A STUDY OF INFRASTRUCTURAL CONNECTIVITY ON A COLLEGE CAMPUS:
THE CASE OF THE UNIVERSITY OF ALABAMA

by

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A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Geography
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2021
ABSTRACT

As the University of Alabama and the City of Tuscaloosa continue to undergo unprecedented growth, more students than ever need to commute to campus. While most students choose to drive to campus, this places stress on the University’s parking lots and development plans. In an attempt to combat that stress, the multimodal network infrastructure was evaluated to identify the overall connectivity for student commuting. This evaluation was completed by using graph theory applications to gauge the overall connectivity of the sidewalk, bike lane, and bus route networks available to students at the University of Alabama. Through GIS mapping, relationships between these networks were identified, as well as gaps in these networks. Along with these graph theory metrics, a survey of student’s commuting patterns was performed to identify how students travel to campus and their overall familiarity with the alternative transportation networks. Together, this data was compiled to identify areas in which connectivity is limiting a student’s ability to commute to campus, either due to gaps in the network or lack of awareness of the network. These results were used to create policy recommendations which sought to improve connectivity metrics and overall mobility for students at the University of Alabama in an effort to combat the recent unprecedented growth.
DEDICATION

To my parents, with whose support I could never have been here without. Thank you for always supporting me and encouraging me to chase my ever-changing dreams. To my friends, especially Sam and Mel for listening to my endless complaints, breakdowns, and breakthroughs. Lastly, to the city of Tuscaloosa, thank you for providing me with a formative college and secondary college experience and a setting for my studies.
ACKNOWLEDGEMENTS

I am honored to have the opportunity to work on such a project and could not have done it without the support of the Geography Department and my advisor, Dr. Seth-Appiah-Opoku. Thank you for pushing me to take my crazy ideas and turn them into real research. You were so supportive and helpful during this entire process and I could not have done it without you. I also want to take the time to thank my committee, Dr. Weber and Dr. Jones, for providing guidance and assistance during this time.
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CHAPTER 1: RESEARCH BACKGROUND

Introduction

Around the United States it is not uncommon to see cities built up around institutions of higher education. These “college towns” can be found in most parts of the United States and surrounding colleges which bring in a student population seasonally. In these cities, finding a balance between what the college wants and what the cities want can be complicated but lucrative if executed correctly. A lot of these cities often cater to their student populations, offering many dining and entertainment options to promote attractiveness to potential students and an economic outlet as well. While most cities provide their residents, both local and seasonal students, with many options for dining, recreation, and entertainment, one thing that can be overlooked is providing mobility options for these residents to move about the cities.

To provide ways for students to travel to and from campus without incident, colleges or universities typically provide bus systems, sidewalks, and bike lanes for students to use, as well as parking lots for those who choose to drive. In some college towns, students are able to live close enough to easily walk or bike to campus, adding to the draw of residing in a college town. Since school provided parking lots can often be found towards to outer parts of campus, this creates a highly motivated group of people willing to walk or take public transit to get to school. To support this, colleges and universities, along with the cities in which they reside, have a responsibility to ensure that students are able to get to campus safely and efficiently. This occurs
by ensuring the network of these modes is both connected and efficient to enhance the student’s mobility. This involves making sure sidewalks are developed, bike lanes line the streets, and bus routes run past large residential areas. While colleges, like the University of Alabama, seem to offer some combination of these networks, the networks require higher connectivity between modes to provide true mobility for their students.

Tuscaloosa, Alabama is home to the University of Alabama and its student body. These two entities co-exist and must function in conjunction with one another as one can impact the others infrastructure and policy decisions. While the city had a total of 90,550 residents during the last census in 2010, (US CENSUS BUREAU) the University had a total of 30,232 students enrolled that year (OIRA.ua.edu). This means that the students create a large influx of bodies, money, and ideas into the city each year- equivalent to almost 1/3 of the population of the city itself. These numbers alone demonstrate the massive impact students can have on demographics of the city of Tuscaloosa. With that being said, the number of students cause a stress on infrastructure forcing the city and the University to find a solution which allows both residents and students to coexist happily. This can be incredibly difficult as the city experiences such rapid growth.

In recent years, unprecedented growth has defined the University of Alabama campus and student body. With as many an increase in enrollment from 26,449 in 2008, the University’s student body is now comprised of over 37,946 undergraduate and graduate students as of the 2018 school year (Writer, 2018). With these new students comes an increased demand for additional staff positions, on-campus resources, and off campus housing. With as many as 6,045 new units built since 2011, housing has become a significant portion of development in recent years (Tusc_HSG_Study_10252018.pdf, 2018). Simultaneously, demand for on campus parking facilities have grown in conjunction with these new housing developments as more and more
students need to reach campus. The University currently offers student parking in twelve commuter lots and an additional four residential lots (http://bamaparking.ua.edu/permits/). These lots are dispersed around campus providing convenient access depending on the location of the student’s classes or the location from which they are commuting. To gain entry to these new parking facilities students must buy a pass which can cost upwards of $155 for one semester (Permit Information – Parking Services The University of Alabama n.d.). While the cost may be thought to be prohibitive, many passes are purchased each year as students drive to school.

The Concept of Infrastructure and Facilities Planning

Infrastructure and facilities planning is at the core of this project, which centers on ensuring there is enough of certain infrastructure to provide mobility for the population. In this case of this study, that refers to ensuring there are enough bike lanes, sidewalks, and bus routes to support the commuting habits of the population of Tuscaloosa, specifically students. As population at the University and within the city continues to grow, more people may need to take alternate modes of transportation to campus, making this a vital part of planning for the future. This assurance of meeting future needs is made possible administrators having the foresight to create long term plans for campus and city wide growth that will address how these facilities will need to change as population changes.

There are six types of basic infrastructure required for university facilities planning. According to Essential Infrastructures for World-Class Universities by Sreeramana Aithal and Shubhrajyotsna Aithal, these infrastructures are: physical infrastructure, digital infrastructure, emotional infrastructure, innovative academic infrastructure, intellectual property infrastructure, and industry networked infrastructure. That study identifies these as essential parts of a successful college campus and success with these infrastructures can take a university from good
to great. These infrastructures ensure that the basic needs and wants of the university are being met through providing these avenues for successful teaching-learning to occur.

Physical infrastructure is the first necessity for long term success in facility planning on a college campus. This is perhaps the one which comes to mind when first thinking of campus infrastructure as it is the physical materials which create a campus. These can include things like property, buildings, classrooms, offices, roads, sidewalks, bike lanes, residential areas, shops, recreation centers, and more. These are the physical things which make a university to both attract potential students and retain the current students. It allows the university to function as an institute of higher education. It makes the residents comfortable and to thrive.

