**Livable Neighborhood Factors Affecting Mode Choices in a Medium Sized University Community**

by

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# ABSTRACT

Communities across the United States are striving to increase walking, biking, and riding transit among their residents and thus become more livable. In order for these communities to become more livable, city planners need to understand what factors affect an individual's mode choice. This thesis uses data collected from the Auburn University Campus Travel Choices Survey and a newly created Neighborhood Walkability Survey. A multinomial logistic regression model was created to determine the influencing factors and the level of influence they had on an individual's mode choice. Along with the model, results from the Auburn University Campus Travel Choices Survey were examined to determine other possible influencing factors of mode choice. The analyses found that built environment factors such as roadway attributes, bicycle facilities, pedestrian facilities, transit facilities, land use, neighborhood reason for visiting campus, neighborhood location, and distance from campus affected mode choice. Socio-demographic characteristics such as age, income, gender, role at Auburn University, and living arrangements were found to significantly affect mode choice. Finally, preference characteristics such as reason for visiting campus, enjoyment of travel, life responsibilities, environmental impacts, traffic congestion along the route, and cost of travel were found to be significantly related to mode choice.

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| | |
|---|---|
| CDC | Centers for Disease Control and Prevention |
| FHWA | Federal Highway Administration |
| TTI | Texas Transportation Institute |
| UCTCS | University Campus Travel Choice Survey |
| NWS | Neighborhood Walkability Survey |
| GIS | Geographic Information System |
| PEDS | Pedestrian Environment Data Scan |
| MNL | Multinomial Logit Model |
| MLE | Maximum Likelihood Estimation |

# CHAPTER 1

# INTRODUCTION

Livable communities are places where people live, work and play that are designed to increase the quality of life by allowing access to jobs, schools, homes, and shops through a variety of transportation modes [1]. There are many ways cities can be designed to support livable and sustainable transportation systems, but much research is still exploring how individuals react to different built environment characteristics [1].

Livable communities address traffic congestion, environmental pollutants, housing equity, and community physical health in a number of ways. In 2014, the Texas Transportation Institute (TTI) estimated that an average American traveling in the peak time period spends an extra 38 hours and 26 gallons of fuel in traffic a year, costing $78 billion annually [2]. Supporting multiple modes in a communities reduces the amount of traffic on those roadways. In recent years there has been a growing concern with the environmental impacts of emissions and runoff generated by traffic as well [3]. Promoting active travel and reducing traffic congestion idling reduces greenhouse gas emissions [4]. Active travel is mainly walking or cycling but can be any type of travel that focuses on physical activity instead of motorized transport. In general, states with the largest percent of active travel have the lowest percent of obesity [5]. An estimated $147 billion was spent on medical expenses in 2008 because of obesity [5], which could be avoided by promoting more walking and cycling in communities.

As a results, government agencies have recently started a plan to increase the amount of livable communities across the U.S. In 2009, the U.S. Department of Transportation, U.S. Department of Housing and Urban Development, and the U.S. Environmental Protection Agency partnered to start an initiative to help communities become more livable [6]. The Call to Action states five goals: making walking a priority for everyone; community design should be walkable for people of all ages and abilities' encourage walking programs to help support walking at home, school, and work; deliver evidence to increase walkability; and fill research gaps associated with walkability [7].

Communities can achieve different shades of livability. For example, a community with an abundance of sidewalks but poor connectivity to mixed land uses would be considered to have a low level of livability. A community that is very well connected with mixed land uses and offers bicycle, pedestrian, and transit facilities would be considered to have a high level of livability. These different shades of livability show that there is a wide spectrum when considering a community's livability.

Individuals' mode choices are a key component of livable communities for two main reasons: first, the observed mode choices indicate how truly multimodal a community is and second, planners can identify factors influencing mode choices as well as the importance of each of these factors to the local population to make improvements to their community. Individual mode choice is affected by many different characteristics including demographics, preferences, and the built environment. In 2013 the US Census estimated that 86% of all Americans commuted to work by a personal vehicle (76.4% drove alone and 9.4% carpooled) while 5.2% used public transportation, 2.8% walked, and 0.6% rode a bicycle [8] Planners can use the results from mode choice analyses to develop location-specific solutions to promote modes other than personal vehicles. The implementation of complete streets and other livable community designs has resulted in livable communities that decrease congestion, spending, maintenance, energy, and fuel [9]. Livable communities also provide people of all abilities and ages a way to safely get to their destination in an environmentally friendly way [9].

