Understanding Cyclist Perceptions of Road Adjacent Shared-Use Paths: A Comprehensive Study of Both Stated and Revealed User Preferences

by

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Abstract

Road adjacent shared-use paths are a valuable transportation facility for rural and suburban communities looking to reap the benefits of increased active transportation. Shared-use paths have the ability to immediately accommodate multiple types of active transportation users all within one facility and separated away from the hazards of motor vehicles. However, there are known operational challenges when they are implemented adjacent to a roadway and many regular cyclists do not prefer them as they generally increase travel time and require mixing with slower moving path users. With these known conflicts, transportation agencies are unclear if a shared-use path is the right decision for their particular project or community. Additionally, most active transportation research and practice is focused on urban solutions that have very different needs than those in rural and suburban communities. Therefore, this dissertation provides a comprehensive analysis of user perceptions of road adjacent shared-use paths that will allow transportation professionals to better understand the needs of the varying types of path users.

Using a stated preference survey along with a big data revealed bike share analysis, a new framework guidance plan for implementing road adjacent shared-use paths was developed. This new framework is based on entirely originally collected data and analysis that documents the preferred physical conditions for a road adjacent shared-use path as well the preferences of different users. The majority of users were shown to have a preference towards road adjacent shared-use paths compared to non-separated facility options. Additionally, those shown to prefer road adjacent shared-use paths were the least confident user type who needs more accommodations to increase their amount of active travel.

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List of Abbreviations

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
ADA	Americans with Disabilities Act
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GIS	Geographic Information System
GPS	Global Positioning System
ISTEA	Intermodal Surface Transportation Efficiency Act
ITE	Institute of Transportation Engineers
KML	Keyhole Markup Language
LTS	Level of Traffic Stress
MPH	Miles Per Hour
MUTCD	Manual on Uniform Traffic Control Devices
NACTO	National Association of City Transportation Officials
NYC	New York City
PROWAG	Public Rights-of-Way Accessibility Guidelines
SIM	Subscriber Identification Module
UCLA	University of California, Los Angeles
USDOT	United States Department of Transportation

Chapter 1: Introduction

Transportation agencies are promoting active transportation, notably cycling and walking, to address environmental (Woodcock et al., 2009; Hartog et al., 2010), health (Bassett et al., 2008; Physical Activity Guidelines Advisory Committee, 2008; Kelly et al., 2014), economic (Litman, 2003; FHWA, 2014), equity (Sandt et al., 2016) and traffic congestion challenges (Twaddell et al., 2016). At the national, state and local levels, policy, land use, and program initiatives are all ongoing to increase cycling and walking, especially in suburban and exurban communities that have an overwhelming dependency on motor vehicle travel. These efforts have marginally paid off as there has been a small increase overall in the share of walking and cycling trips nationwide (U.S. DOT, 2017; ACS, 2014). However, there is still a heavy reliance on motor vehicle travel with the latest National Household Travel Survey reporting over eighty percent of trips made via motor vehicle (U.S. DOT, 2017). Researchers are looking for opportunities to increase active transportation, namely cycling, which currently only accounts for 1% of trips nationwide.

One major initiative to encouraging additional cycling is building enhanced bicycle infrastructure. Research has shown the quality and type of bicycle infrastructure plays a significant role in an individual's decision to choose a bicycle over other transportation modes, namely a motor vehicle (Dill & Carr, 2003; Buehler & Hamre, 2014). There are many types of bicycle facilities – from shared streets, where cyclists ride among motor vehicles; to conventional bicycle lanes, where a striped line separates cyclists from motor vehicles; to separated facilities which provide a physical separation between cyclists and motor vehicles. In an effort to engage the most potential users, recent emphasis has been on separated facilities with research finding many cyclists prefer separated bicycle facilities to that of a non-separated facility such as a conventional bicycle lane (Akar & Clifton, 2009; Goodno, et al., 2013; Buehler & Dill, 2015).

Separated bikeways and protected cycle tracks are two popular types of separated bicycle facilities that can be either one or two-way and provide a dedicated space for cyclists separated by a curb, landscape or other barrier from both pedestrians and motor vehicles. These facilities are commonly found in urban locations, as they support high pedestrian and cyclist volumes within constrained right of ways. However, separated facilities are also being implemented in suburban contexts through shared-use paths. Shared-use paths provide a travel area separated from motor vehicle traffic, but unlike other separated cycling facilities, are simultaneously used by multiple non-motorized transportation users including pedestrians, bicyclists, skateboarders and others (Hummer et al., 2006). Many times, shared-use paths are constructed for recreational purposes away from a roadway. However, they are also being implemented parallel to roadways to accommodate active transportation within a right-of-way that in many cases does not provide any non-motorized facilities.

Road adjacent shared-use paths are surprisingly complex in nature with limited existing design guidance. On one hand, shared-use paths are the most separated bicycle facility option, allowing cyclists to fully operate away from motor vehicle traffic and thus making them appealing to less confident cyclists. On the other hand, there are known operational challenges between the path users themselves (Aultman-Hall & LaMondia, 2005) and with motor vehicles when located adjacent to a roadway (AASHTO, 2012; Rome et. al., 2013; Teschke et al., 2014). Additionally, it is currently unclear how different cyclist behaviors vary related to adjacent shared-use path design characteristics. Therefore, the goal of this dissertation is to understand how the different cyclist types perceive and use road adjacent shared-use paths. This understanding will empower transportation decision makers with a tool to inform them if a shared-use path is the appropriate facility for a specific location, demographic or project. To achieve this goal, this dissertation has three objectives:

- First, use self-reported path user preferences from a travel survey to identify significant individual and physical environmental factors influencing stated-use, satisfaction and perceived safety of a road adjacent shared-use path.
- Second, use a big-data revealed cyclist typology and observed cyclist routes to identify significant individual, pathway and roadway factors influencing observed non-separated and separated facility choices.
- Third, synthesize the stated and revealed factors to generate a framework for appropriately selecting and implementing road adjacent share-use paths that support the complex needs of varying cyclist types.

1.1 Dissertation Objectives

The results from this dissertation will help transportation officials consciously determine if a road adjacent shared-use path is the appropriate choice for a particular project based on the project goals and local demographics. With varying cyclist types having different infrastructure preferences, it is critical to understand both what all user types say they desire in road adjacent shared-use paths as well has how they are actually using this specific type of bicycle facility. The overall goal to provide guidance on shared-use path implementation based on roadway and user characteristic is achieved through three objectives and methodologies (seen in Figure 1).

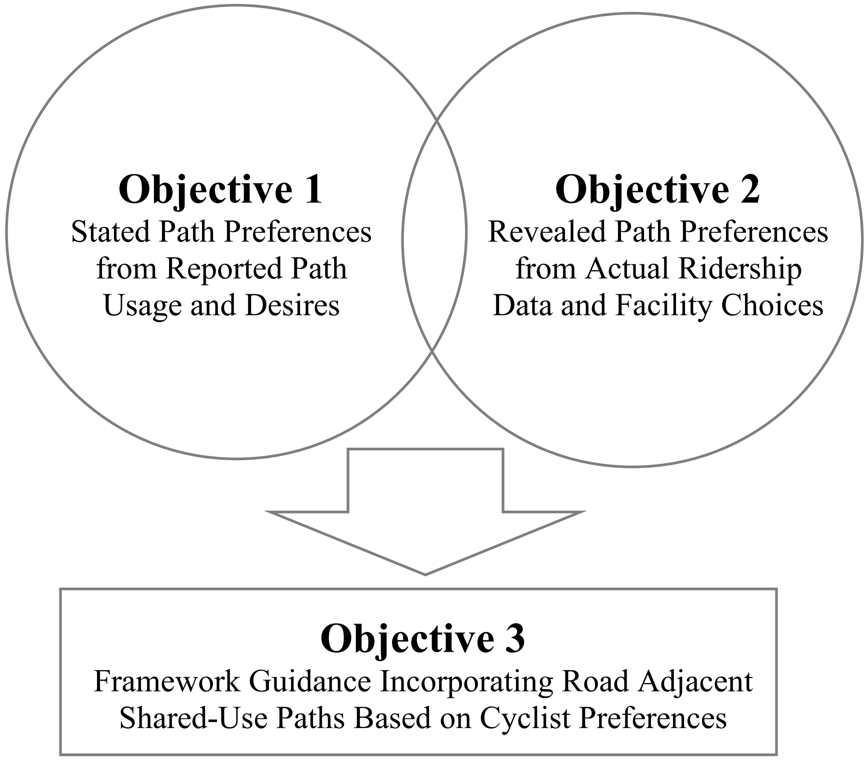


Figure 1: Dissertation Objectives Exhibit

The first objective utilizes an original stated preference survey of more than 300 active shared-use path users in the Auburn, Alabama area to gain insight on user perceptions of road adjacent shared-use paths. The survey specifically examines the perceptions of the shared-use path based upon key design parameters (path width, path material and offset from the roadway) along with the user's self-reported activity levels. The survey design provides multiple images of shared-use paths displaying the various combinations of design variations and asks how they impact the stated use, satisfaction and perceived safety of the shared-use paths. An ordered logistic regression model was selected to analyze the data and determine which variables impact the user's perception of stated-use, satisfaction, and safety. The variables analyzed include user demographics, active travel tendencies, and the path components to give a broad view of the perceptions including but beyond just the physical components.

The second objective is to analyze when and why cyclists choose to utilize separated facilities including road adjacent shared use rather than non-separated options (or vice versa). The revealed preference study utilizes three years' worth of ridership data obtained from the campus bike share program at Auburn University named War Eagle Bike Share. A campus bike share program provides a unique perspective with the members themselves being the next generation of transportation users and most likely less experienced (or they would be riding their own bicycles) but interested in cycling (or they would not be participating in the program). The dataset includes almost 9,000 users and over 100,000 trips with the route location of the trips tracked with point data in totaling almost 9 million points. This big data allowed for an execution of a detailed geographic information systems (GIS) analysis to determine the ridership and route information for all users and execute a cluster analysis to develop four new user typologies based on actual ridership information. These new typologies along with variables of the physical environment (roadway features, traffic conditions and path characteristics) are used to determine if a cyclist chose to use a separated facility such as a shared-use path or sidewalk or on a non-separated facility whether that be a conventional bicycle lane or shared lane condition. Each study location contains varying roadway conditions including speed limit, number of lanes, vehicular traffic volume, and width of bicycle lane along with varying non-roadway conditions including path width and offset distance from the roadway. The choice between a non-separated and separated facility selection was analyzed with a binary regression model. This regression model includes the independent variables that make up the physical environment (of the path and the adjacent roadway), the trip information, and user information including the new bike share typologies. The model provides valuable insight into which parameters influence a cyclist in whether they feel comfortable riding on the road or separated on an adjacent shared-use path or sidewalk.

The third objective combines the findings from the previous two analyses to develop a framework of typical road adjacent shared-use path configurations based on the preferences of various cyclist types. The framework guidance provides a valuable reference for transportation agencies, engineers and planners considering road adjacent shared-use paths. This new information, along with an understanding of the community's cycling needs, will help make more informed decisions whether to recommend a road adjacent shared-use path.

1.2 Dissertation Organization

This dissertation is organized with six subsequent chapters following this initial introduction. The next chapter provides a thorough background literature review with topics that include: 1) past and present cycling policies in the United States; 2) overview of the various bicycle facility types; 3) comparison between separated versus non-separated bicycle facility preferences; 4) review of the different cyclist types and abilities; 5) exploration of the role of bike share programs and their users; 6) current design guidance for shared-use paths; and 7) past shared-use path research. After the literature review, the main body of the dissertation will be covered in chapters three through six. Chapters three and four cover the first two objectives previously described. Meanwhile, chapter five provides a case study using the bike share data analyzed in the chapter four for at one specific location. West Samford Avenue on the Auburn University campus contains both a road adjacent shared-use path and a conventional bicycle lane for approximately 1.1 miles. It is unusual to have a location that provides two of the most common rural or suburban bicycle accommodations parallel to each other. With this unique setting, a further detailed study was conducted to understand which users prefer to use the more direct bicycle lane or the physically separated shared-use path. This chapter adds to the understanding of the comprehensive nature of this user analysis where there will be a complete view of how users perceive and also embrace road adjacent shared-use paths.

Chapter six takes the information from chapters three, four and five and creates a framework guidance plan for typical road adjacent shared-use path configurations based on varying preferences and confidence cycling levels. The framework guidance plan provides a high-level structure for transportation policy and project decision makers to better understand which users will be served given a specific roadway and path configuration. The final chapter details the overarching conclusions and take-aways from the dissertation. The chapter will not only summarize the findings from the previous chapter but also provide overarching guidance to transportation practitioners on how they can use this new information and also to future researchers on how to build upon it.

Chapter 2: Background

Despite the recent modest increase in pedestrian and cycling trips nationwide, the United States continues to have among the lowest share of active transportation trips compared to other western civilization countries leading to public health problems from inactive and sedimentary lifestyles (Buehler & Pucher, 2012). Furthermore, the United States has the highest fatality and serious injury rates for walking and cycling compared to these peer countries (Pucher & Buehler, 2016; Buehler & Pucher, 2017). Many researchers point to adding separated bicycle infrastructure to make advances in correcting both statistics. While studies have found the presence of conventional bicycle lanes do increase the number of bicycle commuters (Dill & Carr, 2003), recent research and practice has looked toward countries with high cycling levels such as the Netherlands, Germany, Switzerland and Denmark to influence United States active transportation infrastructure improvements. As a percentage of all trips, cycling accounts for less than 1% of trips in the United States as compared to those countries where cycling accounts for more than 10% of the trips (Buehler & Pucher, 2017). Policy, land-use and demographic variables are all key components in increasing cycling but a major difference between the United States and those countries is the practice of physically separating bicycle facilities from motor vehicle traffic (Pucher & Buehler, 2008).

There are different types of separated cycling facilities with the focus of this dissertation specifically on shared-use paths. Shared-use paths are, as the name describes, simultaneously shared by all non-motorized user types. Shared-use paths have been used to serve many functions. At times, shared-use paths are located in settings away from a roadway such as along an existing or abandoned railroad or utility corridor, inside a park, or along a stream or other natural resource. While shared-use paths in these settings could provide an important transportation link as part of an overall network, they are typically used primarily for recreation and exercise. Typically, the most direct route for a cyclist to a particular destination is along a roadway corridor. To promote more utilitarian bicycling trips that replace trips that would have been made in a motor vehicle, shared-use paths are increasingly located alongside a roadway (often referred to as sidepaths) (AASHTO, 2012). Even with documented operational issues due to conflicts with turning motorists not anticipating the bi-directional path of users traveling in the opposite direction (AASHTO, 2012), shared-use paths provide a viable infrastructure option for suburban or rural communities that generally have more adjacent right-of-way, lower pedestrian and cycling users, and less overall density. In many cases, roadway corridors in these areas have no bicycle or pedestrian infrastructure in place, making shared-use paths an intriguing option for these communities to address the needs of both cyclists and pedestrians.

This background section consists of seven connected topics that will lay the foundation for satisfying the dissertation's three objectives and overall goal. The first topic highlights the history of the United States transportation policies and practices that have influenced bicycle and pedestrian facility development and implementation. This is an important area as this history is key to understanding the current practice of designing pedestrian and bicycle facilities. This will lead into the second topic documenting the various types of cycling facility types and a third topic that specifically explores the difference between separated and non-separated bicycle facilities. The fourth topic covers the past and current understanding of the different types of cyclists. Cyclists have varying infrastructure needs and preferences based on their experience levels and trip purpose. To accommodate cyclists sufficiently, there needs to be a clear understanding of the different types of cyclists. The fifth topic highlights the rise of bike share, and its role both in modern active transportation and also in research and understanding cyclist's infrastructure preferences. The sixth section specifically documents the current design standards specifically for road adjacent shared-use paths. The final background topic, and likely most important, will provide a summary of the past research efforts connected to this dissertation's topic on shared-use path preferences. This research review will explore past research methods for data collection, analysis and methodology, and results from past research efforts.

2.1 United States Multi-modal History

Even though recent practice, research and policies in the United States have advocated for or required accommodating pedestrians and bicyclists in new roadway designs (FHWA, 2010), transportation facilities have not historically accommodated the needs of other transportation modes beyond motor vehicles since the early 20th century. Cycling initial growth in the United States occurred in the 1890s due to the development and popularity of the safety bicycle (Herlihy, 2004). Around the turn of the century, cycling popularity continued to grow which led to infrastructure initiatives championed by the League of American Wheelmen to pave city roads for smoother travel and construct bicycle-only paths like in Brooklyn in 1895 connecting Prospect Park and Coney Island (Herlihy, 2004). These infrastructure initiatives fell quickly with the spread of the personal automobile in the early 1900s. The previously shared city streets became more congested and the conflict between motorized and non-motorized users began with pedestrians blaming the rich "joy-riders" and motorists irritated by the boorish "jay-walkers" (Norton, 2014). Throughout the 1900s the use of the automobile spread and the use of cycling as a mode of travel decreased but was still used for recreation. Illinois constructed 40 miles of trails through forest preserves outside of Chicago and New York City opened a cycle path in Central Park and paved over 20 miles of inner-city pathways all in the early 1900s

(Herlihy, 2004). With growth of personally owned automobiles, by 1930 most roadways were used almost solely for vehicular traffic (Schloemer, 2015). Furthermore, what later became known as the mandatory sidepath law and an important part of the United States' multimodal history, the 1944 Uniform Vehicle Code included a provision that "Wherever a usable path for bicycles has been provided adjacent to a roadway, bicycle riders shall use such paths and shall not use the roadway." Most states have since repealed such language with a few exceptions, including Alabama (where most of the data for this dissertation was collected) that still includes this provision in the state code (Alabama Constitution of 1901, Title 32)

The subsequent decades saw roadway infrastructure improvements geared almost entirely towards the automobile until the late 1960s. During the late 1960s and early 1970s there was a slight increase in cycling activity following decades of stagnation for a number of reasons, including improved bicycle technology, fitness advocates, and the energy crisis (Longhurst, 2017). In Davis, California, public works and university officials were the first in the United States to create a city-wide cycling network (Buehler & Handy, 2008). Their experimentation in accommodating cycling included both non-separated bicycle lanes as well as separated facilities similar to the European models with separated bicycle paths as well as road-adjacent shared use path (Pucher & Buehler, 2012). Lawmakers and researchers took notice of the new roadway concepts implemented in Davis and two separate groups published reviews and recommendations in 1972 based upon evaluating the Davis bicycle network. The *Bikeway Planning Criteria and Guidelines* from the University of California, Los Angeles (UCLA) evaluated the Davis methods along with international guidance and research and concluded that protected bicycle facilities resulted in increased bicycle safety and increased ridership while also noting that the protected facilities required additional treatments at some intersections due to a higher number of bicycle crashes with motor vehicles (Fisher et al., 1972). The DeLeux Cather study separately concluded that bicyclists and motorists preferred roadways with bicycle lanes and that separated bicycle facilities provided an increased user comfort (DeLeux Cather, 1972). These two publications were key components of the first American Association of State Highway and Transportation Officials (AASHTO) Bicycle Guide in 1974 (Schultheiss et al., 2018). The 1974 AASHTO Bicycle Guide recommended non-separated bicycle lanes as the preferred facility type due to the previously noted conflicts in the separated facilities. It also suggested bicycles lanes be used on roadways with motor vehicle volumes exceeding 2000 annual average daily traffic; motor vehicle speeds were greater than 30 miles per hour; and bicycle volumes were greater than 200 per day. While non-separated bicycle lanes were the preferred type, the 1974 AASHTO Bicycle Guide recognized separated facilities provide a more positive means of controlling motor vehicle encroachment.

These new bicycle facilities in the United States were not without its critics. Led most famously by John Forester, an avid road cyclist, there was concern that these new bicycle networks developed would require avid cyclists to operate on narrow sidewalks and deficient pathways citing the 1944 Uniform Vehicle Code (Longhurst, 2017). Forester vehemently opposed separated bicycle facilities arguing they were not safe and that bicycles should operate in the roadway and be treated as a motor vehicle (Forester, 2012). Forester's advocacy greatly influenced the creation of another California-based bicycle facility manual, the 1978 CalTrans Guide, which was the key document in updating the AASHTO Bicycle Guide in 1981 (Schultheiss et al., 2018). The updated guidance manual took a dramatic shift to the language in the original 1974 document increasing the design speed from 15 to 30 miles per hour and prohibiting protected bicycle lanes. Similarly, the 1991 update continued the prohibition of protected bicycle lanes and extended it by discouraging the construction of the road adjacent shared-use paths or sidepaths. From these revised policies and guidance, the 1980s saw diminished federal spending for new research or bicycle projects (Schultheiss et al., 2018).

Changes occurred following the 1991 passing of the federal transportation act, Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA compelled states and metropolitan planning organizations to provide bicycle and pedestrian accommodations within their transportation planning. It also required states to designate a bicycle coordinator, and specifically identified funding to transportation infrastructure for cycling and walking. Under ISTEA, $972 million of federal expenditures were allocated toward cycling infrastructure from 1992 – 1997, compared to $41 million in federal spending from the previous 20 years (FHWA, 2002). Moreover, 86% of the bicycle spending was used for separated paths and trails with the remainder used for non-separated facilities (Pucher, et al, 1999).

The 1999 update to the AASHTO Bicycle Guide was the first edition following the passing of ISTEA and acknowledged the different experience and confidence levels of cyclists for the first time by identifying the need for protected facilities on certain roadways for the less confident riders (Schultheiss et al., 2018). A subsequent update to the AASHTO Bicycle Guide in 2012, in addition to numerous other publications that will be discussed in the background section covering current guidance, have included more progressive language and encouragement for separated bicycle facilities. These policy changes and designated funding has led to increased cycling levels, even doubling or tripling in many American cities since 1990 (Pucher & Buehler, 2012). More recently, the American Community Survey has documented increased cycling nationally by 61.6% from 2000 to 2012 with a total of 865,000 Americans commuting via bicycle (McLeod, 2013). The FWHA has since published a Strategic Agenda for Pedestrians and

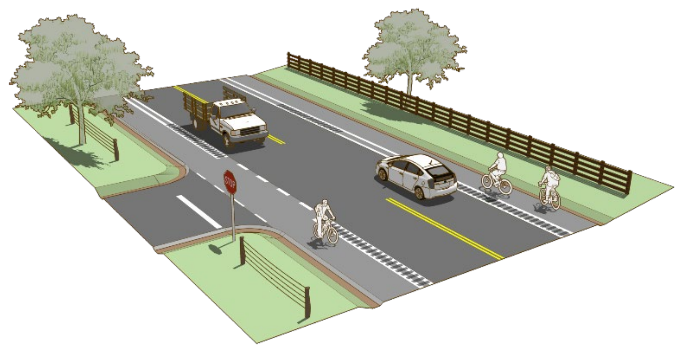
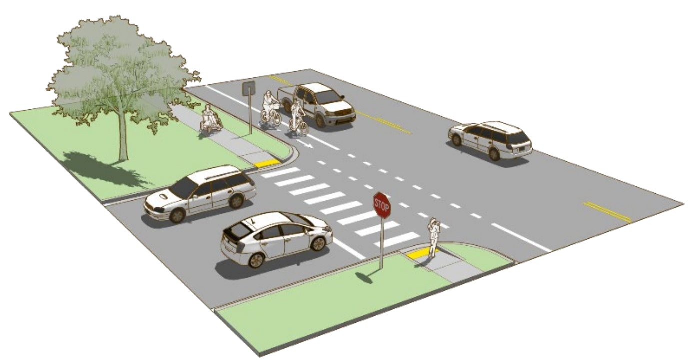
Bicycle Transportation in 2016 that documents the department's commitment toward innovative and separated active transportation infrastructure to help them meet two main goals:

1. Reduce cycling and pedestrian fatalities and serious injuries by 80% over the next 15 years and to zero in 20 to 30 years (Twaddell et al., 2016).
2. Increase share of cycling and pedestrian trips of short trips (less than one mile for walking and five miles for cycling) to 30% by 2025. This would be a 50% increase from the 20% share in 2009 (Twaddell et al., 2016).

2.2 Bicycle Facility Options

Current national guidelines provide transportation professionals with various bicycle facility types. The specific selection of a cycling facility has many variables but are primarily influenced based on the roadway characteristics (vehicular traffic volume and operating speed), land use, available right-of-way, and community or project goals (Schultheiss et al., 2019). Figures 2 and 3 highlight the most common facility types utilized today in suburban or rural locations across the United States. The two figures break the bicycle facilities into two groups – non-separated versus separated, and in general are organized with the least separation first progressing towards the most separation at the end. The separated facilities are those that have a physical barrier between cyclists and motor vehicles, while the non-separated contains only a visual barrier (at most).

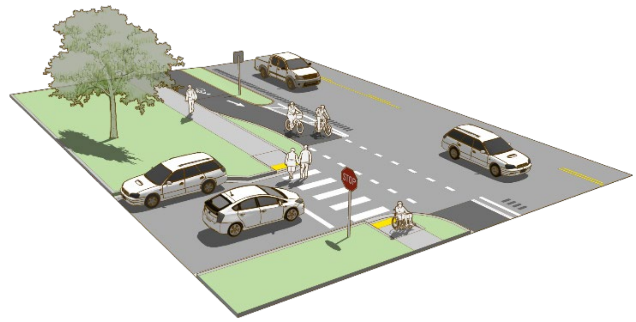
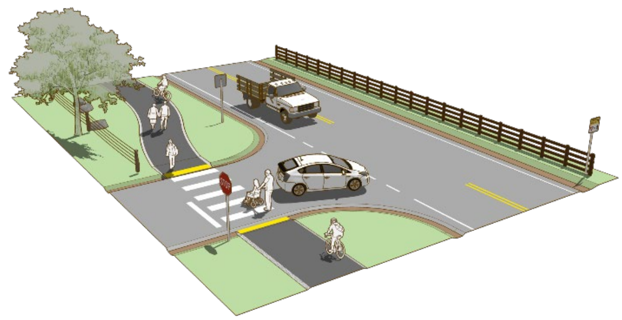
Figure 2 contains the non-separated bicycle facilities, with the first type identified as a shared street condition. A shared street does not contain any physical bicycle facility components and requires cyclists to ride amongst motor vehicle traffic in a mixed environment. This condition provides the least amount of cycling accommodations and is only comfortable for the majority of cyclists in very low volume and speed roadways. Shared street designs should produce motor vehicular speeds between 5 and 15 miles per hour to comfortably support active transportation users (Elliott et al., 2017). An option for enhancing shared lane streets include adding shared lane markings, commonly referred to as sharrows. These markings, and optional supplementary signage, do not provide an independent location for cycling but do help inform cyclists where to operate and notify motorists of their likely location mixing with traffic. These shared lane markings do not make high speed or multi-lane roadways comfortable for cycling to the majority of cyclists with suggestions that they not be used for roadways with speeds greater than 35 miles per hour (MUTCD, 2012). Local low-volume and low-speed streets with shared lane marking signage and striping are commonly referred to as bicycle boulevards. In some cases, local streets designated as bicycle boulevards could be used as part of a bicycle network, making connections to other bicycle routes (Twaddell et al., 2018). Paved shoulders adjacent to a vehicular lane can be used to designate a location for bicycles to operates. This can assist with cyclist comfort but care should be given if rumble strips are provided on the edge of the lane as they are a hazard for cyclists (Schultheiss et al., 2019). Finally, bicycle lanes are the most recognized type of non-separated bicycle facilities. Bicycle lanes designate an independent space for cyclists through a striped line separated from motor vehicles. Conventional bicycle lanes only have one single stripe between the designated space for cyclists and that from motor vehicles. Additional separation between the two user groups can be provided with further horizontal separation and another longitudinal stripe. These facilities are identified as buffered bicycle lanes but still are designated as non-separated facilities because there is only striping between cyclists and motor vehicles. However, just the additional separation and striping has been found to increase cyclist comfort compared to conventional bicycle lanes (McNeil, et al, 2015).