Digital infrastructure allows those that use the campus to do their job. This can include internet, a webpage, WIFI and the ability for those that need to communicate to be able to do so. Any type of digital communication can be vital to ensure collaboration and communication between different groups within a campus setting. This is not only useful from a research and education perspective but also from an administrative perspective as well. When discussing communication amongst the administration, the third type of infrastructure, emotional infrastructure, can be discussed. This infrastructure focuses on having a strong leader, strong communications, and cherished traditions. These create a sense of place or emotional connection to a place for those that experience it.

This leads into the fourth type of infrastructure, innovative academic infrastructure. This infrastructure is the purpose of higher education- learning. Innovative academic infrastructure is the course work, subject matter, planning, and education which is at the heart of higher education. It is this material which allows higher education institutions to be just that- places of higher education. This infrastructure creates a curriculum where students and faculty can thrive
and achieve excellence. When achieving academic excellence at an institution of higher education, there is typically a research or advance degree program which drives forward innovation at a university. This is fifth type of infrastructure, intellectual property infrastructure. This involves a campus having targeted research goals and faculty which holds advanced degrees as well as educates those seeking advanced degrees. Research educations are highly revered and can enhance the value of a university as it attempts to achieve excellence.

The last type of infrastructure is network infrastructure, which ensures that the university is connected with other educational institutions, with businesses, with alumni and any other groups that foster collaborative success. This infrastructure allows some of the other infrastructure to succeed, as they foster connections that emotional infrastructure and academic infrastructure require to succeed ((PDF) ESSENTIAL INFRASTRUCTURES FOR WORLD-CLASS UNIVERSITIES n.d.).

While all these infrastructures are necessary to the success of a college or university, however this study will only focus on the first type of infrastructure. This physical infrastructure contains the necessary items which create a connected mobility network for students, faculty, staff, and visitors to utilize the university space. This study specifically looks at the physical infrastructure that facilitate student’s commutes to and from campus which includes: bike lanes, sidewalks, roads, and bus routes. These examples of physical infrastructure provide an attractive level of connectivity or “walkability” which draw student and faculty to places such as Tuscaloosa, Alabama.

For this study, the term infrastructure is defined as the basic physical and organizational structures and facilities (i.e. buildings, roads, power supply) needed for operation of a society. Specifically for this study, infrastructure will refer to those which support multimodal
commuting methods such as bike lanes, sidewalks, and bus routes. The term “limiting” is defined as a lack of access or connectivity which makes walking, biking, or taking transit to school impractical. This also includes looking at places where certain periodic events make commuting without a car impractical—such as crossing train tracks which run parallel to campus and can create temporary disconnect in the network. This study then sought to make recommendations for future sidewalks, bike lanes, and transit stops to increase the service area and connectivity of the transit systems.

To address these limiting issues, college campuses must work with city officials to create long term plans which address the needs of both students and residents as they use the infrastructure throughout the city. There may be a disconnect between the city and the university goals, which can create a disconnect in the connectivity. This issue is not specific to the University of Alabama and the city of Tuscaloosa however, and can be seen in many other places.

The Case of the University of Alabama

This brought the study to this point of assessing the impact that bike lane, sidewalk, and bus route connectivity in Tuscaloosa, Alabama have on the student’s overall mobility. As stated in the introductory paragraph, the University and City are currently experiencing unprecedented growth which are creating both problems and opportunities for multimodal networks. With limited parking facilities and an increase in demand for on-campus parking, there is a need for a person to have the ability to reach campus without taking a trip in a personal vehicle. With existing infrastructure at the University of Alabama and in the City of Tuscaloosa, residents have a myriad of choices on how to travel to campus. However, as evidenced by the data collection in this study, many choose to pay the expensive fee to park their car on campus. Car free transit has
been studied to some extent both by the City of Tuscaloosa and the University of Alabama however, their studies look at the extent of the networks in their respective domains, but fail to analyze connectivity of the bike lanes, sidewalk and bus routes all together as one system.

To look at the overall mobility and connectivity of the University of Alabama and surrounding area, the available literature was searched to determine the current state of all multimodal networks. The University of Alabama Pedestrian System Plan, published in 2010, outlines their plans for the multimodal transportation network on campus. It outlines the future bicycle and pedestrian connections. It also classifies tiers of ‘walks’ which is the Pedestrian Systems Plan’s method of prioritization of the future sidewalk connections. These tiers are based on most used corridors by students and highest priority connections. This method of visually demonstrating connectivity is depicted in Figure 1 below. In this Figure, highly important connectors are shown in red and denominated as Primary Walks. These bring pedestrians through major parts of campus and presumably see the most foot traffic. The green paths, named Secondary Walks denote vital connections between primary walks and areas of interest. Lastly there is tertiary walks which fill in the gaps of the other two levels of walks and may not see as much traffic as the rest. From this map, it can be noted that the University of Alabama campus is relatively well connected using sidewalks. There are sidewalks, or plans for sidewalks, along major roads and near areas of interest. This provides students with a safe was to express mobility around campus. However, once the sidewalks reach the end of campus that is where the sidewalk system starts to lose some of that connectivity (University of Alabama Pedestrian System Plan 2018).
In Figure 2 below, one can also see the University of Alabama bicycle system plan. These connections are mostly on-road bike lanes and stretch across most of campus near major attractions. This provides students with mobility via bicycle on campus, but when they leave campus there is often very little connectivity for bicycles within the city of Tuscaloosa. It is worth noting that there are no maps that demonstrate both of these networks and all connections via bicycle or sidewalk.
Figure 2: University of Alabama bicycle network plan from the "Existing Conditions Assessment: Transportation and Mobility"

This figure was published in the city of Tuscaloosa’s most recently revised draft to their Existing Conditions Assessment: Transportation and Mobility in February of 2019. This publication is part of the larger comprehensive planning process, Framework, which the city is currently undertaking. This piece of literature covers the current bicycle network, sidewalk, and transportation connectivity. The Existing Conditions Assessment also included public input stating that there are gaps in the bicycle and sidewalk networks, with some paths leading to nowhere. One of the key points of the Bicycle and Pedestrian Plan section of the Existing Conditions Assessment was a need to increase connectivity of the multimodal transportation network, hence the goal of this study. This is a common theme in this research project, as it attempts to describe the connectivity of the entire network as well as how to better improve the
network.