The majority of past research on livable neighborhoods considers large urban areas, but this research looks into livable neighborhoods within a medium sized university community. In both large urban and medium sized communities, the most populated neighborhoods are located in the suburbs that surround the city [10]. Although the U.S. Census classifies the population in either urban or rural areas, there is an estimated 53% of the population living in the suburbs [10]. Suburbs are usually a far distance from the city thus causing their residents to predominantly drive to and from work [11]. Also, suburban neighborhoods mainly laid out with cul-de-sacs that have very low connectivity compared to a grid pattern that has high connectivity [12]. Because of this suburban commuters are the leading source of transportation emissions of all residents [11]. Biking or walking to work from the suburbs is very challenging mainly because of distance [13]. It is important to understand how individuals in medium sized communities commute to work or school because over half of the U.S. population is living in this type of setting.

This papers objective is to identify demographic, preference and built environment factors that support a variety of mode choices, which affect physical activity and livable communities. This is important because it will help researchers understand why individuals choose a particular mode of transportation. Researchers are still trying to figure out socio-demographic, individual preference, and built environment characteristics that influence an individual's decision when commuting or exercising. Understanding the reasoning behind an individual's decision can lead to the development of livable communities in the U.S.

To complete this objective, a multinomial logit model was used to understand the significance of factors on each specific travel mode. The dataset for this model was created from two surveys: 2014 University Campus Travel Choice Survey (UCTCS) and Neighborhood Walkability Survey (NWS). These surveys gathered variables on socio-demographic characteristics, individual preference characteristics, and built environment characteristics. Utilities were calculated for walking, bicycling, and driving and compared to a base of transit.

The medium sized university community of Auburn, AL was selected for data collection of this research. Auburn is the largest city in eastern Alabama with a population of 60,258 and is home to Auburn University [14]. Auburn University is a public university with over 27,000 students and 4,800 full-time employees [15]. In 2010, the U.S. Census determined that Auburn's population had a median age of 23.3 years and family income of $72,771. The size of Auburn, along with its bronze level award of being a bicycle friendly community and young population, make it an ideal area to observe livability [16].

The remainder of the thesis is structured as follows: Chapter 2 examines previous work complete on the topic, including factors significantly related to mode choice and physical activity. Chapter 3 examines the data used in this research along with its source and the collection method. Chapter 4 examines the methods used for the analysis of mode choice including the assessment of the model. Chapter 5 presents the results from the multinomial logit model. Chapter 6 examines the conclusion of the work presented.

# CHAPTER 2

# LITERATURE REVIEW

Past research has mainly looked into socio-demographic, individual preference, and built environment variables affecting mode choice. Although most of these sets of variables have mainly been researched in large urban settings, there has been some work done on smaller sized communities. This chapter reviews previous work on socio-demographic, preference, and built environment factors to inform the model developed in this thesis as well as data sources and model specification. Because this thesis focuses on a medium sized university community, living arrangements and role at Auburn University will also be considered. This chapter additionally provides information on potential data sources and model specifications.

## 2.1 Socio-Demographic Factors

The majority of past research on the effect of the built environment on mode choice and physical activity deals with socio-demographic variables. Socio-demographic variables describe the individual and their household. Gender, household income, and age are most often studied socio-demographic variables related to mode choice [17, 18, 19, 20, 21]. These variables are almost always found to significantly affect an individual's travel mode.

Through past research one of the most studied socio-demographic variables has been gender. Work has found that males and females tend to use different travel modes. Females have been seen to have a greater probability of using a personal vehicle to commute than males. For example, Kamruzzaman et al. [22] found a significant positive relationship with females using a personal vehicle and not using an active travel mode. This could be explained by females having a greater need for a personal vehicle because they typically have more household and domestic responsibilities than men [23]. These household and domestic responsibilities could include making stops at shops and schools on the way/leaving work [24]. While females have been linked to personal vehicle use, males are known to use active modes of travel. For example, men have been found to walk and cycle more than women [18, 25, 26]. Livable communities are intended to promote this kind of active travel.