Shared Street Cyclists and motor vehicles operate in the same direction and physical location without striping separating the different users	
Shared Lane Markings Similar to shared streets, cyclists and motor vehciles share the same lane but with added striping to reinfocrce and designate the precence of bicycles	
Paved Shoulder Cyclists operate on the shoulder adjacent to the motor vehicle lane typically separated by striping and potentially rumble strips	
Bicycle Lane Cyclists and motor vehicles each have a dedicated operating space with striping providing a visual separation between the two users	

(Images from FHWA, 2016)

Figure 2: Non-Separated Cycling Facilities

Figure 3 contains the types of physically separated bicycle facilities commonly used in suburban and rural communities. The first type shown is a separated bicycle lane, which can also be referred to as cycle tracks or protected bicycle lanes. When designed to be one-way, these facilities are similar to buffered bicycle lanes but add a vertical element in the space between vehicular lanes and cyclists. This element could be a raised landscape median, flexible delineator posts, bollard, concrete barrier, on-street parking, or landscape planters (Separated Bike Lane Planning and Design Guide, 2015). Separated bicycle lanes can also be designed as two-way where the facilities is located on only one side of the roadway (but still physically separated from motor vehicles) and allows for two-way movement for cyclists. The two-way option can be appealing in physically constrained conditions since there is only one separated area required compare to two on the one-way option. However, care has to be given for two-way separated bicycle lanes at driveway and intersections to reduce conflicts with motorists not yielding to cyclists traveling in the contra-flow direction (Schultheiss et. al., 2019). That specific conflict is also shared with the final separated bicycle facility identified in Figure 3, the shared-use path. Much discussed in this dissertation, the shared-use path operates similar to the two-way separated bicycle lane but also adds other non-motorized users which adds to the complexity of these facilities (and why more study is needed about them).

Separated Bicycle Lane Cyclists are provided a dedicated lane for operation that is physically separated from the adjacentmotor vehicles	
Road Adjacent Shared-Use Path Bi-directional path parallel to the roadway providing a physically separated facility for use by all non-motorized users	

(Images from FHWA, 2016)

Figure 3: Separated Cycling Facilities

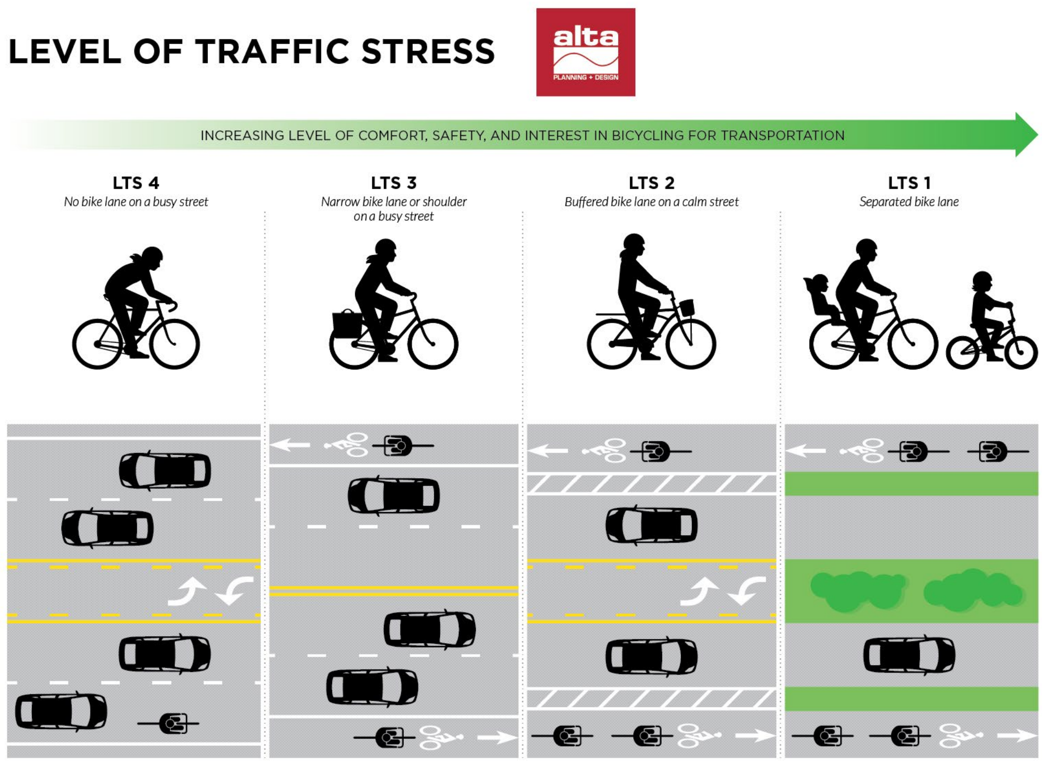
2.3 Evaluation of Separated and Non-Separated Bicycle Facility Types

The rise and advocacy of separated bicycle facilities have led researchers to study these growing facility types and compare them to non-separated facilities. This background section examines the findings of these past studies as well as their methodology. A traditional transportation method of evaluating the safety of a facility is evaluating crash reports. This is problematic for non-motorized travel as the reporting of crashes involving cyclists and pedestrians is not reported consistently (Lusk et al., 2015). To supplement the crash data analysis, researchers have supplemented crash data with hospital records to explore the safety and risk of bicycle facilities. The combination of these tools have led to somewhat mixed findings. One recent report found a lack of evidence to support that physical cycling infrastructure reduces cyclist injuries or collisions but concluded that lowered speed limits could reduce the risk of bicycle crashes (Mulvaney et al., 2015). On the other hand, additional studies have found both separated and non-separated bicycle facilities reduce the number the of bicycle injuries compared to shared street conditions (Reynolds et al., 2009; Wall et al., 2016). Meanwhile, numerous others have found separated bicycle facilities to have reduced bicycle crash risk compared to non-separated facilities (Harris et al., 2013; Lusk et al., 2013; Teschke et al., 2014; Rothenberg et al., 2016). These reduced crash rates have an even bigger impact considering these locations also experience dramatically increased cycling volumes (Goodno et al., 2013, NYC, 2014). Within the separated bicycle facility type, two-way separated bicycle lanes and road adjacent shared-use paths have seen a higher crash rate compared to one-way separated facilities (Reynolds et al., 2009; Schultheiss et al., 2019).

User surveys have also been used to evaluate preferences between separated and non-separate bicycle facilities. Early surveying research projects through data collected online, in-person, through mailings or even placed on parked bicycles, found that many users perceived non-separated bicycle facilities safer than separated facilities (Mortiz, 1998; Aultman-Hall & Hall, 1998; Aultman-Hall & Kaltenecker, 1999). However, with the rise of improved separated facilities, more recent user surveys have overwhelming expressed preferences for physical separation between cyclists and motor vehicles (Dill & Carr, 2003; Dill & Voros, 2007; Buehler & Dill, 2015; McNeil, et al., 2015). One study found that non-motorized users' preference for different facility types concluded that those respondents were willing to travel up to 20 minutes to access a separated bicycle trail than ride on a shared roadway (Tilahun et al.. 2007).

Researchers have also utilized less traditional methods in evaluating user preferences of separated versus non-separated bicycle facilities. Following a review of video footage of riders operating on a range of various facility types, individuals have reported a preference toward separated facilities (Foster et al., 2015). To gain even more direct real-world feedback, GPS technology has been used to analyze route preferences. Through tracking of active cyclists as well as through a city bike share program, users have consistently sought out separated facilities (Dill, 2009; Wergin & Buehler, 2017). Through various analysis methods, recent research is clear that separated bicycle facilities are preferred by a range of users or potential users due to reduced stress and improved comfort.

The Level of Traffic Stress has recently been developed to evaluate and asses the relative comfort of a specific facility and bicycle network to potential user types (more information is provided about cyclist types in the next section). This tool has quickly become a major resource in the transportation industry evaluating bicycle facilities. The criteria for determining the facility's Level of Traffic Stress is based upon vehicular traffic conditions like road width, traffic volume, operating speed, and presence of on-street parking and type of bicycle facility (mixed traffic, non-separated, or separated) (Mekuria et al, 2012). Figure 4 shows how varying roadway conditions influence the Level of Traffic Stress. As one would expect, with increased vehicular lanes, speed and traffic volumes the more cyclist protection is required to meet a lowered Level of Traffic Stress. Conversely, lowered Level of Traffic Stress values can also be obtained without high levels of cyclist protection on local streets with low motor vehicular operating speeds and volumes (Mekuria et al., 2012).



(Image by ALTA Planning and Design, 2014)

Figure 4: Example Level of Stress

Significant to this dissertation, separated facilities including road adjacent shared-use paths produce the lowest level of traffic stress. There are four proposed levels with the largest number containing the highest level of stress. The four levels are summarized as (Mekuria et al, 2012):

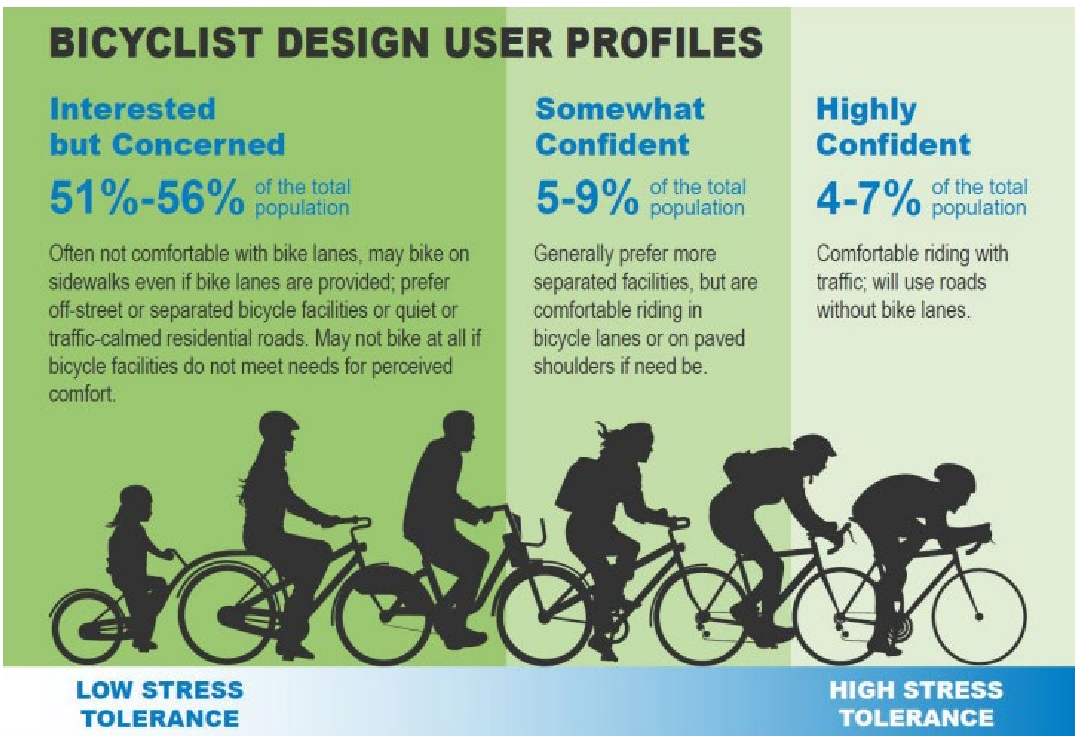
- Level of Traffic Stress 1 (LTS 1) is the lowest stress level and can be tolerated by most children.
- Level of Traffic Stress 2 (LTS 2) can be tolerated by the mainstream adult population.
- Level of Traffic Stress 3 (LTS 3) can be tolerated by current active cyclists.
- Level of Traffic Stress 4 (LTS 4) can only be tolerated by the most advanced group of cyclists.

2.4 Types of Cyclists

Bicycle facility preferences vary based on the type of cyclist – therefore identifying a design user is a major component in selecting the appropriate bicycle facility type. Users have different desires for their infrastructure based upon their experience level, confidence, and reason for travel. By developing user types and splitting up the population, transportation professionals can make more informed decisions by targeting decisions toward a specific user type (Felix, et. al., 2017). Looking at major demographic variables, less experienced cyclists and women have expressed specific preferences toward separated paths from non-separated facilities to avoid high speed and volume motor vehicle traffic (Garrard, et al., 2008; Winters & Teschke, 2010). With perceived safety of the route shown to be highly influential in the decision to cycle (Winters et al., 2010; McNeil et al., 2015), it would lead planners or engineers to believe road adjacent shared-use paths are an exceptional option to accommodate cyclists especially in rural or suburban locations with no existing bicycle or pedestrian infrastructure. However, more experienced cyclists generally have preferences for unimpeded, direct routes that allow them to travel at higher speeds – therefore, they prefer non-separated accommodations over separated paths (Stinson & Bhat, 2003; Hunt & Abraham, 2006; Akar & Clifton, 2009). In many cases, experienced and confident cyclists will choose to operate on a roadway even with no bicycle infrastructure rather than ride on the adjacent shared-use path. This can lead to frustration from motorists who perceive these cyclists slow their travels and continue the conflict amongst various transportation users. Similarly, inadequate on-street bicycle facilities will likely cause less experienced cyclists to operate on an adjacent sidewalk. Narrow sidewalks are not designed for bicycles and will result in conflicts with pedestrians. Previous studies have found cyclists riding on sidewalks to have the highest crash rates due to conflicts with pedestrians and motor vehicles not expecting faster moving users on the sidewalk (Aultman-Hall & Hall, 1998; Godwin & Price, 2016; NHTSA, 2018).

Cyclist classification has been used for more than three decades to help planners and engineers select appropriate facility designs (Larsen & El-Geneid, 2011; Kroesen & Handy, 2013). In the United States, the first classifications were presented in the 1994 FHWA report Selecting Roadway Design Treatment to Accommodate Bicycles, which defined three categories of cyclists as: A) **A**dvanced bicyclists; B) **B**asic bicyclists; and C) **C**hildren (Wilkinson et al., 1994). The 1999 AASHTO Guide for the Development of Bicycle Facilities also referenced these three user types, although it stated that most adult cyclists fell into the 'Basic' category and would avoid roads with high speeds and volumes (AASHTO, 1999). Typologies have evolved as more data is gathered about cyclists in urban and rural communities. For example, the current most referenced cyclist topology, developed by Roger Geller based in Portland, Oregon data, characterized cyclists as: 'Strong and Fearless' (less than 1% of the population which will ride regardless of the roadway conditions), 'Enthused and Confident' (approximately 7% of the citizens who are actively engaged in cycling with interest in improved bicycle facilities), 'Interested but Concerned' (curious about cycling but still apprehensive about riding with vehicular traffic, around 60% of the population), and 'No Way, No How' (citizens have no interest at all in cycling and make up the remaining third of the population) (Geller, 2009). Follow-up research has supported Geller's framework of the four different cyclist types and their general distribution within the population (Dill & McNeil, 2013; Dill & McNeil, 2016). In fact, confirmatory research on the four groups emphasizes users' comfort level cycling in varying environments and not their current bicycle usage and behavior (Dill & McNeil, 2016). For example, many individuals who identify as 'Strong and Fearless' ride less frequently than those in other categories (Dill & McNeil, 2013; Damont-Sirois et al., 2014).

The FWHA Bicycle Selection Guide documents the types of cyclists similarly to Geller's original framework but leaves out the No Way, No How group as this guide is interested in providing the appropriate cycling infrastructure for individuals who have the potential and interest to use it. The three types (Interested but Concerned, Somewhat Confident, and Highly Confident) documented in this recent publication shown in the guide are in Figure 5. The guide recommends the selection of a bicycle facility based on a target user type. With the majority of the population falling in the 'Interested but Concerned' category, the guide advocates for communities targeting all cyclist regardless of age and ability to select low-stress bicycle facilities rather than facilities only comfortable to the highly confident users (Schultheiss et al., 2019).



(Image from FHWA Bikeway Selection Guide, 2019)

Figure 5: Bicycle Design User Preferences

2.5 Bike Share Data and User Types

Bike share is one of the prominent programs being used to increase cycling as it removes the barrier requiring bicycle ownership (Fishman et al., 2013; Krykewycz et al., 2010). While the idea of bicycle sharing is not a new concept, innovations in technology have allowed bike share docking stations and dockless bikes to be easier to manage for communities of all sizes. Most modern bike share programs include GPS tracking technology, which provides not only information to better operate the program but also a wealth of trip and user 'big data'. The ubiquitous availability of bike share, partnered with the ease of access, has led to increased ridership of not only rideshare bicycles but also personally-owned bicycles (Buck et al, 2013; Shaheen et al., 2013).

Public bike share has been in existence for over five decades but has seen significant increase over the past decade due to advanced technology and an increase in the overall number of programs (Shaheen et al., 2013). While bike share models vary greatly, the basic principles are the same. A bike share program provides bicycles on an as-needed basis to users that can make trips that either round trip or one-way. Public bicycle share typically covers the maintenance of the bicycles and allows for users to be long-term members or participate in a trip by trip basis. In 2018, bike share programs nationwide accounted for 52 million trips which is more than double compared to trips just in 2015 (NACTO, 2018). These programs have become essential in first and last mile trip making with urban bike share programs directly linked to reducing the amount of vehicular trips (Shaheen et al., 2013). Bike share has also been found to be a gateway to encourage and engage new segments of the population to increase the overall cycling mode share (Buck et al., 2013, Braun et al., 2016, Curto et al., 2016).

With bike share programs appearing and growing in cities across the United States, researchers have been trying to understand their impacts and users' characteristics. Bike share users make for an interesting study group in facility preference studies as they are a demographic of users that are not quite committed to becoming regular cyclists but are apparently interested in cycling and active transportation (Fishman, 2015). Past studies have found that bike share users name the convenience of bike share as a major benefit and the largest influencer on why it was chosen for a specific trip (Fishman et al., 2013). Interestingly, bike share members are not consistent users of the program overall with irregular usage demonstrating the majority of users do not use the program as their primary or secondary transportation mode choice (Fishman, 2015).

Compared to regular cyclists, bike share users are more likely female, younger, and have lower car and bicycle ownership (Buck et al., 2013). While there are more male bike share users overall, females are better represented than compared to regular cyclists, which is dominated by males (Fishman, 2015). Not surprising, regular cyclists have a lower probability of using a bike share program (Bachand-Marleau et al., 2012). These demographics are promising with the aspiration that bicycle sharing programs can provide expanded transportation access options to an atypical cyclist demographic. Other bike share user demographics have found users to have higher average income and education levels (Fishman et al., 2014, Woodcock et al., 2014) with whites being over-represented compared to both the population and regular cyclist demographics (Buck et al., 2013). Despite its ability for bike share to engage others, United States bike share users have a disproportionately higher education and income levels and are most likely to be a white male (Fishman, 2015).

Bike share trip purposes vary based upon demographic information and program membership types. From an analysis of Capital Bikeshare in Washington, D.C. users with short-term memberships (24 hr or 3 day memberships) made trips containing longer distances, slower, and away from roadways with vehicular traffic compared to long-term memberships (monthly or annual) (Wergin & Buehler, 2017). From a similar study based on the same program, over 40% of long-term users' trips have been found work related compared to just 3% for short term memberships (Buck et al., 2013). There are clear differences in travel patterns based on the trip purpose. Regardless of demographics, it has been shown that bike share users are more likely to prefer improved and separated bicycle infrastructure with less conflicts with motor vehicles (El-Assi et al., 2015, Obrien et al., 2014; Wergin & Buehler, 2017). Users have also consistently documented perceived safety concerns riding with motor vehicles from keeping them from using bike share more frequently (Fishman, 2015).

2.6 Current Shared-Use Path Design Criteria

A number of design manuals provide designers of shared-use paths with design criteria or recommendations when designing a new facility or making changes to an existing path. This literature review section will give an overview on the design requirements for the major path features, including width, striping, separation from the roadway, and path material. Even though shared-use paths are designed to accommodate multiple user types, the design guidance for these facilities are found in mostly bicycle related research or design manuals and thus most manuals within this literature review will focus on cycling guidance. The AASHTO *Guide for the Development of Bicycle Facilities* is one of the most referenced guides on the design of shared-use paths with the most recent update provided in 2012. This reference manual provides recommendations and standards related to the path width, clearance from the roadway and other obstacles, design speed, horizontal alignment, stopping sight distance, and path crossing and intersection design. It also discusses the operational concerns of shared-use paths alongside a roadway, noting that many cyclists may prefer to ride on the road even when a shared-use path is provided since they will not have to pass slower users. For this reason, it states that shared-use paths are not to be used as a substitute for non-separated bicycle facilities (AASHTO, 2012). The Guide for the Development of Bicycle Facilities, however, does acknowledge the rationale for providing shared-use paths along a road corridor when an independent right-of-way is not available. The four conditions where a shared-use path alongside a roadway could be considered include: 1) along a high-volume and high-speed roadway where bicyclists may not be comfortable riding on the roadway; 2) the shared-use path connects an independent pathway network or other bicycle route; 3) the location will have minimal roadway or driveway crossings; and 4) the shared-use path can be turned into a location that is compatible for bicyclists (AASHTO, 2012).

Some of the key design components for a road adjacent shared-use path include striping and signage, path material, width, and separation from the roadway. The standard width for a typical shared-use path is 10 to 14 feet with an exception of providing eight feet in width in very rare circumstances with low expected usage and constrained sites (AASHTO, 2012). The Federal Highway Administration's (FHWA) Shared-Use Path Level-of-Service calculator notes that rather than considering path widths in two-foot increments, it is valuable to consider them in one foot increments. Specifically, there is measurable improvement in paths with high usage and diverse mode splits to increase the width to eleven feet from the standard ten-foot-wide path. An eleven-foot-wide path allows three users to operate alongside each other and increases the ease in passing (FHWA, 2006). A study commissioned by the Florida Department of Transportation (FDOT) developed a sidepath safety model that stated narrower paths provide a safer design with the hypothesis that the narrower path would slow bicycle path users thus improving safety at the noted conflict points (Petritsch et al., 2006). It should be noted that it is possible for shared-use path designers to choose a wide typical path to encourage usage and passing but narrow the path width at locations to slow users and improve safety at locations such as driveway crossings. It is currently not defined what specific pathway volume thresholds would require increasing the path width or what users perceive is the most appropriate width.

The minimum separation between a shared-use pathway and a hazard is 5 feet in width. A hazard could be a natural resource such as river, a steep slope or elevation drop, or a roadway. If the minimum separation is not met, a barrier or safety rail should be provided (AASHTO, 2012). The FDOT sidepath safety model found a safety correlation between the separation of the roadway and a shared-use path where in general the findings saw safety improvements separating the shared-use path beyond the minimum 5 foot requirement (Petritsch et al., 2010).

The *Manual on Uniform Traffic Control Devices* (MUTCD) provides an option for using a center line pavement marking where a shared-use path is wide enough to provide two lanes (MUTCD, 2009*)*. The manual allows for a dashed yellow stripe to be used where passing is allowed and a solid yellow stripe where it is prohibited. Centerline striping has been shown to effectively delineate two travel lanes and limit users, particularly bicyclists, to the opposing lane of traffic only when passing slower users *(*Patten et al., 2006*)*. While this may be perceived negatively and reduce a Level of Service score for fast moving bicyclists, the safety and operational benefits of a centerline stripe are important to consider during design. Another striping option that could be considered in the design of shared-use paths, is providing three striped lanes where two unidirectional lanes are designated specifically for higher speed users including bicyclists and skaters with the third bidirectional lane used for slower pedestrian users. This path design could help alleviate the concern of slower users creating congestion and conflicts for the faster path users. To incorporate three lanes the shared-use path width would need to be a minimum of 15 feet (Patten et al., 2006).

Shared-use path accessibility requirements are based upon the American's with Disabilities Act (ADA) standards that dictate path material and maximum path slope. The path cross-slope is required to be less than 2% while the longitudinal slope should have a maximum of 5% (ADA, 2010). Specific to shared-use paths alongside roadways, the United States Access Board has compiled supplementary guidance for accessibility requirements in the Public Right-of-Way Accessibility Guidelines (PROWAG, 2011). PROWAG acknowledges the physical restraints locating a facility within a right-of-way when a project is required to be contained within a specific right-of-way. The most notable exception in PROWAG is allowing paths and sidewalks within a right-of-way to have a maximum longitudinal grade up to the roadway grade rather than 5% as required in the ADA regulations (PROWAG, 2011). Accessibility requirements for a path material are descriptive rather than prescriptive stating a material surface shall be firm, stable, and slip resistant (ADA, 2010). It is possible to achieve the accessibility requirements with an unpaved surface material but it could be more difficult for wheelchair and bicycle users and nearly impossible for small-wheeled devices such as skateboards, inline skates, and kick scooters (Landis et. al., 2004).

With AASHTO's shared-use pathways warnings and still limited guidance on other protected bicycle infrastructure, the National Association of City Transportation Officials (NACTO) published the *Urban Bikeway Design Guide* to provide guidance on the newer cycling options that are becoming more prevalent across the country. The Federal Highway Administration (FHWA) acknowledged the need for innovation in bicycle and pedestrian design when they issued a memorandum endorsing the use of both the NACTO Urban Bikeway Design

Guide and Institute of Traffic Engineers (ITE) *Guide Designing Walkable Urban Thoroughfares: A Context Sensitive Approach* in addition to the AASHTO guide material (FHWA, 2013). However, because it is focused on urban conditions the NACTO guide does not discuss shared-use paths which are generally found in more suburban or rural conditions. The recently published *Small Town and Rural Design Guide* by the FHWA, however, does include guidance on shared-use paths and sidepaths. The new manual reflects many of the past design guidelines on width, striping, separation and material but does add guidance on shared-use path separation from the roadway at intersections. Based upon the adjacent roadway speed limit, the path can be pulled away from the roadway up to 24 feet at the intersection to increase visibility and slow path users at these critical crossings (FHWA, 2016). This new manual is important as it not only provides more national guidance on road adjacent shared-use paths but also identifies a legitimate facility type when selected in the correct setting.

