ASSESSING THE ROLE OF BIKESHARING IN TRANSIT-ORIENTED DEVELOPMENT: A CASE STUDY OF BIRMINGHAM

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ABSTRACT

Transit-oriented development (TOD) is a community development strategy that has increasingly gained exposure in urban areas across the United States as a method for reducing sprawl and increasing community vitality. Specifically, bikesharing is seen to play a major role in the success of transit-oriented development across urban communities as it increases travel possibilities, encourages public transit connections, and provides opportunities for recreation. This research employed a case study of Zyp BikeShare, a point-to-point bike rental program that began in Birmingham, Alabama, in 2015. Here, we analyzed the bikesharing program in terms of implementation and development, user catchment, transit paths, and usage trends. In doing so, we were able to create a methodology for analyzing specific bikeshare programs. Similar methodology can be applied to other bikesharing programs as the transit-oriented development technique continues to grow and develop in American cities.

LIST OF ABBREVIATIONS

CaBi	Capital BikeShare
CMAQ	Congestion Mitigation and Air Quality
GIS	Geographic Information System
GPS	Global Positioning System
EPA	United States Environmental Protection Agency
IT	Information Technology
JARC	Job Access Reverse Commute
RPCGB	The Regional Planning Commission of Greater Birmingham
SPSS	Statistical Package for the Social Sciences
TIGER	Topologically Integrated Geographic Encoding and Referencing
TOD	Transit-oriented development
VMT	Vehicle Miles Traveled
ZCTA	Zip Code Tabulation Area

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CHAPTER 1

RESEARCH BACKGROUND

1.1 Introduction

Transit-oriented development is a growing community and economic development technique that has recently gained currency in cities across the world and United States. TOD is a development approach that focuses directly on land uses around a transit corridor or station ("Transit-Oriented Development," 2013). It refers to communities that are intentionally planned in proximity to a transportation node or to areas that happen to be within the prescribed proximity of a transportation node. In recent years, urban planners have used transit-oriented development (TOD) as an antidote for urban sprawl in major U.S. cities. This chapter reviews the concept of TOD and the role of bikeshare programs in this growing development trend.

1.2 The Concept of Transit-Oriented Development

Currently, cities across the country employ TOD strategies and are embracing development around transit nodes. Transit-oriented development (TOD) is often defined as the radius within a 10-minute walk (approximately ¼ to ½ miles) of a transit node (Hess & Lombardi, 2004). A main characteristic of TOD, in addition to the fact that it generally falls within the ¼ to ½ mile radius of a transit hub, is that it is compact and contains a mixture of uses ("Transit-Oriented Development," 2015). On a basic level, this mixture of uses often includes retail space, commercial office space, residential space, and open space (Hess & Lombardi, 2004). On a more specific level, TOD best practice generally includes a mixture of density, type of building, pricing, and ownership patterns (Calthorpe, 1965). This mixture of uses allows for an expansion of lifestyle choices for individuals who reside in or visit the TOD (Cervero, 2004). This clustering of many services serves to attract people and to provide them with several transit opportunities (Calthorpe & Fulton, 2001).

The perimeter of transit-oriented development around the transit node is a walkable radius called a shed ("Infrastructure Financing Options for Transit-Oriented Development," 2011; "Transit-Oriented Development," 2013). Figure 1. represents an example of a ¼ mile pedestrian shed around a transportation node.

Figure 1. Pedestrian Shed

The introduction of TOD generally includes the shifting of some households within the community. As households shift toward the inner city, the length of automobile trips decreases. Likewise, increased mobility options allow individuals to mode-shift toward other forms of transportation like public transit, walking, or biking (Nahlik & Chester, 2014).

1.3 TOD as a Remedy: The Rationale for Transit-Oriented Development in American Cities

According to Calthorpe and Fulton (2001), public transit is an essential catalyst for healthy urban growth and revitalization. Maintaining and improving existing city infrastructure to incorporate public transportation, sidewalks, and bicycle paths is an important method for addressing environmental problems through alternative transportation methods ("Sources of GHGE," 2016). As problems associated with urban sprawl, a warming climate, changing ecosystems, growing populations, and environmental pollution increase, one way communities across the United States are meeting the need for combating these issues is through the integration of transit-oriented development into pre-existing city infrastructure.

TOD promotes trends surrounding the integration and adoption of active or human-powered transportation ("Healthy Places," 2011). One of the main goals of transit-oriented development is to encourage people to drive less and use mass transportation or alternative active transportation methods like walking or biking more (Lund, 2006). Hence, TOD best practice often integrates plans for improving urban infrastructure to accomplish the goal of reducing auto dependence. According to Calthorpe (1965), pedestrian-minded community planning should not seek to eliminate the automobile, but to balance the interactions between the automobile and existing community. Transit-oriented development and resultant pedestrian and biking programs will likely have major implications for the future of addressing automobile-related greenhouse gas emissions in American cities.

The U.S. Environmental Protection Agency (EPA) has set forth a series of guidelines for reducing transportation emissions. With greenhouse gas emissions posing one of the most serious threats to public health in this century, it is imperative to consider environmental pollution in planning practice (Maizlish et al., 2013). In addition to improving operating practices and fuel efficiency, the EPA cites the crucial need to employ urban planning practices to reduce the total vehicle miles traveled (VMT). Efficiency measures like pedestrian and biking programs have the ability to combat some of these problems (Bishop, 2015; "Sources of GHGE," 2016).

Recently, technological advances have been made in the hopes of reducing harmful pollution emissions from vehicles. Nonetheless, according to the EPA, there are over 143 million people in the United States living in zones classified outside the healthy standards for pollution by the National Ambient Air Quality Standards (Nazelle, 2010). In 2013, transportation alone accounted for almost 30% of total greenhouse gas emissions in the United States. In addition to carbon reductions per mile traveled, a reduction of total VMT is a key component of combating automobile-related pollution rates. Between 1990 and 2000, the average commute time for the American worker increased by three minutes. This figure steadily continues to rise in many American cities (Cervero, 2004). According to the National League of Sustainable Cities Institute, studies examining TOD have found a 25% to 50% reduction in traffic congestion and resultant air pollution ("Transit-Oriented Development," 2015).

Additionally, transit-oriented development has the potential for a major influence on the vitality of communities. Transit-oriented development around transit hubs is beneficial for attracting people, goods, and services to the community. In Belzer et al.'s (2011) study, transit nodes were examined before and after the implementation of transit-oriented development. After the implementation of TOD, arts, food, entertainment, and recreation land uses increased by 14%, social assistance increased by 9%, and healthcare increase by 10%. The mixture of uses important to the TOD environment increased the value of the area as a “live, work, play” community.

The Center for Transit-Oriented Development is a national entity that supports innovative research and implementation of transit-oriented development techniques (“What We Do,” 2016). In a study of American communities, the Center for Transit-Oriented Development (2011) found that transit-oriented development is related to available land, proximity to the central business district and employment, neighborhood amenities, and infrastructure (Belzer et al., 2011). Through the process of neighborhood vitalization, TOD is seen to increase social capital. Kamaruzzman et al. (2014) found that people that live within a transit radius considered to be a TOD generally have higher levels of trust and connection among neighbors, as well as increased social sustainability.

On an economic level, TOD can have major impacts on property levels. In addition to an increase in social capital and mode shifting that adds to the vitality of communities, drawing people and businesses to the area, TOD often leads to a shifting of community residence trends. Currently, many TOD projects are implementing a growing emphasis on “transit dependent by choice” populations (Belzer et al., 2011). Resultant increases in the migration of higher income populations and the simultaneous increased central city desirability often occur as a result of transit-oriented development, further increasing the vitality of communities as we know them.

1.4 The Role of Bikeshare Programs in Transit-Oriented Development

Biking as a form of transportation within a transit-oriented development can greatly improve accessibility and viability of TOD and planning techniques surrounding these ideals. Because many urban automobile trips could easily be walked or bicycled and cold starts from short trips disproportionately add to emission totals, walking and bicycling can have major implications for the city environment (Maizlish, 2013; Nazelle, 2010). The Federal Highway Administration cites that a bike commuter who travels four miles to work by bicycle five days a week will avoid around 2,000 vehicle miles traveled and 2,000 pounds of carbon dioxide emissions per year (“Environmental Benefits of Bicycling and Walking,” 2016).

Maintaining and improving existing city infrastructure to incorporate public transportation, sidewalks, and bicycle paths is an important method for lowering emissions through alternative transportation methods (“Sources of GHGE,” 2016). While not all TOD plans specifically incorporate a comprehensive plan for biking, TOD rests on the general notion of increasing pedestrian and bike friendliness and many reports mention the integration and redevelopment of existing biking infrastructure. Best practice for bikeway networks in TOD includes the incorporation of many different types of bikeways. Shared-use paths, bike boulevards, shared lanes, and separate bicycle paths are among these (Lydon, 2010 (a)). Likewise, safer biking infrastructure is among other necessary considerations for successfully implementing bikeshare technology (Klein, 2014). Safer biking conditions attract more bikers to the roadway, which creates a more integrated transportation community and increasingly benefits the environment through mode shift away from the automobile (Lydon, 2010 (a)).

Klein (2014) describes bike trips as “mobile-modular mini-TOD sites” and describes how they connect and extend the length of public transportation. Studies have shown that bike and transit travel are more effective when combined. When bicycles are introduced to the planning environment, this greatly increases the area of access. The average bicyclist can move about three times as fast as a pedestrian, greatly improving transit node catchment areas. Figure 2. represents potential shed differences as a result of utilizing a bicycle instead of walking. Here, the bicycle shed is depicted as a ¾ mile radius to account for both increases in speed and distance. However, potential bicycle trips for many users could extend up to two miles. As up to two miles is an acceptable and common distance for many bike riders, the capacity for bicycle and transit integration is great for the American city.

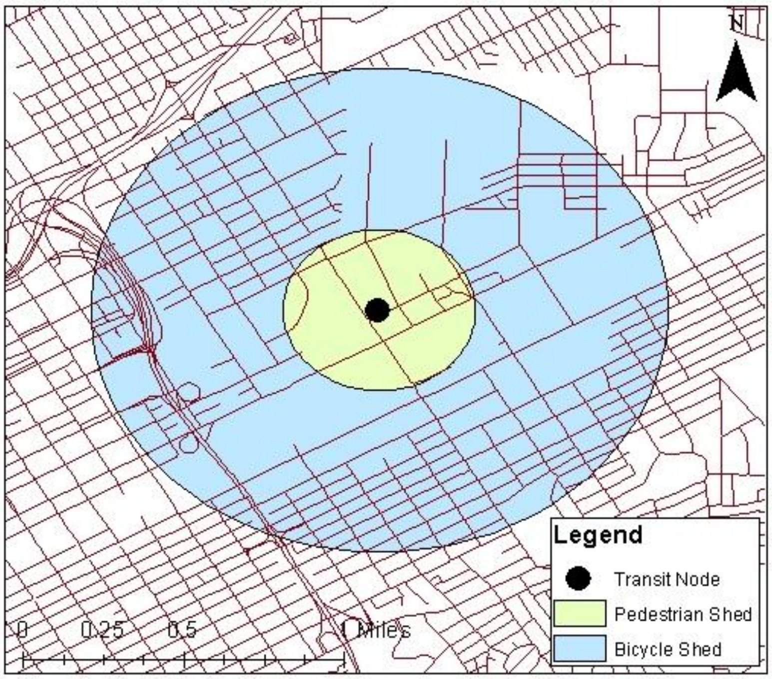

Figure 2. Bicycle Shed

Yesteryear's cityscapes, once dismantled by the increase of scattered automobile-dominated neighborhoods, now have the possibility to reemerge through the resurgence of pedestrian and bicycle friendly TOD (Cervero, 2004). Bicycle-transit integration, similar to transit-oriented development as a whole, increases shed catchment, improves mobility, combats ridership barriers such as weather, safety, topography, and infrastructural problems, and reduces environmental problems (Wang and Liu, 2013).

Bikesharing and the resultant movement towards bicycling as a basic form of transportation have great potential within the American city (Klein, 2014). Bikeshare (also sometimes referred to as BikeShare or bike share) is a public transportation method that has evolved throughout recent planning history. Bikesharing refers to a transportation program that allows for point-to-point bicycle rental from bicycle stations ("Bike Sharing," 2016). Bikesharing is comprised of many self-serve stations that users can visit to check out a bike for use within a specific area ("Bike Sharing," 2016). Typically, bikeshare users can check out a bike at a station and later return the bike to the origin or another station within an allotted period of time ("Bike Sharing," 2012).

As of 2015, it was estimated that about 1 million bicycles were used as a part of bikesharing programs across the world ("The Bike Share Boom," 2015). Additionally, as of 2015 about 855 bikeshare programs existed worldwide (Stein, 2015). The number of bikesharing programs continues to grow and an increasing number of cities across the country are proposing the integration of bikeshare transit technology. While bikesharing and bike facility suggestions are often described in transit-oriented development best practice reports, they are not always fully integrated (Lydon, 2010 (b)). This is likely because bikesharing is a relatively new urban planning technique with less research surrounding it than other classical techniques. The following section will discuss bikeshare technology and growing literature surrounding it.

As an increasingly common component of transit-oriented development systems across the world, bikesharing meets the needs of many of the societal improvements TOD encompasses. As with typical, independently owned bicycles in a city environment, bikesharing can have important physical and environmental impacts. In addition to increasing physical activity and reducing greenhouse gas emissions through a reduction in VMT, bikeshare programs are seen to improve public transit connections. Bikesharing offers an alternative to the first and last mile problem (Buck et al., 2013). First and last mile trips are defined as bike trips that are associated with transit hub connections. As station or stop density is an important determinant of transit ridership, the density of bikeshare stations within a transit service area plays a potentially large role in transit system ridership. A bikeshare service area is the name given to the geographical area where a bikeshare program serves users ("Bike Sharing," 2012).

The Pedestrian and Bicycle Information Center is a U.S. Department of Transportation funded entity that provides research to planners and policymakers regarding the integration of active transportation to the urban environment ("Who Are We," 2016). The Pedestrian and Bicycle Information Center provides a number of methods for gaining the greatest possible efficiency for a bikeshare system. First, bikeshare systems should consider patron feedback to enhance system performance. Second, systems should use mobile technology and web applications to provide users with real-time data for their ride. Additionally, data analysis is important. The Pedestrian and Bicycle Information Center suggests that new programs promote open data to increase research and support from the public ("Bike Sharing," 2012). Another important consideration for bikeshare systems is the possibility of using pedelec bikes. Pedelec, or pedal-assistance bikes, are electric powered bikes. According to DeMaio (2009), bikeshare systems should include pedelec bikes as a fraction of their total bike fleet. Genoa and Monaco were two of the first cities to employ the use of pedelec bikes, and many cities have followed suit in integrating pedal assistance bicycles to their bikeshare fleets. Other considerations that are important for bikesharing systems include the integration of bikeshare with other transportation, as mentioned previously, and the goal of reaching lower income populations (DeMaio, 2009).

1.5 Evolution of Bikeshare Programs

Historical understanding of bikesharing is generally comprised of three distinct generations (DeMaio, 2009). Bikesharing first began in Amsterdam, Netherlands, in 1965 (Buck et al., 2013). The first trial in bikesharing, Witte Fietsen was comprised of bicycles that were painted white and provided to the public for shared use. This program collapsed quickly though, with many bikes stolen or abandoned in Amsterdam's canals (DeMaio, 2009). Advanced technology in the form of coin-deposit systems was characteristic of the second generation of bikesharing. These coin-pay systems were also the first to use docking mechanisms that held the bikes in place until a payment was made (Buck et al., 2013). Denmark was one of the first countries to implement second generation bikeshare technologies (DeMaio, 2009). Second generation bikesharing, however, collapsed due to that fact that the anonymity of patrons did not provide for a way to successfully prevent theft. Technological advances in telecommunications led to third generation bikeshare systems, which allow advanced system operatorship and data collection (Buck et al., 2013). Currently, new bikeshare systems are considered to be third generation systems. In the United States, Washington, D.C., was the first city to integrate modern bikeshare technology ("Bike Sharing," 2012). Now, dozens of cities across the country are implementing and proposing the integration of bikeshare technology.