Another socio-demographic variable that has been thoroughly researched is household income. For example, household income is typically found to be negatively correlated with using a non-motorized mode of transportation [27]. This is because household income has a positive impact on the ownership and use of a personal vehicle [20, 19]. When an individual owns a vehicle and has enough money to pay for vehicle expenses, they are usually found to use that vehicle as their main travel mode. For example, the number of cars in the household per driver has been found to have a negative relationship with the likelihood of walking trips [28]. This can be seen as households with higher incomes are more likely to have enough money to use a personal vehicle as their mode choice.

The age of the individual has been seen in previous work to affect mode choice and physical activity. In general, older people rely more on motorized vehicle use and less on active travel. For example, commuters over the age of 35 are less likely to use a bicycle and more likely to use a personal vehicle [21]. This has also been seen with walking trips. The older an individual is, the less likely they are to walk to their destination [28]. Health could be a factor associated with different age groups having active travel. In general, senior citizens need to use a motorized vehicle more than children. Also, in university communities many older individuals live farther from the campus than younger individuals. This could affect their mode choice when traveling to campus.

The role of the individual at the university has also been seen to have a relationship with travel mode choice. This could be because of how far individuals live from campus. For example, students normally live closer to campus and are known to have a greater willingness to use an active mode of transportation [23, 29]. Staff and faculty generally live farther away from campus and thus use a non-active mode of transportation [23, 29]. Staff and faculty are also usually much older than students and as previous work has shown the age of an individual affects mode choice as does the distance they live from campus.

Although there is less previous research on household living arrangements than other socio-demographic variables, it is still very important to look into. In previous research on university students, different living arrangements were found to be significantly related to mode choice [30]. For example, students living by themselves or with other students decreased the use of walking, driving, and transit riding compared to living at a family home [30]. This might be related to the idea that students moving to a new area have an inclination to try a different mode than their established routine at home [30]. Another living arrangement that has been found to affect mode choice is having children. For example, in prior research on the living arrangements of all types of people, couples with at least one child are more likely to use a personal vehicle for commuting than any other mode compared to living alone [22]. Perhaps this is due to the fact that using a personal vehicle gives the individual flexibility. Having flexibility can help if there is an emergency with the child and a parent needs to get to him/her quickly.

## 2.2 Preference Factors

In addition to socio-demographic characteristics, we can look at how individual's preferences affect mode choice and physical activity. Although less research has been completed on individual's preference characteristics, Pinjari et al. [31] believes that an individual's attitudes may have more to do with mode choice than the built environment. Preference variables can range from an individual's trip purpose to the pleasure they gets from an active travel mode.

One of the most researched preference variables in regards to mode choice is trip purpose. The reason an individual is traveling to a destination can greatly affect the mode of travel they choose. For example, Cervero et al. [25] created two different models to determine preference factors that are significantly related to mode choice. In the walking choice model, trip purpose heavily affected mode choice with a strong positive relationship of walking to activities such as social, recreation/entertainment, eating, shopping, and weekend trips. In the bicycle choice model, trip purposes such as recreation/entertainment and social had a positive effect on the odds of biking. These models clearly showed that trip purpose significantly affected an individual's mode choice.

Although trip purpose has been greatly researched in past work, individual's perception of comfort, safety, enjoyment, and environmental benefits have been thoroughly looked into as well. These preferences have been seen to have a significant relationship with mode choice and physical activity, especially with the active transport modes [32, 33, 21, 20]. The perceptions of these preferences can be related to the quality of the trip to the individual. For example, both biking and walking have a relationship with the quality of the trip, which includes the view of comfort and safety [33]. This means that people who consider walking to their trip destination as safe and comfortable have a much greater likelihood of walking [21]. The quality of the trip also plays a role in physical activity. For example, individuals who view their neighborhood as safe have much higher odds of leisure walking than if they did not [34]. Also, cyclists typically believe it is important that their mode is relaxing both mentally and physically and is environmentally beneficial [32]. They are much more likely to bike to their destination if they have an optimistic attitude towards bicycle comfort and safety [21]. Having a feeling of comfort and safety while bicycling can be tied to how the road is designed. Individuals are more likely to bicycle for physical activity if they believe the appearance of the roads are esthetically pleasing [34]. When perceptions of comfort and safety are high, individuals enjoy their trip more than if they were low. If an individual enjoys walking he/she is much more likely to choose to walk [20]. This can also be said about individuals that enjoy driving. If an individual enjoys driving then he/she is more likely to drive because of the pleasure he/she receives from driving [35]. The same can be said about attitudes towards environmental impacts. Individuals that have a compassion for environmental impacts are more likely to use an active mode choice and will try to limit their personal vehicle use [22, 27]. This is because these individuals want to leave as small of a carbon footprint as possible.