2.7 Past Shared-Use Path Research

Past researchers have understood the need to learn more about shared-use path operations and provide further guidance to practitioners considering road adjacent shared-use paths as a part of community's overall transportation network. The most debated and complicated aspect of the road adjacent shared-use path is whether the known inherent operational conflicts result in more risk than the benefit of separating users from motor vehicle traffic. Through crash evaluations and comparisons to other bicycle facilities, recent studies have shown shared-use paths crashes are overrepresented when compared to conventional bicycle lanes or other separated bicycle facilities but underrepresented compared to shared roadways (Rome et al., 2013; Teschke et al., 2014). Researchers have focused on how developing potential countermeasures to improve the safety of road adjacent shared-use paths which have focused on path specific design elements as well as the roadway environment. For the path elements, greater separation between the path and roadway along with geometric changes to reduce path user speed (primarily at intersections) have been identified as design factors to potentially reduce crash risk (Petritsch et al, 2006). Other studies have examined the separation variable and concluded further distance provides for increased perceptions as well as safety (Petritsch et al., 2010). A separation of 40 feet or greater has been shown to operate similarly to shared-use paths on independent alignments away from a roadway (Petritsch et al., 2010). Roadway elements that could be harder to control is the posted speed limit and number of lanes from the adjacent roadway (Petritsch et al., 2006). Without the ability to make physical changes to the roadway environment, transportation professionals are encouraged to provide more robust countermeasures (like further separation) when the adjacent roadway has increased speeds and number of travel lanes (Petritsch et al., 2006; Petritsch et al., 2010).

In addition to these safety and operational studies, other research projects have evaluated shared-use path design parameters using video simulation. In one study, over 100 viewers evaluated 36 video clips of 10 different pathways and found path width was an important variable in user satisfaction as ratings increased from 8 to 14 feet wide (Hummer et al., 2005). However, that finding did not continue evaluating the 20-foot-wide path Lakefront Trail in Chicago as it includes a very heavy user volume and conflict locations (Hummer et al., 2005). The results of this study highlight the conflict among the various user types is not a surprise and consistent with past findings (Aultman-Hall & LaMondia, 2005; Teschke et al., 2014). Additional concern of the conflict between various path users have been raised by individuals with either visual or hearing impairments (United States Access Board, 2013). Some mitigating countermeasures to reduce the conflict among the various users have been developed and studied. Traditional centerline path striping has been shown to reduce conflicts by keeping users in the correct path location to avoid other users (Jordan & Leso, 2000). AASHTO allows for further separation (either physical barrier or striping) between pedestrians and cyclists on "extremely heavy" path volume conditions but warns pedestrians will violate the bicycle spaces unless there are high cycling volumes (AASHTO, 2012). This guidance has been confirmed through a study of the shared-use path on the Brooklyn Bridge that separates pedestrians and cyclists with striping. This study saw violations by both groups and noted they were found at locations where one or the other were constrained by narrowed lane widths or increased user volumes (Zheng et al., 2019).

Overall, the transportation profession has embraced many of the identified techniques to mitigate the known conflicts with these countermeasures adopted in some of the most recent design manuals (FHWA, 2016). However, much of the research that has produced these countermeasures currently implemented are more than a decade old. With the majority of current separated active transportation research focused on urban conditions, road adjacent shared-use paths are less studied (despite their known complexities). There is still a need for further research to better understand and provide practitioners with guidance on the influence of roadway and user characteristics. Therefore, this dissertation focuses on increasing the understandings of this facility type by focusing on a comprehensive evaluation of road adjacent shared-use paths.

Chapter 3: Shared-Use Path Design Criteria from a Stated Preference Survey

This chapter explores the dissertation's first objective to expand the understanding of user preferences for shared-use path design elements. Current design guidance and past research provides engineers and planners with design parameters when implementing road adjacent shared-use paths. However, as displayed in the previous chapter, there are variations allowed in design and conflicting user reviews and desires. Additionally, current research is focused primarily on urban cycling with seemingly limited upcoming research to expand the knowledge of road adjacent shared-use paths preferences. Therefore, the findings from this objective are necessary in completing the overarching dissertation goal but also independently provide guidance on how specific shared-use path design elements support different types of cyclists' needs and safety expectations.

This first objective proposes to provide expanded guidance and direct feedback on the various path design options through a web-based stated preference user survey. A stated preference survey gathers categorical information from respondents based on experimental conditions. The survey was created and distributed to individuals in the Auburn-Opelika region of eastern Alabama, which has recently implemented or planning road adjacent shared-use paths. The survey utilized the principle design characteristics to quantify and model individuals' likelihood of using, satisfaction, and perceived safety of road adjacent shared-use paths based on varying combinations of path elements. These three questions provide a complete perspective on individuals' self-reported demands, expectations and needs for future road adjacent shared-use paths with limitations that the survey respondents were mostly from a college town (Auburn, Alabama) with many themselves being college students. With that known limitation, the conclusions raised from this chapter are still key in completing the dissertation goal in understanding how the different cyclist types perceive and use road adjacent shared-use paths. This will also be used later in this dissertation to develop the new framework guidance for transportation professionals implementing road adjacent shared-use paths.

3.1 Data Collection: Auburn-Opelika Community Survey

An original web-based study was created to better understand how varying path users perceive road adjacent shared-use paths and to assist engineers and designers in selecting appropriate design elements based on given user types. This survey (which is included in Appendix A) was designed in Qualtrics surveying software and organized in sections to gather information on the individual, their current self-reported activity level, including cycling, and their preferences of the path design components. The first section gathered information on the individual's physical activity level as well as shared-use path experience and desire for more access to shared-use paths. The individual's demographic information of age, gender, commute time, household income, and presence of children in the household was also collected at the end of the survey.

The remainder of the survey was dedicated to gathering specific information from the path users on their reported perceptions to variations of the key design elements previously found to be impactful to path users. Six randomly selected (but uniformly distributed across all users) path images from a potential set of 21 images with different combinations of path widths, offsets from the roadway, and surface material were displayed to the user. These images were photoshopped from existing facilities based in Auburn, Alabama so the theoretical facilities would feel familiar and stated preferences would be more accurate. Figure 4 represents examples of the 40-foot offset with all 21 images provided in Appendix A.

Figure 4: Example Survey Scenario Images

Four width options included 8-feet, 10-feet, 15-feet with a standard striped centerline, and 15-feet striped for dedicated bidirectional cycling lanes and a marked separated pedestrian lane. Three roadway offsets included directly adjacent to the curb, approximately 20-feet from the roadway, and approximately 40-feet from a roadway (the latter being far enough from the roadway that it may feel more like an independent alignment (Petritsch et al., 2010). Two pathway materials were also included: paved asphalt or unpaved gravel. The survey did not provide specific details of the shared-use path beyond the images, such as level of compaction of the gravel, adjacent roadway speed or volume, and mode split or volume of the shared-use path. The gravel option was graphically shown appearing a loose gravel to clearly show a visible difference compared to the asphalt path material. As described in Chapter 3, to comply with accessibility regulations the gravel would have to be a finer gradation to meet the firm and stable requirements. The images were consistent in showing one cyclist and two pedestrians along the path, and an appearance of a low volume suburban roadway in each image. These images represent typical shared-use path applications rather than in high volume urban settings. Survey participants rated each randomly assigned image on three important aspects that need to be considered during design: a) likelihood using the path during a typical week, b) satisfaction using the path (i.e. level of service), and c) perceived safety of the path.

The survey was distributed electronically June 15 to June 29, 2016 to participants in the Auburn, Alabama; Opelika, Alabama; and Columbus, Georgia communities. The survey was first sent directly to the three city's bicycle committee members, engaged citizens in the ongoing Bicycle and Pedestrian planning through the Auburn-Opelika Metropolitan Planning Organization, and Auburn University bicycle permit holders. Additionally, the survey was shared through social media avenues including the Auburn and Opelika Parks and Recreation departments, local bicycle groups, and multiple Auburn University organizations. Finally, surveys were collected in-person via iPads at a pet-friendly Auburn park to target citizens using the paths and trails. This in-person survey collection effort was executed to ensure well-rounded responses from all types of path users and not solely from the already engaged cycling community.

3.2 General Preferences: User Survey Summary

Following the two-week data collection effort, the survey was closed with 330 fully completed surveys. Table 1 provides a full summary breaking down the respondent demographics. The majority of the respondents resided in Auburn, Alabama likely due to much of the outreach being connected to the City of Auburn and Auburn University. The sample saw an even split between males and females completing the survey but found the age of participants skewed younger than the national average. Additionally, a large portion of the group, 82%, reported having short daily commutes of less than 15 minutes. Finally, the household income was distributed across all options with the largest representation in the lowest income bracket. Finding a sample skewed younger, with short daily commutes and lower income is due to numerous current Auburn University students completing the survey. There is some concern that the data does not represent the general population given the influence of a large number of college students, who have much different travel patterns. However, this demographic group is extremely important in understanding reported desires about shared-use paths. This younger demographic can provide insight to explore facilities that should be planned and designed moving forward with this group being the future users. Additionally, individuals with short commute times and lower incomes are also likely searching for affordable transportation options both as a mode of travel in addition to recreation. The final individual category reported in Table 1 is bicycle ownership. This information is relevant especially for this dissertation topic and shows the majority of this survey sample, 92%, owns a bicycle and therefore at a minimum are intrigued by cycling enough to purchase a bicycle. This final piece of information reaffirms the sample provides good insight into individuals who would be interested in road adjacent shared-use paths.

Table 1: Survey Respondent Demographics

Gender	
Male	56%
Female	44%
Other	0%
Age	
19 to 25	53%
26 to 35	18%
36 to 45	11%
46 to 55	8%
56 to 65	8%
65 or Older	2%
Residence	
Auburn, AL	86%
Opelika, AL	6%
Columbus, GA	1%
Other	7%
Daily Commute	
Less than 10 minutes	44%
11 to 15 minutes	39%
16 to 30 minutes	14%
More than 30 minutes	3%
Annual Household Income	
Less than $20,000	38%
$20,000 to $39,999	10%
$40,000 to $59,999	8%
$60,000 to $79,999	11%
$80,000 to $99,999	12%
$100,000 or more	21%
Bicycle Ownership	
Yes	92%
No	8%

In addition to the demographic information, the survey gathered data on the respondents physical activity and use of shared-use paths. Overall, the survey respondents were found to be extremely active which is not surprising considering the majority of the individuals solicited for the survey were engaged somehow with local active transportation. The survey asked in a typical week what type of physical activity the individual participated in with options for walking, running, cycling, and working out. Figure 5 summarizes the breakdown between the four physical activity options per day of the week. Monday saw the most activity with least activities on Saturday and Sunday. Table 2 breaks down those physical activities summarized for the whole week on the frequency an individual either walks, jogs/runs, bikes, or works out. Walking was the most frequent physical activity followed by cycling, then working out, and finally running.

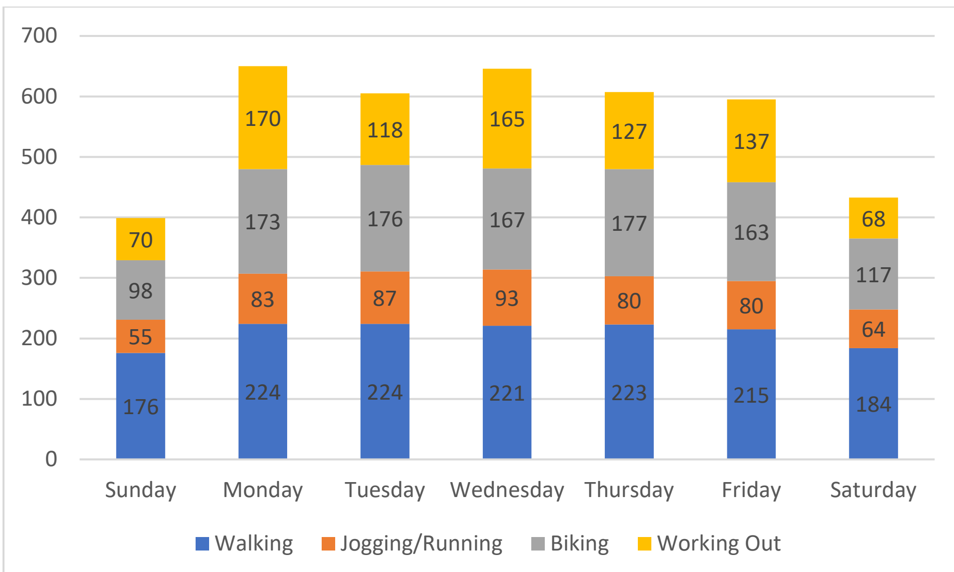


Figure 5: Reported Daily Physical Activity

Table 2: Physical Activity Frequency

Physical Activity	Mean Frequency per Week
Walking	5.5
Jogging/Running	3.5
Biking	4.6
Working Out	3.8

For this study, understanding where the physical activity occurred is just as important as knowing the individual's overall physical activity. Knowing the activity location allows for an understanding of how the physical infrastructure impacts an individual's behavior and mode choice. Therefore, the survey asked the location where each physical activity occurred with options for sidewalk/path, trail, roadway, gym, park, and home. As shown in Figure 6, the sidewalk/path option was the highest reported cumulative location most notably for walking. For cycling, roadway was the highest followed by sidewalk/path and then trail. Of particular interest to this dissertation topic, this respondent group has a good mix of cyclist types operating in both separated and non-separated environments. It is compelling to see how most of the physical activities are located along public locations like sidewalk, paths, trails, roadway and parks and reinforces how essential these areas are in promoting active transportation and activity.

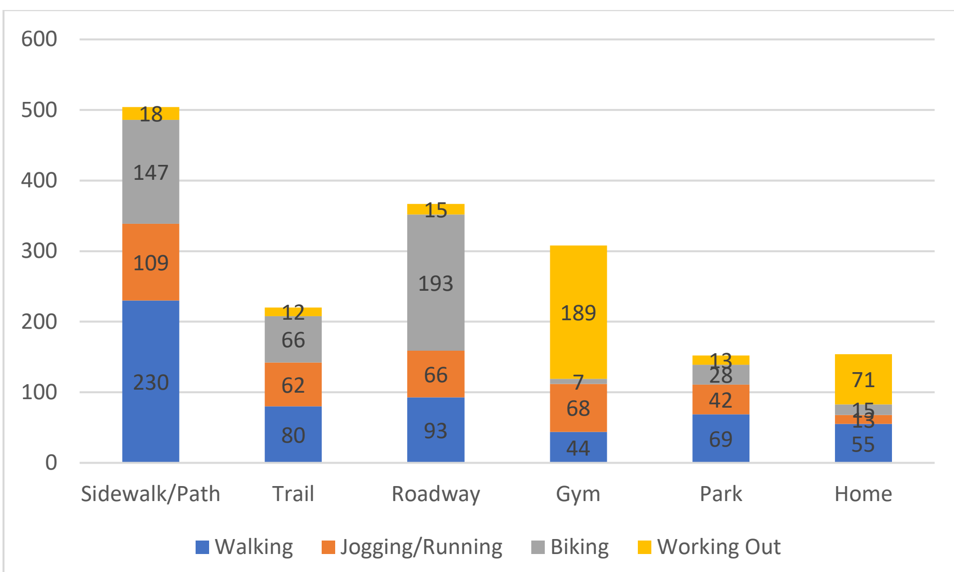


Figure 6 : Physical Activity Location

Specific to the use of shared-use paths, the survey gathered information on the frequency of using local shared-use paths, their specific physical activity, and reason for using shared-use paths. Table 3 provides the breakdown for each of those three topics. Values sum to greater than 100% for the type of use and reason for use as respondents had the option to select more than one answer. The survey participants reported a high usage of local shared-use paths with 59% responding often and only 2% responding never. Walking was the highest physical activity with cycling following closely behind. A somewhat surprising trend was found in the highest reason for using a shared-use path was for a mode of travel, which was used to describe more utilitarian type trips that essentially would replace an automobile trip (which has important public health, environmental, traffic congestion reduction implications). Exercise was closely behind the mode of travel designation, but it is interesting that many of the respondents viewed and currently use shared-use paths not only for recreation but as an essential component of the transportation network.

Table 3: Local Shared-Use Path Reported Use

Frequency of Use		*Type of Use*		*Reason for Use*	
Often	59%	Walking	74%	Exercise	67%
Sometimes	27%	Jogging/Running	37%	Leisure	47%
Rarely	12%	Cycling	67%	Mode of Travel	72%
Never	2%	Other	2%	Other	1%

In a series of follow-up questions, the individuals were asked what barriers prevent more use of local shared-use paths, and if they were removed, what activities would occur. Over 70% respondents they would use local shared-use paths more frequently if the paths were more convenient or connected to their travel destination. The respondents overwhelmingly chose these location and proximity options over enhanced safety and having more time to use shared-use paths. When asked if they would like more access to local shared-use paths, 32% responded yes for more exercise and recreation and 62% said they would use them to bicycle, walk or skate to work, shop or other destination. Additionally, the highest reported physical activity from these individuals responding they would like additional shared use paths for utilitarian purposes was for cycling. These results reiterate the past findings that these participants view shared-use paths as a component of the overall transportation network in addition to recreation and exercise. This is an important finding in this survey. However, numerous commenters voiced concerns similar to the literature review over conflicts between cyclists and pedestrians as well as reported problems at intersections and cautioned the ability for shared-use paths to meet the needs of their trip purposes. This difference of results show cyclists themselves have varying preferences.

Following the general physical activity and shared-use path questions, the survey presented the varying shared-use path images with different design components. The survey asked three questions for each shared-use path image presented: 1) how likely would you use the shared-use path for any activity or reason in a typical week; 2) how satisfied would you be with the shared-use path; and 3) how would you rate the safety of the shared-use path. The responses for three questions were relatively consistent. Most respondents provided positive reviews of the shared-use paths with the few negative responses being consistent. This shows, in general, that the stated preferences of shared-use path users exhibit some correlation among the likelihood of using, satisfaction and perceived safety. Overall, individuals have positive responses to proving shared-use paths. In fact, correlation between likelihood of use and satisfaction was 0.86, correlation between likelihood of use and perceived safety was 0.77, and correlation between satisfaction and perceived safety was 0.83. Figures 7 - 9 summarize the results for all three questions based on listed path design characteristic, independent of any variations in the other characteristics or influences.

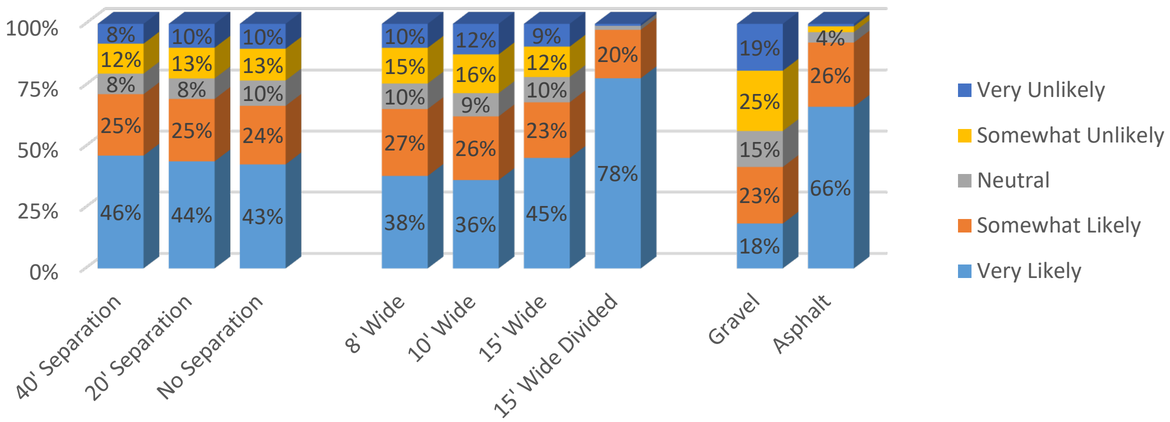


Figure 7: Likelihood of Using Shared-Use Paths

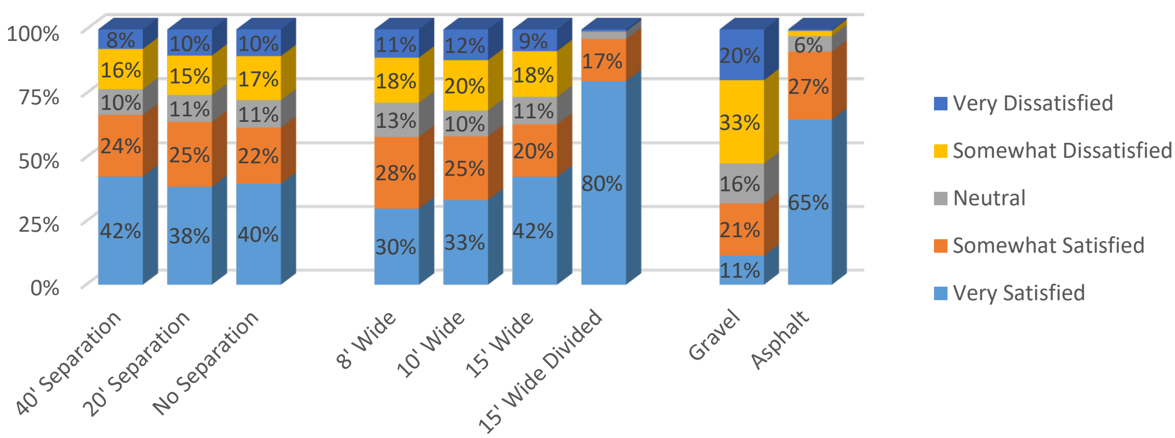


Figure 8: Satisfaction Using Shared-Use Paths

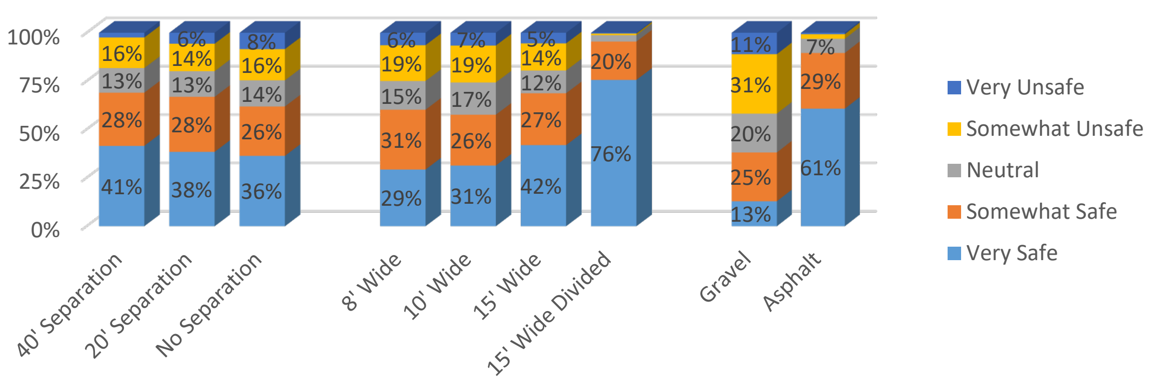


Figure 9: Perceived Safety of Shared-Use Paths

Figure 7 highlights that material and width affect respondents' likelihood of using shared-use paths. In fact, there was almost no difference in likelihood of use across the distance from roadway. It also saw little to no difference between the rating of 8 foot or 10 foot widths but an increase towards the wider 15-foot-wide path and an even greater increase stating their use of the path would be much greater if it were 15-foot-wide and provide the separated lanes for the different activities. The greatest impact towards the reported likelihood of use was the path material, which heavily favored the asphalt path compared to the gravel option. Only 4% of the responses classified the asphalt paths as very or somewhat unlikely to use the path compared to 44% for gravel. This is not terribly surprising considering the high number of cyclists completing the survey, but it provides a significant measurable difference between these two material options.

Respondents' satisfaction with different pathway elements were relatively similar as shown in Figure 8. This was as expected as a user would not likely use a facility that would make them feel unsatisfied. The separation from the roadway appears to have even less of an impact on the satisfaction compared to the likelihood of use which is somewhat surprising. The width results showed a little preference toward 10-foot wide compared to 8 but then saw again greater partiality toward the 15-foot wide path and even more so towards the wide path with three striped lanes separating cyclists from pedestrians. The satisfaction difference between the two material options provided the greatest difference compared to the three questions posed in the survey. Sixty-five percent reported they would be very satisfied when shown a path with an asphalt surface compared to only 11% when shown a gravel shared-use path. It is interesting that, although slight, the survey results show that some users would likely choose to use a gravel shared-use path but would not be satisfied with its use.

Finally, Figure 9 shows that respondents' perceived safety is most closely tied to variations in design elements. Respondents reported an increase in perceived safety the further the pathway was from the roadway, which is consistent with past research (Petritsch, et al., 2006; Petritsch, et al., 2010). The path width and material option results are similar to the likelihood of use and satisfaction where perceived safety ratings significantly increase with the path width and choosing asphalt over gravel. The 15-foot wide path received a very safe rating from 42% of the respondents compared to 76% for the 15-foot wide path with the striped dividing lanes. It should be noted that for these generalized perceptions that ignore the relationships between the design variables, all three questions saw noteworthy differences between the 15-foot-wide path and the 15-foot-wide path with the dividing lanes. This is likely due to the preference for users to have some level of separation between the activities that have different speeds. However, it is also because the 15-foot wide options were shown to be gravel and asphalt (with many users responding poorly to the gravel surface) and the 15-foot wide divided option was only asphalt since it was a striped solution and could not occur on gravel. This leads one to believe that the material options and the strong preference toward a hard surface could be increasing the results for this particular comparison. To determine the interplay between the design options a model was developed to further this analysis.

