td>
<td>7</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Westnedge at Wheaton</td>
<td>NW Corner</td>
<td>8</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Westnedge at Forest</td>
<td>NW Corner</td>
<td>9</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Westnedge at Howard</td>
<td>NW Corner</td>
<td>10</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Park at Balch</td>
<td>SE Corner</td>
<td>48</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Park at Forest</td>
<td>SE Corner</td>
<td>49</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Park at Burr Oak</td>
<td>SE Corner</td>
<td>50</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Park at W. Vine</td>
<td>SE Corner</td>
<td>51</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Park at 519 Walnut</td>
<td></td>
<td>52</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Westnedge</td>
<td>Park at Lovell</td>
<td>SE Corner</td>
<td>53</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland &amp; Eddies Ln/Lovell</td>
<td></td>
<td>138</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland &amp;</td>
<td></td>
<td>139</td>
<td>Sign not found</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland &amp; Grant NW</td>
<td></td>
<td>140</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland &amp; Oliver</td>
<td></td>
<td>141</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland @ Phoenix Alt Ed</td>
<td></td>
<td>178</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland &amp; Grant SE</td>
<td></td>
<td>179</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland &amp; Lot #4</td>
<td></td>
<td>180</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Oakland</td>
<td>Oakland &amp; Lovell</td>
<td></td>
<td>181</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Lovell</td>
<td>W. Michigan &amp; Eddies Ln</td>
<td></td>
<td>471</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Lovell</td>
<td>Lovell &amp; Westnedge</td>
<td></td>
<td>628</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Lovell</td>
<td>Lovell &amp; Oak</td>
<td></td>
<td>629</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Lovell</td>
<td>Lovell &amp; Davis</td>
<td></td>
<td>630</td>
<td>Sign not found</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Lovell</td>
<td>South &amp; Westnedge</td>
<td></td>
<td>641</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
3.2.3 Preprocessing

Some of the data layers retrieved had to be modified to fit the requirements of the analysis; for a brief overview of this process, see table 5. The roads and terrain data layer were both clipped to the extent of their study area, as excess data caused data calculation lag and errors. The Kalamazoo Metro layers were modified to remove bus routes not important to the neighborhood, and the Kalamazoo Neighborhood boundaries layer was modified to remove all neighborhoods except for the Vine.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Modifications Made</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrain</td>
<td>Layer clipped to extent of study area</td>
</tr>
<tr>
<td>All Roads</td>
<td>Layer clipped to extent of study area</td>
</tr>
<tr>
<td>Kalamazoo Metro Bus Routes</td>
<td>Irrelevant routes removed. Remaining routes corrected to match current information.</td>
</tr>
<tr>
<td>Kalamazoo Neighborhood Boundaries</td>
<td>Irrelevant neighborhoods removed.</td>
</tr>
</tbody>
</table>

Table 5: Layer Preprocessing

3.2 Data Analysis

The next part of this study will be devoted to describing the process used to analyze the aforementioned data. The initial goal of this research was to determine a process to evaluate the safety and convenience of public transit within a neighborhood. While there are multiple ways to accomplish this, this study focused on using GIS to analyze and spatially model traffic safety, road elevation, current service areas, and bus stop infrastructure, so as to evaluate the different areas of the neighborhood instead of the neighborhood overall. This process allows the neighborhood to determine which areas should be prioritized with infrastructure improvement or new bus stops. The factors listed above could also be determined remotely through pre-existing data which was valuable during the Covid-19 pandemic. The following section will explain the methods used to examine and quantify relationships between these factors and geographic location in GIS.

3.2.1 Traffic Safety

Transit users are generally much more likely to be involved in a traffic crash when travelling to and from a bus stop compared to when they are riding the bus itself (Vaa, 1993). Therefore, to understand
the safety of public transit, it was important to look at general pedestrian safety within a region, as it would be unwise to have bus stops located near intersections prone to transit/pedestrian/cyclist (non-motorist) related crashes. Thus, it was important to determine where these areas were, using the table retrieved from Michigan Traffic Crash Facts (MTCF) (Michigan Office of Highway Safety Planning, 2020).