Travel time is one of the most researched and significant preference variables. In general, individuals want to arrive at their destination in a relatively short amount of time. For example, past research has shown that active transport modes are significantly related to shorter travel times while public transportation and personal vehicle are used more when travel times increase [22, 19, 23]. While these travel times are also correlated with travel distance, they are still important to the individual. For example, Whalen et al. [30] concluded that time spent traveling is viewed as a cost by many people and as a result has a negative relationship with walking. This makes sense for longer distance trips but when the travel distance is short one may decide an active transport mode is worth the difference in travel time.

Another preference variable that has been researched is time of arrival/departure. Work has found that there is a relationship with mode choices and different time periods of the day. For example, there is a lower probability of people biking before sunrise or after sunset [25]. This could be due to the fact that it is dark during these time periods and tougher for drivers to see thus causing the individual to have less of a sense of safety. Another active travel mode that is reduced during nighttime is walking. For example, Liu et al. [36] found that there is a higher likelihood of using a personal vehicle than walking or public transportation at night. Again this could be related to an individual's perception of safety.

Weather has also been a component in affecting individual's mode choice. In general, rain and other bad weather events are known to cause people to use a different mode choice than they usually would. For example, rain has been observed to have a negative effect on cycling [37]. Cyclists may not enjoy bicycling in the rain because of how wet they will get. Rain has also been seen to influence walking trips. For example, Cervero et al. [25] found that the amount of rain in 24 hours had a negative relationship with the likelihood of walking. Clearly individuals have a preference against taking active modes of transportation when it is raining.

Another variable that can have an impact on travel mode is the perceived convenience. This has especially been seen with bicycling. Piatkowski et al. [17] found that perceived convenience of bicycling compared to other mode choices is significantly related with the decision of using a bicycle for commuting. For example, people who consider bicycling to be less convenient than driving or riding transit will probably not use a bicycle to commute [17]. It is interesting to note that individuals that cycle may perceive cycling as convenient while individuals that have never cycled might not believe it is convenient. Although these individuals have never tried cycling, they may not think it is convenient and therefore not ever use that mode.

Having to drop off/pick up kids or run errands can be hypothesized to affect mode choice. In general, individuals that have to do these tasks need the flexibility of a personal vehicle. For example, running errands has been found as a reason to use a personal vehicle or transit [38]. This can be explained because some errands require items to be picked up/dropped off and having the flexibility of a personal vehicle can carry these items.

In major cities congestion has been known to cause individuals to take alternative modes. For example, having congestion on the route to the destination has been found to change individual's mode choice from personal vehicle to transit [39]. Generally in large cities, transit can get an individual to a destination quicker than if they drove a personal vehicle. Congestion has also been linked to causing individuals to have higher levels of stress. People that have high stress while driving will try to limit their amount of driving by using other modes such as walking or transit [40]. These alternative modes can reduce stress levels and make an individual happier.

The cost of travel mode choice has been a factor when determining mode choice. Active travel modes have a much lower direct cost than motorized vehicles. For example, one of the main reasons people choose to walk is because of trip cost [28, 29]. Walking is free while owning and operating a personal vehicle is exponentially more expensive.

## 2.3 Built Environment

The last group of characteristics that can be looked at are of the built environment. Built environment characteristics have been known to alter an individual's mode choice. For example, individuals are much more willing to walk in a community if there is a sidewalk present [23]. These characteristics range from pedestrian facilities, bicyclist facilities, land use, etc. There has been a great deal of previous work on finding the role the built environment plays in mode choice.

Throughout past research, no single factor has been connected more to alternative mode choices than trip distance. Work has found that the farther a person travels, the less likely he/she is to walk or bike to their destination [25, 21, 33, 28, 29]. For example, Lundberg et al. [29] found that commute distances of 0.5 miles was positively related to walking at the University of Alabama. Instead, personal vehicles are preferred for further distances [21]. Intentionally, almost 0.5 miles is the typical max distance travelers are willing to walk and 2 miles is the typical max distance travelers will bike. Distance preferences also vary by trip purpose. Working trips are usually a shorter distance than leisure trips [41]. Perhaps due to the greater time constraint attributed to work activities.