3.3 Model Methodology: Ordered Logistic Regression

An ordered logistic regression model was selected and run for each of the three user questions to gain further insight on the influence and preferences for the various road adjacent shared-use path design elements. The regressions followed a traditional structure, where independent variable weights and outcome thresholds are estimated to most accurately predict an ordered categorical dependent choice variable. In this study, each of the three models had a different dependent choice variable comprised of five alternatives: 1) likelihood of using a shared-use pathway (very likely, somewhat likely, neutral, somewhat unlikely, very unlikely), 2) satisfaction with shared-use pathway (very satisfied, etc.), and 3) perceived safety of the shared-use pathway (very safe, etc.). The same independent variables were considered in each individual model. These include the demographic variables as reported in Table 1 (age, gender, commute time, income and children present in home), physical activity participation from the reporting of Figure 5 (walking, running, biking and working out), experience with shared-use paths (uses local shared-use paths, uses non-local shared-use paths, and desires more access to shared-use paths), and finally the key design variables varying in the path images (path material, path width and separation from the roadway).

The model assumes there is an unobserved continuous underlying latent function (Y_i^*) approximating individuals' perception level for each dependent variable choice set written as:

$$Y_i^* = \sum_{n=1}^{N} \beta_n x_{ni} + \varepsilon_i \quad (1)$$

where *I* is the number of individuals, *N* is the number of independent variables, x_{ni} is the value of variable *n* for individual i, β_n is the coefficient weight of variable *n*, and ε_i is a random error term assumed to be normally distributed. The actual choice Y_i an individual makes from among the *j* alternatives (e.g. perceived level of safety) depends on his/her latent perception level value Y_i^* relative to thresholds that define the categorical choices from the continuous latent scale γ_j, such that:

$$Y_i = j \ if \ \gamma_{j-1} < Y_i^* \leq \gamma_j \quad (2)$$

Therefore, the probability of an individual i selecting alternative j is:

$$P(Y_i = j) = \frac{e^{(\beta x_i - \gamma_{j-1})}}{1 + e^{(\beta x_i - \gamma_{j-1})}} - \frac{e^{(\beta x_i - \gamma_j)}}{1 + e^{(\beta x_i - \gamma_j)}} \qquad (3)$$

The parameters β_n and thresholds γ_j were estimated using maximum likelihood estimation in SPSS software. These parameters can be found in Tables 4 through 6, and parameters significant at a 90% confidence level are identified in bold. The confidence level is the percentage of the entire population that is expected to be included within the estimated parameters. The log-likelihoods of the 'likelihood of using', 'satisfaction', and 'perceived safety' models are -2108.57, -2075.02, and -2098.62, respectively. The log-likelihood values can be used to compare fit of the models with all three models reporting similar values. Chi-square tests show that each model is significantly better than the constant-only version, at any level of significance.

3.4 Shared-Use Path Stated Preference Results

The estimates from the three ordered logistic regression models help determine how combinations of shared-use pathway design elements influence different types of users' perceptions on likelihood of use, satisfaction, and safety. The models include consistent independent variables that described user demographics, experience, and current physical activities. The base demographic for the models are women aged 18 to 25 with a commute time of 10 minutes or less and earn less than $20,000 a year. For an ease of comparison, these base or reference demographic are the lowest values for each of the categories. Table 4 summarizes the model results and reports on the significant factors influencing how likely an individual is to use a shared-use pathway. The table is broken into respondent demographics, physical activity, experience with shared-use paths and the shared-us path characteristics with positive coefficient values indicating a positive preference. The demographic variables highlight the younger professionals who are budget conscious and active are most likely to have a bias towards using these pathways. Specifically, women, individuals aged 26 to 35, infrequent walkers, those who use shared-use paths outside the local area, and those who self-reported an interested in more shared-use paths are more likely to use the pathway. The heavy cyclist group and those who do physical activities with other adults are less interested in using pathways and, while the income results vary slightly, those with higher incomes are also generally less interested. Interestingly, the presence of children at home or even with a physical activity does not significantly affect an individuals' interest in pathway use. This could be a reflection of many of those respondents reporting that many use shared-use path for commuting or utilitarian trips. Interestingly, not many of the physical path characteristics were found to influence an induvial likelihood of using a path. All users would use the 10-foot wide pathway the least, while infrequent cyclists preferred the 15-foot pathway and frequent cyclists preferred the 15-foot pathway with a dividing line. These trends make sense, as inexperienced or casual cyclists would enjoy the wider pathways for travel and dedicated cyclists would prefer not slowing down to manage interactions with other users. Also, not surprisingly, all users stated they would use the pathway that was 40-feet from the roadway more than the roadway-adjacent or 20-feet separated pathways. Infrequent walkers also presented an additional lack of interest in pathways with 20-feet separation. Across all users, asphalt surfaces were a major factor for increased use.

Table 4: Likelihood of Using Shared-Use Path Estimation

	Parameters	*Coeff.*	*t-stat*
Thresholds			
γ_1		-0.189	-0.85
γ_2		0.570	2.58
γ_3		0.972	4.39
γ_4		1.882	8.40
Respondent Demographics			
Aged…	…26 - 35 Years Old	0.140	1.68
	…36 - 45 Years Old	0.117	0.96
	…46 -55 Years Old	-0.012	-0.09
	…56 - 65 Years Old	0.079	0.64
	…65 or Older	-0.162	-0.50
Gender…	…Male	-0.284	-4.77
	…Other	-1.038	-2.23
Commute Time…	…11 - 15 min	0.022	0.35
	…16 - 30 min	-0.080	-0.93
	…30 min or more	-0.107	-0.59
Income…	…$20k - $39k	-0.250	-2.48
	…$40k - $59k	-0.131	-1.16
	…$60k - $79k	-0.106	-0.99
	…$80k - $99k	-0.442	-4.19
	…$100k or more	-0.249	-2.66
Children Present in Household		-0.087	-0.79
Respondent Physical Activity Participation			
Walks…	…Infrequently	0.922	2.58
	…Frequently	0.205	1.37
Runs…	…Infrequently	-0.058	-0.20
	…Frequently	0.036	0.29
Rides Bicycle…	…Infrequently	-0.171	-0.50
	…Frequently	-0.271	-2.03
Works Out…	…Infrequently	-0.156	-1.00
	…Frequently	0.045	0.69
Completes Activities with…	…Adults	-0.139	-2.18
	…Children	0.116	0.94
	…Pets	0.002	0.03
Respondent Experience with Shared-use Paths			
Uses Local SU Paths		0.043	0.51
Uses Non-Local SU Paths		0.247	3.95
Wants Access to More SU Paths		0.831	7.41

Parameters	*Coeff.*	*t-stat*
Shared-use Path Characteristics		
…has Asphalt Surface	1.567	24.87
...is 10ft Wide	-0.384	-1.97
x Infrequent Walker	-0.140	-0.33
x Frequent Walker	0.276	1.62
x Infrequent Runner	-0.187	-0.53
x Frequent Runner	-0.002	-0.01
x Infrequent Cyclist	0.482	1.05
x Frequent Cyclist	0.254	1.72
...is 15ft Wide	0.101	0.50
x Infrequent Walker	-0.362	-0.86
x Frequent Walker	0.027	0.15
x Infrequent Runner	-0.188	-0.56
x Frequent Runner	-0.040	-0.27
x Infrequent Cyclist	0.790	1.72
x Frequent Cyclist	0.207	1.33
...is 15ft Wide w/ Dividing Line	0.306	1.04
x Infrequent Walker	-0.711	-1.07
x Frequent Walker	-0.195	-0.74
x Infrequent Runner	0.121	0.18
x Frequent Runner	-0.266	-1.29
x Infrequent Cyclist	0.165	0.27
x Frequent Cyclist	0.461	2.04
…has 40ft Separation	0.351	1.80
x Infrequent Walker	-0.195	-0.47
x Frequent Walker	-0.191	-1.13
x Infrequent Runner	0.393	1.14
x Frequent Runner	-0.120	-0.88
x Infrequent Cyclist	-0.47	-1.11
x Frequent Cyclist	-0.017	-0.12
x Aged 65 or Older	-0.331	-0.75
…has 20ft Separation	0.043	0.22
x Infrequent Walker	-0.697	-1.71
x Frequent Walker	-0.020	-0.12
x Infrequent Runner	0.385	1.16
x Frequent Runner	-0.027	-0.20
x Infrequent Cyclist	0.110	0.25
x Frequent Cyclist	0.045	0.31
x Aged 65 or Older	0.213	0.46

Table 5 similarly summarizes significant factors influencing how satisfied an individual is with a shared-use pathway design (i.e. a pseudo level-of-service measure). Most notable is the lack of many significant pathway design elements, which underscores the inherent demographic biases in what users will accept for pathways. Again, the demographic biases are similar with women, infrequent walkers, those who use shared-use paths outside the local area, and those who are interested in more shared-use paths are more likely to use the pathway. Frequent cyclists, those who do physical activities with other adults, and those with higher incomes are also less interested in using pathways. However, age no longer affects satisfaction whereas commuters with 16-30 minute times are less satisfied with pathway designs. Additionally, using local pathways decreases satisfaction with pathways, perhaps emphasizing frustration with locally experienced conditions. Width does not affect users' satisfaction with a pathway, except for infrequent walkers (who are severely dissatisfied with the 15-feet width with dividing line) and frequent cyclists (who are more satisfied with the same 15-feet width with dividing line). This further emphasizes the conflicting needs of different pathway users: the cyclists are satisfied with the design that allows them to travel at uninterrupted high speeds but pedestrians would not be satisfied being restricted to a smaller space for walking. Across all users, asphalt surfaces were a major factor for increased satisfaction.

Table 5: Satisfaction with Shared-Use Path Estimation

Parameters		***Coeff.***	***t-stat***
Thresholds			
γ_1		-0.128	-0.57
γ_2		0.841	3.79
γ_3		1.334	5.99
γ_4		2.277	10.04
Respondent Demographics			
Aged…	…26 - 35 Years Old	-0.012	-0.15
	…36 - 45 Years Old	0.089	0.73
	…46 -55 Years Old	-0.013	-0.10
	…56 - 65 Years Old	-0.002	-0.02
	…65 or Older	-0.121	-0.37
Gender …	…Male	-0.233	-3.95
	…Other	-0.981	-2.12
Commute Time…	…11 - 15 min	0.020	-1.00
	…16 - 30 min	-0.170	-2.78
	…30 min or more	-0.182	-0.94
Income…	…$20k - $39k	-0.276	-2.78
	…$40k - $59k	-0.107	-0.94
	…$60k - $79k	-0.100	-0.93
	…$80k - $99k	-0.321	-3.03
	…$100k or more	-0.308	-3.32
Children Present in Household		0.077	0.70
Respondent Physical Activity Participation			
Walks…	…Infrequently	0.715	2.01
	…Frequently	0.150	1.00
Runs…	…Infrequently	-0.070	-0.24
	…Frequently	0.052	0.42
Rides Bicycle …	…Infrequently	-0.442	-1.33
	…Frequently	-0.254	-1.92
Works Out…	…Infrequently	-0.227	-1.48
	…Frequently	0.099	1.54
Completes Activities with…	…Adults	-0.123	-1.93
	…Children	-0.002	-0.02
	…Pets	0.072	1.02
Respondent Experience with Shared-use Paths			
Uses Local SU Paths		-0.155	-1.80
Uses Non-Local SU Paths		0.267	4.27
Wants Access to More SU Paths		0.914	8.12

Parameters	***Coeff.***	***t-stat***
Shared-use Path Characteristics		
…has Asphalt Surface	1.904	29.02
...is 10ft Wide	-0.164	-0.84
x Infrequent Walker	0.107	0.24
x Frequent Walker	0.172	1.02
x Infrequent Runner	0.083	0.24
x Frequent Runner	0.091	0.66
x Infrequent Cyclist	0.329	0.71
x Frequent Cyclist	0.194	1.32
...is 15ft Wide	0.247	1.21
x Infrequent Walker	-0.119	-0.28
x Frequent Walker	0.019	0.11
x Infrequent Runner	0.043	0.13
x Frequent Runner	0.003	0.02
x Infrequent Cyclist	0.453	1.04
x Frequent Cyclist	0.183	1.18
...is 15ft Wide w/ Dividing Line	0.379	1.27
x Infrequent Walker	-1.799	-2.92
x Frequent Walker	-0.378	-1.38
x Infrequent Runner	0.062	0.10
x Frequent Runner	-0.200	-0.98
x Infrequent Cyclist	0.677	1.15
x Frequent Cyclist	0.648	2.92
…has 40ft Separation	0.29	1.48
x Infrequent Walker	0.028	0.07
x Frequent Walker	-0.096	-0.56
x Infrequent Runner	0.339	0.99
x Frequent Runner	-0.023	-0.17
x Infrequent Cyclist	-0.183	-0.44
x Frequent Cyclist	-0.085	-0.58
x Aged 65 or Older	-0.055	-0.12
…has 20ft Separation	0.011	0.06
x Infrequent Walker	-0.201	-0.49
x Frequent Walker	0.116	0.70
x Infrequent Runner	0.416	1.26
x Frequent Runner	-0.078	-0.58
x Infrequent Cyclist	-0.002	-0.01
x Frequent Cyclist	-0.107	-0.74
x Aged 65 or Older	0.194	0.42

Lastly, Table 6 summarizes significant factors influencing how an individual perceives the safety of a shared-use pathway. Here, pathway design elements are finally significant and relevant. In terms of design, pathway widths were not significantly important for users except cyclists. Infrequent cyclists felt the 10-foot wide pathway is more safe, whereas frequent cyclists felt that 10-foot wide and 15-foot wide pathways are more safe (and about equally so) than 8-foot pathways and 15-foot wide pathways with a dividing line are safest. Alternatively, separation from the roadway is most significant. All users feel the 40-foot separation is the safest option above the two others. Based on the calculated coefficient values reported in Table 6, infrequent runners felt this separation was twice as safe compared to the entire aggregated survey respondents while frequent cyclists felt it was half as safe as other users. Demographics account for inherent perceived safety as well: women, infrequent walkers, and those who frequently work out felt pathways were inherently more safe; individuals that commute between 11 and 30 minutes to work, have higher incomes, are frequent cyclists, and who use pathways in groups find pathways inherently less safe. Interestingly, if an individual uses pathways locally but not elsewhere, he/she feels they are less safe; alternatively, if an individual uses pathways elsewhere but not locally, he/she feels they are safer. These results further emphasize the need for more shared-use pathways in an area: with fewer pathways currently in the local region, users are less aware of proper behavior, yielding, etc. which can lead to conflicts and perceptions of unsafe facilities. As more people are active on shared-use paths, seen in non-local areas, expected behaviors are more consistent, resulting in facilities that are perceived to be safer.

Table 6: Perceived Safety of Shared-Use Path Estimation

Parameters		*Coeff.*	*t-stat*
Thresholds			
γ_1		-0.558	-2.53
γ_2		0.520	2.38
γ_3		1.110	5.06
γ_4		2.138	9.61
Respondent Demographics			
Aged…	…26 - 35 Years Old	0.025	0.31
	…36 - 45 Years Old	-0.152	1.29
	…46 -55 Years Old	-0.030	-0.23
	…56 - 65 Years Old	-0.017	-0.14
	…65 or Older	0.283	0.83
Gender…	…Male	-0.163	-2.80
	…Other	-1.123	-2.42
Commute Time…	…11 - 15 min	-0.146	-2.35
	…16 - 30 min	-0.367	-4.31
	…30 min or more	-0.013	-0.07
Income…	…$20k - $39k	-0.192	-1.96
	…$40k - $59k	-0.027	-0.24
	…$60k - $79k	-0.184	-1.75
	…$80k - $99k	-0.429	-4.14
	…$100k or more	-0.161	-1.75
Children Present in Household		-0.051	-0.47
Respondent Physical Activity Participation			
Walks…	…Infrequently	0.815	2.28
	…Frequently	0.130	0.89
Runs…	…Infrequently	-0.109	-0.38
	…Frequently	0.071	0.58
Rides Bicycle…	…Infrequently	-0.275	-0.82
	…Frequently	-0.296	-2.26
Works Out…	…Infrequently	-0.179	-1.17
	…Frequently	0.120	1.89
Completes Activities with…	…Adults	-0.121	-1.94
	…Children	0.116	0.94
	…Pets	0.108	1.55
Respondent Experience with Shared-use Paths			
Uses Local SU Paths		-0.266	-3.10
Uses Non-Local SU Paths		0.225	3.65
Wants Access to More SU Paths		0.985	8.85

Parameters	*Coeff.*	*t-stat*
Shared-use Path Characteristics		
…has Asphalt Surface	1.625	25.96
...is 10ft Wide	-0.304	-1.58
x Infrequent Walker	-0.139	-0.32
x Frequent Walker	0.108	0.65
x Infrequent Runner	0.057	0.16
x Frequent Runner	0.088	0.65
x Infrequent Cyclist	0.865	1.81
x Frequent Cyclist	0.390	2.66
...is 15ft Wide	0.151	0.76
x Infrequent Walker	-0.396	-0.94
x Frequent Walker	-0.053	-0.31
x Infrequent Runner	-0.154	-0.46
x Frequent Runner	0.050	0.35
x Infrequent Cyclist	0.511	1.17
x Frequent Cyclist	0.397	2.58
...is 15ft Wide w/ Dividing Line	0.329	1.13
x Infrequent Walker	5.693	0.00
x Frequent Walker	-0.374	-1.40
x Infrequent Runner	-0.246	-0.42
x Frequent Runner	-0.109	-0.53
x Infrequent Cyclist	0.282	0.43
x Frequent Cyclist	0.855	3.88
…has 40ft Separation	0.498	2.59
x Infrequent Walker	-0.016	-0.04
x Frequent Walker	-0.038	-0.23
x Infrequent Runner	0.588	1.70
x Frequent Runner	-0.050	-0.38
x Infrequent Cyclist	0.185	0.44
x Frequent Cyclist	-0.257	-1.78
x Aged 65 or Older	-0.444	-0.98
…has 20ft Separation	0.277	1.46
x Infrequent Walker	-0.308	-0.73
x Frequent Walker	0.009	0.06
x Infrequent Runner	0.171	0.53
x Frequent Runner	-0.058	-0.44
x Infrequent Cyclist	0.142	0.34
x Frequent Cyclist	-0.110	-0.77
x Aged 65 or Older	-0.175	-0.38

3.5 Shared-Use Path Stated Preference Conclusions

This analysis was able to verify past research with new data from current path users and also make multiple new conclusions that will help in future planning or designs of new and improved shared-use paths. For the framework that will be developed in the later portions of the dissertation, major results from this stated preference survey include:

- Users consider shared-use paths as a facility that can be used for utilitarian trips in addition to recreation and exercise. The largest response for path usage was found to be mode of travel, higher than both exercise and recreation. This was found across all demographics including cyclists.
- A hard surface such as asphalt or concrete is heavily preferred compared to gravel. The path material had the largest influence among all the design options presented in the survey. This reiterates the need for a hard surface to accommodate cyclists. If gravel is to be used on the path for budgetary or efforts to reduce impervious cover, care should be given to ensure the path material is fine, compacted, and ADA compliant. The survey participants were shown a loose gravel image and it was apparent the reaction was negative.
- Shared-use path users prefer wider paths separated further away from the roadway. While not as clear of a preference than choice of path material, users reported a general preference towards wider paths set further away from the roadway. This is in line with general perceptions and past research and models.
- Frequent cyclists are interested in a path design that separates bicyclists from pedestrians. Through all three measures (likelihood of use, satisfaction, and perceived safety) frequent cyclists were the only path user type that the model found bias towards this specific

design option. This shows the difference between experienced cyclists who would be frustrated using a shared-use path slowed by other users and infrequent cyclists that are content being separated from vehicular traffic.

- Across all three measurements, the use of non-local shared-use paths resulted in a higher preference and two of the three measurements had the opposite result for local shared-use path usage. This brings a conclusion that the more experience a user has with these facilities, the more comfortable they become.

The findings from this analysis show the importance of understanding user preferences prior to designing a new facility. With this analysis showing the continued demand for protected multi-modal facilities separate from motor vehicles, engineers and planners should consider these type of facilities in suburban and rural locations as well as dense, urban environments that are currently garnering the majority of the research and funding. With national goals to increase the non-motorized mode share in the United States, this study shows road adjacent shared-use paths could be used in rural and suburban communities to provide the necessary infrastructure to meet those goals. However, it is important to understand that a shared-use path is not the solution to every scenario looking to satisfy the needs of all transportation modes. Therefore, the next section of this dissertation will focus on determining how cyclists use road adjacent shared-use paths and how the adjacent roadway impacts the facility choice.

Chapter 4: Shared-Use Path Revealed Preferences from a Bike Share Route Analysis

The second objective of the dissertation is covered in this chapter and focuses on revealed preferences from cyclists' actual facility and observed route decisions. This objective builds and expands upon the findings performed in Chapter 3 and completes one of the three objectives for the overall dissertation's goal. The stated preference analysis from the previous chapter provides useful and powerful guidance to better understand the perceived demand and needs of road adjacent shared-use paths. However, by its intentional focus specifically on pathway design elements it does not take into account the impacts of the adjacent roadway and is based exclusively on self-reported preferences. With this dissertation's goal to provide a full comprehensive analysis of shared-use paths preferences, a completely new data set and analysis is required to learn more about the other preference influences.

This chapter captures the impacts of the adjacent roadway by gathering real bicycle ridership data from a campus bike share program at Auburn University. The analysis in this chapter used three years' worth of ridership data that included over 100,000 trips and almost 9,000 users. This allows for a true big data analysis which is defined as increasingly larger data volume and frequency due to new data sources. The bike share technology provides both larger and more frequent data that would not have been able to have been gathered without the program. The data set allowed for a unique analysis of route choices based upon rider, infrastructure, and trip variables. First, new bike share user typologies were created based on user travel characteristics. Second, nine specific locations with varying physical conditions were identified where it could be determined whether cyclists were riding in a non-separated (either a conventional bicycle lane or shared street condition) or separated bicycle facility (in a road adjacent shared-use path or sidewalk). Both the new user typology and location of the rider are used in a binary regression model to determine what factors are significant for users when choosing specific facilities. By completing this objective, transportation professionals will be able to see actual facility preferences of different types of users.

4.1 Data Collection: War Eagle Bike Share GIS Analysis

The rise of bike share programs worldwide not only provides access to bicycles for potential users but also allows for valuable opportunities to obtain real time ridership information. Many modern bike share programs provide actual route tracking to determine not only the route choice but also bicycle facility chosen, either non-separated or separated. This is the case with Auburn University's campus bike share program, named War Eagle Bike Share. War Eagle Bike Share began in February 2016 with 75 bicycles and 10 hubs under the management of university's parking services office and through the vendor Gotcha Bike. During the first three years of existence, the program has grown to 200 bicycles and expanded hubs to off-campus locations through a partnership with the City of Auburn. The program's model provides any individual the ability to sign up and unlock a bicycle through a smartphone application. The users are required to provide an email address and current credit card information. Users can ride the bicycles without any charge for up to two hours a day regardless of their university affiliation. Fees are assessed when usage exceeds two hours in one day or a bicycle is locked outside of a hub. The financial model for the program relies on these fees, advertisements, and subsidies from Auburn University and the City of Auburn.

Each of the War Eagle Bike Share's bicycles are equipped with a global positioning system (GPS) receiver that tracks and records the location of the bicycle approximately every 30 seconds. This technology allows for the bicycle locations to be consistently tracked and monitored as well as minimal infrastructure needs for the bicycle hubs. For this specific bike share program, the identified hubs are simply standard bicycle racks with signage informing users of its location and instructions for using the program. Unlike some of the larger city programs that require bicycles to be locked up in robust bike corrals with a large amount of infrastructure, these bicycles each contain their own u-lock that when engaged completes the ride. Each hub is identified in the smartphone application and geofenced so the bicycle's GPS position identifies if the bicycle is locked up within the identified hub location. Each bicycle's GPS is powered by a small solar panel located on the bicycle and communicates to the system's central server through a standard SIM card on a wireless network. Like all wireless communications, signals are sometimes interrupted or quality reduced. However, overall the system has been shown to produce a high level of accuracy identifying bicycle locations with the vendor reporting typical accuracy within 10 feet of the actual location.

From the bicycle tracking, a summary of each trip is recorded that can also be associated back to the specific user's account number. This information is powerful and will be utilized in this chapter, as it allows for trip and user specific studies to understand potential motivations and deterrents for cycling. The software for the system reports in real-time the location of the bicycles and a summary of past trips. The summary identifies the user, trip distance, trip duration, trip date, trip time, original and final hub location. This summary information was obtained for each trip during the program's first three years. The initial dataset included 132,057 individual trips. Extensive data management was required to administer this large data file with the initial step being data cleaning. The first step was to remove the trips that produced incomplete records. These 14,641 incomplete trips had missing values for some of the trip descriptions. These are likely due to a malfunction in the GPS unit or loss of power from the solar panel. Second, trips were associated with an administrator user account that was mostly used during bicycle rebalancing or removing bicycles for repair or service. These trips were identified by unique administrator user account numbers. The bike share bicycles require rebalancing when there are large cluster of bicycles at the same hub and limited bicycles found at other hubs. University personnel are required to relocate those bicycles, and many times the bikes were unlocked during this process so a trip was recorded. In total, 10,947 trips were removed as they were registered to an administrative user account.

After removing the 25,588 administrative, bike-rebalancing, and incomplete trips, 106,469 trips taken by 8,812 unique users remained. The trips are further broken down with 42,781 taken in year one; 34,940 in year two and 28,748 in year three. Even though the program has added bicycles and hubs over the three years of operations there is a distinct trend downward in usage likely due to the loss of intrigue and marketing that occurred when the program first began. Figures 10 and 11 break the 106,469 trips based on time of day and by month of the year. Both figures also distinguish between which year the trip occurred during the life of the bike share program. The figures show a peak in seasonal usage during the fall semester which aligns with the highest populations, activity and visitors at Auburn University and also contains the most accommodating weather for cycling. The data does not exhibit a drastic apparent peak time of day distribution. Unlike typical motor vehicular morning and afternoon commuter peaks, the bike share has its highest usage in the middle of the day which likely shows the campus bikes share program is utilized for travel across campus and also for recreation. Additionally, college students (which is the primary target demographic of the War Eagle Bike Share program) do not have the same peak consistent morning and afternoon travel times as working adults.