While the University area shows higher levels of connectivity and mobility with many sidewalks, bike lanes, and bus routes, the city of Tuscaloosa remains less connected. Figure 4 below shows an example of the shared use paths which the city has constructed and plans to construct. As one could observe, this network is highly disconnected and fails to provide any true mobility options for the students and residents of Tuscaloosa and the University of Alabama.

The *Existing Conditions Assessment* includes a sidewalk inventory created in 2015 as well as a short description of the public transportation system. This will serve as a starting basis for this study. Figure 3 below shows the extent of the sidewalk inventory, yet it is worth noting most

*Figure 3: Shared Use Paths in Tuscaloosa from the "Existing Conditions Assessment: Transportation and Mobility", 2019*
parts of the University of Alabama’s campus is not included in this inventory. The public transportation system portion references the Tuscaloosa Trolley and the services which it offers. As of the date of publication of the *Existing Conditions Assessment*, two bus routes offered by the City of Tuscaloosa provide service to The University of Alabama’s campus. These routes are the University Shuttle Route and the V.A./University Route (*Existing Conditions Assessment* 2019).

All together, the University of Alabama and the surrounding Tuscaloosa area are responsible for a large amount of commuters to and from campus every day. These commuters require safe, connected infrastructure such as sidewalks, bike lanes, and bus routes to make their commutes. As seen in the existing conditions above, the University and Tuscaloosa have a lack
of connectivity within those networks. This disconnect can create commuting problems and establish dis-interest or inability to commute to campus.
CHAPTER 2: RESEARCH METHODOLOGY

Introduction

While looking at the existing data surrounding the City of Tuscaloosa and the University of Alabama’s transit, bike lane and sidewalk systems, there are a few patterns that emerge. These patterns such as missing pieces and lack of connectivity to areas of interest demonstrate the purpose behind this study. The study aimed to identify the overall connectivity of the multimodal network and then inform future decisions regarding this network. This process was able to occur through identifying goals, and then proceeding to collect data for analysis.

Research Problem and Objectives

This study sought to identify if, and how, multimodal transportation infrastructure, such as sidewalks, bike lanes, and bus routes, limits student’s access to the University of Alabama’s campus. Specific objectives are to:

1) Explore the level of infrastructure connectivity on campus.

2) Identify how mobility is impacted by infrastructure connectivity on campus.

3) Discuss the policy implications and a way forward.

By improving infrastructure such as sidewalks, bike lanes, and bus routes located within the
multimodal network, the results of this study would hope to increase the number of people that the bus can provide service to, as well as have the potential to increase the number of people who choose to forgo their private vehicle or bus completely. This result could have the capacity to alleviate the increasing demands for parking on and near campus as well as promote environmentally friendly commuting practices. The connectivity analysis will also add additional literature to graph theory applications and to the multimodal network mapping within Tuscaloosa, Alabama as well as create a dataset of all networks as a result of the analysis.

As Tuscaloosa and the University of Alabama continue to grow, the ability for students to travel without personal vehicle will become increasingly important. The objectives outlined in this study are vital to understanding the multimodal network design. The study identifies areas which present challenges to the current network and creates an entirely new dataset for the network. Additional information is created to help identify patterns within the transit network as well as areas of interest.

**Data Collection Methods and Analysis**

**A case study approach**

The study region is The University of Alabama campus and the immediate surrounding area within the City of Tuscaloosa. With this as a reference, census tracts were chosen as the basis for the mapping study due to the high amount of data readily available about them, including population numbers and age demographics. By using the census tracts which are near the University area, the study confined the focus area to places where biking, walking, and transit were the most feasible. The University area is bordered to the west by Lurleen Wallace Boulevard, which contains two lanes of traffic in each direction as well as to the east by
McFarland Boulevard. The lanes present challenging barriers to walking and biking as they are high-traffic and high speed areas. The University area is also bound to the north by the Black Warrior River, so only census tracts south of the river were utilized in this study. These census tracts and major routes can be seen in the figure below.

Figure 5: Study Area

The study also used the location of current sidewalks, bike lanes and bus routes. These networks are hosted by both the University of Alabama and the City of Tuscaloosa. Due to the recent rapid development in the area surrounding the University, the extent of these networks are quickly changing. As new housing is built in Tuscaloosa, new sidewalk and bike lane infrastructure is built along with it- changing the network and increasing connectivity. For this reason, it was important to also identify any off-campus housing locations which are currently available to students at the University of Alabama. These were identified from https://offcampushousing.sa.ua.edu, the online resource for student housing. Those locations can
be seen below in Figure 6 with the census tracts. These apartment complex locations were used in conjunction with the newly mapped sidewalk, bike lane and transit networks to identify places where larger numbers of students may live and where the network may require more connectivity.

In mapping all the collected data, the entire multimodal network system was able to be visualized on one map. Through this, network connectivity metrics were then able to be applied to identify the degree of connectivity within the networks, as well as to identify any critical points of the network. These metrics and the map were then used to identify places in which connections would have the most impact, both with population values as well as by increasing the connectivity metrics. This provided a data driven methodology which would allow the impacts of connections to be seen in real time and can provide a basis for places to create connections as well as to ensure new nodes connect to or near the critical node.
The final part of this study involved a survey with the students at the University of Alabama to identify habits in student’s commuting patterns as they travel to and from class. The survey covered many different aspects of a student’s commute, including time spent traveling, methods used, and knowledge of the existing infrastructure. The results of the study were used to corroborate the areas of interest identified by the mapping procedure and the connectivity metrics, providing a data driven and holistic approach to the overall connectivity of the multimodal transportation network.

Data Collection

Data for this study was collected in two ways. First, a computer mapping software with aerial imagery, Google Earth, was used to identify locations of bus stops, sidewalks, and bike lanes. This was used in conjunction with the above figures of the current networks. For sidewalks, the Tuscaloosa Transit Plan sidewalk figure was the main reference point, as well as utilizing Google Earth aerial imagery for any additional sidewalks which were not on the map from the City of Tuscaloosa. From there the latitude and longitude of the beginning and end of each sidewalk segment was collected and placed into an Excel document to later be put into ArcGIS. To map the bus routes, a similar process was performed utilizing the University of Alabama transit website (Crimson Ride – | The University of Alabama n.d.) as well as the City of Tuscaloosa Transportation department website (Tuscaloosa Transit Authority - Home Page n.d.). These websites also provided mobile apps, Pasio GO! for the Crimson Ride and TransLoc for the Tuscaloosa Trolley which were utilized as reference material as well. The bus stops’ latitude and longitude were recorded and were then placed into an Excel document for later analysis in ArcGIS. For bike lanes, the above figures from the Tuscaloosa Framework Plan were utilized as
references for locating the starting and ending point of each lane. Lanes were verified via aerial imaging and then the starting and ending latitude and longitude were collected in an Excel document for later analysis in ArcGIS. For bike lanes, a column denoting on-street facilities or off-street facilities was also added to help differentiate the varying levels of safety which the different methods provide. Any locations that were not immediately apparent from the aerial imagery was field verified to ensure the infrastructure still currently existed.