Existing literature on bikesharing systems is an important component of analyzing bicycle-supportive transit-oriented development strategies and understanding the steps and challenges associated with implementing and managing such technologies. Washington, D.C., has been a major area of bikeshare research as the first bikeshare location in the United States. In 2008, the public-private partnership SmartBike D.C. opened in the city. According to an analysis of bikeshare trends by Buck et al. (2013), SmartBike D.C. failed within a few years due to low ridership, expansion inability, and a lack of electrical connections at each bikeshare station. The failure of this program gave way to CaBi, a new bikeshare program in the city. While SmartBike D.C. only housed 10 stations and 120 bikes upon implementation, the CaBi system is comprised of 114 stations and 1110 bicycles. A major study of CaBi patrons was undertaken and provided a great deal of insight into the system. CaBi users were given the option to use the system for a short-term or long-term membership. The majority (53%) of short-term users reported their usage reasoning as tourism. For long term users, personal use (44%) and work (43%) were the main reasons for usage. Many users also reported that their bikeshare trips replaced some public transportation and walking trips (Buck et al., 2013). Shaheen et al. (cited by Buck et al., 2013) conducted another survey of bikeshare users in Washington, D.C., Minneapolis, Montreal, and Denver. Results from each city found that an average of 60% of users were under the age of 34. Additionally, they found that an average of 80% of users were white and 85% were highly educated. For all systems, commuting to work or school was the main usage reasoning. Such information is used to tailor bikesharing systems to meet the needs of the specific city environment. Understanding the intricacies of each particular system can help to develop a particular framework for assessing future success of bikesharing.

As third generation bikesharing is a relatively new concept, information is still being collected on the nature of many bikeshare technologies. Long-term success for bikesharing will hinge on its ability to serve many populations (DeMaio, 2009). A great deal of the existing literature on bikeshare looks at use determination (Buck et al., 2013). The future success of bikeshare systems will rest partially on research conducted in the field. Case study analysis of specific systems framed in the context of the urban environment and transit-oriented development will provide insight into location, usage trends, and potential bikesharing improvements.

CHAPTER 2

FIELD RESEARCH AND DATA COLLECTION METHODS

2.1 Introduction

A review of the literature has established the importance of bikeshare programs in transit-oriented development. Bikeshare programs are at a rudimentary stage in the United States. Currently, there are relatively few bikesharing programs in Alabama and adjacent states. The distribution of bikeshare systems in the country can be seen in Figure 3. This study is intended to investigate the operation of a bikeshare program and how it could be replicated in other parts of the US. This exploratory case study examined the four research objectives in great detail, in order to more closely understand bikesharing in the context of Birmingham, as well as in the context of a wider urban transportation environment. This study considered both the operation and limitations of such a system.

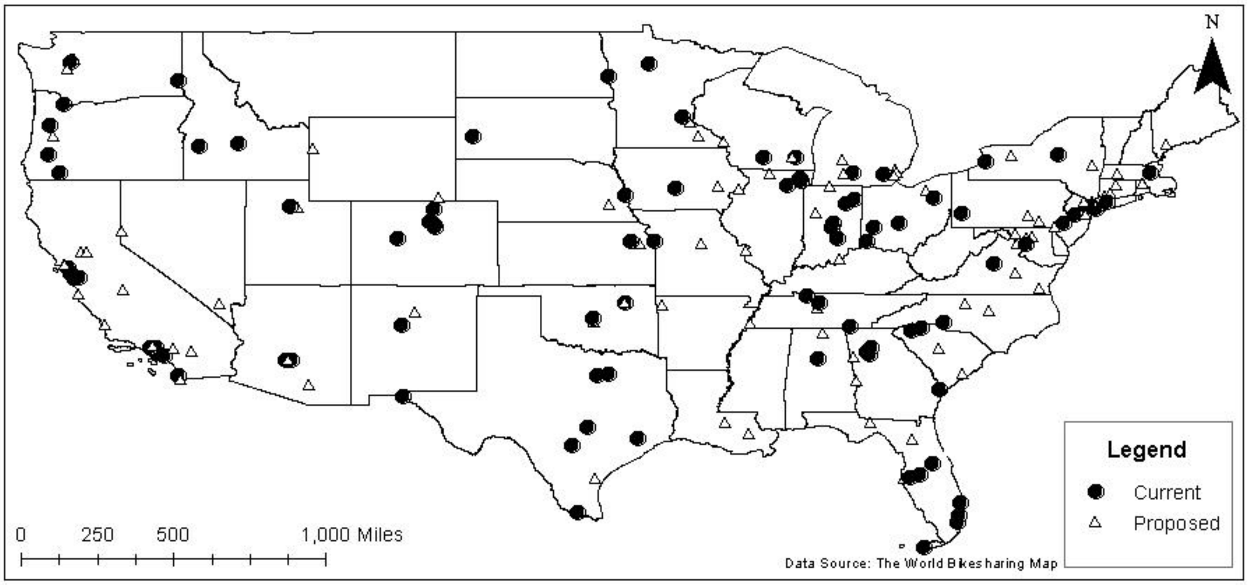

Figure 3. Bikesharing programs in the Continental United States

2.2 Goals and Objectives

This project will examine bikesharing and its connection to wider goals of transit-oriented development. As bicycle integration is an important part of TOD considerations and cities that that implement it undoubtedly see the need for bikesharing to fill important transportation roles in the urban environment, successfully implemented bikesharing programs will certainly contribute to the success of TOD. The literature review has substantiated the fact that bikeshare programs play a major role in transit-oriented development. The only bikeshare program in Alabama is found in Birmingham. This study will undertake the following research objectives:

1. Investigate how the program is being implemented in Birmingham
2. Determine catchment area of users
3. Determine transit paths of patrons
4. Examine usage trends

5. Development of lessons and replication methods for other parts of Alabama

2.3 Research Methods

A case study approach was used to investigate research objectives in the context of Alabama. Zyp BikeShare in Birmingham was the focus of the investigation. This investigation of Zyp BikeShare provided insight into the operation, challenges, and lessons learned from the integration of a bikesharing program into a city environment. A data exploration lent to a broad understanding of the system and a framework of suggestions for evaluating bikesharing systems and success.

2.3.1 How the Program Works

To investigate how the program works, personal interviews were conducted with the program managers. In addition, the contents of secondary data were analyzed. Sources of secondary data included program brochures, flyers, internet sources, etc.

2.3.2 Catchment Area of Users

Next, we sought to determine the catchment area of Zyp Bikeshare users. Here, we used the phrase *catchment area* to refer to the areas within the transit service area where patrons utilize bikeshare technology. Key research questions included the following:

- Where are Zyp Bikeshare stations located across the Birmingham landscape?
- What is the spatial distribution of Zyp BikeShare members?
- What is the distribution of patrons' beginning and end points?

Determining where bikeshare docking stations are located was key for initial understanding of the scope and implications of the program. First, coordinates for each bikeshare location were determined from Zyp BikeShare's mapping system, which is made publicly available on their website. These were mapped to show the comprehensive network of bikeshare technology in Birmingham. Appendix 1. includes a list of Zyp BikeShare stations used in the analysis and mapping of trends throughout this study. Here, "Undetermined" was used to reference data in which part of the data for the bikeshare trip was indeterminable.

Locations of users of Birmingham's bikeshare program were determined using compiled data on the bikeshare program. For determining the catchment area of users, the main source of data was through data collection from the Zyp BikeShare user database. Zyp BikeShare has a number of independent, wireless bicycle stations across the Birmingham area (Zyp BikeShare, 2016). Each time a user checks out a bike, data is collected on the time, date, length, type of membership, type of bike, beginning point, and end point. The data has been compiled since Zyp BikeShare began service in October 2015. For the purposes of this project, data collected in the eight and a half months (October 15, 2015 to June 30, 2016) following the system's integration into the Birmingham community were utilized. Although Zyp BikeShare participates in a number of community events throughout the year and data is recorded for these events, this data was not included in the analysis of Zyp BikeShare patron catchment. Additionally, bikeshare trips taken by Zyp technicians were removed, as many of these trips are for servicing purposes.

Another important part of understanding the catchment areas of patrons was examining residential trends of bikeshare users. Zyp BikeShare collects zip code information at the time of purchase for long-term memberships. As short-term users are not required to provide their zip code when purchasing a membership at a Zyp docking station, this information is not available for short-term memberships. However, as it is highly possible that many short-term memberships are used for the purpose of joy rides or leisure, examining the long-term members' spatial distribution by zip code will prove sufficient in examining a map of users' spatial distribution and will provide information at a basic level of overarching distribution trends. Data for long-term user zip codes was used to create a dot density map in ArcGIS Version 10.3 representing the distribution of users by zip code in Jefferson County, Alabama, by Zip Code Tabulation Area (ZCTA). Zip codes that fell within ZCTAs outside of the immediate service area were considered but not included in mapping as they were seen to not directly affect transportation trends and associated bikeshare use in the urban environment.

Additionally, determining patron catchment included an initial determination of patrons' beginning and end points for each bikeshare journey. Data collected from Zyp BikeShare's user database allowed for the determination of exact beginning and end locations at docking stations throughout the city for each journey taken in Zyp's first eight and a half months. For each bikeshare trip taken in Birmingham, a start and end point was recorded. Initial analysis to determine the spatial distribution of patrons' beginning and end points included mapping of start counts at the Zyp BikeShare docking stations in ArcGIS. In the case that a technological or recording error occurred, these trips were listed as "Undetermined."

Mapping exercises in ArcGIS Version 10.3 allowed for an analysis of differences in start and end journeys at specific destinations, which provided insights into the spatial distribution of Zyp BikeShare patronage. First, Zyp BikeShare patronage was analyzed in terms of patrons' beginning points. This refers to the specific docking station where a user checks out a Zyp bicycle, as documented by the Zyp user database. Maps were created by determining start counts at each individual Zyp docking station. Spatial analysis was conducted through a consideration of mapping of Zyp user start counts by station. The same analysis was conducted for patron end points in order to show differences in numbers of patrons ending their journey at each particular docking station. Individual docking stations were considered against themselves in terms of start and end journeys in order to examine user distribution more closely. Further analysis will more closely examine trends associated with these start and end point distributions. Understanding patron catchment area is essential in bikeshare implementation as bikeshare programs grow and develop.

2.3.3 Transit Paths of Zyp Patrons

Next, we aimed to determine the transit paths of Zyp BikeShare patrons. Understanding specific transit paths and transit path relationships provided information on the success of bikesharing in the context of transit-oriented development. Key research questions included:

- What are the paths that patrons follow while using the system?
- Where do typical Zyp transit paths interact and cross the existing public transportation network in Birmingham?
- Which land uses are adjacent to typical Zyp BikeShare transit paths?

In order to determine transit paths that Zyp BikeShare patrons follow while using the system, a connectivity matrix was utilized. The connectivity matrix was designed to show all stations in the Zyp BikeShare system in graphical form and to represent areas where direct connections occur. After the connectivity matrix was created, a network analysis was conducted in ArcGIS Version 10.3 to visualize the transit paths of patrons. Another matrix was then created in order to represent the exact counts of Zyp journeys happening between each station. While it is impossible to represent exact visualizations of every Zyp journey without GPS data for the individual ride, it is possible to determine trends associated with certain stations and make assumptions about various trip characteristics based on common trends and network data. This variation of the connectivity matrix was created in order to visualize areas where the most connections were occurring, and thus lend insight into frequently used transit paths of patrons.

Connection counts and destinations were examined closely for each docking station and individual bikesharing journey. For each station, we examined Zyp user data for individual journeys and determined the number of bikesharing trips that were returned to the same station. In doing so, we were able to make assumptions regarding trip determination of some users within the system.

Additionally, this research examined the Zyp BikeShare system and how typical transit paths interact with existing bicycle infrastructure in Birmingham. To investigate how individual Zyp transit paths interact and cross the existing public transportation network, we drew on the previous considerations of start and end points in conjunction with data analysis on Birmingham's transportation network. This included information regarding Birmingham-Jefferson County Transit Authority (BJCTA) buses, bus stops, transit service areas, active transportation, and other transit infrastructure. Initial mapping in ArcGIS was conducted to show presently existing transit infrastructure. Using data from the RPCGB on transit infrastructure throughout the city, we were able to examine use at particular stations in relation to transit infrastructure in the Zyp service area.

Next, transit infrastructure was considered in its relationship to classically defined ideals of transit-oriented development. Here, we used buffers in ArcGIS to determine transit relationships in the Zyp BikeShare service area and to examine the concept of bikesharing in the context of transit-oriented development sheds. As TOD often deals with areas in the ¼ mile of a transit node, buffers of ¼ mile were first applied around the Zyp BikeShare stations and used to represent the radius in which pedestrians could easily travel around a transit node. While it is recognized that pedestrians might not necessarily travel in this exact radius around a Zyp station, especially if Zyp stations were not implemented or utilized, these locations were deemed sufficient for analysis as they were chosen as a part of a feasibility study for bikesharing locations and carefully selected to be centers of activity. Additionally, a ¾ mile buffer was applied around these locations to show the increase of shed extent created by utilizing a bicycle rather than foot journey. A comparison of these buffers applied around Zyp docking stations was used in conjunction with data from the Regional Planning Commission of Greater Birmingham on Birmingham's transportation network. Zyp stations were considered to be the transportation nodes of interest, around which we consider the sheds to be a part of a transit-oriented development. These Zyp stations were considered points of interest as they were chosen as part of a feasibility study of Birmingham's landscape for effective bikesharing and transportation placement. These points can be considered as typical locations where people in the Birmingham community might be trying to travel from one location to another. Using ArcGIS, we examined differences in the amount of bus connections in the two shed variations.

Additional considerations for the transit paths of Zyp patrons included determining land uses adjacent to bikeshare docking stations. Using land use data provided by the RPCGB, adjacent land use for each docking station was determined. In some cases, nearby land uses were recorded and listed as secondary or tertiary land uses.

2.3.4 Usage Trends

The analysis of Zyp BikeShare included an exploration of specific bikesharing usage trends throughout the first eight and a half months of implementation. Key research questions included the following:

- What are the usage trends throughout the day?
- Can land use help to predict bikeshare usage?
- What is the relationship of population to bikeshare usage?
- How does usage differ between standard bicycles and pedelec bicycles?
- What are usage trends across membership types?

Daily usage trends were examined using Zyp's user database. This data includes a start time for all bikeshare trips between October 2015 and June 2016. Data was grouped into categories by hour and graphed to show the distribution of trips throughout the day. Additionally, data was compiled from the Regional Planning Commission's Birmingham Bikeshare Feasibility Study. This study undertook a series of planning analyses and community surveys to examine potential bikeshare use. Here, we considered survey responses collected by the feasibility study in reference to usage reasoning throughout the day to reinforce and to compare usage trends determined from the time of day analysis.

Another research question involved consideration of the predictive quality of land uses adjacent to docking stations for determining start and end count. In the initial discussion of patron catchment, we determined major land uses surrounding each station. Here, we classified these land uses into categories based on use. These included: Public/Semi-Public, Parks/Recreation, Technical, Commercial, and Housing. Here, Public/Semi-Public referred to land deemed public or partially public in nature. This included, but was not limited to, schools, churches, building setbacks, building facades, or landscaping ("Future Land Use, Regulations, and Urban Design," 2016). Here, Parks/Recreation referred to areas managed with the intention of public access for recreational purposes. This included parks, managed green space, playgrounds, or recreation fields. Technical land use categorization included utilities, industry, and auto-related uses. For the purposes of this project, areas deemed Commercial encompassed retail and office space. Housing was grouped to include single and multi-family dwellings, both attached and separate. An Independent-Samples Kruskal-Wallis test was conducted in IBM SPSS Statistics 22 to test the hypothesis that a statistical difference existed for start counts across land use categories. This non-parametric test was selected as data did not follow a normal distribution. An additional Independent-Samples Kruskal-Wallis test was conducted in SPSS for end counts across land use categories.

Transit-oriented development seeks to establish a "live-work-play" environment; thus, it was essential to examine the ways in which Birmingham residents live, work, and play around particular stations in order to successfully understand the role of Zyp within the urban community. The methodology for understanding these usage trends involved determining the relationship between the location of Zyp technology and people. Relationships between adjacent population and station usage were examined spatially and statistically. Census block group level population data was collected for the areas surrounding each specific station. Using Zyp start counts to represent individual bikesharing trip origins, we compared usage and population to determine the Pearon's correlation coefficient between the two.