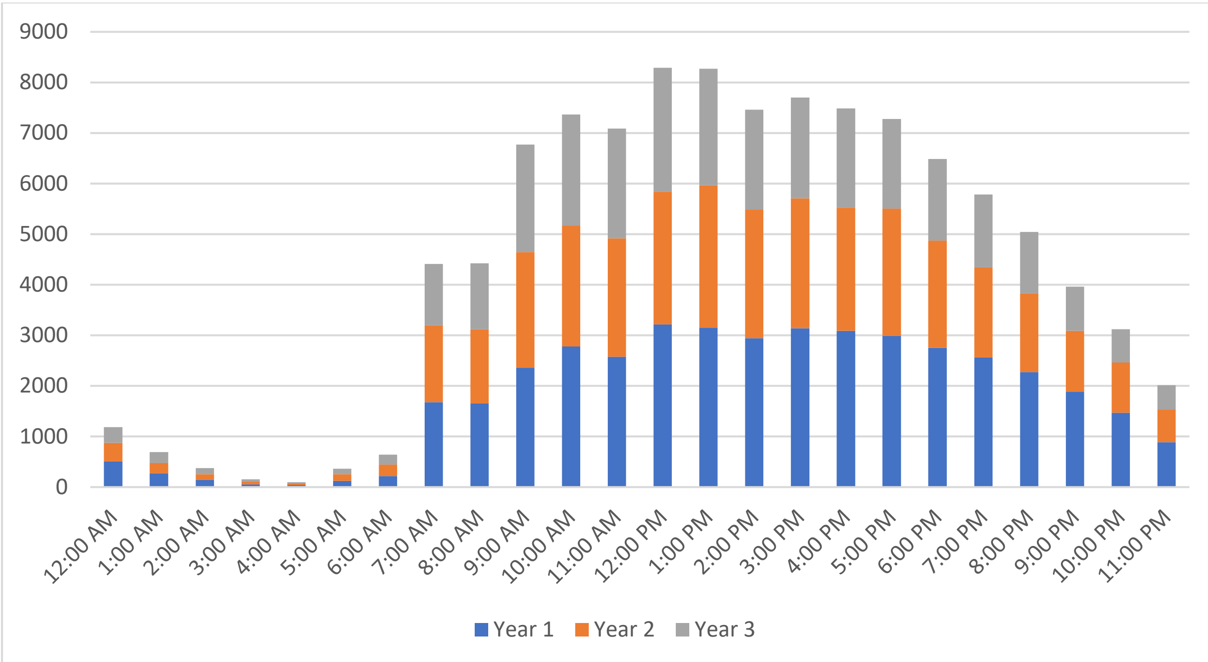


Figure 10: Bike Share Trip Summary - Time of Day

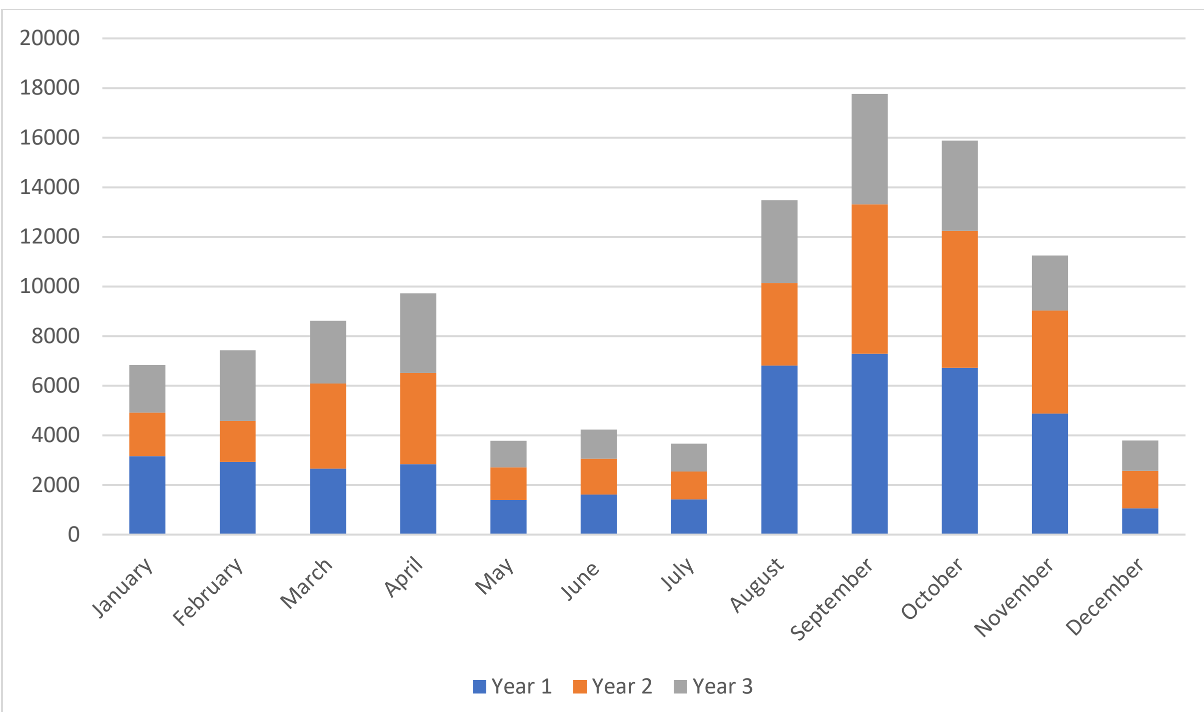


Figure 11: Bike Share Trip Summary - Month

The trip summary data alone provides a very compelling overview of cycling transportation on the university campus. However, with the bicycle's continuous GPS tracking even more information can be gathered studying the trip routes. While not part of the vendor's standard back of office reporting, the bike share program does allow for a data download of the trip route locations. This download produced a dataset of 8.94 million GPS points in a Keyhole Markup Language (KML) file that record the physical location of each point along with trip and user identification. These points are converted into shapefiles and analyzed in ESRI ArcGIS software ArcMap. With almost nine million recorded points, the file sizes were extremely large requiring them to be broken into individual months rather than for the entire three years or even an individual year.

Figure 12 illustrates one month of point files (March 2016) that highlights the extensive usage of the bike share program. Not surprisingly , the largest clustering of points is located in the middle of the Auburn University campus but there are a number of trips made outside the university campus to destinations like the municipal tennis complex, post office, Chewacla State Park, grocery store, and off-campus housing complexes. This is even more interesting since this example month was during the first year of operation so the agreement with the City of Auburn was not yet in place that expanded hubs outside of the campus boundary. This visualization of a month of the War Eagle Bike Share program ridership shows that it is not only utilized for just internal campus mobility but also used for utilitarian trips outside campus.

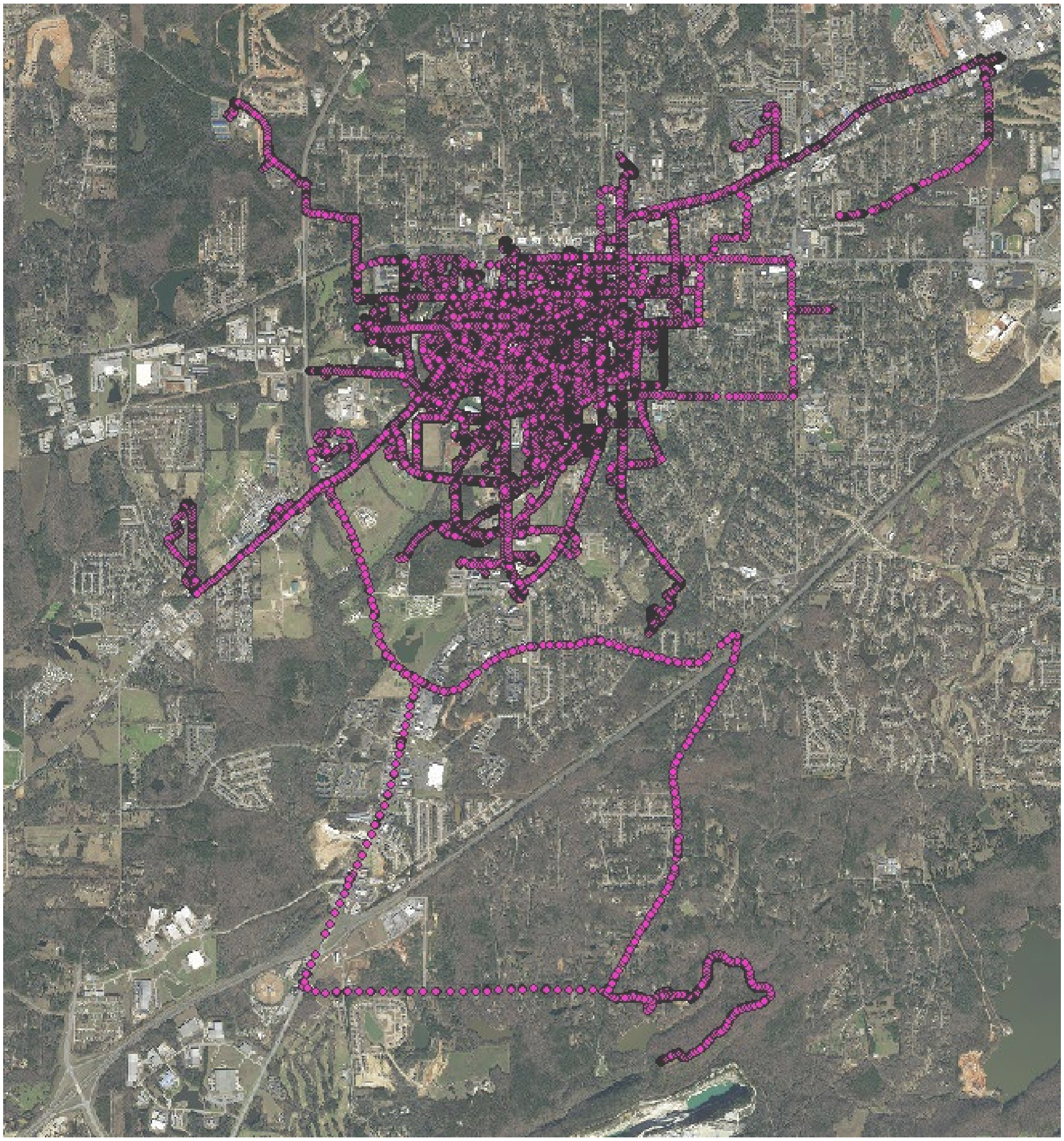


Figure 12: Example Bike Share Mapping - Overall

With manageable monthly trip point files, further analysis can be performed on the entire three-year dataset beyond the overall observations of trip patterns and summary information that includes start and end hub locations. For example, Figure 13 highlights one specific trip made by a user during March 22, 2016. As seen in the illustration, the entire route can be displayed and studied among the entire collection of trips that month. For this specific trip, the initial hub was at the Science Center Classroom near the middle of the Auburn University campus and final hub was at the Village Dining Hall located on the western side of campus. However, the user's route was not direct and essentially circumnavigated the campus core. This could be due to avoidance of pedestrian conflicts, to gain more exercise, or simply is a recreation trip.

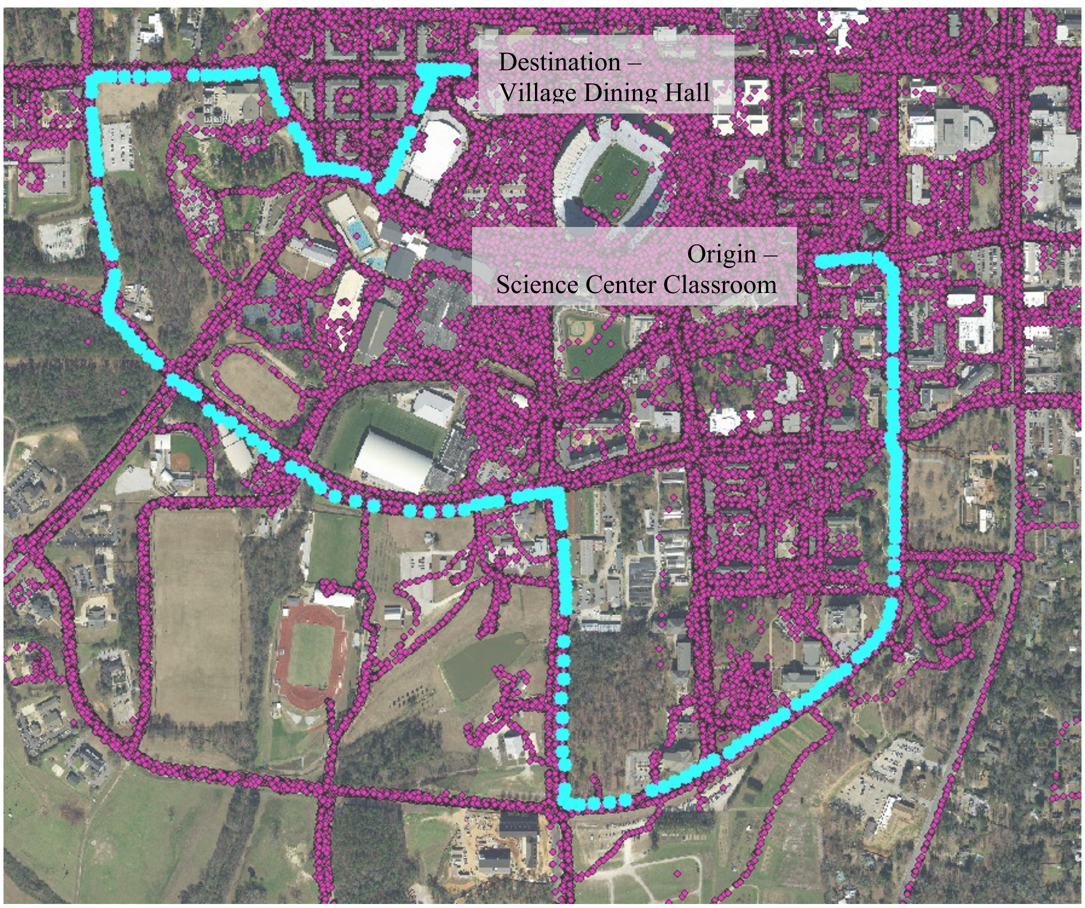


Figure 13: Example Bike Share Mapping – Trip

Furthermore, studying the route at the next level down shows the ability to understand if the user chose separated or non-separated bicycle facilities. Figure 14 again shows an entire month of points and highlights in blue the points for the one trip that was shown in its entirety in Figure 13 but is zoomed in to view in a smaller scale. The accuracy of the GPS data allows the location of route to be identified and in this case the user rode on a combination of sidewalks and road adjacent shared-use paths compared to the shared-lane and conventional bicycle lane options. The stray points shown in the landscape between the path and roadway demonstrate the typical variance of the GPS bicycle tracking with the majority of the points located within a specific facility and the others within the ten foot of accuracy.

Figure 14: Example Bike Share Mapping – Route

The War Eagle Bike Share trips vary in distance, route (and thus trip purpose), speed and location. To quantify the trip location, a GIS analysis was performed to determine if the trip was contained entirely on the Auburn University campus or left the campus boundary. Again using ArcMap software and in this instance the join feature, each point was assigned a specific descriptive attribute if it fell in or outside of the Auburn University property. If all the points associated with a specific trip contained the on-campus attribute, then that trip itself was categorized as an on-campus trip. Conversely, if at least one point fell outside the boundary and contained an off-campus description, then the entire trip was tagged as off-campus. A summary of the complete trip dataset is included in Table 7 (including trip location). The average trip was less than a mile and lasted less than 10 minutes, highlighting that this campus bike share program is primarily used for quick trips and generally not used for longer distance trips away from the university campus. The majority of the trips made with the War Eagle Bike Share were confined to the Auburn University campus. This again shows that while the program does facilitate utilitarian trips, the majority of the trips are generally not used to replace commuting trips to and from campus but is primarily used for intra-campus travel.

Table 7: Bike Share Trip Summary

Trip Location	
On-Campus	89,595 (84%)
Off-Campus	16,874 (16%)
Trip Duration (minutes)	
Minimum	3.00
Average	8.52
Maximum	158.00
Trip Distance (miles)	
Minimum	0.15
Average	0.80
Maximum	17.42
Trip Speed (mph)	
Minimum	3.00
Average	6.46
Maximum	20.00

4.2 General Preferences: User Summary and New Bike Share Typology

Full demographic information is not known for the bike share users with the only information needed to become a member of the program is an active email address and credit or debit card. However, each recorded trip from the bike share program contained a unique user identification number which was used to aggregate the trip data from the trip level up to the user level. This led to defining 8,812 bike share users that each have known variables and characteristics based on their trip characteristics. Notable variables include number of trips, percentage of trips off campus, average trip distance, average trip duration, average speed, maximum trip distance, maximum trip duration and maximum trip speed. Table 8 provides a summary of the user characteristics for number of trips, percentage of trips on-campus and average trip statistics.

Table 8: Bike Share Users Travel Summary

Number of Trips	
Minimum	1
Average	12
Maximum	962
Percentage Trips Off-Campus	
Minimum	0%
Average	25%
Maximum	100%
Average Trip Duration (minutes)	
Minimum	3.00
Average	19.75
Maximum	158.00
Average Trip Distance (miles)	
Minimum	0.16
Average	1.52
Maximum	14.04
Average Trip Speed (mph)	
Minimum	3.00
Average	5.29
Maximum	19.60

This analysis and the previous trip summary show there are many variations between the types of bike share trips as well as the users themselves. There is a very large range in the overall number of bike share trips made with over half of the bike share users only using the program once or twice. This could show dissatisfaction with the program, only mild interest, only needing the program due to their personal bicycle being unavailable, or purchasing their own bicycle. On the other hand, there are also some very frequent users and regular users of the program but at a lower percentage with just over 2% of the total users making 100 trips or greater. The average percentage of trips off-campus also has a similar range with some user exclusively riding on-campus while others are exclusively off-campus. As expected, the users' average trip duration, speed and distance also vary with some long distance and higher speed trips and other short and slower trips.

The large range in how individuals use the War Eagle Bike Share program highlights the need to break the users into corresponding groups for further analysis. Developing a bike share user typology will help understand the varying types of individuals using the bike share program that will lead to a study of infrastructure needs for each user type. An iterative process using K-means clustering analysis within IBM's SPSS software was used to select the specific variables used to define the typology. Ultimately, the data responded best with the partitioning technique of the K-Means cluster analysis since the goal of this analysis was to find exclusive groups with the hierarchical relationships of these groups not specifically necessary. The K-Means cluster algorithm mathematically associates a user to a centroid of each cluster based upon specified variables. The variables that were included in the analysis were percentage of trips off-campus, average trip distance, average trip duration, average trip speed. Interestingly, although number of trips was considered in the clustering process, it was not included in the final clusters because there was too much variability without patterns in the data. Specifically, the cluster analyses that included the number of trips produced only two major groupings due to so many users making only one or two trips. Following trials with different clustering variables and number of clusters, four clusters were found to best fit the dataset following an ANOVA test being able to reject the hypothesis that the clusters should be combined with a 99% confidence level. Four clusters also align with the typical number of groupings used in past cyclist typology research.

The newly defined clusters from this analysis allow for a better understanding for how users are using the program based upon their travel patterns. These clusters are used to define the four new bike share typologies which define a spectrum of users with varying trip characteristics and frequencies. The new travel patterns from each of the typologies were examined so that each new group could be named based on the bike share data and described as follows:

- **Unsupported Users** (3% of the sample) typically use bike share only once to make a trip far off-campus to a location without a rack where they can “check-in” their borrowed bicycle, resulting in significantly longer trip durations. Average speeds are low because a portion of the trip is when the bicycle is not in use. These users are likely confident cyclists to travel further distances. It is interesting that these users utilize the bike share once and do not repeat their trip, perhaps because a) they hope that it would be a feasible trip but learn that it is inconvenient/difficult and do not wish to repeat it or b) know that it is inconvenient/difficult but are forced to take the trip without another means of transportation.
- **Aspirational Users** (13% of the sample) are similar to the first group, in that they are using bike share to reach off campus destinations and traveling further distances, on average, but they are able to “check in” their bike to designated rack at their destination

(resulting in higher average speeds and shorter trip durations). Some members of the group use bike share to make many more trips to these destinations, but the majority make about two trips. Again, these cyclists are likely confident biking with traffic to reach off-campus destinations. This further emphasizes that while there is a population that wishes to use bike share for off-campus activities, they are not supported in doing so due to inconvenient/difficult off-campus access. There is not a great difference between this group and the former, except this group was willing to use bike share for longer distances, use it more frequently and selected destinations that had been set up to accommodate the bike share program.

- **Flexible Users** (24% of the sample) use bike share more often to access both on and off-campus destinations, with members of this group using bike share more frequently. The average trip distance and durations are shorter than the previous two groups, although there is a greater range of maximum distances demonstrated by these users. Members of this group may be using bike share for a variety of purposes, and have adopted it as a part of their transportation choices. If improvements were made to the bicycle network, they would most likely be the first to adopt bike share for more activities.
- **Purposeful Users** (60% of the sample) are the largest proportion of users. While they use the bike share system the most (over 18 times, on average), they predominantly only use bike share to access on-campus destinations. The short distances and durations likely indicate these users have found specific utilitarian uses incorporating bike share into their life (e.g. for getting around campus between classes, to attend meetings, or for social activities). These users are for whom the bike share system was originally designed, and it is positive to find that it is reaching its intended audience. It is possible that these users

could be encouraged to join the flexible user group if access to other destinations is made more seamless and easy.

Table 9: Bike Share User Cluster Summary

	Overall		Variables In Cluster Analysis				Additional Variables			
	No.	Percent	Percent Off-Campus	Avg Distance (miles)	Avg Duration (minutes)	Avg Speed (mph)	Avg No. of Trips	Avg Max Distance (miles)	Avg Max Duration (minutes)	Avg Max Speed (mph)
Unsupported Users	267	3%	65%	5.27	79.89	3.98	1.25	5.45	82.90	4.06
Aspirational Users	1144	13%	49%	3.36	46.45	4.40	1.76	3.77	52.55	4.65
Flexible Users	2101	24%	32%	1.98	25.95	4.71	2.47	2.54	34.00	5.18
Purposeful Users	5300	60%	16%	0.76	8.50	5.77	18.67	1.41	17.37	7.61

Table 9 shows the summary statistics of the clustering variables used to define the typology along with other descriptive statistics. It is interesting that 84% of the bike share users fall into either the flexile or purposeful user categories. These two groups not only account for the majority of the users they represent, but also the vast majority of the trips, as the other two groups use the bike share less frequently. These two groups are also likely less confident and experienced cyclists compared to the unsupported and aspirational users. This presents an interesting condition and shows the impact of bike share where the majority of the users are likely the least experienced cyclist. With these known conditions, it is important that future programs engage these two groups and the cycling infrastructure is made to accommodate these users. Figure 15 demonstrates the changes in distributions for important variables across the typology using box and whisker plots. These new typologies can be used by bike share program managers to understand their users and also by transportation officials who want to gain insight in accommodating interested bicycle users in their communities.

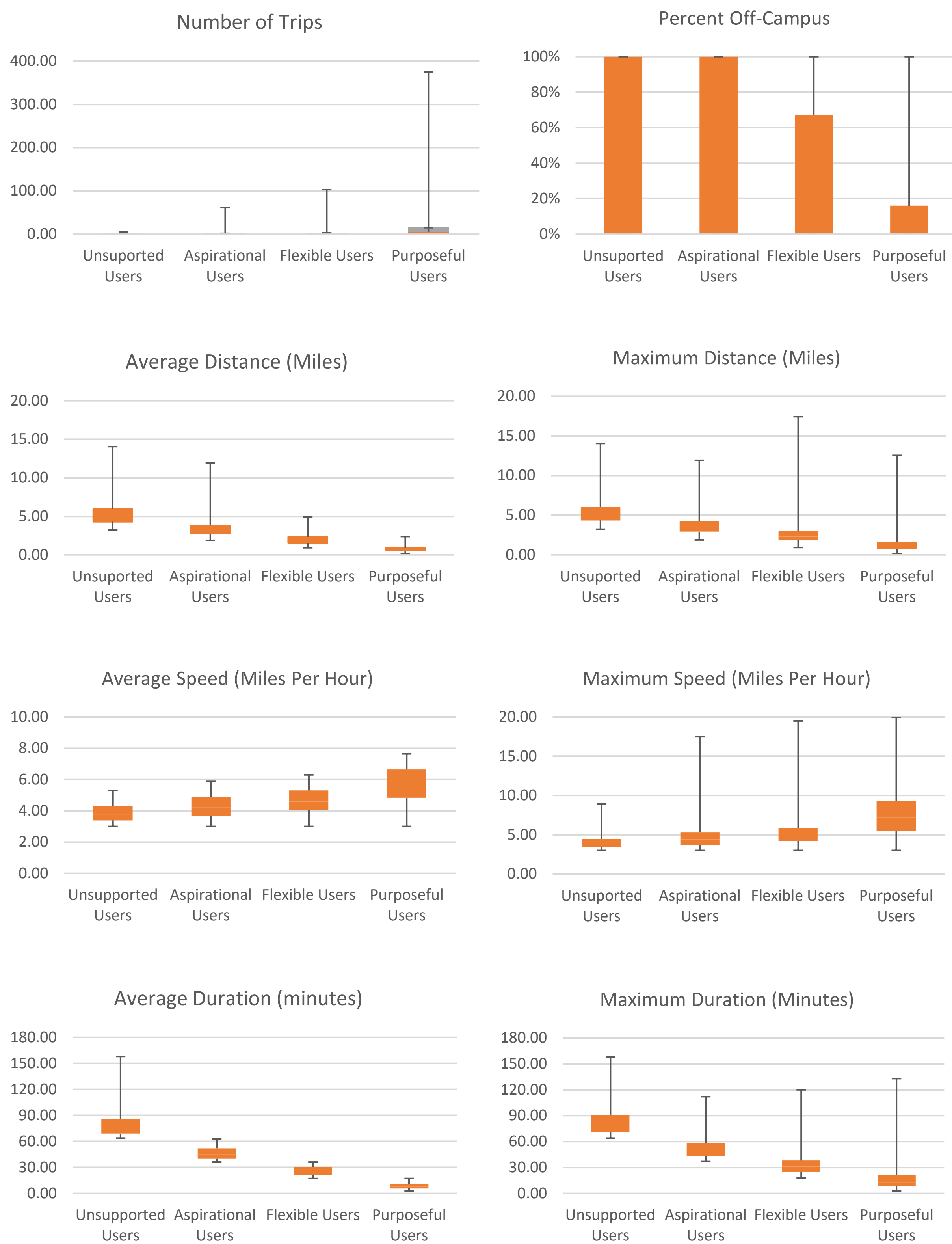


Figure 15: Cyclist Typology Distribution

4.3 Route Analysis: Non-Separated versus Separated Facility Selection

Of major interest to this dissertation topic, the next phase in the bike share analysis used the three years of data from the War Eagle Bike Share to understand the influence that the previously created bike share user group membership has on preferences for separated and non-separated bicycle facilities. The GPS data was again utilized to identify for specific trips whether a cyclist chose to ride on the road on a separated facility (either a sidewalk or road adjacent shared-use path). Nine locations, shown in Figure 16, were selected that have both separated and non-separated options from which cyclists may choose. All locations are outside of the campus core, which has a limited vehicular presence, as this analysis is interested in whether individuals demonstrate a preference for traveling near or far from motor vehicles. The nine locations were dispersed so that five are located on the Auburn University main campus and four just outside campus and within the City of Auburn. The study locations were also selected that had a significant distance between the roadway and the separated bicycle facility (i.e. not on the back of curb). This allowed for a GIS route analysis to be performed given the known margin of error from the bike share bicycles.