The first step for this analysis was to create a new field in the Crash Data table to normalize data calculations. This field indicated the percent of traffic crashes involving non-motorists out of total crashes (see figure). This function was necessary for analysis because the amount of total crashes at various intersections varies greatly, but by normalizing the data and determining what percent of crashes involve non-motorists, the analysis is better able to draw comparisons between minor and major intersections. In other words, this analysis determined the intersections where pedestrian related crashes made up large portions of total crashes. This table was imported into ArcGIS Pro, then the XY data was displayed as vector point data. (See Image)

\[
f(x)=\frac{(C_{\text{pedestrian}}+C_{\text{cyclist}}+C_{\text{bus}})}{C_{\text{intersection total}}}\]

*Calculation for Crashes Involving Non Motorists, as a Percent of Total Crashes*

### 3.2.2 Slope Suitability

The slope or grade of roads and their surrounding area was necessary to evaluate whether current bus stops were in suitable locations based on the incline of the road, as well as to evaluate whether the slope of pedestrian routes encouraged walkability and access to transit. Because transit services have to be located along a road, research focused on slopes just along the road corridors within Vine, rather than the slope of the entire neighborhood.

The process of determining slope suitability was done within ArcGIS Model Builder (Figure 11). The analysis process used both vector and raster datasets, although the final result was a vector data layer.

![Figure 11: Workflow from Modelbuilder to Determine Road Slope](image-url)

First, the All Roads layer was clipped to the extent of the transit study area to create a VineRoads line layer. Next the buffer tool was used to create a 30 ft boundary around the line features in this layer.
and all output features were dissolved into a single feature using the Dissolve Type parameter. This process created polygons which included the road area and surrounding sidewalk space.

While this occurred, the raster with the slope of the study area was reclassified into a new raster with only two values, one to represent areas with a 0-4% slope and the other to represent areas with a 5%+ slope (see table). This study considered areas with a 1 value suitable for a bus stop and areas with a 10 value unsuitable.

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>76</td>
<td>10</td>
</tr>
</tbody>
</table>

*Table 6: Reclassification Values for Slope Raster*

After reclassification, the raster was converted to vector data using the ‘Raster to Polygon’ tool in ArcGIS based on the new values. Within the parameter options for this tool, simplify polygons and create multipart features were both checked so that the process would create only two features with simplified shapes. The last step to analysis was to clip the new polygon layer with the wide road polygon to isolate the slope analysis to areas used by transit and transit users.

### 3.2.3 Service areas

The next portion of the analysis revolved around determining what areas of the neighborhood are served by current public transit routes. This was accomplished by performing a service area analysis around current routes to show what areas are within 400m of a bus stop by the road network. Instead of using a buffer layer which would be a 400m boundary around each stop based on Euclidean distance (as the crow flies), a service area analysis focuses on the road network used to reach destinations similar to traveling along city blocks.

The next step in analysis was to create a new service area analysis layer in ArcGIS Network Analysis workflow. Once this was created bus stops were imported as facilities that service areas would be created around. Walking distance was selected as the travel mode, which was measured in kilometers towards facilities. Cutoffs of 400 and 600m (1312 and 1969 ft) were used as the cost attribute, marking pedestrian unlikeliness to walk beyond this distance. Output geometry was represented as lines to show paths to transit, as well as polygons to show the overall served area.

### 3.2.4 Bus Stop Infrastructure

The final process of data analysis regarded data gathered on various types of bus stop infrastructure. The analysis of this data was not spatially modeled like the other three transit indicators,
although it was still associated with geographic locations. The infrastructure looked for bus stop amenities including bus shelters, benches, and stop/route information, however, as all stops with shelters also contained benches and all stops with benches also had shelters, this field was combined, meaning it indicated stops with shelters AND benches (not or). I calculated what percent of bus stops featured these amenities using the following equations.

\[ S = \text{Number of Stops} \]
\[ f(x) = \frac{S_{\text{Shelter and Bench}}}{S_{\text{Total}}} \]

*Equations for Stop Infrastructure Analysis*

4 Results

The following section will briefly explain the results of data analysis, primarily through maps and other spatial data. Discussion on these findings will be reserved for section 5.