GIS data was also collected from the United States Census Bureau. This included files for the street network in Tuscaloosa as well as the population demographics within the chosen census tracts from the most recent years available. Unfortunately, due to the timing of the thesis and the late arrival of the 2020 census numbers, this study utilized 2010 numbers. Once the census tracts were compiled, the location of apartment complexes found of the University of Alabama off-campus housing website were found and record in an Excel sheet. These location values were found using Google Earth. A base map was also used in ArcGIS to allow clear visualization of locations on the map.

**Data Compilation and Analysis**

The data was placed in ArcMap in different layers. There was a layer created for each type of feature. These features were built in ArcMap using network analyst functions to create routes and provide an analytical basis. From these networks, the study identified the location of missing sidewalk and bike lane connections, along with crosswalk and condition information, to see if and where access to transit stops is being prevented.

Another aspect of this analysis was using graph theory to describe the shape and connectivity of the multi-modal transportation network. This took into account bike lanes,
sidewalks, and bus routes as independent routes as well as one continuous route. This analysis was be completed using graph theory applied to transportation networks. This process was modeled after the analysis completed by Mishra, et al. in their 2012 paper, *Performance indicators for public transit connectivity in multi-modal transportation networks*. This paper utilized graph theory to determine the degree of centrality for nodes in their network and to determine both line connectivity and node connectivity. To do this, I calculated the beta, gamma, degree, and alpha values associated with connectivity metrics as outlined in Equations 1, 2, 3 and 4 above. These measures then provided the data to assess how connected each area or the entire network is. This process proved useful to my own study, by utilizing their proposed measurement indexes and potentially by weighing my census tract regions by population as the study did with their own measurement regions.

In this portion of the project, I utilized graph theory and critical node identification methods as seen in the 2018 paper, *Enhanced connectivity index: A new measure for identifying critical points in urban public transportation networks*. This paper focuses on the methodology necessary to nodes which are crucial to transportation networks. They do this by utilizing graph theory to model the network first, and then to identify critical nodes by calculating the node degree. Node degree refers to the number of links that pass through a node. These critical nodes were used to identify patterns in distribution and provide guidance when attempting to choose future connections. Recommendations for future connections were based on which locations improve graph theory results, including alpha, beta, gamma and degree calculations, as well as centrality values. New bus stops, sidewalk connections, and bike lane connections are based on those locations which improve the connectivity of the network the most, based on the above values. Lastly, I will compiled all of the networks, and recommendations, into an easy to
understand and utilizable map in ArcMap to succinctly communicate my findings.

**Graph Theory Applications in Connectivity Analysis**

When discussing transportation networks such as the ones outlined above, many different ways to define the connectivity of these networks have been examined. One such method involves using graph theory to measure the connectivity of different transportation networks using a series of equations focusing on nodes, links, and loops. This method is one of many applications of graph theory. Graph theory recognizes and describes the geometric nature of phenomenon in a myriad of fields such as mathematics, science, social sciences and more. Originally stemming from the mathematician Leonhard Euler in an attempt to solve a transportation problem, graph theory identifies the number of edges or links, the number of vertices or nodes, and the number of loops in a network. This can be demonstrated by the following equations and values thought out by the mathematician Berge.

\[ \mu = e - (v - p) = e - v + p \]  

The above equation identified the number of cycles in a network with \( \mu \) being the cyclomatic number, \( e \) being the edges (links), \( p \) being the sub-graphs, and \( v \) being the vertices (nodes). The idea here being focusing on the number of cycles or loops which a network forms to identify the degree of connectedness for a network. From there, this idea was further developed was applied to urban planning and the transportation network systems (Derrible and Kennedy 2011).

Graph theory as developed by Euler and Berge can then be applied to transportation networks to identify their connectivity. The higher the connectivity, the more ideal the transportation network is. It is a very useful in transportation geography as a method to display transportation networks as a “graph”. The following Figure from Rodrigue’s book, *The...*
Geography of Transport Systems, demonstrates the simplification that occurs when moving from a real network to a graph representation of that network as seen in the figure below (Rodrigue, Comtois, and Slack 2013).

![Real network vs Graph representation]

Figure 7: Graph Representation of a Network, Rodrigue

This idea of visually representing terminals and intersections as nodes and the “in-betweens” as links becomes increasingly important when using graph theory to define connectivity. From those levels of connectivity, there are a few indices used to measure that connectivity displayed by the graphic representation. While there are indices for measuring things like cost of the network, or the spatial efficiency of the network, the simplest indices to measure connectivity alone are: alpha, beta, gamma, and degree. While only using links, nodes, loops, these simple yet effective measures can be an efficient method to identify general connectivity in planar transportation networks.

The alpha index measures the number of loops currently in a network (u, as seen in the Berge equation above) to the number of loops which are possible in that network using the number of nodes. The range of possible alpha values goes from 0 to 1 with 1 being complete connectivity. The formula for calculating alpha can be seen in Equation 2 below.
\[ \alpha = \frac{u}{2v-5} \]  \hspace{1cm} (2)

The beta index is calculated similarly and finds the level of connectivity by finding the ratio of links (e) to nodes (v) in the network. For the beta coefficient, the higher the resulting value is, the higher the degree of connectivity is. In this, a value of 1 is connected, less than 1 is not connected, and more than 1 is highly connected. The equation for calculating the beta coefficient can be seen below in Equation 3.

\[ \beta = \frac{e}{v} \]  \hspace{1cm} (3)

The gamma index measures the ratio of links to possible links, with a value of 1 being completely connected and a value of 0 being not connected. The equation used to calculate the gamma index can be seen in Equation 4 below.

\[ \gamma = \frac{e}{3(v-2)} \]  \hspace{1cm} (4)

Lastly, the degree coefficient measure the number of links connected to a node and can help to represent the importance or “centrality” of a node. This can be useful to identify hubs or other areas of importance within a transit systems. The higher the degree of a node, the more central it is to the network. This would be in contrast to terminal nodes, at the end of links or end of a network, which would have a low degree due to lack of links connected to it. This number, in conjunction with the alpha, beta and gamma coefficient can be a useful way to measure the connectivity and efficiency of a planar network, such as a sidewalk, bus, or bike lane network (Rodrigue, Comtois, and Slack 2013).
Considerations for Data and Data Analysis

Like any scientific study, certain areas of the study require extra attention to ensure the results are accurate and up to date. In this study, this meant that ensuring the most up to date data is used when analyzing road and sidewalk data, population metrics, and housing areas. This includes being accurate on population data for the on-campus residences and more short term rental options near campus. While census data from the 2020 census was not available at the time the analysis was conducted, the next most recent census data, from 2010, was used for the analysis. To combat the ages of the aerial imagery and graphics from both the University and the City of Tuscaloosa, locations of infrastructure was verified in field when anything was unclear.