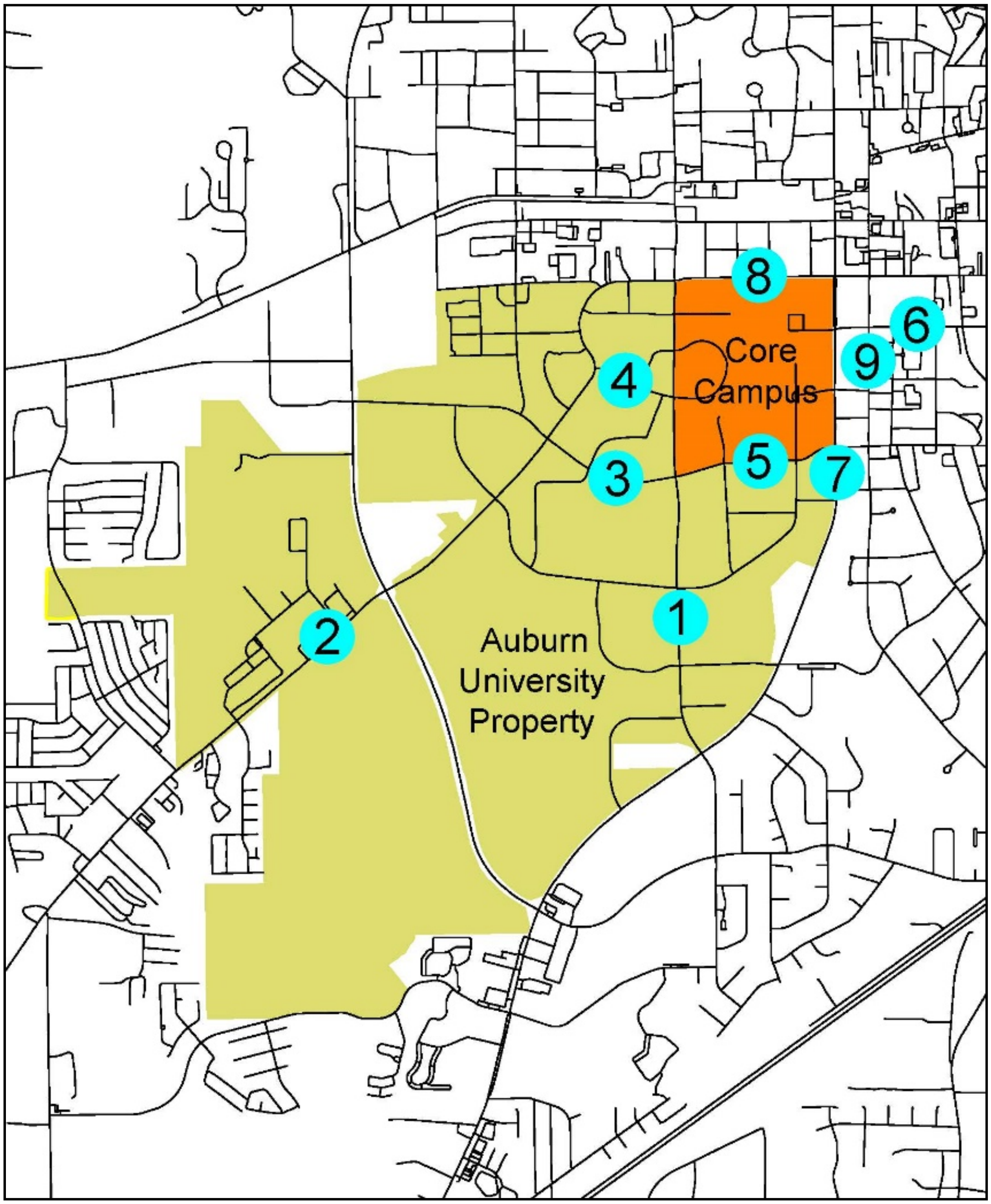


Figure 16: Site Study Location Map

Three facility categories were selected as study locations (with three unique locations demonstrating each): 1) a road adjacent shared-use path; 2) a sidewalk adjacent to a roadway with a conventional bicycle lane; and 3) a sidewalk adjacent to a shared roadway. While sidewalks under 10 feet are not allowed for bicycles in Auburn, a large percentage of cyclists still use them as a way to avoid interacting with traffic and can be used to understand preference for being physically separated from traffic. For this study, it is assumed that if a user chose to ride on an adjacent sidewalk, they would be riding on a legitimate separated bicycle facility, if available. The roadways themselves also have varying conditions with a range of lanes, speed limits, traffic volume, and lane width along with conventional bicycle lane width (documented in Table 10). The intent of the roadways selected are they consistent with typical roadway environments experienced in suburban communities across the United States with lane widths from two to five lanes and daily traffic volumes from 6,000 to 12,000 vehicles. Images of the nine site locations are shown in Figures 17 – 25 that demonstrate a wide range of physical environments included in this study.

Table 10: Site Summary

	Route		Physical Conditions						
			Vehicular Lane Width	Vehicular Lanes	Posted Speed	Daily Traffic	Bicycle Lane Width	Walk or Path Width	Distance from curb
Shared-Use Path	1	Donahue Dr	12 ft	4	45 mph	11,000	N/A	10 ft	30 ft
	2	Wire Rd	12 ft	5	55 mph	12,000	N/A	10 ft	25 ft
	3	Samford Ave	12 ft	3	35 mph	8,000	6 ft	10 ft	40 ft
Bicycle Lane with Sidewalk	4	Heisman Dr	11 ft	2	30 mph	6,000	5 ft	15 ft	10 ft
	5	Samford Ave	11 ft	2	25 mph	7,500	5.5 ft	6 ft	14 ft
	6	Thach Ave	11 ft	2	25 mph	8,300	3.5 ft	4 ft	10 ft
Shared Lane with Sidewalk	7	College St	12 ft	4	35 mph	15,500	N/A	4 ft	6 ft
	8	Magnolia Ave	11.5 ft	3	25 mph	7,500	N/A	6 ft	14 ft
	9	Gay St	14 ft	2	25 mph	9,000	N/A	5 ft	8 ft

Figure 17: Location 1 - Donahue Dr

Figure 18: Location 2 - Wire Rd

Figure 19: Location 3 - Samford Ave

Figure 20: Location 4 - Heisman Dr

Figure 21: Location 5 - Samford Ave

Figure 22: Location 6 - Thach Ave

Figure 23: Location 7 - College St

Figure 24: Location 8 - Magnolia Ave

Figure 25: Location 9 - Gay St

The same GIS technique (the join command) that was used to identify off-campus trips was utilized in determining the number of trips that occurred along the nine locations. Of the 106,469 total trips, 10,327 trips were along one of the identified nine locations. Each one of the trips that passed through a study area was spatially coded to identify whether it was located in a non-separated or separated facility. GPS points were collected frequently such that each trip was represented by enough points to accurately determine whether the cyclist was within the lane or using the facility, despite typical noise and error in GPS data. To increase the accuracy in determining the physical location of the bicycle, the analysis location was selected where there was the greatest horizontal distance between the roadway and the separated facility. This allowed for any error in the GPS tracking to be overcome due to the site study location. Overall, approximately one-third of the trips were made on the road with the remaining two-thirds in a separated facility, either a road adjacent shared-use path or sidewalk. Table 11 breaks down each of the nine locations for which trips were designated as occurring in a non-separated or separated facility. A subtotal is included for three facility types: a road adjacent shared-use path; a sidewalk adjacent to a roadway with a conventional bicycle lane; and a sidewalk adjacent to a shared roadway.

Table 11: Non-Separated vs. Separated Summary

		Route	Non-Separated	Separated	Total
Shared-Use Path	1	Donahue Dr	57	367	424
	2	Wire Rd	12	128	140
	3	Samford Ave	780	885	1665
		Subtotal	849 (38%)	1380 (62%)	2229
Bicycle Lane with Sidewalk	4	Heisman Dr	1239	3107	4346
	5	Samford Ave	553	1103	1656
	6	Thach Ave	110	74	184
		Subtotal	1902 (31%)	4284 (69%)	6186
Shared Lane with Sidewalk	7	College St	6	23	29
	8	Magnolia Ave	526	1267	1793
	9	Gay St	15	75	90
		Subtotal	547 (29%)	1365 (71%)	1912
		Total	3298 (32%)	7029 (68%)	10,327

The results are interesting and show how the aspects of the physical infrastructure influence a user's route choice. One might expect the category providing an intentionally design road adjacent shared-use path to have the largest representation of separated cycle usage. However, the shared-use path category actually has the lowest overall separated percentage than compared to the other two categories. This is due to a large percentage of users riding on road at location three, Samford Avenue, which also contains a conventional bicycle lane. This unique condition of providing a shared-use path and bicycle lane in the same corridor will be explored in depth in the following chapter.

The newly created four typologies are cross-referenced in Table 12 with the non-separated and separated facility choices for the three main facility condition types. For consistency all 10,327 trips are included in the table but the same individual may be represented by multiple trips. As mentioned previously, it is not surprising that 62% of users chose the shared use path over traveling in the vehicle lane. Unsupported Users and Purposeful Users groups were shown to be more willing to bike in traffic rather than use the path and the Flexible Users group noticeably more likely to use the path. However, it is interesting that 69% of users chose to use the sidewalk instead of a painted bike lane (although Unsupported Users were more likely to use the bike lane than any other group). Even more users, 71%, chose to use the sidewalk when faced with biking with traffic in a shared lane. However, Unsupported Users were found to be more likely to do this than the other groups. For the first two facilities, the groups increasingly chose to bike separated from traffic from Unsupported Users, Purposeful Users to Flexible Users and Aspirational Users, respectively. However, Unsupported Users preferred the sidewalk when no separated facility was present (85%) and Purposeful Users were more willing to ride with traffic than use the sidewalk with only 70% using the sidewalk. This likely indicates that the purposeful users trip type of a shorter, more direct trip could influence the decision of riding on the more direct and faster facility type for this specific comparison.

Table 12: Non-Separated vs. Separated User Breakdown

		Unsupported User	Aspirational User	Flexible User	Purposeful User	Total
Shared-Use Path	Non-Separated	17	51	61	720	849
		44.74%	*32.28%*	*26.99%*	*39.85%*	*38.09%*
	Separated	21	107	165	1087	1380
		55.26%	*67.72%*	*73.01%*	*60.15%*	*61.91%*
Bicycle Lane with Sidewalks	Non-Separated	29	139	227	1507	1902
		44.62%	*29.89%*	*27.52%*	*31.19%*	*30.75%*
	Separated	36	326	598	3324	4284
		55.38%	*70.11%*	*72.48%*	*68.81%*	*69.25%*
Shared Lane with Sidewalks	Non-Separated	4	51	93	399	547
		15.38%	*26.15%*	*24.73%*	*30.34%*	*28.61%*
	Separated	22	144	283	916	1365
		84.62%	*73.85%*	*75.27%*	*69.66%*	*71.39%*
Total	Non-Separated	50	241	381	2626	3298
		38.76%	*29.46%*	*26.70%*	*33.02%*	*31.94%*
	Separated	79	577	1046	5327	7029
		61.24%	*70.54%*	*73.30%*	*66.98%*	*68.06%*

4.4 Model Methodology: Binary Logistic Regression

The non-separated versus separated facility data collection and cleaning provides multiple characteristics, including the bike share user typologies, which likely influence the cyclists' facility choice. A statistical method that can be used to predict the effect these characteristics have on facility choice is a logistic regression model. More specifically, with the dependent variable, denoted as y, being set as only one of two options (non-separated or separated), a binary regression model can be used. For a given specific trip, if the user operated non-separated $y = 1$ and conversely if the user rode separated $y = 0$. The independent or explanatory variables, denoted as x, are broken into facility characteristics (which involve all physical attributes), specific trip variables, and bike share user information including the four typologies. Most of the explanatory variables are continuous following data collection but were coded in SPSS to be categorical or dummy variables. For example, the time of day trips were reorganized from the specific time to morning peak, lunch peak or afternoon peak if the trip occurred between 7:00 and 9:00 a.m., 11:00 a.m. to 1:00 p.m., or 4:00 to 6:00 p.m. respectively. This recoding occurred for all independent variables so all values are categorical.

With the dichotomous dependent variable and multiple categorical independent variables, the probability of an individual choosing to ride in non-separated environment versus separated facility is written as:

$$P(Y) = \frac{e^{(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n)}}{1 + e^{(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n)}} \quad (4)$$

The regression coefficient, β, is determined based on each predicter variable. The regression coefficient represents the change or effect in the facility choice selection while the other predicter variables are held constant. With the base alternative identified as preference for using separated facility compared to an non-separated option, positive coefficients in the results show a preference for using bikeshare on a non-separated facility (shared lane or bike lane) and negative coefficients indicate preferring to bike on a separated facility (shared use path or sidewalk). The chi-square tests show the model is significantly better than the constant-only version, at any level of significance.

4.5 Shared-Use Path Revealed Preference Results

The binary logistic regression results from the analysis described in the previous section are displayed in Table 13. Base categories and variables not significant at a 95% confidence level are greyed in the table. The revealed preference regression results highlight how important and influential both the physical condition of the roadway and bicycle infrastructure plays on a cyclist's facility choice. In fact, facility characteristics were found to be the most influential set of factors, compared to trip and user characteristics. The analysis found that design provisions for vehicle accommodations greatly influence cyclists' perceptions as cyclists were more likely to choose separated facilities on roadways with wider travel lanes, a greater number of lanes, higher speed limits and larger traffic volumes. Alternatively, the presence of bicycle lanes was associated with riders operating on a non-separated facility (in those specific facilities) while wider sidewalks and pathways as well as greater separation distances are associated with cyclists choosing separated facilities. Engineers and planners should take note of these cyclist preferences and reactions when making design decisions in future projects.

The trip characteristics modeled include distance, duration, speed, season of the year, time of the day, and whether the trip was contained solely on the Auburn University campus or not. The results indicate that cyclists on trips that are longer than 20 minutes are more likely to use the separated facilities, whereas those traveling faster are more likely to bike in the roadway. This is a logical result as most cyclists are able to operate faster non-separated condition compared to on shared-use paths or sidewalks. Interestingly, trips made during the morning peak had a preference towards non-separated facility while afternoon peak trips had a preference to separated facilities. This could be that the morning trips were potentially more utilitarian and made by confident commuters which lead to faster travel that non-separated facilities offer while afternoon trips did not have the same amount of urgency.

The final set of user characteristic variables indicate that average and maximum trip distance, duration and speed were significant, with trip duration having the most significant values. Somewhat unexpected, greater average duration was found to lead toward a preference to separated facility choice and maximum duration showing a preference toward non-separated options. This shows could show that frequent long-distance trips could be made more leisurely and on a separated facility while less regular longer utilitarian trips could be made on a non-separated facility by some of the more confident users. The bike share typology results confirmed the hypothesized facility preferences from the cluster analysis. With the base condition being the unsupported user, the aspirational cyclist did not have a statistically significant difference in facility preference while the hesitant participant and engaged sharer both showed preference to separated facilities. This reaffirms the notion that those two user typologies are less confident riding with vehicular traffic and in need of protected bicycle facilities to feel accommodated. With those two typologies groups making up over 80% of the bike share population, it is fundamental that separated bicycle facilities be implemented to make substantive change to the overall share of bike trips.

Table 13: Non-Separated vs. Separated Estimation

Parameters		*Coeff.*	*T-Stat*
Facility Characteristics			
Lane Width (ft)	…> 12	---	---
	…12	2.275	3.81
	…< 12	1.232	4.16
Vehicular Lanes	…2 lanes	---	---
	…3 lanes	-0.425	-4.98
	…4 lanes	-1.966	-4.06
	…5 lanes	-3.045	-5.02
Posted Speed (mph)	…< 35	---	---
	…35 – 40	0.210	0.43
	…45 – 50	-1.266	-0.97
Traffic Vol. (ADT)	…< 10,000	---	---
	…> 10,000	-1.229	-9.83
Bike Lane Width (ft)	…0	---	---
	…< 5	1.013	6.06
	…> 5	0.296	5.92
Walk Width (ft)	…< 5	…	…
	…5 - 6	0.236	3.60
	…> 6	-0.203	-4.14
Offset Distance (ft)	…< 10	---	---
	…10 – 20	0.805	3.31
	…> 20	1.241	4.98
Trip Characteristics			
Distance (miles)	…< 0.25	---	---
	…0.25 – 0.5	-0.404	-0.96
	…0.5 – 1.0	-0.701	-1.66
	…1.0 – 2.0	-0.734	-1.70
	…> 2.0	-0.431	-0.94
Duration (mins)	…< 5	---	---
	…5 – 10	-0.048	-0.55
	…10 – 20	-0.179	-1.39
	…20 – 30	-0.667	-3.67
	…> 30	-0.653	-3.03
Speed (mph)	…< 5	---	---
	…5 – 7.5	0.034	0.45
	…7.5 – 10	0.287	2.92
	…> 10	0.678	4.83
Season	…Fall	---	---
	…Spring	-0.111	-1.76
	…Summer	0.210	3.03
	…Winter	-0.174	-2.61
Time of Day	…Non Peak	---	---
	…Morning Peak	0.279	2.73
	…Lunch Peak	-0.009	-0.01
	…Afternoon Peak	-0.141	-2.24
Location	…On-Campus	---	---
	…Off-Campus	0.750	9.28

Parameters		*Coeff.*	*T-Stat*
User Characteristics			
Avg Distance (miles)	… 0.25	---	---
	…0.25 – 0.5	-0.243	-1.03
	…0.5 – 1.0	-0.095	-0.52
	…1.0 – 2.0	-0.027	-0.17
	…> 2.0	-0.220	-3.79
Avg. Duration (mins)	…< 5	…	…
	…5 – 10	-0.559	-4.69
	…10 – 20	-0.907	-5.59
	…20 – 30	-0.901	-3.60
	…> 30	-1.346	-4.39
Avg Speed (mph)	…< 5	---	---
	…5 – 7.5	0.121	1.23
	…7.5 – 10	0.529	4.07
	…> 10	0.665	0.71
Max Distance (miles)	…< 0.25	---	---
	…0.25 – 0.5	0.503	0.59
	…0.5 – 1.0	0.493	3.12
	…1.0 – 2.0	0.316	3.57
	…> 2.0	-0.135	-3.14
Max Duration (mins)	…< 5	---	---
	…5 – 10	1.458	1.77
	…10 – 20	1.767	2.13
	…20 – 30	2.246	2.70
	…> 30	2.506	2.99
Max Speed (mph)	…< 5	---	---
	…5 – 7.5	0.204	1.68
	…7.5 – 10	0.366	2.23
	…> 10	0.095	0.54
Number of Trips	…< 6	---	---
	…6 – 25	-0.145	-1.59
	…26 – 50	-0.338	-2.83
	…51 – 75	-0.532	-3.96
	…76 – 100	-0.782	-5.33
	…> 100	-0.666	-5.17
Percent Trips Off-Campus	…< 1%	---	---
	…1 – 5%	-0.053	0.68
	…6 – 10%	-0.329	-3.82
	…11 – 25%	-0.436	-4.96
	…26 – 50%	-0.385	-4.16
	…> 50%	-0.308	-3.32
Bike Share User Typology	…Unsupported Users	---	---
	…Aspirational Users	-0.386	-1.83
	…Flexible Users	-0.896	-3.05
	…Purposeful Users	-0.813	-3.39

4.6 Shared-Use Path Revealed Preference Conclusions

Overall, the objective of this chapter was to use actual ridership data from a campus bike share system to develop new bike share user typology groups and determine their impacts to non-separated or separated bicycle facility preferences. This allowed for advanced analysis expanding on the previous objective. While there are limitations correlating a campus bike share program to city system, a greater understanding of a mostly college-aged demographic can provide powerful planning information with this population being the majority of the facilities currently planned or designed. The results from this chapter highlight just how important the bicycle facility conditions, roadway configurations, and user preferences all are significant in understanding the preferences and needs towards road adjacent shared-use paths.

Two key takeaways from this analysis were how impactful the physical infrastructure and user types are on user preferences. The physical environment itself was shown to be most impactful on preference and choice of riding on a non-separated facility with vehicular traffic or separated on a sidewalk or road adjacent shared-use path. Notably, the roadway characteristics creating a more intimidating environment for vulnerable active transportation users (higher vehicular volumes, increased number of vehicular lanes, and higher speed limits) found cyclists choosing separated facilities away from motor vehicles. Conversely, design elements aimed at providing more engaging physical environments for cyclists saw them being used and significant. The presence of non-separated bicycle lanes was found to influence users to ride in a non-separated environment, while more accommodating separated options like wider paths and further separation were influential in users riding in a separated facility.

The two new typologies that were found to be significant in the revealed preference regression analysis were the flexible users and purposeful users. Both of these new typologies were found to more likely choose separated facility types. With these two types accounting for over 80% of the bike share population, it leads to a conclusion that physically separated facilities are preferred by a large portion of the bike share user demographic representing young individuals interested in cycling. An additional conclusion could be added that since this user group is a good planning demographic for future transportation infrastructure, transportation agencies attempting to engage more active users should be adding separated bicycle facilities like road adjacent shared-use paths.

Chapter 5: Facility Selection – West Samford Avenue Case Study

One of the nine study locations included in the route analysis documented in Chapter 4 provides a unique physical configuration that is worthy of further and deeper analysis. West Samford Avenue (location three from the previous chapter) provides cyclists with both non-separated and separated accommodations through a conventional bicycle lane and a parallel road-adjacent shared-use path. This setup, located on the Auburn University campus, is rare and is a result of the university's growth and efforts to provide pedestrian and bicycling facilities where none originally existed. Like many suburban corridors, neither cyclist nor pedestrian accommodations were originally constructed at this location with it being on the perimeter of the historic campus core and not at the forefront during design. The current facilities are a result of a past road diet on West Samford Avenue and construction of a shared-use path. The road diet was a typical conversion of four vehicular lanes to three vehicular lanes and conventional bicycle lanes during a scheduled asphalt resurfacing. The traffic volumes on West Samford Avenue did not warrant four lanes, and the conversions provided dedicated left turn lanes with campus growth along this corridor. The shared-use path was installed primarily to add pedestrian accommodations along West Samford Avenue. A shared-use path was selected when design guidance was still in its infancy and it was viewed advantageous to also address cyclists with just a few extra feet of pathway. While having both bicycle facility types along a single corridor is uncommon, the rationale on how each were installed is similar to many of the decision being made today in communities looking to add active transportation infrastructure.

The West Samford study section is a three-lane facility carrying approximately 8,000 Annual Average Daily Traffic (AADT) with two 12-foot-wide thru lanes, a 12-foot-wide center turn lane, and two 6-foot-wide conventional bicycle lanes. The surrounding land-uses at the study location are athletics facilities, intramural sports fields, and a passive park. Being outside of the campus core and the surrounding land use not being dense leads to this path containing light pedestrian traffic subsequently not producing many conflicts for bicyclists. The cyclists on this corridor appear to be a mixture of users with some traveling for recreation or exercise and others traveling specifically to the intramural fields or commuter parking lots further to the west. For context, Figure 26 shows the West Samford location while Figure 27 shows an aerial plan view of the location and includes points from the War Eagle Bike Share dataset identifying trips within the bicycle lane and adjacent shared-use path. The varying colors of the points on the Figure 27 represents trips of different months. As has been mentioned previously, with the large dataset and abundance of point data, the trips had to be segregated to months to enable analysis.

Figure 26: West Samford Site Location

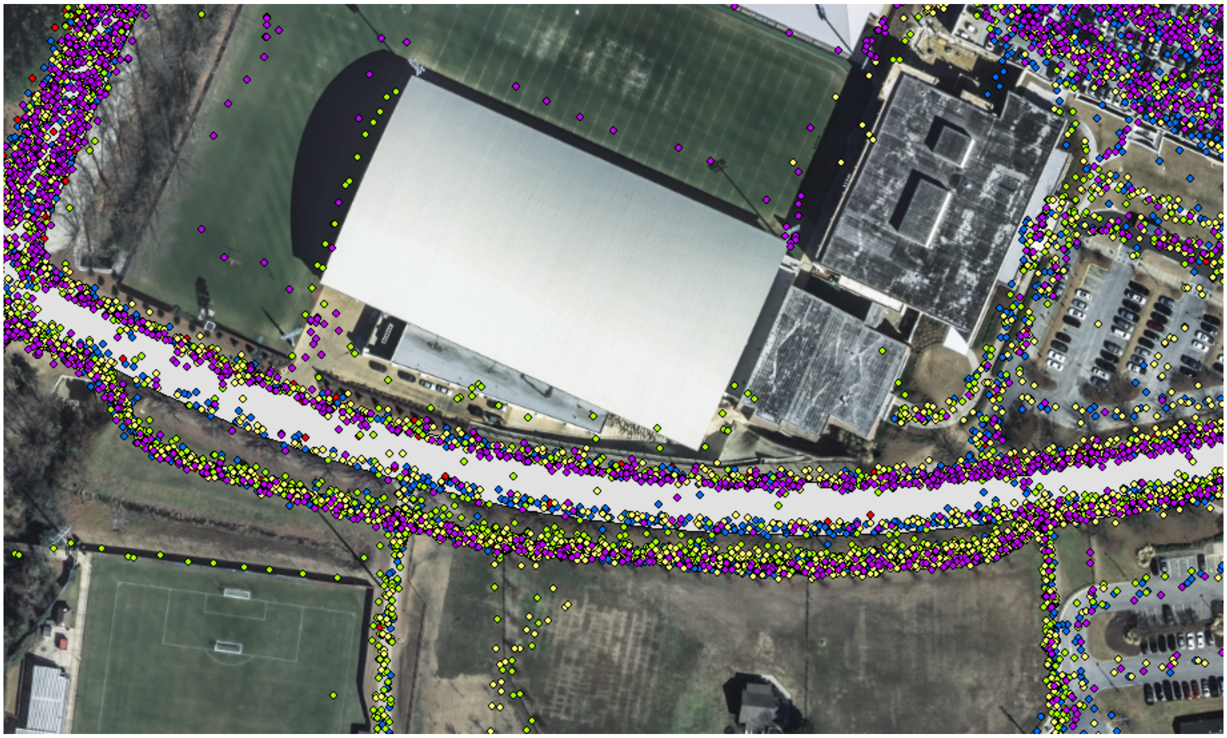


Figure 27: West Samford Aerial

The same War Eagle Bike Share dataset and GIS techniques from Chapter 4 was used to specifically break down the trips along the segment on West Samford. Interestingly, the split between the non-separated and separated trips are close to even. For the 1665 trips along the West Samford location site, 780 (47%) were on the bicycle lane and 885 (53%) were on the shared-use path. It is of interest that the split between the bicycle lane and shared-use path is so close when the previous chapter found that across all nine study locations the split was 68% to 32% in favor of separated locations. Table 14 summarizes the trip and user data between the bicycle lane and shared-use path locations by breaking down the differences between the trip specific and user characteristics.