One of the reasons we selected Zyp BikeShare as the system for this particular case study was because of the nature of the system, which is one of the first in North America to utilize pedelec technology. We suspected that some usage trends might vary between standard bicycles and pedelec bikes. While in the majority of this research, bikesharing trends were considered as a whole to include usage for both types of bicycles, here, we sought to briefly examine differences between the types of bicycles. For all applicable bikeshare trips from Zyp's user database, mileage and trip duration were determined. Then, we were able to determine the miles per hour bikeshare users traveled for each type of bicycle.

Specifically, we questioned pedelec versus standard bicycle use at each particular docking station. Using Zyp's user database, we compiled the number of individual uses at each station taken by each type of bicycle. We were then able to determine the percentage of users at each station that utilized each type of bike.

Pedelec bicycles are often cited as important for their value in traversing more difficult landscapes than regular bikes. To consider this, we examined the use of pedelec bicycles at each docking station in terms of nearby station spatial distribution and elevation changes. Using a Digital Elevation Model from the National Map, we created a slope surface in ArcGIS. Then, pedelec use for each docking station was mapped. Results were visually analyzed to consider trends in pedelec usage and its connection to landscape change.

Pedelec and bicycle typologies were further examined in the analysis of usage trends across membership types. Membership types were determined using data for each bikeshare trip taken in the city through Zyp's user database. Descriptive statistics were used to examine initial trends in bikeshare use across the various types of membership within the system. Additionally, a Chi-Square test was conducted in IBM SPSS Statistics 22 to examine if a relationship existed between categories of membership and categories of bicycle type (pedelec or standard bicycle). Examining these two categorical variables provided insight into the nature of ridership in the city by various populations

CHAPTER 3

RESEARCH FINDINGS

3.1 Introduction

The central theme of this research project was to study how a bikeshare program is being implemented in Birmingham, Alabama. This involved interviews, content analysis, an examination of patron catchment, patron paths, usage trends, and a description of how a similar analysis could be replicated. Research findings of these objectives are detailed below.

3.2 Operation of Bikeshare in Birmingham

Birmingham, Alabama, is a city that has recently integrated bikeshare technology into the urban environment. Each year, the League of American Bicyclists publishes state-by-state report cards on bicycle friendliness. Last year, Alabama was ranked 50 out of 50 with an overall score of 12 out of 100 (“Alabama Report Card,” 2015). However, immense changes have happened in Birmingham in the past year with the integration of Zyp BikeShare into the community. Zyp BikeShare is a new transportation program in the city comprised of 400 bikes and over 30 bike rental stations (“Zyp BikeShare,” 2016). Zyp BikeShare began in October 2015 and is continuing to grow across the Birmingham community (O. Hart, personal communication, April 15, 2016).

Zyp BikeShare is an initiative of REV Birmingham, an economic development program in the city (REV Birmingham, 2016). This program was the first bikeshare program implemented in the United States by the transportation startup, Bewegen (O. Hart, personal communication, April 15, 2016). On their website, Bewegen cites their major goal as providing “next-generation electric-assisted bicycles, combined with cutting-edge technology” to fill a missing link in urban transportation systems. Specifically, they seek to provide efficient, sustainable methods of movement across an urban area. Bewegen serves the Zyp BikeShare system through the integration of initial bikeshare technology and through IT Solution (“Bewegen Technologies,” 2016).

Currently, Zyp BikeShare is made up of 400 bikes, 100 of which have pedelec, or pedal-assist, technology (“Zyp BikeShare,” 2016). Bewegen describes their bike systems as having a distinctive design that has protected components as well as comfortable, ergonomic riding design. Additionally, the lithium-ion battery powered pedelec bikes give riders an extra electric boost and aids patrons in traversing otherwise challenging topography and in traveling further distances, in the meantime requiring less exertion than otherwise necessary (Smith, 2016; “Bewegen Technologies,” 2016).

This program uses independent, wireless charging stations, powered by solar panels (“Zyp BikeShare,” 2016). GPS technology and an IT solution from BikeEmotion allow the Zyp bikes to collect spatial information. The Zyp bikes are communicating with the wider data collection system at all times (“Bewegen is bound,” 2016). The independent, wireless nature of the stations allows them to be modified for special events throughout the city. Software applications and mapping technology allow users to view stations in real time on their phone or computer. (“Zyp BikeShare,” 2016). The initial 30 Zyp BikeShare stations were introduced to Birmingham in Fall 2015 and implementation of new stations throughout 2016 will bring the total number of stations to 40 (O. Hart, personal communication, April 15, 2016).

Figure 4. Zyp bicycles at a docking station in Birmingham, AL (Photo: Caroline Glass)

Users can purchase a short or long term membership to the program, and can thus engage in bikesharing in the city, where they may check out individual bikes for increments of 45 minutes. After 45 minutes have passed, users must return their bike and check out a new bike if desired. Users can purchase a temporary membership card on site at the Zyp kiosk (“Zyp BikeShare,” 2016). The two main membership types used by the system are 24-hour memberships and year-long memberships. The cost is $6.00 for a 24-hour membership and $75.00 for a year-long membership. Zyp BikeShare also has an equity program for $15.00 a year to include “Access for All,” which allows individuals receiving government assistance to gain membership (O. Hart, personal communication, April 15, 2016). Additionally, other membership types exist in the form of gift memberships, short-term memberships for special events, and Ambassador memberships, among others.

Zyp BikeShare was implemented and is made possible through a number of funding sources. The program received a Congestion Mitigation and Air Quality Improvement (CMAQ) grant to help pay for capital costs like equipment. The program received a funding match from the City of Birmingham for this grant. Currently, Zyp is receiving funding from a Job Access and Reverse Commute (JARC) grant, which seeks to address transportation issues for lower income populations (O. Hart, personal communication, April 15, 2016; "Job Access and Reverse Commute Program," 2016). Roughly one-third of the program's funding comes from the JARC grant. Additional funding comes from program sponsors and membership costs. Zyp BikeShare is continuing to apply for funding and grants as the program progresses (O. Hart, personal communication, April 15, 2016). Among Zyp BikeShare's sponsors are Regions, Blue Cross Blue Shield, Alabama Power Foundation, Birmingham-Jefferson Convention Complex, and The Community Foundation of Greater Birmingham. Among its partners are the City of Birmingham and the Regional Planning Commission of Greater Birmingham ("Zyp BikeShare," 2016).

Zyp BikeShare is housed in Downtown Birmingham, Alabama. As of April 2015, the Zyp BikeShare team was made up of 11 members. Half of these are a "fleet team" that works with the bicycles and equipment, while the other half serve administrative roles, customer service, outreach, community development, and more. At the six-month mark in April 2016, Zyp was receiving a great deal of positive feedback and beginning the forth implementation stage for bikeshare technology in the city. Zyp BikeShare continually uses information provided by an initial feasibility study and continues to engage the community, enhance vibrancy, connect people to social services, and create a positive sense of place in Birmingham. Recently, Zyp was awarded a “Champions of Sustainability Award” in the community (O. Hart, personal communication, April 15, 2016).

Zyp BikeShare serves a number of roles in the Birmingham community. Among the purposes of Zyp, cited by Zyp’s Executive Assistant Olivia Hart, are its role as a mode of transit that replaces car journeys, a program that increases access to work and employment, a method of environmental improvement, a benefit to citizen and community health, and a form of recreation for joy rides. The company’s goals include improving sales and usage, reducing car journeys in Birmingham, and building healthier communities. In terms of improving sales and usage, maintaining ridership is a major focus for Zyp. Zyp seeks to increase the number of trips from a business productivity standpoint. While the company does not have specific quantitative goals in terms of automobile usage reduction, the general goal from an environmental standpoint is to reduce auto use and encourage cycling as a form of transportation. Likewise, Zyp seeks to improve the health of the community by adding a heightened sense of vibrancy to the targeted neighborhoods, ideally creating a cultural change through the introduction and integration of cycling (O. Hart, personal communication, April 15, 2016).

While Zyp has experienced great success in patronage and system ridership, they have yet to determine the number of users that are utilizing the system for joy rides or for connections to the wider transportation system in the Birmingham area. In the future, Zyp BikeShare hopes to encourage and foster connections between the community and the community transportation system. For Birmingham, bikeshare has major potential in reducing automobile use and as a “first and last mile” transportation method, which connects people to the larger transit system for the initial and final parts of their commute (O. Hart, personal communication, April 15, 2016). Continued and successful integration of Zyp BikeShare into the wider transportation scene will likely have positive implications for the health, vibrancy, and environmental quality of the community.

Figure 5. Zyp bicycles (Photo: Caroline Glass)

3.3 Catchment Area of Users

The next methodological approach aimed to determine catchment area of Zyp BikeShare patrons. To determine patron catchment, it was essential to determine the location of Zyp BikeShare stations across Birmingham, Alabama. Figure 6. shows the spatial distribution of bikeshare docking stations in the city. Here, the additional data frame represents the distribution of bikeshare stations within Jefferson County. Appendix 1. includes the names of stations included in the analysis.

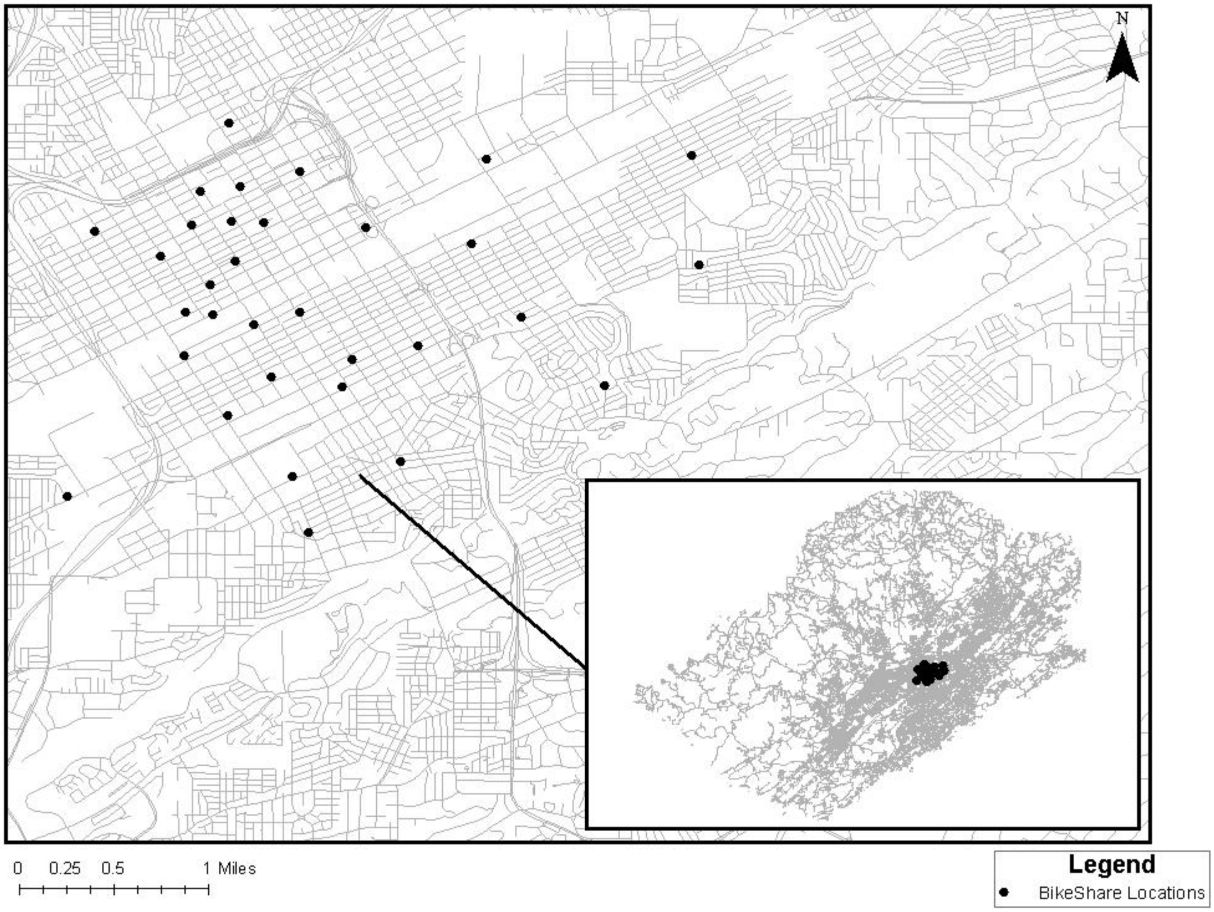

Figure 6. Spatial distribution of Zyp BikeShare docking stations

Moreover, analysis of patron catchment included determining the distribution of patrons themselves across the urban environment. Patron distribution was considered both in terms of residential distribution and in terms of locations where individual users picked up and dropped off Zyp bikes. Using data provided by long-term members, we were able to visually represent patron residential distribution. Although the lack of short-term user residential data could be considered a methodological limitation, through mapping of long-term users we were able to provide a general idea of user trends through Zyp's initial eight and a half months of service

Figure 7. shows the distribution of Zyp BikeShare users by Zip Code Tabulation Area (ZCTA). ZCTA borders are shown here, with a dot density map representing patron frequency.

Here, each patron is represented by a dot. This is not placed at their actual home address, rather randomly within their ZCTA of residence. This mapping exercise led us to determine that ZCTAs closest to the central business district generally contained the greatest frequency of long-term memberships. When considering the spatial distribution of Zyp docking stations in Figure 6., it appeared that these patrons also live in areas nearby bikeshare stations.

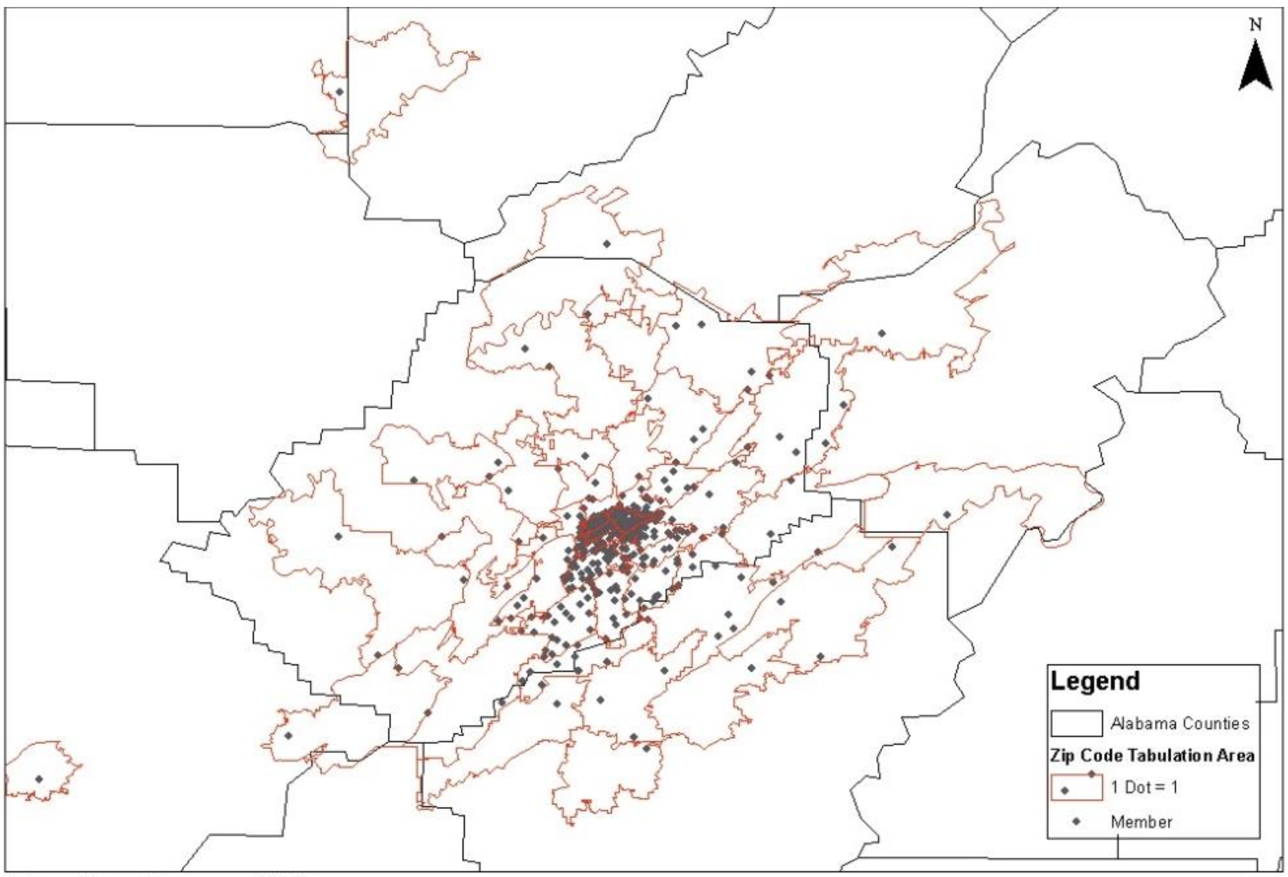

Figure 7. Zyp BikeShare's long-term member distribution by ZCTA

Figure 8. Zyp BikeShare docking station start count visualization

In determining patron catchment, we also questioned the spatial distribution of Zyp BikeShare patrons' beginning and end points. Figure 8. represents the distribution of user start points. This map displays proportional symbols to show the differences in number of patrons starting their bikeshare journey at each particular docking station. This map provides a visualization of which Zyp stations have the highest and lowest number of bikeshare trip starts proportional to other docking stations in the system. Exact numbers of Zyp start counts at each bikeshare station can be found in Appendix 2. It is important to remember that a few of these stations were implemented after the initial Zyp BikeShare launch. However, these numbers are representative of general trends in usage across the docking stations. The same exercise was conducted for patron end points at Zyp docking stations. The map of patron end points can be seen in Figure 9. and exact end counts can likewise be found in Appendix 2.