Student Survey

To assess the opinions of students who commute regularly to the University of Alabama campus area, a survey was created in Qualtrics and deployed to students. The survey, which was approved through the IRB Human Research Certification, was distributed via on-campus student groups, social media posting and anonymous links sent via email. The survey sought to identify broad patterns in student’s commuting habits by asking them their level of familiarity with the multimodal transportation system as well as their preferred commuting method. Other topics surveyed included if students had purchased a parking pass for the year and what influenced that decision as well as asking students to estimate how much time they spent commuting via each of the included methods. The full list and breakdown of student survey questions and all supporting material can be found in the appendix on page 44.
CHAPTER 3: RESEARCH FINDINGS

Introduction

The results for this study are multifaceted and therefore require multiple sections to express. To better understand the data, it is best to express each methods results separately until they could be discussed as a whole. The individual results of each method rely on each other to create the overall analysis. All of these results work to build a comprehensive picture of the multimodal transit network on the University of Alabama campus and in the surrounding area. The following sections will include results for: visual results such as the mapping efforts, graph theory or connectivity metric results, critical node theory results, and student survey results.

Results of Graph Theory Applications

This study utilized graph theory as a way to describe the connectivity of the networks and identify locations where making new connections would have the most impact by changing their connectivity values. To do this, alpha, beta, gamma and degree calculations were used to describe the sidewalk, bus, and bike lane network. The equations for these calculations can be found in the Background and Methods sections above and are labeled Equation 1, 2, 3 and 4. These values were calculated using Microsoft Excel and were done by route, location (on-
campus and off-campus), as well as type of transit as a whole. The results for each type of transit can be seen in the tables below.

Table 1: Bus Routes Connectivity Metrics

<table>
<thead>
<tr>
<th>Mode</th>
<th>Route</th>
<th>Total Nodes</th>
<th>Total Links</th>
<th>Total Loops</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>Tuscaloosa Trolley</td>
<td>199</td>
<td>209</td>
<td>22</td>
<td>0.053</td>
<td>0.952</td>
<td>0.320</td>
</tr>
<tr>
<td>Bus</td>
<td>Crimson Ride</td>
<td>21</td>
<td>35</td>
<td>5</td>
<td>0.077</td>
<td>0.600</td>
<td>0.212</td>
</tr>
<tr>
<td>Bus</td>
<td>Apartments</td>
<td>18</td>
<td>24</td>
<td>27</td>
<td>0.628</td>
<td>0.750</td>
<td>0.272</td>
</tr>
<tr>
<td>Bus</td>
<td>All busses</td>
<td>267</td>
<td>317</td>
<td>61</td>
<td>0.0970</td>
<td>0.842</td>
<td>0.283</td>
</tr>
</tbody>
</table>

Table 2: Sidewalks Connectivity Metrics

<table>
<thead>
<tr>
<th>Mode</th>
<th>Route</th>
<th>Total Nodes</th>
<th>Total Links</th>
<th>Total Loops</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidewalks</td>
<td>City of Tuscaloosa</td>
<td>268</td>
<td>192</td>
<td>0</td>
<td>1.396</td>
<td>0.470</td>
<td></td>
</tr>
<tr>
<td>Sidewalks</td>
<td>University of Alabama</td>
<td>241</td>
<td>195</td>
<td>0</td>
<td>0.809</td>
<td>0.272</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Bike Lanes Connectivity Metrics

<table>
<thead>
<tr>
<th>Mode</th>
<th>Route</th>
<th>Total Nodes</th>
<th>Total Links</th>
<th>Total Loops</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike</td>
<td>UA Campus (on-road)</td>
<td>57</td>
<td>43</td>
<td>14</td>
<td>0.173</td>
<td>1.326</td>
<td>0.463</td>
</tr>
<tr>
<td>Bike</td>
<td>UA Campus (includes Manderson Landing, off road)</td>
<td>16</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0.727</td>
<td>0.267</td>
</tr>
<tr>
<td>Bike</td>
<td>City of Tuscaloosa (on-road)</td>
<td>9</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0.600</td>
<td>0.231</td>
</tr>
<tr>
<td>Bike</td>
<td>City of Tuscaloosa (includes University Blvd, off-road)</td>
<td>10</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0.556</td>
<td>0.2083</td>
</tr>
</tbody>
</table>
Results of the Critical Node Analysis

The degree measurement from the 2018 paper, *Enhanced connectivity index: A new measure for identifying critical points in urban public transportation networks* resulted in identifying the most connected nodes for each method. For this method, the most connected node was the bus hub in the UA Crimson Ride system as well as for the apartment shuttles. They bus hub had 10 connections for the Crimson Ride and 11 for the apartment shuttles. In the Tuscaloosa Trolley, the downtown bus hub had the highest degree with 7 connections. For the UA campus sidewalk system, most nodes had 4 links, particularly near the Quad area and the Shelby Quad Area, due to the geometric nature of the network. The area near the Ferguson Student Center has 4 degrees at the corners nearest it. Overall, the sidewalk network was difficult to do the analysis on, with most having 4 degrees of links coming from each node in the downtown area and the degrees varying from 1 to 4 around the rest of the city. The bike lane networks, both City of Tuscaloosa and the University of Alabama networks, were the least connected overall but the node For the Tuscaloosa sidewalk network, the node where the Riverwalk at Manderson Landing met the UA campus had the most links from it, at 3 total.

Mapping Results

By collecting all the data necessary to do the critical node analysis and graph theory applications, the results data was utilized to create a comprehensive map of the multimodal transportation network in Tuscaloosa and the University of Alabama area. This map demonstrates the interconnectedness of the different modes of transportation. From this mapping, it is apparent that the downtown Tuscaloosa region and campus area is saturated with transit options while areas across the train tracks often have less options. Particularly near Parkview and
15th Street, where many students live, there is a lack of options for transit. Mapping practices also showed a few gaps in the sidewalk network most likely from recent development as new student housing is created. As new developments or houses are built, they build sidewalks along their property, leaving sidewalks in some places and missing in others.