Table 14: Samford Ave Bicycle Lane vs Shared-Use Path

		Bicycle Lane	Shared-Use Path
	Total Trips	780	885
Trip Characteristics	Off-Campus	6%	9%
	Average Trip Distance	1.55 Miles	1.57 Miles
	Average Trip Duration	15 Minutes	16 Minutes
	Average Travel Speed	7.6 mph	7.0 mph
User Characteristics	Percent Off-Campus	10%	13%
	Average Distance	1.18 Miles	1.15 Miles
	Average Duration	12 Minutes	12 Minutes
	Average Speed	7.0 mph	6.6 mph
	Average Number of Trips	76	114

For all bike share trips, the average trip distance was found to be less than one mile and duration was less than 10 minutes. Meanwhile, the trips along West Samford Avenue were found to last approximately 50% longer in time and distance. This is expected with West Samford Avenue study site located just outside of the campus core and away from a bicycle share hub. Comparing the trips occurring in the bicycle lane with those in the shared-use path found the variables very similar with the only notable differences being trips in the bicycle lane were traveling at a higher rate of speed than those on the shared-use path. This supports the notion that users using the bicycle lane are trying to get to a specific location faster while those using a shared-use path are taking trips more leisurely and not in as much of a hurry. Similar to the trip characteristics, the overall user travel characteristics were fairly similar comparing the bicycle lane versus shared-use path trips with the users choosing the bicycle lane typically riding at a slightly higher rate of speed.

Table 15 breaks down the studied trips by facility type and the previously created bike share user typologies. As with the entire dataset, the unsupported users were found to most likely choose a non-separated option. Unsupported users were found to ride non-separated from traffic with the other three user typologies having a higher percentage for riding on separated facilities.

Comparing to the overall dataset, each user typology had a higher representation for non-separated trips. This is likely due to the non-separated facility being a consistent 6-foot-wide bicycle lane and not narrower or intermittent which exist at other study locations. Providing a higher quality non-separated bicycle facility impacts the ridership.

Table 15: Samford Ave User Typology Breakdown

	Unsupported User	Aspirational User	Flexible User	Purposeful User	Total
Bicycle Lane	11	35	56	678	780
	55.00%	*38.46%*	*44.09%*	*47.47%*	*46.85%*
Shared-Use Path	9	56	68	752	885
	45.00%	*61.54%*	*53.54%*	*52.59%*	*53.15%*

Trip patterns were also considered in this analysis. The month of travel is plotted in Figure 28 for all 1665 trips along the West Samford study site. For each month, the split between trips occurring within the bicycle lane and in the shared-use path are also identified. Overall the seasonal travel trends are consistent on West Samford compared to all the bike share trips. It is of note that the summer months, where vehicular traffic is the lowest, there is a distinguishable shift where a larger portion of bike share users riding in the bicycle lane compared to the shared-use path. Specifically, the four highest months with the highest percentage of trips occurring on non-separated conditions were May, June, July and August with June and July being the top two highest. Meanwhile, the five busiest months that cover when the spring and fall semesters are fully in session (February, March, April, September and November) had the largest percentage of separated bike share trips. These season trends are specific to a university campus and it would be expected that a city bike share program would not match these monthly summaries. However, these findings again verify the notion that increased vehicular traffic leads to cyclists seeking separated routes away from motor vehicles.

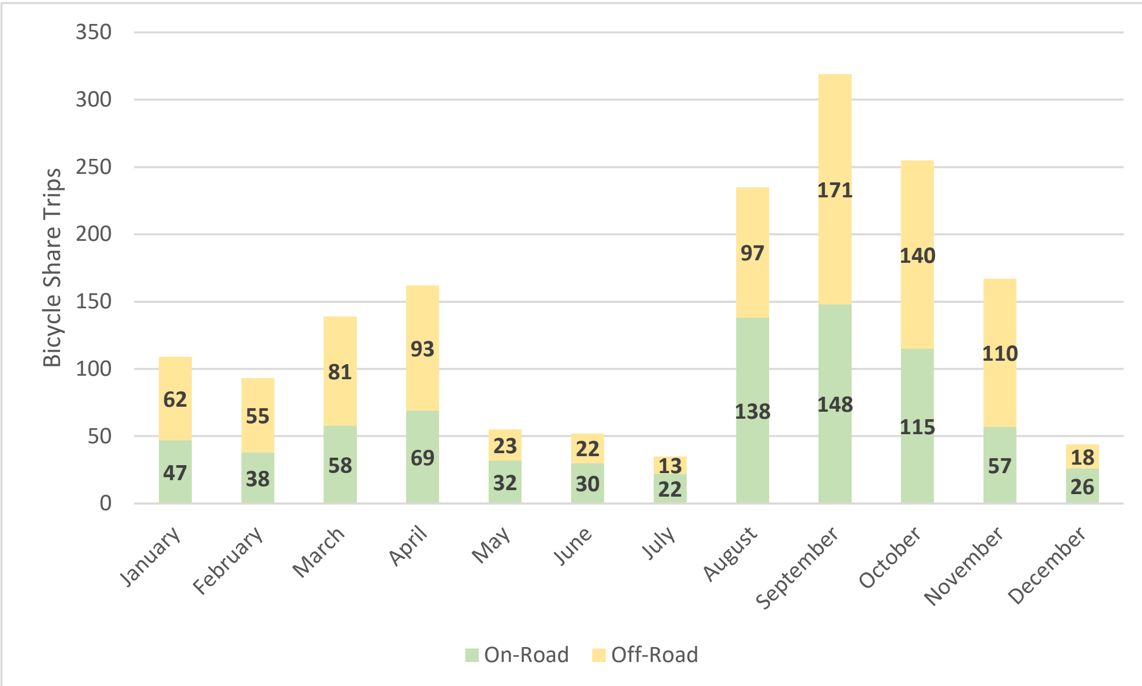


Figure 28: West Samford Trips by Month

Similar to the month analysis, Figure 29 breaks down the West Samford trips by hour of the day to see if time of the day may influence route choice. Compared to the overall trip hourly distribution, the West Samford Avenue trips occur more frequently in the afternoon likely due to its location outside the core of campus. In addition to the trips, Figure 29 also includes the hourly motor vehicle volumes. These were taken with pneumatic tubes on a typical weekday in February 2018 to clearly identify the peak motor vehicle times. Of note, a higher percentage of trips were taken on the shared-use path of 56% during the afternoon peak time between 3:00 PM and 6:00 PM compared to the morning peak of 51% in the morning peak between 7:00 AM and 10:00 AM. Motor vehicle traffic is higher in the afternoon so this may indicate users have a preference to the separated facility when vehicular traffic is at its highest.

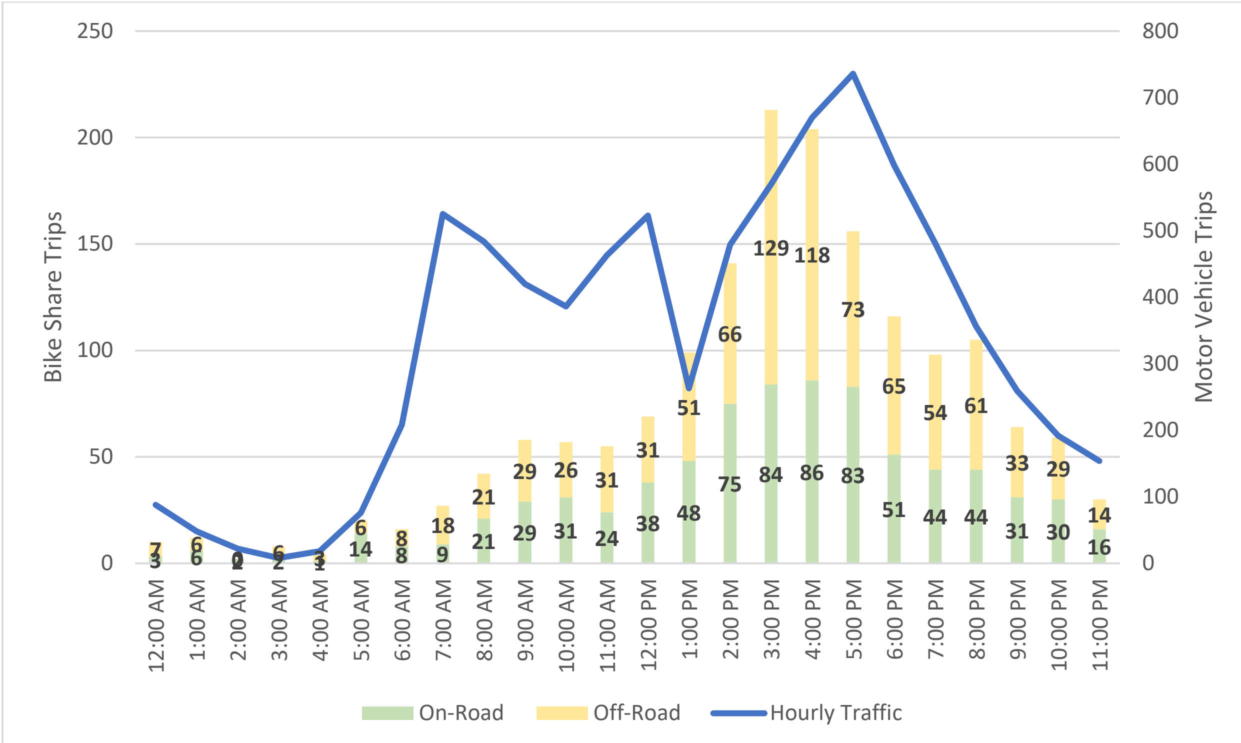


Figure 29: West Samford Trips by Hour

The West Samford study section provides valuable insight on how the physical conditions affect the user's facility choice. Based on current practice and design guidance, the West Samford Avenue provides a desired design scenario for a road adjacent shared-use path with significant separation from the roadway, light conflict with other user types, and paved. Similarly, a conventional bicycle lane being 6-feet-wide with limited driveways also presents a desired option for that facility type. These make for an ideal case study site for better understanding cyclist preferences and their choices for facility types. Even knowing that campus bike share demographics inherently consists of young and less experienced, there still was approximately 47% of users choosing the traditional bicycle lane over the road-adjacent shared-use path. This shows that there are multiple factors that impact a user's route decisions. It also gives credence to AASHTO's recommendations that a road-adjacent shared-use path does not take away for the need for non-separated bicycle facilities. Other conclusions raised form this analysis includes:

- Most of the trip and user characteristics were found to be consistent comparing users who chose the bicycle lane to the shared-use path. The only real notable variable that was different between the two groups was speed which (not surprisingly) was higher for those traveling on the bicycle lane.
- The type and quality of non-separated facilities matter. Compared to other study locations, the West Samford route had a consistent, wide bicycle lane and it had more users choosing to ride on it compared to other locations with narrower bicycle lanes with varying widths.
- Adjacent separated paths are preferred for most users when vehicular road speeds and volumes increase. This study site was along a moderately traveled roadway with a 35-mile-per-hour posted speed limit so it is not a large, high-speed road environment. However, during the afternoon peak, it was found that a higher percentage of trips were made using the shared-use path compared to the bicycle lane. Users were likely looking to avoid higher vehicular volumes during those trips.

Chapter 6: Framework Guidance Incorporating Road Adjacent Shared-Use Paths

Independently, the two analysis methods performed in this dissertation provide valuable insight into user perceptions of road-adjacent shared-use paths. However, a full perspective of user preferences can be achieved by combining the results from both the stated and revealed preference studies. This chapter does just that by synthesizing the key findings from both studies and creates framework guidance on how preferred roadway configurations with shared-use paths potentially will (or will not) be utilized by different cyclist types. Both studies incorporate cycling confidence levels creating a common user characteristic between the two studies. With the stated preference study principally providing insight on the individual path elements, and the revealed preference study documenting the influence of the adjacent roadway, combining the findings allows for all primary elements influencing perceptions of road adjacent shared-use paths to be considered. From the combination of the findings from the two studies, key principles are developed in the process and used in the framework creation. This new framework guidance will help engineers and planners understand the demand and likely usage for a proposed road adjacent shared-use path.

6.1 Typical Road Adjacent Shared-Use Path Design Configurations

The initial step in developing new guidance for user preferences of road adjacent shared-use paths was to document multiple roadway configurations incorporating shared-use paths. The goal from this effort was to detail typical roadway environments where shared-use paths are usually found or are being considered. This alone can be a quick reference guide for typical configurations of road adjacent shared-use paths. The new configurations created are based on a combination of varying roadway and path elements and the results of the stated-use and revealed preference analysis.

The revealed user preference study documented the impact the roadway itself had on users' choices of riding in a shared lane or bicycle lane compared to a separated facility including a road adjacent shared-use path. Specifically, the speed limit, traffic volume, number of lanes and presence of a conventional bicycle lane were all found to be statistically significant (Table 13). These findings are incorporated in the new roadway configurations by varying multiple combinations of lane configurations with and without bicycle lanes. The speed limit and traffic volume impacts are incorporated with the increased number of lanes representing both higher roadway speeds and volumes. Using the number of lanes as a surrogate for both speed limit and traffic volume is consistent with the relationship found at the study locations from the revealed preference study and at other typical suburban locations (where this framework is intended to be utilized). Overall, the roadway elements include two, three, four, and five lane sections both with and without conventional bicycle lanes for each lane configuration. The number of vehicular lane conditions selected for the eight configurations match those observed in the revealed user preference study, and also those typically found in suburban locations where road adjacent shared-use paths are considered.

To combine with the roadway elements identified for each of the eight configurations, separated path components were also detailed for the each of the new configurations. Again, using the findings from the stated and revealed studies, three key path principles were identified to complete the configurations. The key principles include:

- *Principle A: Users overwhelmingly prefer a hard surface material.*

  The stated preference survey found an overwhelming desire for a paved path compared to a gravel option across all user types, but especially cyclists. Therefore, each configuration shows a hard-surfaced path material that could either be constructed of concrete or asphalt.

- *Principle B: The wider the roadway, the greater separation preferred between the path and roadway.*

  Consistent with past studies, users in the stated preference survey report a higher level of perceived safety with further separation between the path and roadway. Additionally, the revealed preference model identified separated facilities are chosen at a higher rate as the number of vehicle travel lanes are increased. With these results, a 40-foot separation (the separation that functions like an independent path alignment) is provided with the roadway configuration demonstrating an environment most intimidating for the path user, the five-lane roadway section. Using the same rationale, the next largest separation of 20 feet is illustrated in the configurations with four vehicular lanes. The 20 foot separation matches the values displayed in the stated preference survey. Finally, a 10-foot separation is shown for the three lane roadways and the 5-foot separation, that AASHTO recommends as the minimum separation, for the two-lane roadway. These separation values may not be achievable based on right-of-way constraints. The key component of this principle is the relationship between separation and number of lanes. Where right-of-way constrains for these ideal separation values to be met, the separation should be maximized where practicable.

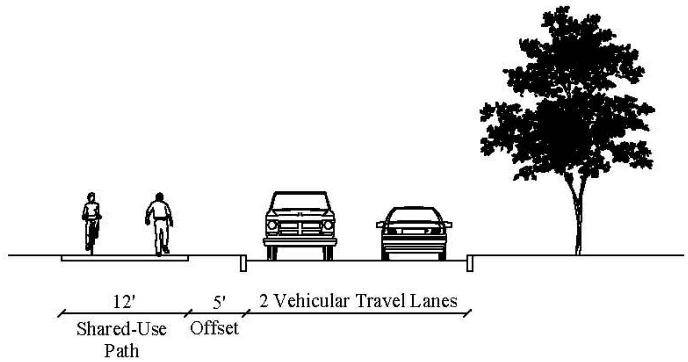
- *Principle C: Wider path widths are preferred when conventional bicycle lanes are not provided.*

  Across all three stated preference models, all user types collectively display a preference toward wider paths. Additionally, frequent cyclists reported a desire for the widest options shown that allow for the most separation between cyclists and pedestrians. Therefore, for the configurations containing bicycle lanes a typical minimum path width of 10 feet is shown while those configurations without bicycle lanes are shown as 12 feet wide. The rationale on the lower path width when bicycle lanes are present is due to the findings that that frequent or highly confident cyclists are more likely to ride in a non-separated environment and thus would not be required to mix on the path with slower pedestrians or less confident cyclists. Similarly, the wider path shown for all configurations without bicycle lanes is due to the reported desires that frequent cyclists (who are more likely to be riding on the path due to no non-separated bicycle facilities) prefer more path space to be less impeded from the slower path users. It is noted that the ultimate selected path width should be selected based upon path volume and mix of user types. The primary goal of this principle is to document the relationship between path width and presence of non-separated bicycle facilities. The 12 foot width was chosen to show as a relationship to the minimum value of 10 foot wide.

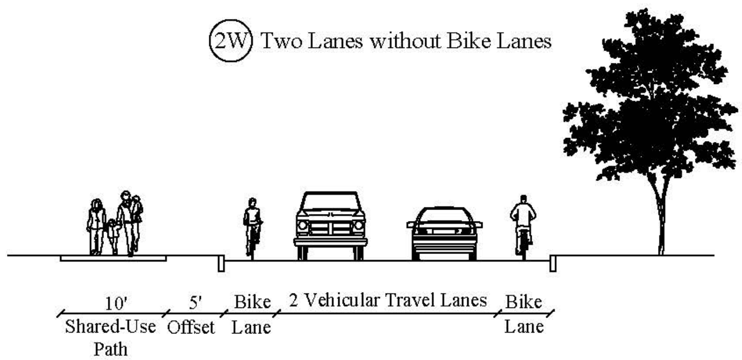
Utilizing the key principles, the eight configurations were created with the major design attributes summarized in Table 16 and drawn in Figure 30.

Table 16: Framework Configurations Summary

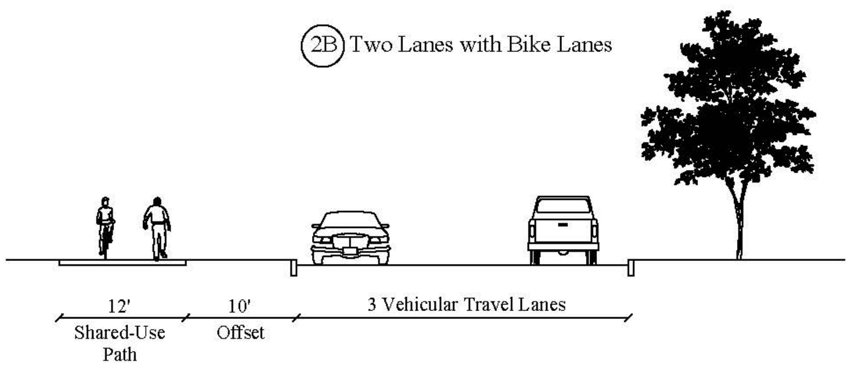
Configuration Number	Number of Vehicular Lanes	Inclusion of Non-Separated Bicycle Facility	Path Material	Path Separation Width	Path Width
2W	2	No	Hard Surface	5 ft	12 ft
2B	2	Yes	Hard Surface	5 ft	10 ft
3W	3	No	Hard Surface	10 ft	12 ft
3B	3	Yes	Hard Surface	10 ft	10 ft
4W	4	No	Hard Surface	20 ft	12 ft
4B	4	Yes	Hard Surface	20 ft	10 ft
5W	5	No	Hard Surface	40 ft	12 ft
5B	5	Yes	Hard Surface	40 ft	10 ft



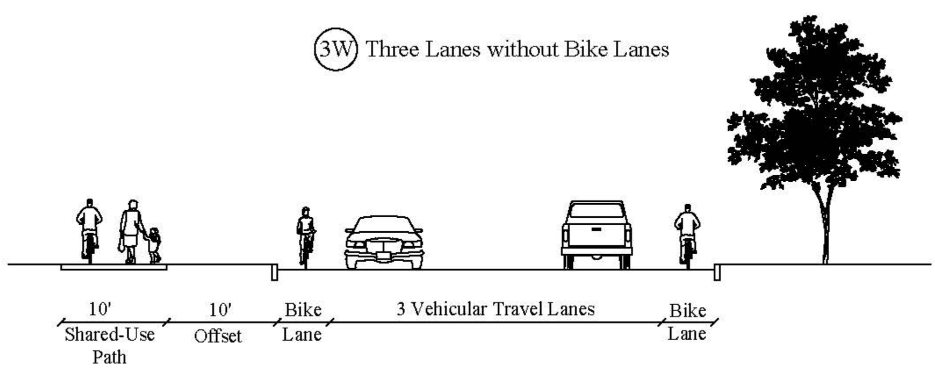
2W Two Lanes without Bike Lanes



2B Two Lanes with Bike Lanes



3W Three Lanes without Bike Lanes



3B Three Lanes with Bike Lanes

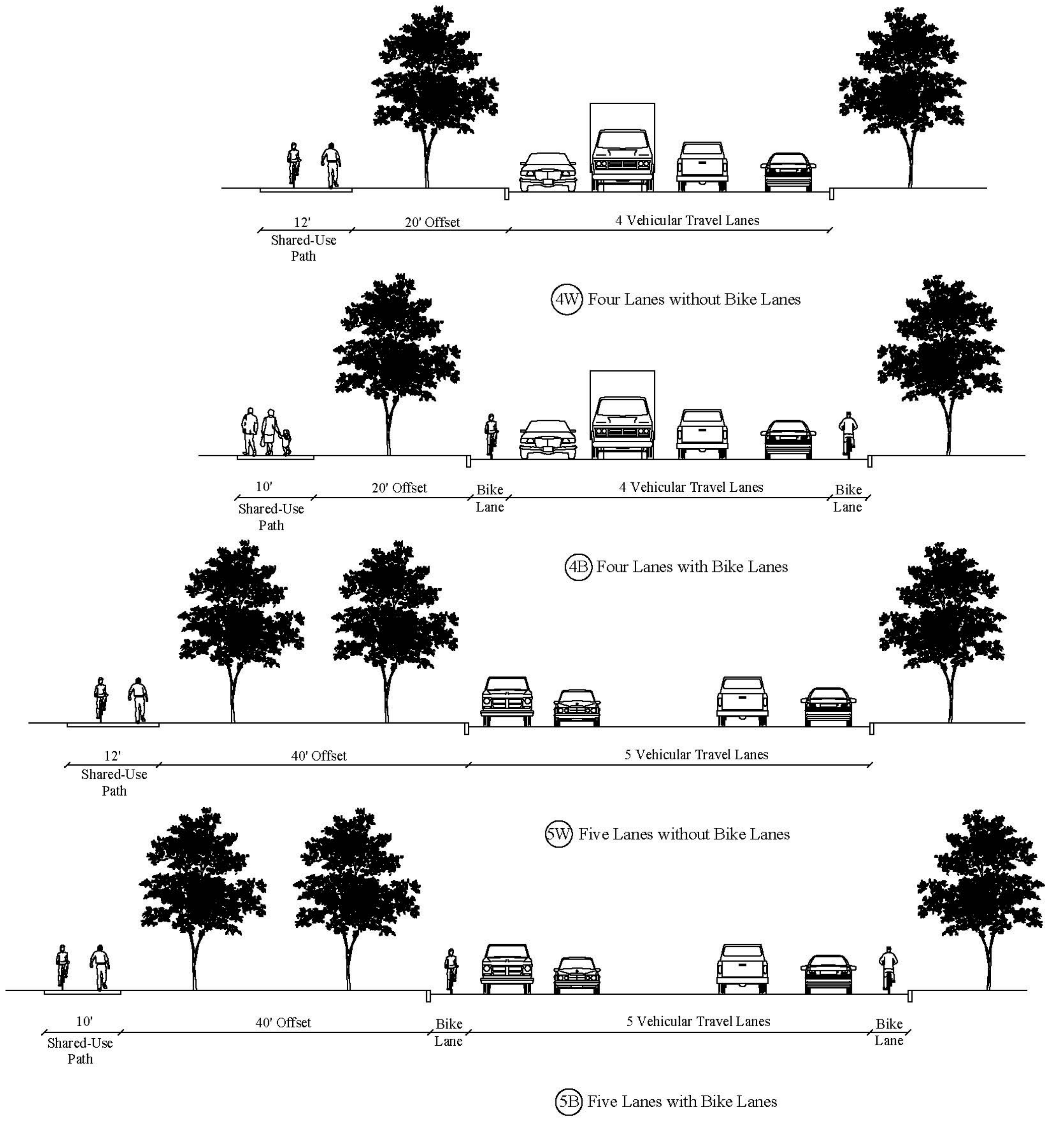


Figure 30: Road Adjacent Shared-use Path Typical Configurations

It is important to acknowledge that while the eight configurations in Figure 30 are backed by the findings from the two analyses, they should not be used as a penultimate guide in selecting the specific elements for a new road adjacent shared-use path. There are endless combinations of path and roadway design components used at any specific physical location. Each location and project have its own unique intricacies that will impact the selected path design elements. However, these general configurations do provide guidance on typical or preferred combinations for use in initial planning as a starting point based on project goals and local parameters. With this in mind, the configurations can be made more valuable and complete the guidance framework by correlating the eight typical configurations to the likelihood of usage from various cyclist types. This will allow transportation professionals to understand the likely demographic served by a specific road adjacent shared-use path configuration based on both roadway and path elements.

6.2 Road Adjacent Shared-Use Path User Matrix

Like the creation of the road adjacent shared-use path configurations, the results from both the stated and revealed preference analyses were utilized in developing the matrix that compares those configurations to the likely path users. With many active users, namely pedestrians, only having the option of using a shared-use path the user type in the matrix focuses exclusively on cyclists as they do have a choice of riding with mixed traffic for each of the configurations. For the matrix comparison, three cyclist types are shown similar to the recent FHWA Bikeway Selection Guide that leaves out the demographic that has zero interest in cycling. To make the matrix flexible and ideally more valuable, the three users types are simply identified based on their cycling confidence levels ranging from low to high. The broad user nomenclature allows for the matrix to be utilized universally as compared to the new bike share typologies from this dissertation or other specific cyclist types which target a specific population.