Figure 9. Zyp BikeShare docking station end count visualization

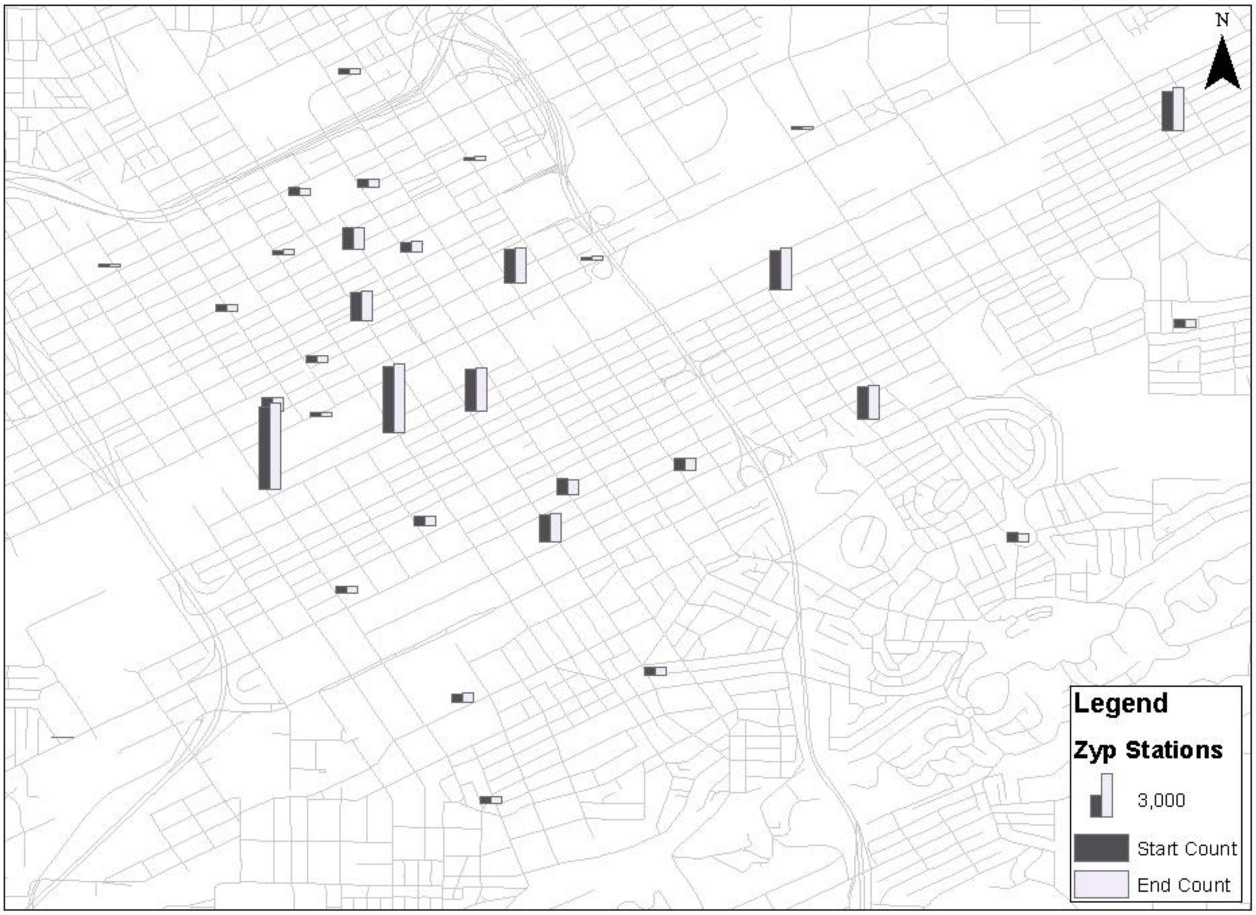

Figure 10. Comparison of start and end counts at each docking station

Figure 10. represents a map of Zyp docking stations with a comparison of start counts and end counts at each particular station. In the analysis of start and end counts, we determined the following stations to be major origins and destinations for travel: RailRoad Park/Regions Field, 18th St S & 1st Ave S, 41st St S & 3rd Ave S, and 20th St S and 2nd Ave S.

3.4 Transit Paths

Further analysis of Zyp BikeShare involved determining the transit paths of patrons. A connectivity matrix was first utilized to gain insight into the transit paths of Zyp BikeShare patrons. The connectivity matrix for Zyp BikeShare trips can be seen in Appendix 3. This matrix displays areas where there is a direct connection (1) and areas where no direct connection exists (0). These values represent an asymmetrical matrix as we sought to determine trips beginning at one place and ending at another, rather than with a connection simply occurring between the two. Connections are represented as origins from the x-axis to destinations on the y-axis. Details of abbreviations for subsequent bikeshare tables can be found in the appendix.

Further network analysis for connectivity showed that some stations through the system were patronized more than others, with more direct connections linked to other stations in the system. The network analysis led us to determine a high degree of network clustering within the central parts of the transportation service area. Perimeter stations were patronized less as a whole than internally located technology. Table 1. includes a more comprehensive representation of connections across Zyp docking stations, with the number of trips departing from each station and connecting to another shown for all of the stations utilized throughout this study.

In further examining connections between specific docking stations, we determined the exact number of journeys between each docking station. Here we considered the number of bikesharing journeys at each station that were returned to the same station. Appendix 4. includes the results of an analysis to determine the percentage of total journeys beginning at each station that ended at the same docking station. We found that on average, 44% percent of bicycles were returned to their origin station.

Table 1. Docking station connection ffrequency

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG
A	111	0	3	246	1	11	0	0	9	7	1	0	1	205	1	0	0	5	4	10	33	0	6	4	2	0	6	0	2	1	0	32	8
B	1	227	11	4	0	22	0	0	0	34	65	0	0	1	9	6	1	3	1	0	0	0	0	2	0	4	26	0	0	0	34	25	11
C	0	3	0	17	2	1	46	0	21	9	75	0	3	1	11	1	0	2	4	1	2	0	11	13	1	6	2	74	0	0	0	13	5
D	0	0	25	0	5	0	49	0	18	32	15	31	2	0	4	1	0	1	2	2	0	6	0	42	0	10	0	69	36	0	1	2	3
E	0	10	18	19	380	0	47	24	0	35	26	93	4	2	0	14	0	30	2	4	0	8	0	21	33	14	19	72	7	0	16	13	7
F	0	0	0	3	29	532	23	39	2	31	3	10	0	0	0	8	0	12	2	11	0	13	0	5	16	0	4	16	3	0	11	0	0
G	10	5	31	31	81	12	2242	91	32	293	98	235	8	27	35	141	1	203	19	0	41	22	0	91	178	0	223	927	101	0	77	16	0
H	4	2	10	22	0	36	78	777	29	145	35	133	0	3	15	36	0	48	49	6	68	31	0	52	84	0	51	108	68	0	16	3	18
I	0	38	5	3	8	4	24	19	245	25	40	8	11	1	3	18	37	24	1	0	0	3	8	2	21	0	15	35	8	0	15	35	13
J	0	7	19	19	79	14	320	171	33	1242	128	185	0	9	21	98	63	117	22	8	34	20	22	43	127	0	207	330	51	13	82	12	9
K	1	90	47	27	35	8	99	37	30	114	715	21	169	7	1	113	57	42	20	18	13	13	16	25	44	0	41	194	7	0	88	92	6
L	2	6	12	40	40	19	0	135	8	187	23	991	32	20	38	79	9	85	50	0	31	24	10	54	192	0	148	213	80	3	26	5	34
M	0	13	0	0	7	1	47	11	15	38	192	18	423	5	0	54	0	19	5	8	3	0	12	0	9	0	21	17	4	0	53	0	0
N	0	0	1	4	0	3	8	31	4	6	8	26	7	0	1	1	0	4	19	1	8	11	3	4	5	0	4	11	11	0	1	0	5
O	0	0	0	2	3	1	53	6	3	12	1	49	6	0	114	4	2	4	3	0	8	0	0	1	16	0	17	17	2	4	2	1	0
P	0	0	0	9	11	3	128	25	18	131	116	88	76	5	9	1172	38	275	9	12	6	26	60	47	58	0	251	211	19	2	66	8	0
Q	1	4	0	3	6	1	16	3	52	39	27	5	12	1	0	61	282	55	1	3	1	0	18	3	7	0	52	29	6	8	8	6	3
R	0	13	12	13	10	0	188	35	17	123	34	96	37	11	6	262	34	1715	9	1	12	3	111	14	66	0	380	301	21	19	42	7	8
S	4	3	1	5	8	16	28	41	2	17	10	55	7	14	1	21	0	6	372	8	19	21	0	6	48	0	16	51	27	2	4	1	9
T	1	0	7	2	2	2	10	8	1	4	21	4	25	2	0	10	0	2	5	192	0	23	0	15	6	0	4	14	1	0	4	0	1
U	3	0	1	6	12	11	39	56	4	41	9	34	4	11	3	13	0	4	5	2	367	8	0	11	76	0	10	24	20	4	2	1	16
V	30	0	2	1	14	14	31	30	9	19	13	6	1	8	0	11	4	1	23	17	9	412	0	25	36	0	12	42	15	1	6	9	0
W	0	1	3	1	3	3	32	1	7	7	19	6	13	0	1	46	26	124	6	2	0	2	386	1	10	0	59	32	5	0	11	1	0
X	6	5	10	14	23	12	60	31	3	42	26	62	12	0	5	62	0	14	13	6	8	17	1	486	73	0	11	124	12	1	17	5	4
Y	3	5	41	46	20	19	214	107	6	126	37	190	17	6	8	61	3	53	47	11	84	36	12	70	955	0	78	239	85	9	21	4	12
Z	0	4	0	0	2	0	3	2	2	3	9		1	2	0	3	0	3	0	0	0	0	0	2	2	130	2	8	0	0	0	0	0
AA	0	9	16	2	28	7	246	45	17	249	30	155	48	3	15	236	39	332	5	0	15	3	54	11	96	0	1228	329	23	14	51	13	8
BB	0	42	79	69	89	17	813	136	47	321	182	183	62	14	14	213	36	285	50	25	46	21	28	107	244	8	307	3562	43	11	69	71	23
CC	1	2	0	11	4	2	87	52	13	45	10	98	11	8	4	21	6	28	23	7	10	14	4	20	85	0	26	38	321	1	18	4	6
DD	2	0	0	0	0	0	17	1	4	7	1	9	3	2	1	10	8	0	0	0	0	5	0	1	5	0	11	17	1	98	3	2	0
EE	0	14	15	5	9	8	58	15	16	75	103	33	41	3	4	75	14	26	12	3	5	9	8	11	23	0	50	66	10	0	547	14	10
FF	0	52	27	1	11	0	22	3	21	10	93	12	6	1	3	8	6	7	0	0	1	9	3	3	20	1	8	71	6	0	19	340	3
GG	10	0	0	0	5	4	15	10	10	12	4	33	3	10	13	3	0	2	13	1	14	3	0	5	19	0	2	15	15	0	7	3	221

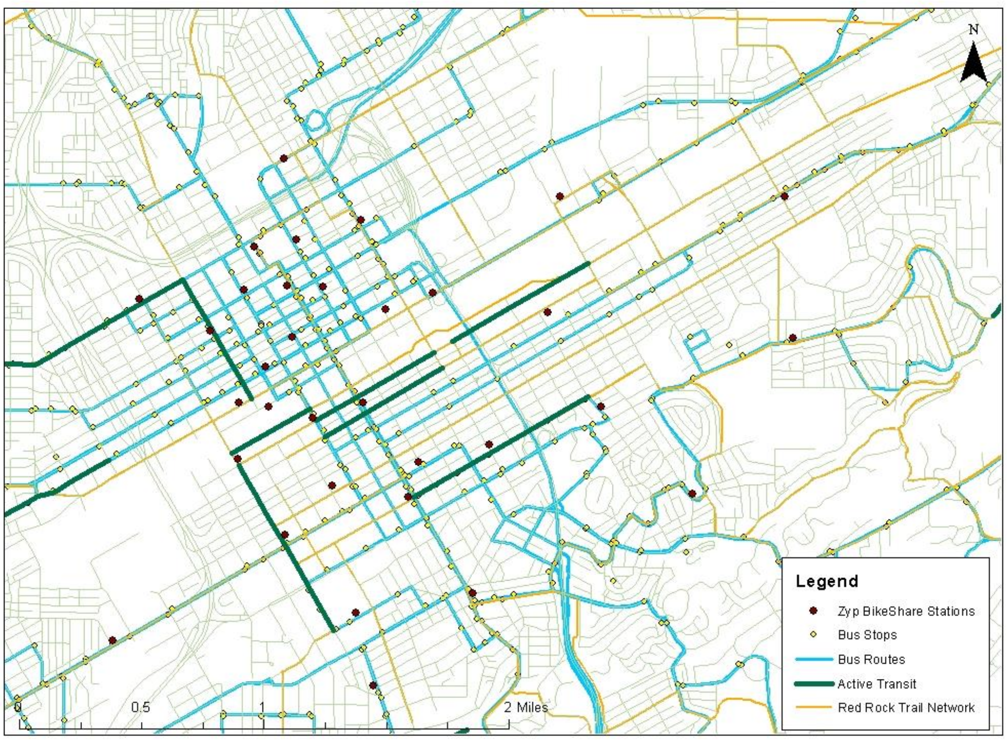

Figure 11. Birmingham transit infrastructure

Public transit network connections were likewise interesting for the exploration of usage trends associated with bikesharing in Birmingham. Figure 11. is a non-exhaustive representation of Birmingham's transit infrastructure. Here, we can see bus stops, bus routes, existing active transit, roads, and Zyp BikeShare stations.

An essential part of this geospatial analysis involved the visualization and analysis of sheds across the transit network. Visualizing shed differences in terms of Birmingham's comprehensive transportation network allowed us to see the differences between on foot journeys and bicycle journeys in the community. As a part of the transit-oriented development system, we were interested in how Zyp contributed to connecting users to the transportation system and within the transit service area landscape. An initial map from this analysis can be seen in Figure 12. This shows the approximate pedestrian shed, by classical consideration of TOD radius length, around each station; i.e., if an individual was to stand at that node, how far they would or could travel by foot. For many of the centrally located stations, these sheds overlap. However, for the stations extended further from the central part of the downtown area, sheds are not connected or are barely connected. A visualization of the Birmingham transportation network extensions as a result of bicycle sheds around Zyp BikeShare docking stations can also be seen in Figure 12. This allowed us to visualize the extension of transportation access from ¼ mile around a transit node to ¾ mile around a transit node (chosen based on the assumption that bicycling eases travel by allowing movement three times as fast, meanwhile extending the length of travel).