Land use is another one of the most researched built environment characteristics that has been found to have an effect on travel mode choice and physical activity. Many studies have found that a higher mix of land use increases the likelihood of people using alternative modes of transportation other than driving [24, 25, 42, 33]. For example, individuals are more likely to walk for physical activity if there is a mixed land use [34]. While a mix of land use can be connected to use of alternative modes, certain land uses have especially been linked to using other travel modes than personal vehicle. For example, single family houses in the origin area decrease the odds of cycling while industrial land use has a positive effect on cycling [42]. Educational and neighborhood commercial land uses in the destination zone has been found to increase the likelihood of cycling [42]. Also, parks and other recreation areas have been found to promote leisure walking [34]. These specific land uses can attract or deter alternative modes choices for individuals arriving or departing from them.

Another built environment characteristic that has been previously tied to alternative mode choice is the availability of sidewalks. Sidewalks have been found to heighten an individual's inclination to walk to campus for work and school trips [23]. For example it was found that the greater the percentage of sidewalks in an individual's route to campus or a transit stop, the higher the odds of walking to campus or walking to use the transit are, respectively [23]. This has been especially true when sidewalks are continuous along the route to an individual's destination. For example, continuous sidewalks to a destination offer a more appealing environment for pedestrians [23]. Pedestrians appreciate being able to take one continuous sidewalk all the way to their destination. Past research has also found that the ratio of sidewalks to roadway centerline miles is inversely related to the likelihood of using a personal vehicle to commute [24]. For example, a greater sidewalk density makes driving a personal vehicle less appealing [30]. Clearly, sidewalk density and continuity have been shown to increase walking trips for work and physical activity.

Not only does the density of sidewalks affect mode choice, but the width of sidewalks does as well. Although there is little research on the effect of sidewalk width on the pedestrian, it has been found to be positively associated with walking [43]. For example, pedestrians greatly value wide sidewalks and take this variable into account when choosing a route [43]. In general, these wide sidewalks make the pedestrian feel more comfortable when walking.

Along with sidewalk width, crosswalks have been found to play a role in mode choice. The presence of crosswalks has a very positive influence on choosing an active mode of transportation [44]. For example, people are more likely to use a crosswalk when crossing a road [45]. This is because they feel that it is safer, more convenient, easier, and they are less vulnerable to traffic when using a crosswalk [45]. These perceptions make the pedestrian more comfortable when crossing and can promote physical activity.

Other crossing aids such as pedestrian crossing warning signs, pedestrian signals, median/traffic islands, and raised crosswalks have been seen in previous research to alter mode choice. For example, pedestrian crossing warning signs have a good motorist compliance rate when used on roads with lower speeds [46]. When the driver compliance rate is high, pedestrians feel safer at the crossing aid. These signs also promote walking as a physical activity [34]. Again this goes back to pedestrians having a sense of safety when crossing the road. Pedestrian signals have been found to have the greatest motorist compliance rate of any crossing aid [46]. This is because a pedestrian signal will have a red light to show motorists they must stop. Also, pedestrians crossing on lower volume roads prefer to use raised crosswalks [47]. Raised crosswalks force the motorists to slow down and let the pedestrian cross. The presence of these crossing aids makes the pedestrian feel safer and as stated before safety has played a key role in the decision to use an active transport mode [32, 33, 21, 20].

Previous research has found that traffic calming features are significantly related to cycling. For example, Winters et al. [48] found that cyclists will take a longer route with a greater amount of traffic calming features, bicycle signs, and bicycle stencils than the shortest route possible. This could be due to the fact that they feel more comfortable on roadways with these features. Physical activity has also been seen to be affected by the presence of traffic calming features. For example, traffic calming features have been found to promote walking for leisure [34]. Perhaps having slower traffic speeds increases the utility of active travel.