4.1 Traffic Safety

The first analysis performed aimed to explore and spatially model crash data. The results of the analysis were symbolized using a bivariate model that showed both frequency of non-motorist crashes, as well as the normalized percentage to indicate what percent these crashes are out of total crashes at the intersection (Figure 12). In the analysis, high crash intersections were shown to be primarily located along busy roads with higher speed limits than the surrounding areas, including S Westnedge, Park, Lovell, and Burdick. The results indicate that many bus stops are located around high-crash corridors, particularly those located along Westnedge and Park St. There are two particular areas with the most pedestrian/bicyclist/bus crashes: the northwest corner of Vine where several roads intersect including Lovell and Oakland, and the neighborhood node located in the center of the neighborhood between Walnut and Vine St.
4.2 Slope Suitability

The next analysis was performed to determine slope suitability for bus stop placement and pedestrian walkability. The results of this analysis determined that most of the roads within the Vine fall below a slope of 4%. While the elevation map retrieved showed multiple large elevation changes within the neighborhood, road grade is generally consistent through these changes, as shown by figure 13. The exception of this is on the west side of the neighborhood, east of Oakland Drive and west of Merrill St and Davis St. This area contains a hill with an incline consistently higher than 4%.
4.3 Service Areas

A service area analysis was done to determine how much of the neighborhood was being served by public transit. Results found that a majority of the neighborhood was located 400m by foot from a bus stop, and that nearly the entire neighborhood was at least 600m by foot from a stop. The areas least likely to be served are the areas on the east side of the hill next to Oakland Drive, partially due to a lack of road infrastructure in that area. The north areas of the neighborhood closest to Downtown Kalamazoo appear to be best served by bus transit, as they are within walking distance of multiple bus routes, and have multiple ways to walk there based on the road network.
4.4 Bus Stop Infrastructure

Analysis regarding bus stop amenities was performed with the goal of evaluating the neighborhood's quality of transit infrastructure, as well as determining the areas requiring improvement. As infrastructure developments are shown to improve perception of public transit, this factor was a key aspect of understanding current transit perceptions.

The majority of stops within the neighborhood were found to have a single sign with no route or stop information (Figure 16a-b). The notable exception is the Route 1 stop Westnedge at Vine-- located next to Chenery Auditorium near the central business hub of the neighborhood-- which had a sign with stop and route information (Figure 16c-d, 17)
Stop Park at Balch on Route 1 and stops Oakland & Grant NW and Oakland@ Phoenix Alt Ed on Route 4 were the only bus stop locations with bus shelters and benches, the latter two also having trash cans (Figure 18 a-b).

5 Discussion and Conclusion

The overall objective of this research was to evaluate the quality of transit in neighborhoods by spatially modeling indicators of transit quality. The resulting data analysis results are used to determine
the geographic distribution of issues and potential improvements. This section of the paper will be devoted to discussing the results from the previous section, and how these results affect transit conditions within the neighborhood. Near the end of this section, a brief summary of challenges faced by this project, particularly those brought upon by the Covid-19 pandemic will be discussed. Finally, there will be a brief conclusion to reiterate topics and findings of this thesis.

5.1 Safety Discussion

Safety regarding public transit was defined as safety getting to and from bus stops, as well as perceived safety of users at the stop. This variable was informed by crash statistics and bus stop infrastructure analysis, although similar conclusions may have been reached by other processes. In the analysis, high crash intersections were shown to be primarily located along busy roads than the surrounding arterial roads, including S Westnedge, Park, Lovell, and Burdick. As these roads also hosted public transit routes, rates of non-motorist crashes indicate that being a pedestrian along transit routes is comparatively less safe, due to their location along busy traffic corridors. However, bicyclists were chosen to be included in the research question which was later determined to be unnecessary as most transit users access transit by foot and there are two major bicyclist corridors in the neighborhood which could affect the data relevance.

Additionally, while it is important to determine what intersections have frequent pedestrian crashes, it should also be noted that bus stops are generally considered ‘pedestrian generators’ for their characteristic of attracting potentially large amounts of pedestrians to a specific location. For example, the mid-block bus stop Westnedge at Vine (located in front of Chenery Auditorium) is located near intersections with high frequencies of non-motorist related crashes. As there are no pedestrian facilities to allow for crossing to this stop, it is possible that the bus stop may be causing a portion of these accidents as a pedestrian generator. This indicates a need for moving the stop or adding crossing facilities.