**Results of the Survey**

The survey, administered through the University of Alabama Qualtrics system from November 2020 to January 2021 was taken by 32 students at the University of Alabama. The first section of the survey, focused on commuting methods, found that the majority of students live off campus. The primary method for traveling to campus was driving, with walking being the second most common method. Four of the responding students utilized apartment shuttles to get to campus as well. Tuscaloosa Trolley was not a commuting method utilized by any of the included survey takers, but the Crimson Ride was utilized by one as their primary method. 14 of the 32 students had a parking pass. These locations were chosen for proximity to classes, and inability to choose other options most commonly.

The second section of the survey focused on commuting times and how much time of the student’s commute is spent on each method of transportation. The figures below demonstrate the student’s responses to how much of their commute is spent on each method of transportation. The most time spent walking during commuting is between 10 and 15 minutes. The most common amount of time spent biking during the commute varied, with increments between 10 and 25 minutes being chose once each. Less than 10 minutes for bicycle commute was chosen twice. The most common amount of time spent on transit during commute is less than 10 minutes. The commute home tends to take the most time. The bus being late is the most common
reason someone may be late or off schedule, with crosswalks or waiting for crosswalks being the next most common reason.

![Figure 8: Commuting Times by Method](image)

The last section of the survey asked respondents to rate their level of knowledge with the sidewalk system, bike lane system and public transit system on the University of Alabama campus and the surrounding area. The results can be seen in the figure below. The respondents were most familiar with the sidewalk network and least familiar with the public. When asked if they could identify the nearest bus stop to their Tuscaloosa residence, 56% of respondents answered “Yes”. Finally, when asked about how they decided how to commute to campus, respondents answered that time was a big factor, followed by distance from campus. For ensuring safety on their commutes, they used word of mouth and high visibility streets to identify which routes would be the best to take.

**Summary of Results**

By looking at different streams of data, such as survey results, graph theory analysis, central
node analysis and mapping, there begins to emerge some patterns. First, the areas near the University and downtown Tuscaloosa are relatively connected with sidewalks and bus routes. The University is connected with bike lanes. However when you look at the study area in a wider lense, thinking of commuting to these places-not just within them, it starts to become apparent that the level of connectivity will make it difficult to achieve a high level of mobility. There appear to be ‘pockets’ of connectivity where mobility may be easier but to get to those places would be difficult. This is explored further when looking for solutions to this connectivity issue in the following sections.
CHAPTER 4: DISCUSSION OF FINDINGS

Introduction

By collecting all of the above results and combining them, a better understanding of the multimodal transportation network in Tuscaloosa, Alabama is created. This is vital as it has previously been established that no prior study has looked at transit between both City and University and between modes as one network before. It was vital to look at the entire network not just purely from the degrees of connectivity and connectivity metrics, as that would exclude the qualitative portion of the network- those that actually use the network as their means of transportation. On the other hand, using only the student surveys would not provide any true analysis of the connectivity of the entire network, just references of familiarity and habits. For this reason, combining the results has given us a better idea of what areas deserve more focus. The ideal transportation network is maximizes connectivity while still remaining efficient, therefore it serves the desired area in a quick, simple, and relatively pain-free manner.

Level of Infrastructure Connectivity on Campus

While analyzing the Graph Theory results from the Alpha, Beta, Gamma, and Degree connectivity metrics, there were a few things to note. First, for each metric, the value seen by the
network as a whole, i.e. the bus network, is just as valuable as the metric from each route specifically. These provided insight into the efficiency or redundancy of each route or method. The higher a score for the connectivity metric, the more connected it is. However, very high connectivity values for any of the calculations can mean that the network is a bit redundant, possibly unnecessarily so. A lower score, that may initially seem dis-connected, may be necessary to ensure the extent or efficiency of the network is as high as possible. The balance between these two extremes ensures you have an easy to navigate and efficient network while still keeping commuting times low and allowing people to travel more places.

We see this phenomenon in the bus network. The Tuscaloosa Trolley network covers most of the City of Tuscaloosa, including many areas which are further from the bus hub, which is located downtown. These routes, mostly The Shelton State Route, and Skyland Route, can take up to an entire hour to complete a loop for. Their alpha scores are 0.148148148 and 0.09756097561 respectively. Alpha values can range from 0-1, representing varying levels of connectivity. Therefore, these routes are not seen to be incredibly connected. However, these two routes do have the highest alpha values of any route, so therefore they are the least efficient routes, but most connected in the Tuscaloosa Trolley system. These routes should be then placed into the larger context of the entire Tuscaloosa Trolley system. The system has an alpha 0.05952380952. This is a relatively low level of connectivity. The other connectivity metrics perform a little better with a beta score of 0.95215311 and a gamma score of 0.3204508857. That beta value qualifies the Tuscaloosa Trolley system as ‘not-connected’, with a score lower than 1. However, it is relatively close, which was given consideration. A gamma value of 1 is completely connected, so the gamma value of the system at 0.3204508857 makes the network not highly connected. Overall, the Tuscaloosa Trolley values all fall onto the more efficiency
based, larger service area scores than they do to overall higher connectivity scores.

When comparing the Tuscaloosa Trolley scores with the Crimson Ride network, the Crimson Ride Network has a higher alpha value but lower beta and gamma values. The Crimson Ride has a higher ratio of loops to nodes in its system, meaning it is capitalizing as much on the connectivity of those nodes. Unlike the Tuscaloosa Trolley, the Crimson Ride utilizes shared stops. Once you board the bus at the Bus Hub, you can easily switch routes at many stops due to the routes overlapping. This can lead to a higher level of connectivity and redundancy, however the Crimson Rides’ lower beta and gamma values still suggest the system is not as connected as it could be. The apartment shuttles fared the best by some of these metrics, with the highest alpha values. This is attributed to the fact that each loop for the apartment shuttles has just 2 or 3 stops and 2 or 3 links and create just a single loop. Overall, none of these routes communicate with each other, sharing just one mutual stop at the bus hub.