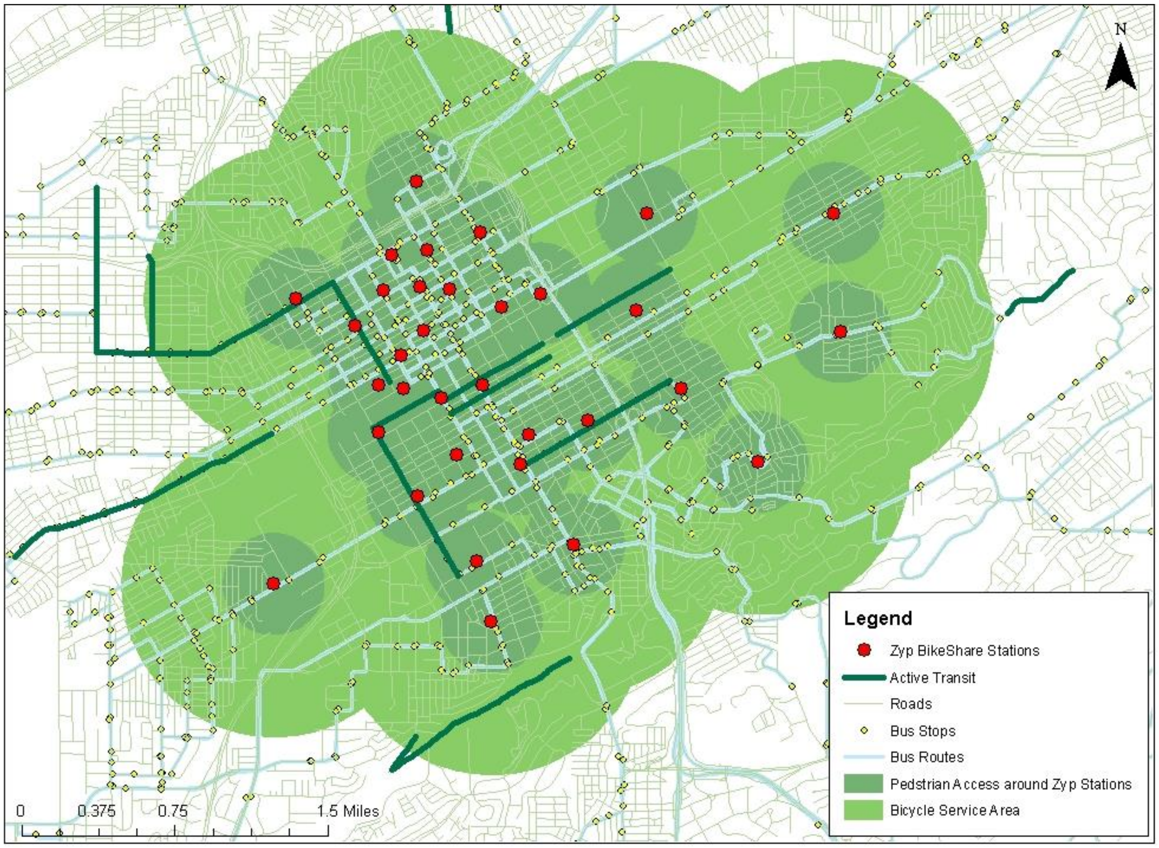

Figure 12. Transportation network with bicycle and pedestrian sheds

Figure 13. shows the BJCTA connections to the pedestrian shed around Zyp docking stations. We determined that 220 BJCTA stations were accessible within the network of pedestrian sheds. BJCTA connections to bicycle sheds around the same transit nodes were mapped in Figure 14. Increasing the buffer by three times to account for bicycle network extensions accounted for access to 440 BJCTA stops.

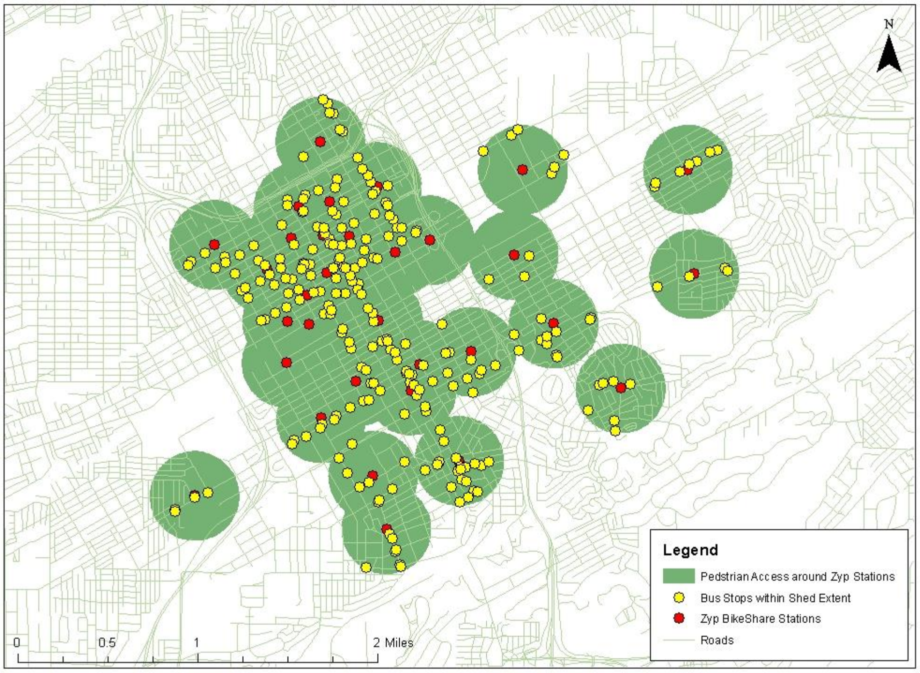

Figure 13. BJCTA bus stops in the pedestrian shed

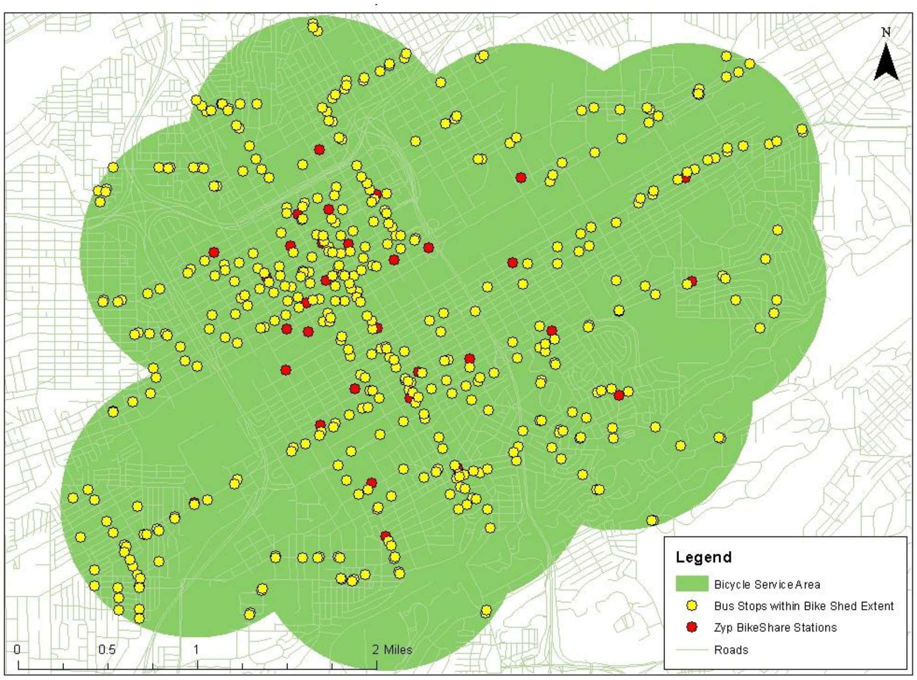

Figure 14. BJCTA bus stops in the bicycle sheds

Results of the mapping exercise for particular transportation infrastructure and Zyp stations can be seen first in Figure 15. In this exercise, we sought to represent connections between active transportation and Zyp BikeShare use within the city. Journey origin counts surrounding Rotary Trail, the major active transportation line through the central city, were relatively high compared to start counts at other stations in the city.

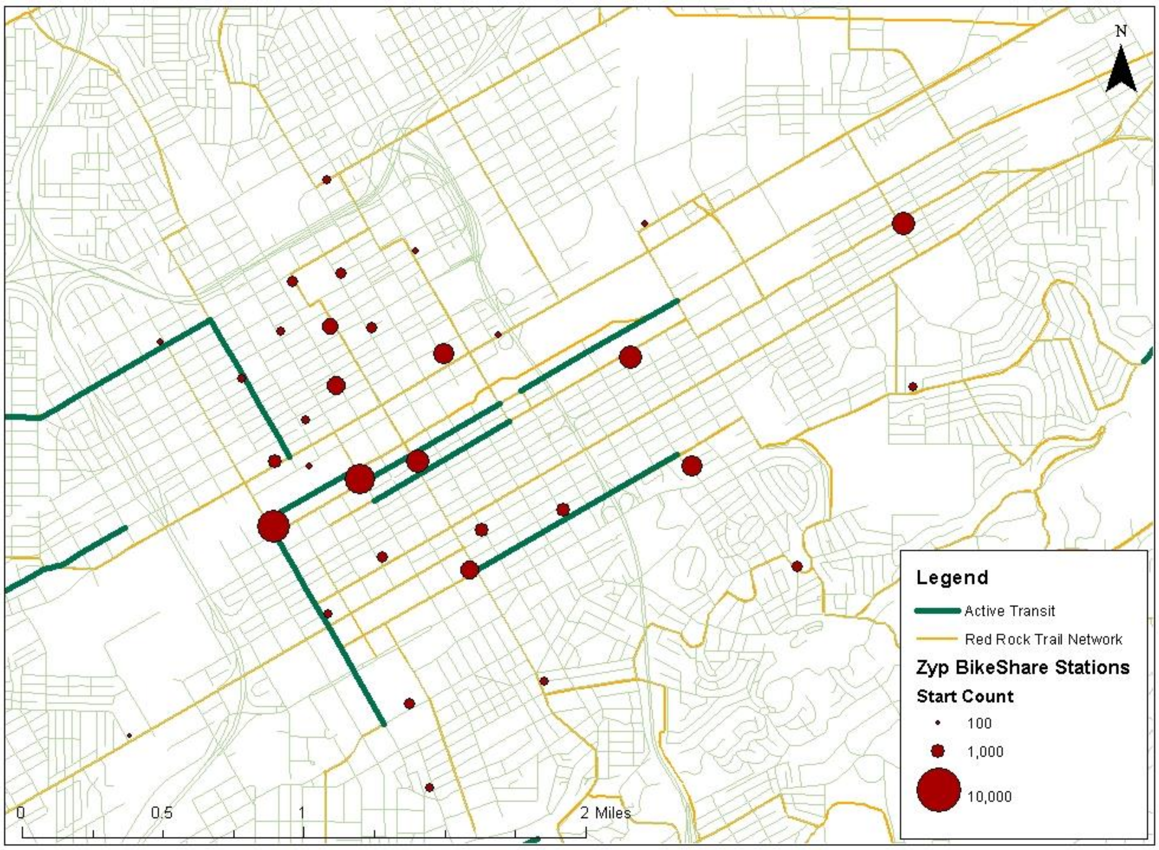

Figure 15. Usage trends and transit infrastructure

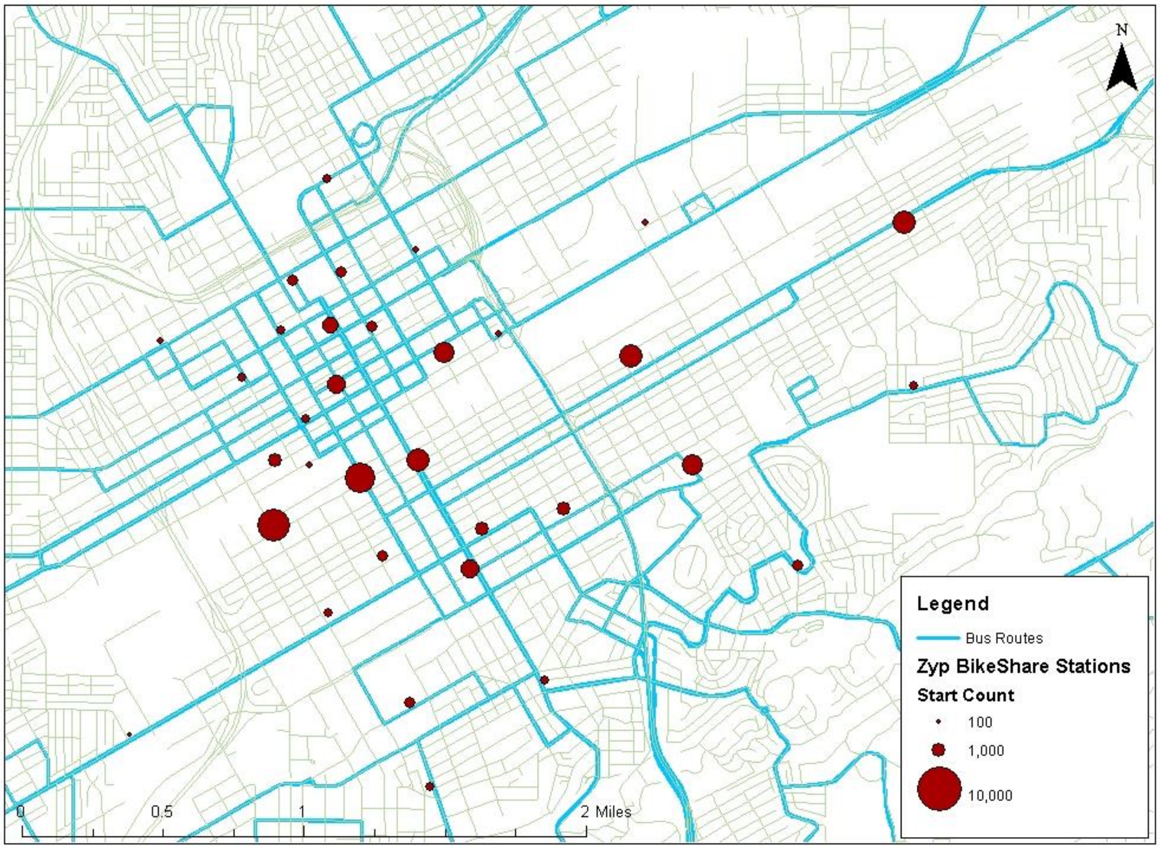

Figure 16. Usage trends and bus networks

Figure 16. represents the results of the mapping analysis of Zyp usage trends and their connection to BJCTA bus routes. Start counts are represented as proportional symbols and can be seen within the transit service area.

Initial considerations of land use involved examining land use parcels in ArcGIS. Land uses were determined for the areas directly surrounding the Zyp BikeShare docking stations used in this analysis and can be found in Appendix 4.

3.5 Usage Trends

The distribution of bikeshare trips on an hour to hour basis can be seen in Figure 17. The x-axis is representative of trips on an hourly basis. Times are represented on a 24-hour clock with the number representative of time spanning throughout that hour (i.e. 8 represents 8:00:00 am to 8:59:59 am).