Crime data was not looked at during this study, but information about transit infrastructure could be used to draw conclusions about the perceived crime safety, as shelters and other bus structure amenities are indicated to positively affect transit usage and perceptions of safety. This being said, the majority of bus stops within the Vine have no amenities to encourage feelings of safety. The exception to this is the three stops with shelters, which allow for a transit user to view their surroundings through clear glass while protected from the elements (Figure 18a-b).
Therefore, improvements to bus stop infrastructure would be a definitive way to improve transit safety perception, as well as quality of life factors for transit users. A bus stop on a sign is the bare minimum a transit system needs to provide to indicate a transit stop, but improvements to the amenities of transit stops, including as shelters, benches, trash cans, and street lighting are a way for a region to show that transit usage and safety is considered a priority.

5.2 Convenience Discussion

The convenience of transit in Vine referred to the ease in which users reached bus stops and used Metro to reach their final destination. While this factor is somewhat interpretable, this research focused on road slope, service areas, and bus stop infrastructure to quantify and discuss elements of convenience.

5.2.1 Transit Service Area

The service area analysis determined that most residential homes in the Vine are within 400-600m of a bus stop along the road network. However, different areas are connected to routes that go in varying directions, meaning users may not be connected to the route they need. The overwhelming majority of the neighborhood was within 400-600m of Route 1 (Westnedge), but only areas roughly north of Walnut St were within that distance from Route 16 (Lovell).
5.2.2 Slope

Additionally, the service area analysis did not include slope as a cost-factor when determining routes. This means that some bus stops are considerably less convenient to walk to compared to others due to the steepness of the route, despite being a similar distance. To determine where this might occur, the slope suitability map was compared to the service area map results. Areas along Merrill, Grant, and Austin St were shown to be within the service area of stops located along Route 4-Oakland, however, most riders would be required to walk on a pedestrian route with a steep elevation to reach these stops. So comparisons of the slope suitability map and the service areas map showed that most areas least served by public transit were located near high elevation changes.

The slope suitability results were also used to determine whether current stops were located on appropriate road grades, as well as why some areas did not have a stop. All routes were shown to be located on road sections with appropriate slopes (≤4%), and are notably on flatter areas of the road they travel on. There are no stops east of Oakland Dr. for a considerable section of the neighborhood, likely due to the aforementioned hill along Merrill, Grant, and Austin St. However, there is a considerable amount of flat roads within the central portion of the neighborhood east of the major elevation change that do not have any stops, although most of this area is just within 400 ft of the Westnedge route. Since all three Vine bus routes turned around at a section of the trip to return to their original location (KTC) along similar road networks, stops are more concentrated and frequent (many have an inbound and an outbound stop), rather than dispersed and less frequent.

5.2.3 Bus Stop Infrastructure

The neighborhood bus stop infrastructure was previously mentioned to have few amenities which encourage safety. In addition, the bus stop data analysis showed that even fewer stops in September 2019 had sort of stop or route information to assist with wayfinding. However, it should be noted that this data analysis may not reflect current conditions, as hopefully other popular stops have adopted a sign like Westnedge at Vine with stop and route information in the past 2.5 years. Additionally, while most bus stops surveyed had no route information, typically Metro provides pamphlets of each route on buses, which is an acceptable solution for the meantime, as funds and public support can be gathered to update the neighborhoods signs.

Additionally, the bus stop infrastructure surveyed was shown to be extremely inconvenient for elderly users or those with disabilities, as they rarely had shelters or benches. Additionally, not all bus
stops surveyed had curb ramps for wheelchair users or those with other mobility issues that would make stepping off a curb difficult. Overall, most bus stops in the Vine are only signified by a generic sign along a sidewalk. This sort of infrastructure is adequate, but does not encourage transit usage or improve perceptions of transit.

5.3 Alternatives to Improve Transit

Based on the results of the analysis, as well as the discussion, the last section of the discussion will be devoted to consider some of the issues discovered to affect transit, and determine potential solutions that ought to be prioritized. This list is brief based on data observed during the process of this research, as well as information from the literature review. If one of these options were to be pursued further, additional research on the particular topic would be necessary.

5.3.1 New bus stop infrastructure

As determined from the Google Street View survey, transit infrastructure other than a lone sign was fairly uncommon. There are several ways to update this infrastructure in a way that promotes transit usage, particularly by updating signs and bus shelters to be unique representations of their location.

5.3.1.1 Signs and Route Information

To improve the convenience navigating transit networks, Vine bus stops would benefit from additional bus route information at bus stop locations. This could include signs similar to the updated one near Chenery Auditorium (which include stop ID, route times, and route name) or even include route/area maps and wayfinding information about destinations nearby. At the very least, signs would benefit from their current generic style to include a stop number and route name to aid riders concerning which stops are which. This improvement would be best prioritized in areas with multiple routes like the north areas of Vine.