The bike lane network is the least connected network of any method in Tuscaloosa, with many gaps and abrupt endings. This leads into a problem for successfully traveling anywhere by bicycle safely. While most of the University of Alabama campus area has bike lanes, it also has a low speed limit which allows for safe on-road cycling. Other areas, such as downtown Tuscaloosa with its pull-in/back out parking and along 15th Street or McFarland with their high speeds pose serious threats to bicyclists. The biggest issue here is that the streets nearest by to campus, such as behind Bryant Denny Stadium and along University do not offer bicycle infrastructure even though those areas are within bicycling range. This lack of connectivity is reflected by the low scores shown by the metrics. The only loops in the system are on the University of Alabama campus with their in-road bicycle facilities. The other routes do not loop or connect. This gave the bike system a low overall connectivity level except for the on-campus,
in road network. That network has a high beta value, indicating it is ‘connected’ and a gamma value nearly halfway to completely connected. This reflects well on the University campus, but in the larger view of the entire network it dominates all other routes.

The sidewalk network was the most highly connected routes, with most metrics falling under ‘connected’. This include the City portion and the Campus portion. The campus sidewalk network is the most developed, with almost no dead ends or abrupt changes. There are crosswalks at most intersections and the connectivity metrics are high. With on-campus travel being mostly on foot, this finding was not surprising. Most people walk from building to building to get to class and the area is pedestrian oriented with many benches and marked intersections. Around the city of Tuscaloosa, the connectivity metrics are a little lower, but their beta value still qualifies them as ‘connected’. The city’s sidewalks gamma value of 0.470175486 suggests that some nodes are still not connecting to things or are dead-ending. This was apparent in some neighborhoods that had sidewalks just on their street, with nothing to tie them into. As more development occurs, the sidewalk network is being patched together piece-by-piece, such it was expected to see some gaps in the network. This is increasingly apparent in the Forest Lake area, where some houses or streets have sidewalks and others do not.

The last portion of the graph theory analysis was degree calculations. While some of these may have initially been obvious, it was helpful to identify places that have the most connections currently so that future connections may be placed in relation to these high-degree nodes. These nodes are essential because they offer the ability to connect to most possible locations. The bus hubs being high degree as well as common junctures in the Riverwalk bike network will serve as starting points for recommendations.
Mapping

The visual results from mapping act as a support to the connectivity metric’s arguments. By mapping these networks all together, the study can see how connected the city truly is. The trends discovered by the mapping identify that most resources tend to be focused heavily towards the major thoroughfares. Jack Warner Parkway, McFarland Boulevard, Skyland Boulevard, University Boulevard and Lurleen Wallace tend to have a high concentration of facilities, however most people, particularly students, do not live along these roads. They live in adjacent neighborhoods which may or may not have the infrastructure necessary to get them safely to the transportation mode. Particularly along Skyland and near 15th Street there are many areas with no sidewalks or bike lanes, and no method for students to get where they need to be. Some bus stops, especially for the Tuscaloosa Trolley are in areas with no sidewalks or safe areas of refuge for the pedestrian to wait. The areas surrounding 15th street tend to have a high concentration of students but a low concentration of amenities for students to use to get to campus.

This mapping effort also demonstrated the impact of development on Tuscaloosa’s transit network. Newer developments, such as some apartment complexes like the Hub or Walk, have sidewalks while adjacent houses do not. While the new sidewalks are a welcomed addition, they highlight the dis-connectededness of the network due to the new wave of development Tuscaloosa has experienced due to the rapid increase in enrollment at the University of Alabama. While these networks will continue to grow, these “sidewalks to no-where” currently serve as a negative when convincing a student to walk to campus.
Mobility on Campus

The survey allowed the study to identify areas of interest based on student’s feedback. While it is important to remember that these results were collected during the COVID-19 outbreak when many students were no longer on campus, the study still used these responses to put the results of the mapping and metrics in context. Overall, students mostly chose to drove to school, with walking being the next most popular. Even students who chose to drive to an on-campus parking lot to get to class utilized the bus system. This suggests they may use the bus to get from the parking lots to their classes or to get between classes. Most time spent on busses was below 10 minutes, also supporting this theory. Biking was not a popular commuting option, however those that did use biking on their commute biked for about 20 minutes. The biggest issue noticed in the survey was the item in the student’s commute which would make them late for class. The bus being late was mentioned numerous times, suggesting that the bus system runs behind from time to time, impacting their arrival at class. Besides that, only 50% of the responses could identify the nearest bus stop to their house and most people were relatively unfamiliar with most networks besides the sidewalk network. This raises some concern, not only for the lack of awareness but the ability to find the information. Many students responded that when deciding how to commute to campus, they asked a friend what was best and wanted to avoid bad weather or traffic. This could be solved by increasing bus presence and promoting multi-modal commutes, such as biking to the bus stop and riding the bus with your bike. However, the low level of awareness of these networks raises a point for this project. There should be a singular place where students could identify their residence and any nearby methods of transportation. The level of awareness and comfort should increase.
Policy Implications

The downtown area and campus areas have a large sidewalk network, which makes walking to campus simple. There is not a long of biking infrastructure, particularly to get to campus. Students must traverse roads with dangers such as high speed limits or drivers backing out of parking spots. Particularly, the areas adjacent to 15th Street require more attention. These areas are home to a high number of students, however there is not much existing infrastructure to assist these students in getting to campus. This area is prime bicycle commuting distance and many businesses on the road do not directly touch the road, creating a good location for bike lanes. Students require more awareness of the transit network and more flexibility with using the network. While the network covers a large extent of land, it does not provide much flexibility with taking its methods. A student could not switch routes, make unplanned stops or change methods too easily with the current network.
CHAPTER 5: RECOMMENDATIONS

From this amalgamation of results and identification of problem areas, certain recommendations can be made which would improve the overall connectivity of the network. These recommendations are based on the following criteria: proximity to a higher degree node, the ability to fill in a missing piece, or the ability to connect a large housing area (i.e. an apartment complex) to the network. While many different new components, whether that be links or nodes, would help the overall network, the following recommendations are were seen to meet the criteria to the highest extent.

The first recommendation is the addition of a new bus hub for the City of Tuscaloosa. By creating a new bus hub further down McFarland, the city opens its options for more bus routes, with higher connectivity. First, it draws the length of the bus routes to be shorter distances. This would allow for some routes to overlap, adding more links with less nodes. This will increase their connectivity metrics. Secondly, this connects the bus routes to a higher portion of people and increases the level of service for each route. With this recommendation, the study believes making a commuter express route between both hubs to allow for quick transfers would be vital. While obviously this recommendation comes at a high cost, from a purely connectivity based approach, this would offer higher connectivity metrics, higher service levels and service areas.
Secondly, this study recommends filling in the gaps in the sidewalk and bike lane network closest to campus first. These gaps, caused by new development, can create limitations to student’s commute to campus. While the downtown and campus area of Tuscaloosa is the most walkable, the focus should continue there and build out. By fulling creating this network, the connectivity metrics will increase and the network will become more connected. It will have a big impact as the network begins to create more loops, raising the metrics. This is valuable also to encouraging students to walk or bike to campus. Bike lane presence in this area must also increase, particularly through the method of using shared road markings to announce the presences of cyclists. Roads nearest the University should be able to get that designation to provide some level of confidence for students and some awareness for drivers.