To complete the matrix, key principles were established similar to those created for establishing the eight configurations. These principles are mostly aligned with the results from the revealed preference analysis and include:

- *Principle D: For all users, the greater the number of vehicular lanes, the larger preference towards separated facilities*.

  As identified in the revealed preference model, each subsequent additional lane above the base condition of two lanes increased the likelihood of using a separated facility.

- *Principle E: The presence of a conventional bicycle lane reduces the number of users on a road adjacent shared-use path.*

  The revealed preference model concluded that despite the specific width just the presence of conventional bicycle lanes decreased the likelihood of users choosing the separated facility.

- *Principle F: Higher confident cyclists choose non-separated facilities more frequently than those with lesser confidence.*

  The user typologies identified as the most confident (unsupported users) exhibited a preference towards non-separated facilities compared to the other typologies.

The three key principles align with the perceptions of bicycle facility preferences and provide a statistical basis to complete the road adjacent shared-use path user matrix. To supplement these principles and complete the matrix, Table 17 was created to compare the roadway environments (number of lanes and presence of a conventional bicycle lane) of the eight configurations to the nine study sites from the revealed preference study.

Table 17: Corresponding Study Locations to Framework Guidance

No.	Framework Guidance Typical Sections	Corresponding Study Locations from Revealed Preference Analysis	Non-Separated	Separated
2W	Two Lanes without Bike Lanes	Gay St	17%	83%
2B	Two Lanes with Bike Lanes	Heisman Dr Samford Ave Thach Ave	31%	69%
3W	Three Lanes without Bike Lanes	Magnolia Ave	29%	71%
3B	Three Lanes with Bike Lanes	Samford Ave	47%	53%
4W	Four Lanes without Bike Lanes	Donahue Dr College St	14%	86%
4B	Four Lanes with Bike Lanes	N/A	N/A	
5W	Five Lanes without Bike Lanes	Wire Rd	9%	91%
5B	Five Lanes with Bike Lanes	N/A	N/A	

For six of the eight configurations, there is a comparable study site from the revealed preference analysis. Table 17 corresponds the eight configurations to the matching study locations and also summarizes the percentage of non-separated and separated trips from the revealed preference analysis. Consistent with the modeling, the percentage of trips occurring on separated facilities increase as the number of vehicular travel lanes increase and when a conventional bicycle lane is not provided. However, there is an exception to this when comparing the corresponding facility preferences of configurations one and two to configuration four. From the analysis and developed key principles, it would be expected that both configuration 2W and 2B would have a higher portion of non-separated users since they reduce the number of travel lanes. However, configuration 3B (three lanes with bicycle lanes) reports a 47% share of non-separated trips while configuration 2B (two lanes with bicycle lanes) contains a 31% share. Even though configuration 2B still corresponds to the second highest portion of non-separated trips amongst all eight configurations, it would have been expected to be higher than configuration 3B. This is likely due to the quality of the conventional lanes in the corresponding study sites. As mentioned previously, the bicycle lanes for configuration 3B's corresponding site (West Samford Avenue) is of a desired width and consistent along the entire corridor while the corresponding sites for configuration 2B contain bicycle lanes of narrower widths and intermittent (many times dropping at intersections for vehicular turn lanes). Configuration 2W also reported a smaller portion of non-separated trips than expected. The corresponding site for configuration 2W (two-lane roadway without bicycle lanes) is study location number nine, Gay Street. This configuration, however, has considerably the lowest number of recorded trips with only 90 trips occurring out of the entire 10,327 trips from the revealed preference study.

The matrix was completed by using a combination of results from the revealed preference analysis and the identified key principles. The key principles are specifically used for the configurations that do not have a corresponding site and for the two irregularities identified for configurations 2W (two lanes without bike lanes) and two (two lanes with bike lanes). The first step in completing the matrix was to fill out the preferences of configuration 3B – three lanes with conventional bicycle lanes. This configuration has the best and most studied comparable site (West Samford Avenue) as it was specifically included as an independent case study in this dissertation. The analysis of that site found an approximately even split between cyclists choosing the conventional bicycle lane compared to the road adjacent shared-use path. Therefore, the matrix identifies the low confident cyclists as a path user and the high confident cyclist as prefer the non-separated facility. With such an even split for this specific configuration, the medium confident cyclist type is shown as having a split preference. These preferences will be used as a benchmark to complete the remainder of the matrix.

Knowing the preferences of configuration 3B (three lanes with bicycle lanes), Principle D can be used to complete the preferences of configuration 2B (two lanes with bicycle lanes). Using Principle D that states a reduced number of vehicular lanes is expected to reduce the preference for separated facilities, shared-use path preferences for configuration 2B are only shown for the low confident cyclists. From there a comparison to configuration 2W (two lanes without bicycle lanes) can be made. Principe E documents that removing a bicycle lane will increase the preference for a road adjacent shared-use path. Therefore, the preferences shown in configuration 2W include a preference for the shared-use path for the low confident cyclists and a split preference for the medium users.

Similar logic is used again to compare configuration 4B (four lanes without bicycle lanes) branching off the base configuration 3B (three lanes with bicycle lanes). As expected, a comparison of the revealed preference analysis of these two configurations show a higher preference for separated bicycle facility. Therefore, both the low and medium confident cyclists are identified as preferring the road adjacent shared-use path in configuration 3B. With this established, preferences for configuration 5W (five lanes without bicycle lanes) can be established. This configuration presents the most intimidating overall environment for active transportation users and also was found to have the lowest corresponding separated facility revealed preference amongst all configurations. With that in mind, all three bicycle user types are identified as preferring the road adjacent shared-use path for configuration 5W (five lanes without bicycle lanes). Principle E is able to be utilized in the comparison of configuration 5B (five lanes with bicycle lanes) to configuration 5W (five lanes without bicycle lanes). This allowed for the determination that the low and medium confident cyclists would prefer the road adjacent shared-use path while the high confident user would prefer the non-separated option. The final configuration off this flowchart branch is configuration 4B (four lanes with bicycle lanes). When compared to configuration 5B (five lanes without bicycle lanes), Principle D can be applied and result in a shared-use path preference for the low confident cyclist and a split preference for the medium confident cyclists.

The final preference is determined for configuration 3W (three lanes without bicycle lanes) based on the revealed preference results finding a higher preference toward separated facilities compared to the based condition of configuration 3B (three lanes with bicycle lanes). This is also aligned with Principle E. Therefore, the preferences of configuration 3W (three lanes without bicycle lanes) are identified with both the low and medium confident cyclist preferring the road adjacent shared-use path. This methodology utilized statistically backed logic and allowed for the final matrix to be completed in Figure 31.

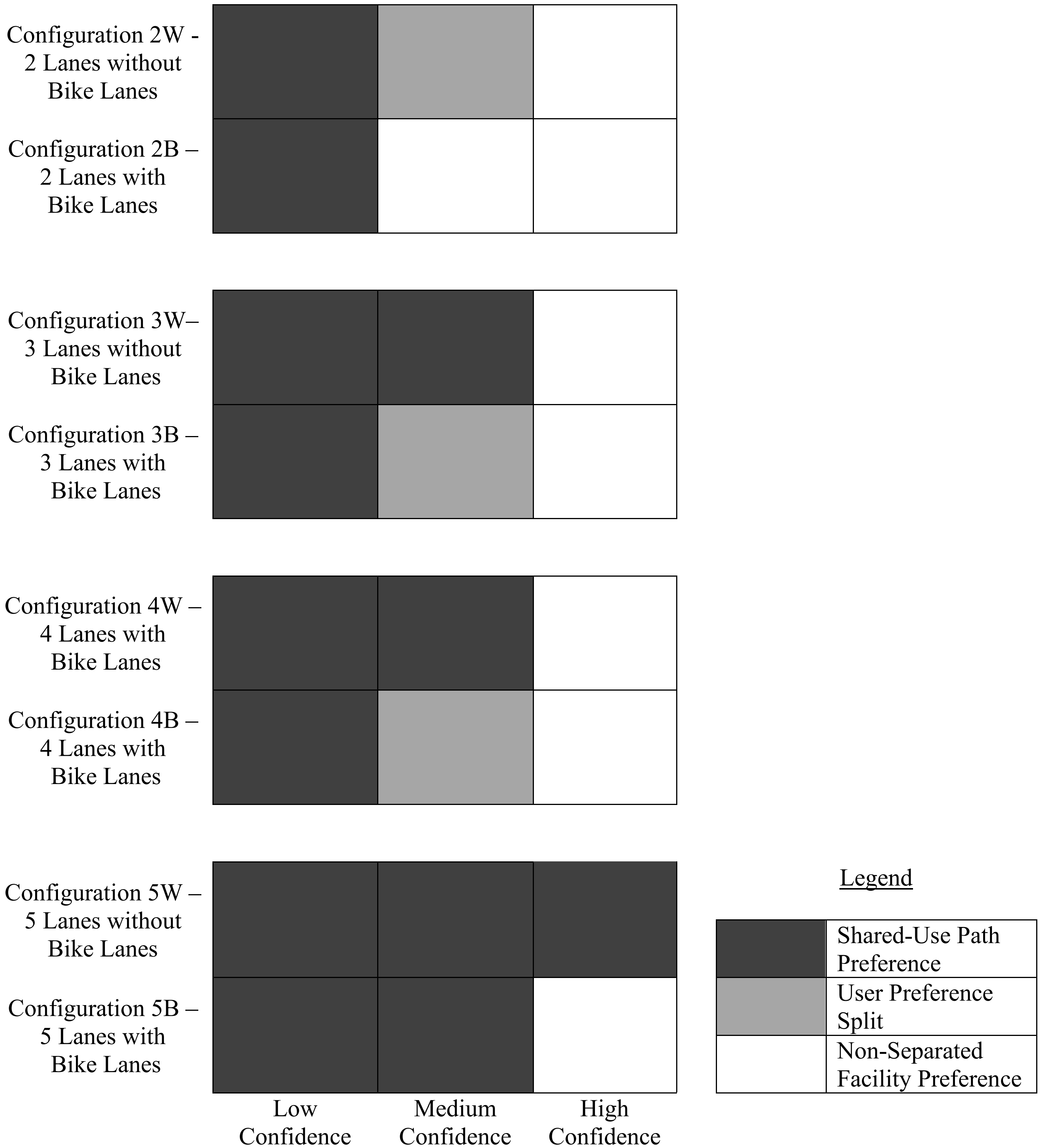


***Figure 31*: Framework Guidance Cyclist Preference Matrix**

6.3 Framework Guidance Example

For an example of an actual application of this new guidance framework, a sample size from the revealed preference was selected. Site number 7, South College Street, was chosen for this example as it exhibits traits that on the surface could make it a candidate for a road adjacent shared-use path. The specific segment for this example is South College Street from Woodfield Drive to Garden Drive, just south of the study site from the revealed analysis. This segment of South College Street contains only a narrow sidewalk on one side of the roadway and exhibits high travel speeds making it a high stress environment for cyclists both in the existing separated and non-separated facility. Additionally, development has significant setbacks from the roadway and contains an existing right-of-way that may allow for a road adjacent shared-use path. The workflow of applying this new framework guidance is summarized in Table 18.

Table 18: Example Framework Guidance Workflow

Number	Step Description	Results
Step 1	Determine existing roadway characteristics	Number of Vehicular Lanes: 4 Traffic Volume: 15,500 Speed Limit: 45 Type of Non-separated Facility: None Type of Separated Facility: 4 ft Sidewalk (one side) Existing Right-of-Way Width: 80 ft
Step 2	Match roadway characteristics with closest framework guidance configuration	Configuration 4W – Four Lanes without Bike Lanes
Step 3	Apply recommended separated and path widths	Existing available Right-of-Way only allows for minimum separation and pathway width.
Step 4	Present project recommendations and report on likely bicycle users	Recommend acquiring additional right-of-way or easement to facilitate path separation closer to framework guidance. If applied, it is expected that the majority of low and medium confident cyclists would prefer this path over a non-separated option.

The first step in the process for a community considering a road adjacent shared-use path along a specific corridor is to gather existing facility data for the roadway. This includes the number of vehicular lanes, traffic volume, speed limit, presence and type of bicycle facilities (separated or non-separated), and existing right-of-way. Based on these findings, a specific configuration from the guidance framework can be selected that best matches the physical roadway attributes. For this example, configuration 4W (four lanes without bike lanes) provided the best match. The third step is to apply the recommendations from the configuration to the site. For the College Street example, on the west side of the road (the side with no current sidewalk or path) there is less than 20 feet from the existing curb to the existing right-of-way. There appears to be adequate right-of-way to construct the minimum path width and separation but not the enough for the ideal conditions documented in the framework guidance (12-foot-wide path with a 20-foot separation) without major changes to the existing roadway. However, it is noted that along this corridor over half of the project distance is adjacent to parcels controlled by a church or university. It is anticipated that these two entities would be receptive to additional right-of-way or easements that could allow this project to maintain a 12-foot-wide path width and a separation further than the minimum 5 feet much closer to the desired 20 feet.

The final step in applying the framework guidance is to summarize and report these recommendations that include the likely users. For this example, the framework guidance recommends installation of a 12-foot-wide shared-use path on the west side of College Street from Woodfield Drive to Garden Drive. The recommended separation away from the roadway is 20 feet but it is acknowledged that it can not all be contained within existing right-of-way. However, this specific corridor of over half a mile contains only seven property owners with a university and church owning the majority of the project frontage. Therefore, the final recommendation is to pursue additional right-of-way specifically from those two entities to create the path with a separation of approximately 20 feet. By doing so this path will be preferred by the majority of low and medium cyclists with only the highest confident cyclist choosing not to use it.

6.4 Framework Guidance Summary

The framework guidance created in this chapter helps transportation professionals better understand user preferences for road adjacent shared-use paths. By combining and synthesizing the major findings from the stated and revealed preference studies in the previous chapters, eight typical configurations were identified that incorporate road adjacent shared-use paths. These typical configurations display the appropriate combinations of shared-use path design elements based on specific roadway configurations of the number of vehicular lanes and presence of bicycle lanes. The associated recommended shared-use path elements for path material, path width and path offset for each configuration will allow practitioners to begin conceptual path designs. The guidance is continued by associating the eight configurations to specific cyclist types in a new matrix that predicts if a cyclist type prefers the road adjacent shared-use path compared to a non-separated option.

With 13 of the 24 matrix scenarios indicating a preference toward the road adjacent shared-use path, it appears that shared-use paths should be considered viable options for transportation agencies. This is reinforced considering that most likely there are more users on the low and medium confidence levels of the matrix than compared to the highest confidence types. Not surprising, the higher populated lower and medium confidence level cyclists are identified in the matrix as overwhelmingly preferring road adjacent shared-use paths. Additionally, the highest confidence cyclists are already active transportation users and not the demographic many transportation agencies are attempting to engage as new users. The findings from this new guidance will allow transportation officials to make more informed decisions based on potential user preferences for a new road adjacent shared-use path. Specifically, knowing how a preferred combination of design elements is perceived by a specific cyclist demographic, practitioners will make recommendations if a road adjacent shared-use path is appropriate given known project demographics and goals.

Chapter 7: Conclusions

In rural and suburban locations throughout the United States, many roadway corridors have no bicycle or pedestrian infrastructure. Adding a shared-use path alongside an existing roadway that can accommodate all active transportation users makes for a compelling option for these communities. However, these facilities are more complex than they seem. There are documented conflicts amongst the path users themselves and with motor vehicles at both driveways and sideroad intersections. While safety countermeasures have been developed to minimize these conflicts, it is still unclear what users, namely cyclists, desire in these types of facilities and if the current design guidance accommodates their needs. Therefore, the objective of this dissertation is focused on expanding the knowledge of cyclist perceptions of road adjacent shared-use paths. Three objectives were identified and met to fulfill this goal that together provide a comprehensive perspective of stated and revealed user perceptions of road adjacent shared-use paths.

The first objective created and distributed a new shared-use path stated preference survey across three communities in the eastern Alabama and western Georgia region to understand what physical path components users desire. With over 300 collected responses, the survey gained valuable insight into users stated-use, satisfaction and perceived safety of a road adjacent shared-use paths. The analysis from the stated use analysis produced findings that better understand how users self-reportedly use shared-use paths and also their preferences for the various design elements. Interestingly, the majority of the survey participants, including cyclists, reported to use shared-use paths for utilitarian type trips more frequently than for recreation or exercise. This was an important distinction as it gives credence to those communities using shared-use paths to accommodate these cycling trip types and somewhat conflicts with past guidance where road adjacent shared-use paths do not substitute to non-separated bicycle facilities. Key design preferences were also identified that include an overwhelming desire for a hard surface path material over gravel and also a preference for wider paths with greater separation from the adjacent roadway. A design option that was found to have support with frequent cyclists was providing path striping that separated cyclists from slower moving pedestrians. This finding demonstrates some of the challenges with road adjacent shared-use path with a major component being that different users have varying preferences. These summarized results met this goal in identifying significant path design characteristics that should be considered when designing and planning new road adjacent shared-use paths.

The second objective collected and analyzed three years of trip and ridership data from Auburn University's campus bike share program to learn what factors influence a user's decision on riding non-separated facilities or on a separated road adjacent shared-use path. This goal allowed for the influence of the adjacent roadway to be analyzed along with the user and path variables that were included with goal one. Following extensive data and GIS analysis, the trip characteristics of the over 100,000 trips were utilized to create new bike share typologies for the almost 9,000 users. These four new typologies highlight the differences between travel patterns and needs for individuals, even for a campus bike share program that fundamentally contains many of the same user types. The new typology coined purposeful users made up for 60% of all users are the likely target audience for the program making frequent, short trips and use bike share to supplement their transportation needs. This group is highlighted as a key grouping to understand their travel pattern since they are clearly interested in cycling but yet not as committed to purchasing their own bicycle. To understand this group and other's bicycle facility preferences, a binary logistic regression analysis was performed based upon choices between non-separated or separated facility choices at nine selected locations displaying a variety of roadway and pathway conditions. The analysis showed how important the physical conditions along with the user typologies are on facility choices and comfort level with non-separated cycling facilities. Users chose to ride separated from traffic when the roadways contained wider lanes, a great number of lanes and contained higher speeds and traffic volume. Bike share users also tended to ride on separated facilities, either sidewalks or shared-use paths, where they were wider and also separated further away from the roadway. Finally, users were more comfortable riding in a non-separated environment when traditional bicycle lanes were provided. The four defined typologies were also found to be influential in the facility choices with the two highest represented types including the key purposeful users preferring the separated option.

The third objective brought together the findings from the stated and revealed user studies by developing a new guidance framework for transportation professionals looking to implement road adjacent shared-use paths. By using the results from the previous studies, eight new typical configurations were created that illustrate the design characteristics users will prefer based on varying roadway conditions. Also using the results from the stated and revealed preference studies, a new matrix was created where it was predicted if a cyclist would choose the shared-use path in a specific configuration or would rather ride on the roadway. The results of the guidance framework will help transportation officials make informed decisions in early project planning on the design needs for a new path as well as understand who would potentially be served by a new facility.

Lack of multi-modal user data (especially when compared to data for motor vehicles) is a challenge with active transportation planning and design. Therefore, it is powerful and unique that this dissertation was able to collect two new separate datasets with similar demographics and obtained in overlapping timeframes. With a known research limitation that the majority of information for both data sources were from college aged users, combining the findings allowed for a full perspective in understanding users' stated and revealed perceptions and preferences. This new data backed guidance provides recommendations on key path design elements as well as predicting which cyclist type a potential configuration will likely serve. By highlighting that not every cyclist will be served through a specific road adjacent shared-use path, transportation decision makers will now be able to prioritize potential projects based upon strategic goals in accommodating targeted user groups.

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Appendix A – User Survey Script

1. PARTICPANT INFORMATION

This survey attempts to find out different user's preferences on various design options for shared-use paths. A shared-use path is a transportation facility physically separated from a roadway that serves non-motorized transportation modes like pedestrians, cyclists, roller skaters, etc.

GENERAL PHYSICAL ACTIVITY

Q1_1: In a typical week, which days did you…

Walk for exercise/leisure	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Jog/Run for exercise/leisure	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Ride a bike for exercise/leisure	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Work out	Sun	Mon	Tues	Wed	Thurs	Fri	Sat

Q1_2: Thinking of a typical week, with whom did you do these activities? (limit based on previous question)

Walk for exercise/leisure	Alone	With Children	With Other Adults	With Pets
Jog/Run for exercise/leisure	Alone	With Children	With Other Adults	With Pets
Ride a bike for exercise/leisure	Alone	With Children	With Other Adults	With Pets
Work out	Alone	With Children	With Other Adults	With Pets

Q1_3: Thinking of a typical week, Where did you do these activities? (limit based on previous question)

Walk	On a sidewalk	On a shared use path	At a gym	At a parkAt my home
Jog/Run	On a sidewalk	On a shared use path	At a gym	At a parkAt my home
Ride a bike	On a sidewalk	On a shared use path	At a gym	At a parkAt my home
Work out	On a sidewalk	On a shared use path	At a gym	At a parkAt my home

GENERAL SHARED USE PATH USE

Q1_4: How often do you use shared use paths IN AUBURN/ OPELIKA/ COLUMBUS:

- ☐ Often
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

Q1_5: What is your primary activity when using a shared-use path IN AUBURN/ OPELIKA/ COLUMBUS? (Unless Never checked in Q1_4)

- ☐ Walking
- ☐ Jogging/Running
- ☐ Cycling
- ☐ Other: ____________________

Q1_6: What is your primary reason for using a shared-use path IN AUBURN/ OPELIKA/ COLUMBUS? (Unless Never checked in Q1_4)

- ☐ Exercise
- ☐ Leisure
- ☐ Mode of Travel (Using the path to get from one location to another)
- ☐ Other: ____________________

Q1_7: How often do you use shared use paths OUTSIDE AUBURN/ OPELIKA/COLUMBUS, like on vacation or visiting friends and relatives:

- ☐ Often
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

Q1_8: What is your primary activity when using a shared-use path OUTSIDE AUBURN/ OPELIKA/ COLUMBUS? (Unless Never checked in Q1_7)

- ☐ Walking
- ☐ Jogging/Running
- ☐ Cycling
- ☐ Other: ____________________

Q1_9: What is your primary reason for using a shared-use path OUTSIDE AUBURN/ OPELIKA/ COLUMBUS? (Unless Never checked in Q1_7)

- ☐ Exercise
- ☐ Leisure
- ☐ Mode of Travel (Using the path to get from one location to another)
- ☐ Other: ____________________

Q1_10: What is the main reason that keeps you from using a shared-use path MORE frequently? (Unless Never checked in Q1_4)

- ☐ I do not have a shared-use path that is convenient to use
- ☐ There is not a shared-use path that connects the destinations I travel
- ☐ I do not feel safe using a shared-use path
- ☐ I do not have time to use a path more frequently
- ☐ Other:__________________

Q1_11: Why have you not used a shared-use path? (If Never checked in Q1_4)

- ☐ I do not have access to a convenient shared-use path
- ☐ I have not had time to use a shared-use path
- ☐ I do not feel safe on a shared-use path
- ☐ I have no reason to use a shared-use path
- ☐ Other: _____________________

Q1_12: Why do you use a path outside of AUBURN/ OPELIKA/ COLUMBUS but not in AUBURN/ OPELIKA/ COLUMBUS? (If Never checked in Q1_4 and not selected in Q1_7)

- ☐ Other locations have more shared-use paths
- ☐ Other locations have more convenient shared-use paths
- ☐ Other locations have safer shared-use paths
- ☐ I have more time to use a shared-use path in another location
- ☐ Other: _____________________

Q1_13: Would you want access to more shared-use paths?

- ☐ Yes, because I would like more opportunities for exercise and recreation
- ☐ Yes, because I would use them to bicycle, walk, or skate to work, shop, or other destinations
- ☐ No, because I do not feel safe on shared-use paths
- ☐ No, because I do not have any interest using any shared-use paths
- ☐ Other: ______________________

2. SHARED-USE PATH OPTIONS

Q2_1: If this pathway was located conveniently to your home, how likely would you use it for any purpose on a typical week?

- ☐ Very likely
- ☐ Somewhat likely
- ☐ Neutral
- ☐ Somewhat unlikely
- ☐ Very unlikely

Q2_2: How would you rate the safety of this pathway?

- ☐ Very safe
- ☐ Somewhat safe
- ☐ Neutral
- ☐ Somewhat unsafe
- ☐ Very unsafe

Q2_3: How would you rate the quality/condition of this pathway from the scale 1-5?

- ☐ 1 (lowest quality/condition)
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 (highest quality/condition)

Path image options (21 total):

I. No separation from roadway
   a. Eight-foot wide gravel
   b. Eight-foot wide asphalt
   c. Ten-foot wide gravel
   d. Ten-foot wide asphalt
   e. Fifteen-foot wide asphalt; yellow dashed striped
   f. Fifteen-foot wide asphalt; separate bike/ped striping
   g. Fifteen-foot wide gravel

II. Ten-foot separation from roadway
   a. Eight-foot wide gravel
   b. Eight-foot wide asphalt
   c. Ten-foot wide gravel
   d. Ten-foot wide asphalt
   e. Fifteen-foot wide asphalt; yellow dashed striped
   f. Fifteen-foot wide asphalt; separate bike/ped striping
   g. Fifteen-foot wide gravel

III. Twenty-plus feet separation from roadway

a. Eight-foot wide gravel
b. Eight-foot wide asphalt
c. Ten-foot wide gravel
d. Ten-foot wide asphalt
e. Fifteen-foot wide asphalt; yellow dashed striped
f. Fifteen-foot wide asphalt; separate bike/ped striping
g. Fifteen-foot wide gravel

3. PERSONAL INFORMATION

Q3_1: Tap on the map approximately where you live to give us a sense of your neighborhood type

Q3_2: What is your household size (including yourself)?

________Adults aged 65 +
________Adults aged 26-64
________Adults 18-25
________Children aged 6-17
________Children aged 0-5

Q3_3: About how long is your daily commute?

- ☐ 0-5 minutes
- ☐ 6-10 minutes
- ☐ 11-15 minutes
- ☐ 16-30 minutes
- ☐ More than 30 minutes

Q3_4: What is your age?

- ☐ 18-20
- ☐ 21-25
- ☐ 26-30
- ☐ ...
- ☐ 65+

Q3_5: What is your gender?

- ☐ Male
- ☐ Female
- ☐ Other

Q3_6: What is your annual household income?

- ☐ Less than $15,000
- ☐ $15,000 to $39,999
- ☐ $40,000 to $64,999
- ☐ $65,000 to $89,999
- ☐ $90,000 to $114,999
- ☐ $115,000 to $139,999
- ☐ $140,000 or more