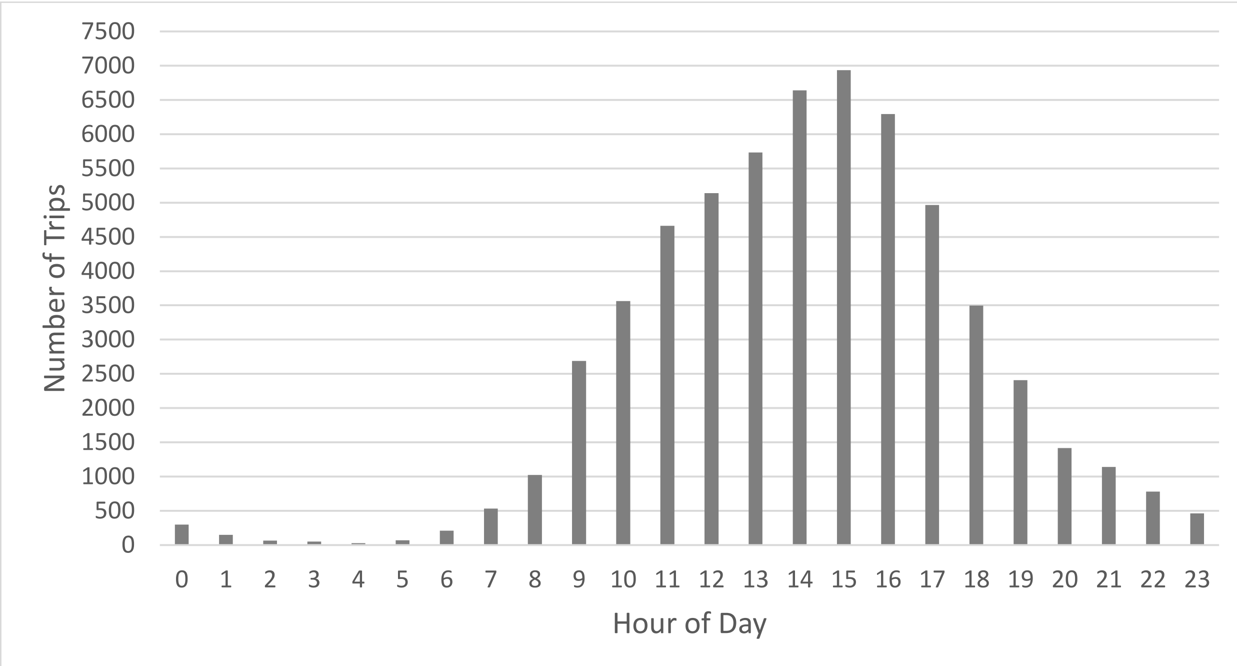

Figure 17. Bikeshare trip distribution

The Regional Planning Commission of Greater Birmingham's Bikeshare Feasibility Study was analyzed to more clearly understand patron usage trends. In a survey of 188 individuals regarding anticipated use of a newly implemented bikeshare station, respondents were asked, "If bikeshare were available, throughout Birmingham what types of trips do you think you would use the bikes for?" Results of the survey of these respondents can be seen in Table 2.

Table 2. Bikeshare trip reasoning survey results

Type of Trip	**Respondent Count**
Exercise	106
Run Errands	124
Meeting Family or Friends	95

Shopping or Eating Out	134
Riding to the MAX stops	21
Going to Work	57
Going to School	27
Going to Meetings	66
Don't Know	12
Other	31

Furthermore, land uses were determined and categorized into broader categories. Results of the Independent-Samples Kruskal-Wallis test in SPSS for start counts yielded a significance value of 0.391 at a 95% confidence level. Results of the Independent-Samples Kruskal-Wallis test for end counts yielded a significance value of 0.348 at a 95% confidence level. Here, we failed to reject the null hypothesis that a statistical difference in bicycle pick-ups and drop-offs was occurring between categorized land uses.

Using determined start counts for each docking station, we compared the relationship between number of trip origins and population using a Pearson's correlation test. Results yielded a r value of -0.23. Here, a very slight negative correlation was found to exist between the two variables of population and number of trip origins.

Usage was then examined between standard and pedelec bicycles. Average travel characteristics were determined for each type of bicycle. Specifically, we sought to determine the miles per hour at which a bicycle traveled for each type. We determined an average speed of 3.87 miles per hour for standard bicycles and an average speed of 5.14 miles per hour for pedelec bicycles. For each individual Zyp docking station, we then sought to determine how much usage was occurring for the two bicycle types.

A Chi-Square test was conducted to determine if there was a relationship between categorical variables of bikeshare membership type and bicycle type. Results of the Chi-Square test yielded a p-value of <0.001. Here, we failed to reject the null hypothesis that no relationship between the categorical variables existed.

Table 3. Pedelec use by docking station

Station	Pedelec Use (%)
14th St N and 8th Ave N	74
14th St S & 14th Ave S	49
14th St S & 6th Ave S	32
17th St N & 2nd Ave N	31
17th St S & 5th Ave S	26
18th St & 6th Ave N	20
18th St S & 1st Ave S	25
20th St N & 5th Ave N	25
20th St S & Highland Ave	45
20th St S and 2nd Ave S	30
20th St S and University Blvd	53
23rd St N and 2nd Ave N	40
24th St and 7th Ave S	31
24th St N & 6th Ave N	33
25th St N & 1st Ave N	33
29th St S & 7th Ave S	35
30th St S & Highland Ave S	54
41st St S & 3rd Ave S	34
Birmingham Central Library	28
Birmingham-Jefferson Co Transit	38
City Hall	32
Civil Rights Institute	35
Forest Park	45
Innovation Depot	35
McWane Science Center	28
Memorial Park Recreation Centre	11
Pepper Place	31
Railroad Park / Regions Field	28
Richard Arrington & 4th Ave N	28
Sloss Furnaces	40
The Kirklin Clinic	32
UAB Green South	35
Uptown at BJCC	29

The mapping results from the elevation analysis can be viewed in Figure 18. Trends in the mapped data showed that the top 20% of stations by pedelec use (as established in Table 3.) fell within areas near an elevation or slope change.

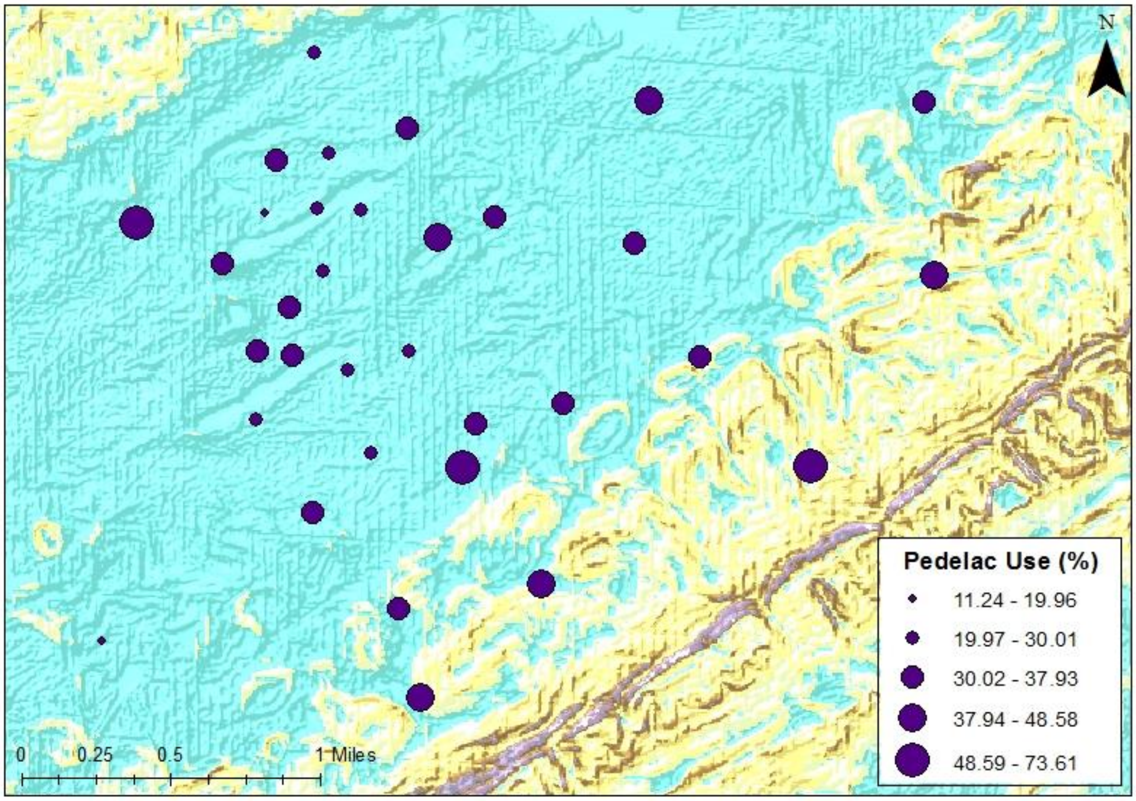

Figure 18. Pedelec usage and elevation

Further descriptive statistics were important in understanding the implications of the results of the Chi-Square test. We understood that membership type was connected to the type of bicycle a patron chose for a particular journey and sought to understand mileage distribution across the different typologies. Figure 19. shows the mean mileage traveled by each membership category, separated to show differences in bicycle type. Here, “Other” represents gift memberships and employee memberships (for Zyp and a number of partner companies).

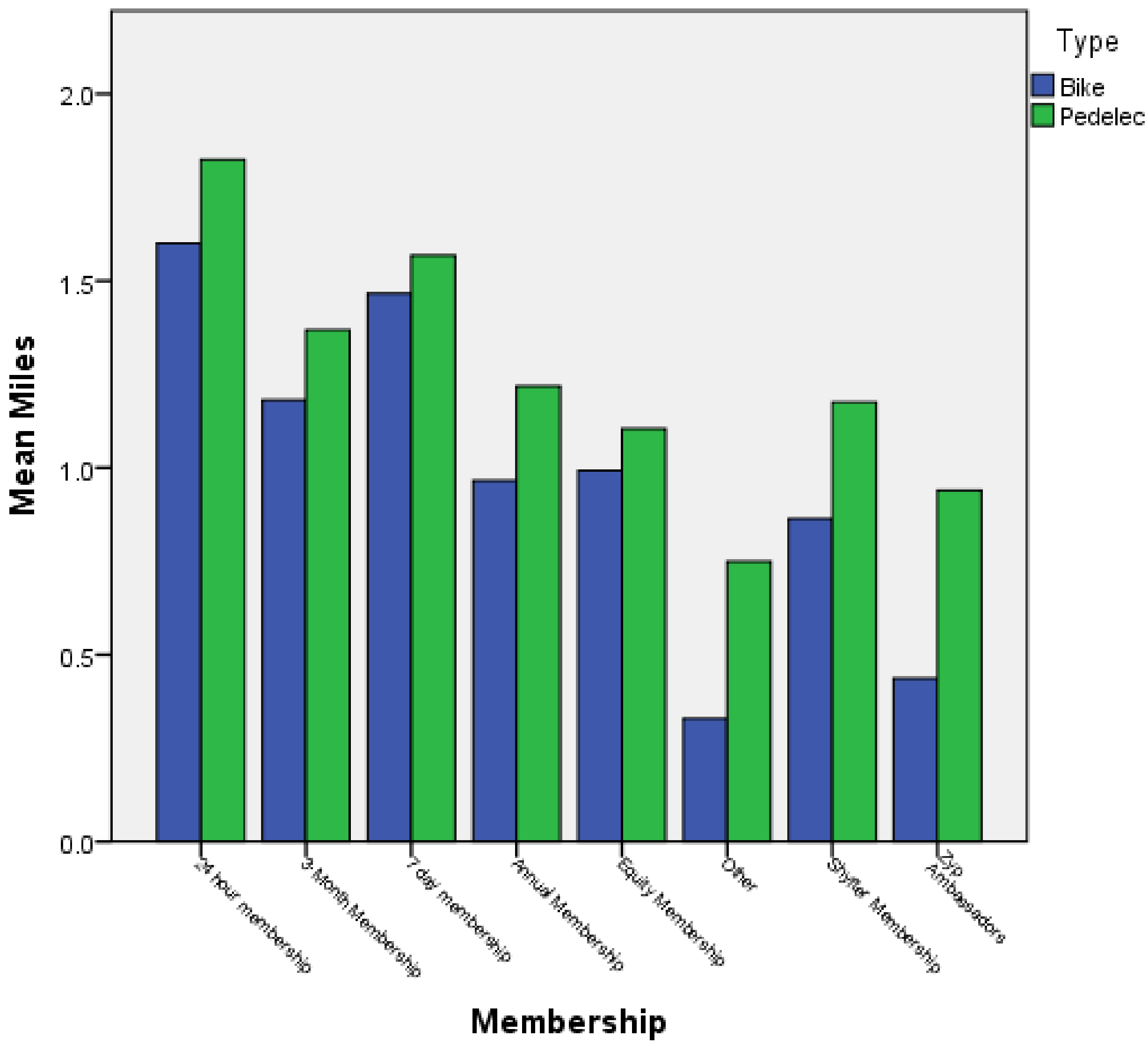

Figure 19. Bikeshare membership descriptive statistics

CHAPTER 4

DISCUSSION

4.1 Introduction

Bikesharing programs undoubtedly play a role in transit-oriented development strategies. The research design and data collection methods for this project sought to determine a method for examining a newly implemented bikeshare program, framed in the light of an essential form of transit-oriented development in the Birmingham, Alabama, landscape. Here, we will discuss the findings of the exploratory methodology for analyzing the case study topic, Zyp BikeShare. Finally, we will provide lessons that will discuss the ability of a replicated project for assessing a bikeshare program in a similar context.

4.2 How the Program Works

The results of secondary data collection and personal interviews provided insight into the nature of how Zyp BikeShare works and functions within the wider community and system of TOD in the Birmingham community. This portion of the research was particularly important and it allowed us to understand the development, implementation, and limitations of such a system. Additionally, it was essential in understanding the delicate balance of timing and actors involved in the growing community of bikeshare programs across the world.

Specifically, we learned the role the Zyp is serving in this particular landscape. In doing so, we learned that similarities exist throughout development and implementation of bikeshare systems. Considerations and questions addressed in this portion of the methodology could be replicated when seeking to determine how other bikeshare programs work. However, we also determined that aspects of a bikesharing program can be highly variable and dependent on funding, community perception, partnerships, and local government in a particular place.

In the case of Zyp BikeShare, we gained a great deal of knowledge into how the particular bikeshare system works. This foundational knowledge was essential in the determination of user distribution, paths, trends, and the over-arching development of a framework for analyzing a program of this type.

4.3 User Catchment

The analysis of Zyp BikeShare was built upon initial understanding of user catchment, namely patron and equipment distribution. First, we examined patron distribution across the Birmingham landscape. Geospatial analysis conducted in the mapping of Figure 6. in ArcGIS 10.2 led us to determine that the thirty-three Zyp docking stations included in this project represented a centralized service area within the urban environment. In determining the location of Zyp's docking stations, we found that the majority of Zyp stations were located in the heart of the central business district. A necessary component of a successful bikesharing system requires a network connected by feasible travel lengths; thus, this distribution of docking stations was expected. As we were interested in bikesharing as a transportation method and vitalization tool, this arrangement within the dense city framework was an essential visualization. Through research and continued fundraising, Zyp BikeShare hopes to extend bikesharing throughout other areas of the Birmingham Metropolitan area. Further analysis considered how the distribution of users, land uses, proximity to other forms of transit, and more affect bikesharing and ultimately the comprehensive urban transit-oriented development network, built on this initial mapping of Zyp BikeShare distribution.

Additionally, we ascertained that long-term patron clustering was occurring in ZCTAs within the central business district in Birmingham. As most of the Zyp docking stations are located in the central business district, this told us that many patrons live in areas close to Zyp stations. This was an important determination in terms of examining Zyp user reasoning. If these patrons live close to Zyp stations, it is less likely that they are utilizing bikesharing for tourism or joyriding purposes and more likely that they are using point-to-point check outs as a method of transportation or commute within the area. While it is impossible to determine exact reasoning behind bicycle use among the patrons represented in this visualization without use of social surveys, it is possible that a number of other long-term users outside of the CBD are utilizing Zyp as a method of commute or transportation. As Birmingham's bus rapid transportation network extends to include a service area of a large portion of the ZCTAs represented in Figure 6., it is possible that users can utilize bikeshare technology as a means of first-and-last mile connections. Further discussion of usage paths and trends considered more closely the relationship to transit infrastructure.

Wider goals of transit-oriented development seek to reduce automobile dependence and, in turn, reduce environmental and social problems associated with this automobile dependence. As seen in a comparison of how bicycle use greatly extends the length of the pedestrian shed, effectively allowing an individual a range of motion much larger and three times as fast as possible on foot, visualizing Zyp users as close in proximity to Zyp docking stations was important to consider. It is highly likely that many of these users are commuting to nearby workplaces, shopping, restaurants, bars, etc., by use of bikesharing technology. If this is the case, previous automobile trips in this area would likely decrease, rendering the area less congested and polluted. While it is impossible to be certain of exact commute reasoning without use of a social survey, this data provided valuable information on Zyp patronage and distribution.