The third recommendation is that the University and the City jointly collaborate on some type of transit map for all networks. This includes increased focus and awareness on multimodal transportation methods. This map could be based on the findings of this study and present students with options for commuting to campus. This would raise student’s level of awareness with their options. It could be pushed out to UA’s off-campus housing department and any off-campus apartment leasing companies. It could be included in their move-in documents. This has many benefits, first being safety of students by making them aware of safe methods of transportation or dangers such as the train. The second benefit is the environmental benefit which comes from choosing public transit, bicycling or walking commutes. The map could even become an app to allow students to plan routes to places off campus they may need to get to. The map has the ability to be a platform for many community groups to get involved and to promote environmental or health benefits.

The recommendations that come from this study can be seen as the final outcome of this
study, or the culmination of all the mapping inputs, survey results, and connectivity metrics. These results can prove increasingly useful to inform future decisions on a University or City level and should work to fill in gaps in the current state of knowledge by analyzing the multimodal network in Tuscaloosa from a qualitative and quantitative perspective.
CHAPTER 6: CONCLUSION

At the completion of this project, the results evaluated the impact of infrastructure limitations on multimodal transit networks and added to existing literature on graph theory as a measure of connectivity in campus transportation networks. The study identified where infrastructure limits people’s ability to commute to campus and how those infrastructure limitations impact the overall connectivity of the network. By utilizing graph theory and ArcGis techniques, this study was able to determine these impacts and provide recommendations for improving connectivity within this network. This expanded the multimodal transportation network and promote interconnectivity between modes. By doing this, more people would be able to commute to the University of Alabama campus without ever getting into their car. This would allow Tuscaloosa to remain competitive with similar size, with an increasing student population and increased demand for parking services, the ability to walk or take transit to campus will become a highly coveted asset for future undergraduate students moving off campus. By planning for more inter-modal connectivity now, we can ensure students have a safe, convenient, and easy commute to campus for years to come.
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November 11, 2020

Emily Schnarr
Department of Geography
College of Arts & Science
Box 870322

Re: IRB # 20-09-3927: “Transportation Awareness and Usage by Students at the University of Alabama”

Dear Ms. Schnarr,

The University of Alabama Institutional Review Board has granted approval for your proposed research. Your application has been given exempt approval according to 45 CFR part 46. Approval has been given under exempt review category 2 as outlined below:

(2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

(i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects.

The approval for your application will lapse on November 10, 2021. If your research will continue beyond this date, please submit the annual report to the IRB as required by University policy before the lapse. Please note, any modifications made in research design, methodology, or procedures must be submitted to and approved by the IRB before implementation. Please submit a final report form when the study is complete.

Sincerely,
Survey Questions

Survey Title: Transportation Awareness of students and its impact on their daily commute.
Purpose: This study seeks to identify commuting patterns of students at the University of Alabama through ranking knowledge of different transportation modes and the student’s personal commuting habits. This study will ask participants questions about the length of their daily commutes to and from campus, as well as the modes they take to commute. It will also ask participants questions to gauge their level of awareness of the available transportation options at the University of Alabama and the surrounding Tuscaloosa area. The results of this study will be part of a larger study regarding the transportation systems in Tuscaloosa and their connectivity.

Survey Questions:
1. Are you currently a student at the University of Alabama?
   a. Yes
   b. No

2. Do you reside on or off campus?
   a. On campus
   b. Off campus

Commuting Methods: These questions are meant to identify how participants travel to and from campus by identifying their primary method or transportation.
3. Which of the following methods is your primary way to get to campus?
   a. Walking
   b. Biking
   c. Transit- Crimson Ride
   d. Transit- Apartment Shuttle
   e. Transit- Tuscaloosa Trolley

4. Do you have a parking pass? (If no, skip to question 7)
   a. Yes
   b. No

5. If you answered yes to question 4, which zone do you have a pass for?
   *Fill in the blanks*

6. If you answered yes to question 4, do you choose your parking based on the location of your classes or the proximity of the lot to your home?
   a. I like to park close to my classes
   b. I like to park in the place closer to my home.
   c. I did not get to choose the zone of my parking pass or had limited options.

Commuting Times: These questions will identify the amount of time or distance that a participant spends on their commute daily, as well as any obstacles they may face while commuting.
7. About how much of your commute to campus is spent walking?
a. 0-5 minutes
b. 10-15 minutes
c. 25-20 minutes
d. More than 20 minutes
e. I do not walk to campus

8. About how much of your commute to campus is spent biking?
   a. 0-5 minutes
   b. 10-15 minutes
   c. 25-20 minutes
   d. More than 20 minutes
   e. I do not bike to campus

9. About how much of your commute is spent on transit?
   a. 0-5 minutes
   b. 10-15 minutes
   c. 25-20 minutes
   d. More than 20 minutes
   e. I do not use public transit to commute to campus

10. How long does your total commute to campus take?
    a. Fill in the blank

11. How long does your total commute home take?
    a. Fill in the blank

12. What is something on your commute that makes you late or off schedule?
    a. The train
    b. Crosswalks or waiting for lights
    c. Bus being late
    d. Other (please elaborate):
    i. Fill in the blank

Transportation System Knowledge: These questions will identify the level of awareness the participant has with the transportation system.

13. How would you describe your level of knowledge with the sidewalks system on the University of Alabama campus and the surrounding area?
    a. I use the sidewalks every day and am familiar.
    b. I use the sidewalks weekly.
    c. I use the sidewalks rarely.
    d. I never use the sidewalks.

14. How would you describe your level of knowledge with the bike lane system on the University of Alabama campus and the surrounding area?
    a. I use the bike lanes every day and am familiar.
b. I use the bike lanes weekly.
c. I use the bike lanes rarely.
d. I never use the bike lanes.

15. How would you describe your level of knowledge with the public transit system on the University of Alabama campus and the surrounding area?
a. I use the public transit system every day and am familiar.
b. I use the public transit system weekly.
c. I use the public transit system rarely.
d. I never use the public transit system.

16. If asked, could you identify the nearest bus stop to your place of residence in Tuscaloosa?
a. Yes
b. No

17. When deciding how to commute to campus, what factors did you consider?
a. Fill in the blank

18. When deciding how to commute to campus, how did you decide the safest route to take?
a. Fill in the blank