5.3.1.2 New/Updated Bus Shelters

The Vine Neighborhood only has three bus shelters within/near the neighborhood, however all three of these are located in areas on the edges of the area. Therefore, the neighborhood would benefit from the addition of new shelters, and modifications of current ones to give route information or make them ADA accessible. Within the Vine Neighborhood Plan, residents expressed a desire for bus infrastructure that represented the unique culture and values of the community, this could be accomplished by a bus stop redesign of a popular stop to designate it as a place of social infrastructure, as well as transit infrastructure, by including benches, public art, more waiting space, and better lighting.
Particularly, the stop along S. Westnedge route in the commercial area of Vine would be an ideal location to create a transformed bus stop that a community could enjoy traveling to and using. As this area has a high propensity for pedestrian and other crashes, this improvement could improve both ridership and safety.

5.3.2 New or Alternative Routes
The final alternative considered to improve transit regards changing bus routes themselves, to allow for more convenient bus stops within the neighborhood. As mentioned previously, much of the neighborhood is only within the service area of a particular route, and is therefore limited by their destinations. Particularly, the Lovell Route which travels through the north edge of the neighborhood before stopping at the nearby university’s campus, does not include much of the neighborhood at all. If this route were to be modified so instead of turning on Lovell the bus continued south on Westnedge, stopped at the stop Westnedge at Vine before turning into the neighborhood on Vine St and making a right turn onto Davis to return to Lovell. This lap would significantly increase residents' connectivity through the neighborhood and transit system.

5.4 Other Discussion
Prior to beginning the conclusion, this section is dedicated to discussing potential errors within the research design as well as other notes discovered during the process of analysis.

5.4.1 Data Collection Issues (Covid-19 and other setbacks)
This research thesis was completed during the Covid-19 pandemic, which severely restricted the data available for analysis. As the original objective of the thesis was to evaluate transit within the Vine Neighborhood based on a survey collected in person, major changes had to be made in the past year to accommodate health concerns regarding this research method. Additionally, this research intended to use parking pass data collected from Western Michigan University but was unable to retrieve it due to new security regulations for student information. These two setbacks significantly affected the accuracy of the final work, as it demanded a reliance on dated internet sources.

5.4.2 Accuracy Concerns
Due to the forced overreliance on internet sources, there are some particular concerns about the accuracy of collected data and analysis results. As mentioned multiple times in previous sections, the dated nature of Google Street View made it difficult to know if changes had been made that would affect data results. Additionally, Metro has made several large changes to its routing during the Covid-19
pandemic, which may or may not be permanent, for example the removal of Route 12- Duke. If further analysis was to be done using conclusions reached in this study, it would be necessary to evaluate if these route changes were permanent or temporary.

5.4.3 Factors Not Discussed

There are several other factors affecting neighborhood transit usage brought up in literature but were left out or only touched on briefly during the research due to project constraints and oversight. For example, this research primarily focused on the built environment, leaving out many of the ‘human’ components of transit usage, such as ridership data from Metro, local zoning policies, population distribution, and crime statistics. Additionally, the research focused on factors which were geographically distributed, therefore technology advancements for riders and environmental impacts of transit were not looked at specifically although they would be necessary for future discussions. All of these factors could further inform the Vine Neighborhood and Metro regarding which transit improvements might be most successful and which would be unlikely to produce results.

5.5 Conclusion

While the Vine boasts being a walkable neighborhood, public transit can be inaccessible or inconvenient for many residents, due to stop location, stop infrastructure, and safety concerns. This is a problem common to small-urban neighborhoods, which often lack the amenities to provide safe and convenient bus networks. This research thesis used the case study of Vine Neighborhood in Kalamazoo to draw conclusions. During the course of this research, data from Vine, Kalamazoo was retrieved, analyzed, and spatially modeled according to the aforementioned methods, in order to draw conclusions regarding the quality of public transit within a specific transit service area. By spatially displaying and analyzing slope, traffic safety, and bus infrastructure it is possible to draw conclusions on the conditions of transit within a neighborhood, as well as how these conditions are geographically distributed. While further research would improve the quality of these findings, this is the first step in creating a safe, user-oriented transit system that improves the quality of life for residents.
Bibliography