Furthermore, we conducted an analysis of patron start and end points across the Zyp system. Analysis of start and end points was extremely important in the fact that it allowed us to understand and pinpoint the major origins and destinations for travel. Here, we determined the exact number of start and end counts at each station and found that Railroad Park / Regions Field, 18th St S & 1st Ave S, 20th St S and 2nd Ave S, 23rd St N and 2nd Ave N, 41st St S & 3rd Ave S, and Pepper Place docking stations were receiving the greatest amount of traffic within the Zyp system. Knowledge of which stations have the largest number of patron journeys is important for future planning and redevelopment techniques in the city. In doing so, we can tailor community development techniques to connect transit routes and infrastructure, and to generally support trends that benefit community vitality. In examining patron transit path location through start and end counts, we found that similar assumptions could be made regarding start and end locations. As a preliminary study of the bikesharing program, pinpointing start and end points provided an early account of which stations are being patronized most frequently, and thus contributing most to the success of the program from a business and use frequency standpoint. Likewise, this allowed us to determine which stations were not patronized as frequently in the system. After sorting data regarding usage times, we determined the Memorial Park Recreation Center docking station was patronized much less frequently than other stations.

In Figure 10., we compared start and end count against each other. This confirmed the idea that similar assumptions could be made when considering the usage values for each docking station. In Figure 10., we determined that use remained relatively constant for each station in terms of bike pick-ups and drop-offs. This was important in terms of wider transportation infrastructure and connections. This research continues by analyzing station density in terms of Birmingham's existing infrastructure and specific usage trends.

4.4 Patron Transit Paths

An important part of analyzing the bikeshare program and its role as a critical link in the transit-oriented development system involved understanding the movement of Zyp patrons. The connectivity matrix allowed us to interpret areas where common connections occur and what specific locations are being connected as a result of Zyp. While it is understood that any area within the Zyp BikeShare service area could be connected by means of a Zyp bike, it was important to see which actual connections patrons are making in order to understand distribution within the system and tailor future improvements to common uses. Here, we could see that stations that were previously identified as major origins and destinations for travel were represented in the connectivity matrix more than other locations. As expected, they were contributing more to the connectivity of the bicycle network within the city. Interpretation of the connectivity matrix in Table 4. allowed us to see that particular areas like Memorial Park Recreation Center and stations along 14th Street were experiencing less direct bikesharing connections by users than other stations.

Consideration of network connections between stations lent further insight to Zyp usage in the community. Stations on the perimeter of the system were found to experience less connections to other stations, as expected. Within the more centralized areas where the distribution of stations is denser, a great deal of connection overlap occurred. Likely, the prevalence of cycling culture is exacerbated by increased visibility, as many stations experience close connections and more cyclists are interacting within this centralized area. The connectivity table in Table 1. provided a more specific look into bikesharing connections. An interesting determination of this connectivity table was that connection counts were generally extreme in nature. For each station, it was common to find that each station was experiencing most connections from a varying group of stations, with most other stations connected a handful of times. These groups varied for individual stations. This is important in its connection to future research regarding the program. Knowing this, we know that there are likely numerous most-traveled paths from a particular station, rather than a randomized web of paths extending outward from each. If GPS data is made available for each particular route and heatmapped, these high frequency connections can be used to implement more biking infrastructure, safer biking infrastructure, and increased signage.

Visualizing public transit infrastructure and Zyp infrastructure as a whole was essential in examining usage trends. If successful, by design, bikesharing should be contributing to the success of transit-oriented development in the community. Thus, it was necessary to consider the Zyp stations and other transit connections in Birmingham in the light of transit-oriented development design and goals, namely if bicycles are being utilized and replacing car journeys in areas that could directly benefit from the integration of active transportation. Initial mapping of Birmingham's public transit infrastructure showed Zyp in the context of this existing transit infrastructure.

The application of buffers in ArcGIS lent to understanding of individual transportation trends and abilities based on the transit environment. Results of the visual analysis of shed mapping (Fig. 12) suggested that many centrally located transit nodes had overlapping pedestrian sheds. However, as stations were extended further outside of the central business district, the sheds were generally not connected. In the case of overlapping sheds, it would be feasible for an individual to walk from one particular location to a nearby one within the shed buffer. Figure 14. represented Birmingham bus stops located within the pedestrian shed. Namely, if an individual was at one of the transit nodes, which bus stops they could access within walking distance. In terms of bus transportation, this was extremely important. As the BJCTA buses operate on nearly forty routes, it is unlikely that an individual would take a bus trip from one specific location to another specific location without having to transfer buses. Adding a bicycling aspect to the journey could potentially cut down on journey time, and falling in line with the goals of transit-oriented development reduce emissions, decrease traffic congestion, and create a healthier commute for the patron. For the BJCTA bus routes, 240 bus stops fell within the pedestrian sheds surrounding Zyp BikeShare docking stations. If pedestrians were to maintain the convention of a ¼ mile feasible walk around these transit nodes, bearing in mind that this is not exactly accurate based on considerations of where bus stops fall, they would maintain access to these 240 bus stops.

Figure 12. likewise included bicycle sheds around Zyp BikeShare docking stations. This allowed us to visualize the extension of transportation access from ¼ mile around a transit node to ¾ mile around a transit node. By tripling the extent of movement around each node, transportation access is greatly increased. In doing so, all of the Zyp bikeshare station locations are connected within the bicycle shed extent, meaning that trip viability been these hubs is much easier with the employment of bicycle technology. If individuals traveling within the downtown landscape were to utilize bikesharing technology, their range of movement would be dramatically increased. Figure 15. visualizes of BJCTA connections to the Zyp bicycle shed. By

increasing the buffer by three times to account for bicycle network improvements, the bicycle access network around Zyp stations then accounted for access to 440 BJCTA stops.

It is worth noting that in many cases individuals could walk from one bus stop to another in order to travel on different BJCTA routes. That being said, utilizing a Zyp bike may not be necessary. It is an important distinction that utilizing a bikesharing technology might not be a feasible or useful method of transportation for every type of commute. However, recent trends in transportation technology and a growing interest for sustainability in American cities support the hypothesis that technologies like Zyp are useful parts of urban infrastructure. As seen above, programs like Zyp may dramatically increase transportation connectability. Even if individuals were able to transfer buses or ride bus rapid transit (BRT) for the duration of a commute, the integration of technology like Zyp allows for user choice. Rather than being reliant on one form of transportation, people in the downtown area can now choose between bus and bike transportation. Figure 14. And Figure 15. highlighted the dramatic increase of BJCTA stops that have increased connections through the implementation of these initial Zyp stations. As Zyp stations continue to be added throughout the city, these connections will continue to grow.

Determination of land use adjacent to Zyp docking stations was important for initial considerations regarding Zyp use and placement. Further analysis included statistical analysis to examine land use in the light of usage trends.

4.5 Usage Trends

Analyzing and sorting data in terms of individual journeys and start and end destinations provided a good deal of insight into Zyp usage. For each Zyp docking station, we were able to determine the approximate count of times that each station connected to any other station in the system. Particularly, we considered the number of times that each bicycle that was checked out was returned to the same station as the origin. As a whole, we can assume that any bicycle returned to the same station it was removed from was used for recreational purposes or for a short trip with a duration of less than forty-five minutes. Overall, we determined that for each station, an average of 44% of bicycles were returned to the origin. While surprising, this lends insight into the nature of Zyp usage. While these users may not be utilizing Zyp as a transit connection because they are returning to the same origin, this is undoubtedly adding to community vitality. While Zyp patrons might have previously not ventured outdoors or used a vehicle to make a short commute to a store, the introduction of Zyp BikeShare provides an alternative method for short trips. Additionally, this lends to the "live-work-play" atmosphere important to transit-oriented development as it adds individuals to the community landscape and provides a method of recreation. Determination of the fact that nearly half of the users of the Zyp stations are utilizing the bicycles for point-to-same point trips suggests that consideration of bikesharing cannot simply be understood in the sense of transit connections and wider mass transportation, but also in the wider lifestyle trends and community development that transit-oriented developments seek to attract and support.

As understanding usage trends was a major part of this analysis, examining usage trends throughout the span of a day provided insight into Zyp BikeShare patron use reasoning and characteristics and was significant in understanding commute times and travel trends. We determined that the majority of bikeshare trips were occurring within the afternoon and evening hours. Thirty-seven percent of total Zyp bikesharing trips occurred between 3:00:00 pm and 6:59:59 pm.

Results from the Birmingham Bikeshare Feasibility Study conducted by the Regional Planning Commission of Greater Birmingham lend insight into travel trends associated with time of day and usage reasoning. In a survey of 188 individuals regarding anticipated use of a newly implemented bikeshare station, respondents were asked, “If bikeshare were available, throughout Birmingham what types of trips do you think you would use the bikes for?” Around 30.3% of respondents said that they would use bikesharing for going to work. Morning commute hours were underrepresented in the time of day analysis, which showed that while users were using the system in morning hours, a disproportional number of users were utilizing the system during afternoon and evening. Around 7% of bikeshare trips were taken between 7:00:00 am and 9:59:59 am (considered here to be morning commute hours).

A number of trips were also found to occur during late night hours. BJCTA buses run from 4:00 am to 11:30 pm on Monday-Friday and from 4:00 am to 12:00 am on Saturday. Buses do not run on Sundays or major holidays. Analysis of the distribution throughout the day suggests that Zyp is filling a late-night transportation gap in the city. The reduction of late-night automobile use has potentially major implications for the vitality and safety of the transit-oriented development network. TOD seeks to improve the “live-work-play” atmosphere of transit adjacent areas. With the integration of public transit infrastructure that is available at any time of day, increased ease of transit, and safety improvements associated with decreased automobile use at late-night hours, this allows users to live, work, or play at any hour.

Results of the Pearson’s correlation test showed a slight negative correlation between population and station usage. While limitations associated with the collection of Census data undoubtedly exist, this result was not unexpected when analyzing the system. As many of the trips within the system have been understood to occur for recreational purposes, these trips do not constitute a commute and would not necessarily commence beside a residential area. Likewise, some users are utilizing Zyp for point-to-point rentals where multiple bikes are checked out because of time limitations. Thus, any bikeshare trip taken after the first trip would not commence by the residence of the patron. The fact that this r-value was so close to zero suggested the relationship between these variables is almost random. This particular analysis once again supports the dual-use nature of Zyp, which occupies a niche in both transportation and recreation benefits in the city.

The results of the Independent-Samples Kruskal-Wallis tests conducted for start and end counts both resulted in us failing to reject the null hypothesis that no statistical difference was occurring across categories of land use for variations in patron start counts and end counts. While these results were initially surprising, they suggest that other factors may be holding more explanatory value in predicting where major bikeshare traffic and utilization is occurring. Infrastructural considerations such as bike lines and safe biking conditions, availability of bikes (pedelec versus standard bikes), and socioeconomic factors might be among other things affecting the distribution of patron start and end locations for bikeshare journeys. While land uses should not be eradicated completely for considerations of the bikesharing technology, it is an important distinction that they do not necessarily hold major predictive value for the system. Many studies of bikesharing systems have utilized land use considerations in an analysis of patron trends. However, this proves an essential point that bikeshare systems are extremely variable and have location-specific characteristics that vary based on implementation, community design, urban planning, cultural tendencies, and more. Further analysis should consider the importance of other variables in determining bikeshare patronage and usage trends.

Standard bicycles and pedelec bikes were compared in the analysis of usage trends. One of the major observed differences between standard bicycles and pedelec bicycles was the ability of pedelec for further and longer travel, as suspected due to the fact that pedelec bikes have electric-assist. It is understood that pedelec bicycles typically ease bicycle travel by providing riders with an electric boost. In examining usage characteristics between the two types of bicycles, we found that pedelec bikes offered a 33% increase in speed over standard bikes. In the analysis of transit-oriented development networks, we considered shed increases as a result of bicycling as a whole. As pedelec bicycles are not available at every station and exist in much smaller quantities that standard Zyp bicycles, representing pedelec trends was not representative of the experience of every bikeshare user. However, it is worth noting that pedelec bicycles are utilized frequently and offer an extended transportation network beyond even the extensions described in Figure 12.

Pedelec bicycles were also compared to standard bicycles to examine their value as a method of traversing more complicated landscapes. In creating a slope surface in ArcGIS, we were able to visualize which areas have changes in elevation. Evaluation of the Zyp docking station network in the context of elevation showed us that pedelec usage was undoubtedly higher in areas near slope changes and in docking stations that were more distant from centralized stations. This discovery suggests that pedelec bicycles are serving their purpose as a method for improving and expanding upon the standard usage of bicycles.

Another way by which use was examined was across patterns of membership. Many membership types exist within the Zyp BikeShare program. This is in order to target different populations, with the option to purchase just a short trip or the option to commit for a year at a time. Special memberships have existed throughout the initial months of patronage for brand ambassadors, community partners, and more. Additionally, membership is offered to patrons that are not able to pay membership fees. We suspected, as use determination might be different across these groups, that differences in usage trends would exist. The statistically significant results of the Chi-Square analysis supported the claim that bicycle type and categories of membership are related. This suggests that certain users are more likely to use pedelec bicycles than other types of users. In understanding this, this provides a further avenue for targeting specific users and marketing pedelec technology. The fact that some groups are more likely to use pedelec technology may be due to the fact that specific users are unaware of what pedelec technology is and the benefits of electric assist. Using a mapping analysis, we were able to examine the differences in miles traveled by bicycle type. In understanding this, we see once again that pedelec technology allows users to travel further in terms of distance. Through this visualization, it was clear that the categories had a good bit of variability in bicycle use. For instance, “Other” and “Zyp Ambassadors” had a much larger difference in users who utilized pedelec bicycles and standard bicycles that other categories of membership. This suggests that awareness plays a role in utilization of pedelec technology, as the community partners and ambassadors would undoubtedly have an awareness of electric technology. Knowledge of this allows for an understanding that marketing and awareness of new technological trends is necessary, as some patrons might be unware of the differences between the two bikes.

Likewise, 24-hour users traveled the longest distances, with a mixture of pedelec and standard bicycle use. It is more likely that long term users are utilizing Zyp for commute purposes, while short-term users are utilizing it for recreational purposes. Wider goals of transit-oriented development involve drawing people into areas surrounding transportation nodes and meeting the need for increased community vitality and decreased automobile dependence.

Assumptions regarding long-term patrons coupled with an analysis of users throughout the project suggest both an awareness of pedelec technology and a distribution near the bicycle docking stations. Determining short-term ridership is more difficult and requires more assumptions, but it is likely that many short-term riders are riding for tourism and recreation, as the cost associated with riding numerous times supports attaining a long-term membership for frequent patrons. While tourism has increased with recent revitalization efforts in the downtown Birmingham area, it is essential that many people are utilizing Zyp bikes as a means of tourism and recreation. In doing so, less people are driving between destinations. Both community health and environmental health benefits are reaped.

CHAPTER 5

CONCLUSION

The final objective of the design of this project was to examine lessons learned from this exploratory study. Data analysis is a very important method for analyzing a bikesharing system. We sought to prove that data can be analyzed in such a way as to understand the implications of a bikesharing system within a transit-oriented development and to provide a valuable methodology for future analysis. In this project, we examined Birmingham's Zyp BikeShare from a number of angles. While we sought to address various aspects of the program, the methodology used here was certainly not exhaustive and could be expanded to examine the Zyp user database that grows daily.

Determination of user catchment was an important strategy for the analysis of a bikeshare program. Here, a careful consideration of the distribution of the necessary parts of a bikeshare program was essential: equipment and patrons. In the replication of an exploration of bikesharing, these components will be key. Future analysis should consider a more comprehensive methodology for examining patron distribution if data is available.

Origins and destinations for travel played a major role in the exploration of Zyp BikeShare. In examining these start and end counts, we were able to determine areas where major patronage was occurring, as well as areas that were patronized less frequently. Further examination of start and end count trends and careful consideration of station characteristics can have major implications in the establishment and integration of new bikesharing infrastructure.

Transit path considerations were likewise essential in understanding the distribution of users as they move throughout the transit service area and urban landscape. Through a network analysis of Zyp bikeshare journeys, we were able to ascertain which stations experienced direct connections to other stations within the system. The results of data collection and analysis for connectivity showed station relationships that happened frequently. This or similar techniques are extremely useful for the integration and maintenance of bicycle and transit infrastructure in the city. Those seeking to determine which areas of a city receive clustering of bicycle traffic should consider using a network analysis. Understanding connection overlaps and heatmapping potential from this type of analysis will be critical in understanding the linkage of the vast network of bikeshare trips.

While an adequately planned bikeshare program would have undoubtedly included a feasibility study that considered existing transportation, visualizing transit infrastructure in the urban environment was exceedingly important. As even slight changes in infrastructure or land use can have a major impact on other transit infrastructure and trends, it is essential to consider infrastructure at all stages of the project. Here, we found that the recent introduction of an active transportation network through the center of Downtown Birmingham was both validated and is experiencing use in conjunction with Zyp BikeShare. Findings like this are made possible through transit considerations and mapping and have invaluable magnitude within the extent of a program like Zyp.

The use of buffers and consideration of bikesharing programs as an essential part of a transit-oriented development system was paramount in this project. The application of buffers around transit nodes was an effective method for simplifying and visualizing TOD trends. Many sources of funding for bikesharing programs involve the inclusion of populations with a critical transit need. Through the application of buffers, we were able to determine that the introduction of bicycles to the planning environment could potentially triple the extent of sheds in the area. In doing so, critical first and last mile connections can be made. In conjunction with the Access for All program through Zyp, establishing the fact that the program encourages transit connections and meets this critical need could be extremely important in funding and advertising for such a program.

Use determination is an important consideration, as understanding a target demographic is essential for increasing patronage, applications for funding, and meeting the needs of a community. Likewise, this ensures that bikeshare employees do not target demographics without a need or that are already being targeted. Through a consideration of origins and destinations and usage trends throughout the day, we found that a seemingly equal division of the population was utilizing Zyp for recreation and commute or travel from one point to another. The completion of this study substantiated the fact that a user survey which questions use determination would be a more specific and accurate method for examining use determination. Further studies and replicated projects should consider methodology used here and reflect on possibilities associated with more specific knowledge of bikeshare use.

Statistical analysis in this project determined that land uses and population were not necessarily linked to patronage. This is interesting, as a review of the literature suggested the analyses of other bikeshare systems found a link between these variables. This was extremely valuable as it substantiates the fact that each bikesharing program is extremely dependent on the unique aspects of each community. While certain evaluations can be replicated, an individual consideration of each is essential to account for differences that are a result of the distinctive attributes of each city. While the results for these analyses were not the same for Birmingham as many other cities, this is still a critical consideration to make to consider what aspects of a community are affecting or could affect the patronage of a bikeshare program.

Examination of Zyp users by time of day was perhaps one of the most insightful analyses of this project. Simple consideration of user trends suggested the division between both recreation and commute use determination in the city. Likewise, we found that Zyp was filling a potential late night transportation need, with trips being taken late at night when BJCTA buses are not in service. Time of day considerations will allow those analyzing such a project to examine the selected bikeshare program in the light of its role in a "live work play" community and as a critical part of community vitality as supported by its role as a part of the transit-oriented development in the area.

The selling point of many new and proposed bikeshare systems is the inclusion of pedelec, or electric-assist bicycles. These bicycles are cited as important for their value in allowing patrons to move faster and across more complicated landscapes. Specific analysis of pedelec bicycles is useful in providing statistics to support the establishment and sustainability of a bikeshare program. Analysis of bicycle use across the slope surface supported the notion that pedelec bicycles extend the possibilities of regular bicycles. For a particular system's proposal or analysis, such a visualization supports the value of including pedelec technology in implementation. Further analysis of patronage and pedelec bicycle usage showed us that bicycle type usage differences across categories of membership. Knowing this is important in understanding which demographics to target with more specific information on pedelec bicycles. As bikeshare technology is a new and growing area of transit infrastructure, it is likely that many people are unaware of what pedelec bicycles are, and understanding this lends value to advertising and marketing for community development surrounding the bikeshare program.

Implementation of a new bikeshare system and the study thereof are not without limitations. A number of limitations for the system were cited directly by Zyp employees. A particular complication of 3rd generation and the future of bikesharing is the reliance on technology (O. Hart, personal communication, April 15, 2016). Zyp BikeShare is a technology heavy program that relies on the data working consistently at all times. When network errors occur, data recording errors likewise occur and misrepresent data. Similarly, users may not be able to physically utilize bikesharing technology fully when a technological error occurs as use of the program relies on using a computer powered docking station and bicycle. When analyzing this project, technological considerations were important. In many cases, data recording errors prevented us from fully analyzing data on bikeshare trips. Throughout our analysis, we were forced to disregard trips recorded as "Undetermined" as origin and/or destination could not be determined. While not a major implication for the success of the program, technological limitations were undoubtedly important in this consideration of bikesharing use.

Additional limitations include timing. According to Zyp employees, the implementation of Zyp BikeShare in Birmingham took over two years. Implementation and integration is a continuous process that must work to exist and thrive within the ever-changing urban environment. With infrastructural changes in the service area, bikes in the adjacent areas are likewise affected. Programs like this are forced to be ever-aware of changes happening in the nearby environment and react to those changes as necessary. As timing is often an issue associated with this, thoughtful consideration of the urban environment is necessary to anticipate future changes and plan for a system that can easily adapt and react to these changes. In analyzing data regarding use, timing is undoubtedly a limitation. The Zyp system is continuously collecting data. Thus, speedy and deliberate analysis is necessary to encompass current trends in bikesharing, as new data is recorded by the Zyp system in real-time as each user checks out a bike.

The anonymous nature of bikesharing data collection likewise provided limitations. While an exploratory analysis of Zyp was certainly possible without more specific information regarding riders, demographics, use determination, and more, the addition of these details to the exploration would undoubtedly add value to the study. Future research involving social surveys to discuss bikesharing after the implementation of the system to the city would be beneficial to analyzing and supporting many of the claims made in this project.

Analysis of Zyp BikeShare has shown that the bikesharing program has been experiencing success in its first months. This system has received media attention, reached ridership goals set forth by the system, and a number of lessons have been derived from the analysis of this system. We suspect that an analysis of a new type of transit-oriented development technique that is quickly taking off in American cities will aid future planners and developers in the implementation and evaluation of the growing network of bikeshare programs.

The future of bikesharing programs will depend on the analysis of data made possible through third and fourth generation bikesharing technology. As data collection techniques mature, we expect this preliminary evaluation can be taken further to include a more comprehensive approach to understanding the implementation, maintenance, and limitation of such a system. If a similar project was undertaken, or if this project was replicated for Zyp in the future, researchers could consider the adoption of techniques such as social surveys, evaluation of GPS data, and seasonal changes in bikesharing. As Zyp BikeShare approaches its one-year anniversary, the program serves as a shining example for the possibilities of bikesharing in an urban community. Through the evaluation of such a program, we hope to encourage the use of such a program and foster positive change in the study of this important and growing component of transit-oriented development.

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APPENDIX 1: Zyp BikeShare Stations

14th St N and 8th Ave N
14th St S & 14th Ave S
14th St S & 6th Ave S
17th St N & 2nd Ave N
17th St S & 5th Ave S
18th St & 6th Ave N
18th St S & 1st Ave S
20th St N & 5th Ave N
20th St S & Highland Ave
20th St S and 2nd Ave S
20th St S and University Blvd
23rd St N and 2nd Ave N
24th St and 7th Ave S
24th St N & 6th Ave N
25th St N & 1st Ave N
29th St S & 7th Ave S
30th St S & Highland Ave S
41st St S & 3rd Ave S
Birmingham Central Library
Birmingham-Jefferson Co Transit
City Hall
Civil Rights Institute
Forest Park
Innovation Depot
McWane Science Center
Memorial Park Recreation Centre
Pepper Place
Railroad Park / Regions Field
Richard Arrington & 4th Ave N
Sloss Furnaces
The Kirklin Clinic
UAB Green South
Undetermined
Uptown at BJCC

APPENDIX 2: Zyp Origin and Destination Counts

Location	Start Count
14th St N and 8th Ave N	156
14th St S & 14th Ave S	429
14th St S & 6th Ave S	453
17th St N & 2nd Ave N	411
17th St S & 5th Ave S	639
18th St & 6th Ave N	316
18th St S & 1st Ave S	4560
20th St N & 5th Ave N	1435
20th St S & Highland Ave	533
20th St S and 2nd Ave S	2858
20th St S and University Blvd	1855
23rd St N and 2nd Ave N	2277
24th St and 7th Ave S	854
24th St N & 6th Ave N	176
25th St N & 1st Ave N	259
29th St S & 7th Ave S	2213
30th St S & Highland Ave S	618
41st St S & 3rd Ave S	2679
Birmingham Central Library	562
Birmingham-Jefferson Co Transit	231
City Hall	543
Civil Rights Institute	521
Forest Park	531
Innovation Depot	885
McWane Science Center	1934
Memorial Park Recreation Centre	53
Pepper Place	2698
Railroad Park / Regions Field	5656
Richard Arrington & 4th Ave N	699
Sloss Furnaces	155
The Kirklin Clinic	1040
UAB Green South	581
Undetermined	2310
Uptown at BJCC	356

Location	End Count
14th St N and 8th Ave N	189
14th St S & 14th Ave S	440
14th St S & 6th Ave S	452
17th St N & 2nd Ave N	470
17th St S & 5th Ave S	691
18th St & 6th Ave N	323
18th St S & 1st Ave S	4751
20th St N & 5th Ave N	1470
20th St S & Highland Ave	555
20th St S and 2nd Ave S	2959
20th St S and University Blvd	1950
23rd St N and 2nd Ave N	2372
24th St and 7th Ave S	869
24th St N & 6th Ave N	220
25th St N & 1st Ave N	288
29th St S & 7th Ave S	2347
30th St S & Highland Ave S	569
41st St S & 3rd Ave S	3023
Birmingham Central Library	584
Birmingham-Jefferson Co Transit	241
City Hall	536
Civil Rights Institute	540
Forest Park	575
Innovation Depot	862
McWane Science Center	2062
Memorial Park Recreation Centre	68
Pepper Place	2883
Railroad Park / Regions Field	5918
Richard Arrington & 4th Ave N	765
Sloss Furnaces	188
The Kirklin Clinic	1001
UAB Green South	658
Undetermined	273
Uptown at BJCC	393

APPENDIX 3: Docking Station Connectivity Matrix

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG
A	1	0	1	1	1	1	0	0	1	1	1	0	1	1	1	0	0	1	1	1	1	0	1	1	1	0	1	0	1	1	0	1	1
B	1	1	1	1	0	1	0	0	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	0	0	1	1	1
C	0	1	0	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1
D	0	0	1	0	1	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1	0	1	0	1	0	1	0	1	1	0	1	1	1
E	0	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1	1	1	1	1	1	0	1	1	1
F	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1	1	1	0	1	0	1	1	0	1	1	1	0	1	0	0
G	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	0	1	1	0
H	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1
I	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	0	1	1	1
J	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
K	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1
L	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1
M	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	0	1	1	1	0	1	0	0
N	0	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1
O	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	0
P	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0
Q	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1
R	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
T	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1	1	0	1	1	1	0	1	0	1
U	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
V	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0
W	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	1	1	0
X	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Y	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Z	0	1	0	0	1	0	1	1	1	1	1	0	1	1	0	1	0	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
AA	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1
BB	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
CC	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
DD	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	1	1	1	1	0
EE	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1
FF	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1
GG	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1

Appendix 3 Legend

Symbol	Station
A	14th St N and 8th Ave N
B	14th St S & 14th Ave S
C	14th St S & 6th Ave S
D	17th St N & 2nd Ave N
E	17th St S & 5th Ave S
F	18th St & 6th Ave N
G	18th St S & 1st Ave S
H	20th St N & 5th Ave N
I	20th St S & Highland Ave
J	20th St S and 2nd Ave S
K	20th St S and University Blvd
L	23rd St N and 2nd Ave N
M	24th St and 7th Ave S
N	24th St N & 6th Ave N
O	25th St N & 1st Ave N
P	29th St S & 7th Ave S
Q	30th St S & Highland Ave S
R	41st St S & 3rd Ave S
S	Birmingham Central Library
T	Birmingham-Jefferson Co Transit
U	City Hall
V	Civil Rights Institute
W	Forest Park
Y	Innovation Depot
Y	McWane Science Center
Z	Memorial Park Recreation Centre
AA	Pepper Place
BB	Railroad Park / Regions Field
CC	Richard Arrington & 4th Ave N
DD	Sloss Furnaces
EE	The Kirklin Clinic
FF	UAB Green South
GG	Uptown at BJCC

APPENDIX 4: Origin returns by station

Station	**Same Start/End (%)**
14th St N and 8th Ave N	53
14th St S & 14th Ave S	41
14th St S & 6th Ave S	42
17th St N & 2nd Ave N	39
17th St S & 5th Ave S	41
18th St & 6th Ave N	68
18th St S & 1st Ave S	42
20th St N & 5th Ave N	40
20th St S & Highland Ave	35
20th St S and 2nd Ave S	36
20th St S and University Blvd	33
23rd St N and 2nd Ave N	35
24th St and 7th Ave S	38
24th St N & 6th Ave N	54
25th St N & 1st Ave N	33
29th St S & 7th Ave S	40
30th St S & Highland Ave S	40
41st St S & 3rd Ave S	48
Birmingham Central Library	47
Birmingham-Jefferson Co Transit	53
City Hall	44
Civil Rights Institute	54
Forest Park	49
Innovation Depot	41
McWane Science Center	37
Memorial Park Recreation Centre	75
Pepper Place	37
Railroad Park / Regions Field	49
Richard Arrington & 4th Ave N	32
Sloss Furnaces	50
The Kirklin Clinic	41
UAB Green South	46
Uptown at BJCC	49

APPENDIX 5: Land Uses by Docking Station

Location	Primary Land Use	Secondary Land Use	Tertiary Land Use
14th St N and 8th Ave N	Public/Semi-Public	Light Industry	
14th St S & 14th Ave S	Parks/Recreation	Multi-Family	Single-Family Detached
14th St S & 6th Ave S	Public/Semi-Public	Utility	
17th St N & 2nd Ave N	Utility	Commercial	Auto Parking
17th St S & 5th Ave S	Auto Parking		
18th St & 6th Ave N	Office	Public/Semi-Public	
18th St S & 1st Ave S	Parks/Recreation		
20th St N & 5th Ave N	Office	Public/Semi-Public	
20th St S & Highland Ave	Commercial		
20th St S and 2nd Ave S	Multi-Family	Auto	
20th St S and University Blvd	Public/Semi-Public	Auto Parking	
23rd St N and 2nd Ave N	Commercial	Multi-Family	
24th St and 7th Ave S	Commercial	Auto	
24th St N & 6th Ave N	Parks/Recreation	Multi-Family	
25th St N & 1st Ave N	Auto	Commercial	
29th St S & 7th Ave S	Single Family Detached	Commercial	
30th St S & Highland Ave S	Parks/Recreation	Multi-Family	
41st St S & 3rd Ave S	Commercial		
Birmingham Central Library	Public/Semi-Public	Parks/Recreation	
Birmingham-Jefferson Co Transit	Commercial		
City Hall	Public/Semi-Public	Parks/Recreation	
Civil Rights Institute	Public/Semi-Public	Parks/Recreation	
Forest Park	Commercial	Single-Family	Multi-Family
Innovation Depot	Auto	Warehouse/Storage	
McWane Science Center	Public/Semi-Public	Commercial	
Memorial Park Recreation Centre	Parks/Recreation	Public/Semi-Public	
Pepper Place	Auto	Warehouse/Storage	Industrial
Railroad Park / Regions Field	Parks/Recreation		
Richard Arrington & 4th Ave N	Commercial	Public/Semi-Public	
Sloss Furnaces	Light Industry	Open Space/Passive Recreation	
The Kirklin Clinic	Office	Auto Parking	
UAB Green South	Public/Semi-Public		
Uptown at BJCC	Commercial		