Different types of streets can play a role in the decision making process of mode choice. There has been found to be a positively significant relationship between the ratio of major roads (highway and arterial) to minor roads (local and collector) and personal vehicle use [21]. For example, bicycling and walking both have a strong negative relationship with the ratio of major roads to minor roads [48, 21]. This can be attributed to the fact that major roads have much higher traffic volumes than minor roads. In general, higher traffic volumes have been known to deter pedestrians and bicyclists from using those roadways. Also, the amount of busy streets that have to be crossed along a route results in a much less likely chance someone will bike to their destination [49]. Crossing busy streets is one of the most dangerous things a bicyclists has to do when traveling. When a bicyclists has to cross many busy roads he/she may feel a lower level of safety than if he/she only had to cross a few roads.

Previous work has shown that the amount of intersections along the route also affects mode choice. For example, intersection density has a negative impact on active transport modes especially walking [22, 50, 51]. This could be because pedestrians do not like crossing so many roads to get to their destination. The number of intersections actually increases the likelihood of cycling. For example, Winters et al. [42] found that a higher intersection density at the origin of the trip and throughout the route actually increased the probability of cycling. It is believed that this is because it gives cyclists a higher route connectivity. Higher route connectivity results in a shorter travel distance and time. Although Winters et al. [42] and Kamruzzaman et al. [22] have conflicting results on the relationship between intersection density and cycling, it has been found that intersection density and driving has a very strong positive relationship [51]. Again this can be related to the fact that a higher connectivity results in a shorter travel distance and time.

Another built environment characteristic that has been seen in past work to affect mode choice is roadway lane width. Individuals deciding whether to walk or not can be impacted by roadway lane widths. For example, lane width has been found to effect pedestrians' view on the walkability of an area [43]. In general, roadways with wider lanes can influence speeding and thus making them not viewed as walkable.

Along with lane width, another roadway characteristic that can affect mode choice is the number of lanes. For example, the number of lanes on a roadway has a negative relationship with pedestrians' walking preferences [43]. This makes sense because roadways with a greater amount of lanes also have a higher speed limit. These characteristics can deter the pedestrian from believing it is a walkable area. For example, speed limit has been found to have a negative relationship with active travel [44]. As seen before, pedestrians want to feel safe when walking in a community. Areas with these types of roadway characteristics hurt the pedestrian's view of the walkability.

Past work has also shown that slope can effect an individual's mode choice. For example the greater the slope along the route, the less likely someone is to walk to their destination [25, 23]. In general, it requires a great amount of energy to walk up a hill. Most pedestrians do not want to exert this amount of energy and will choose other modes to get to their destination.

Another variable that has an effect on cycling is the amount of driveways that are present along the route. For example, a higher number of driveways that have to be crossed by a cyclist have a negative relationship with cycling as a mode choice [52]. The amount of driveways usually signify how busy a roadway is and it has previously been seen that busy roadways decrease the likelihood of cycling.

Past work has looked into transit facilities and mode choice having a connection. For example, the number of transit stops in a region has been observed to effect mode choice of individuals [53, 23, 51]. In general, a greater amount of access to transits can increase transit ridership. For example, living close to a transit stop greatly increases the probability of using transit compared to a personal vehicle [53, 51]. When transit is easily accessible it becomes a better mode to use than driving. It can also promote active travel to and from the transit stops. For example, the greater percentage of transit stops along an individual's route to campus results in a greater likelihood of walking or using the transit [23]. Individuals can get their physical activity from walking or biking to a transit stop, then take the transit to their destination. The transit headway can also play a role in individual's mode choice. For example, a larger transit headway result in less people using that transit [54]. This relates back to the influence of travel time on an individual's mode choice. The greater the travel time, the less likely an individual is going to use that mode of travel.

## 2.4 Data Sources and Collection

Throughout past research there has been one main way to collect data on mode choice and physical activity. One of the primary ways to collect data has been through the use of trip records. Trip records are detailed accounts of where household members or individuals went when leaving their home location and the frequency of their trips. Trip records also include the mode of transportation and other variables that are being considered in the analysis. For example, Cervero et al. [25] collected trip records of household members in the San Francisco

Bay Area over the course of a two day period. These trips consisted of travel and out-of-home daily activities of all household members. Trip records are the best way to collect information on mode choice and physical activity because they give detailed accounts of where individuals go and what mode of travel they use. Collecting data on the built environment characteristics has different methods, but the same end result. Built environment data usually consists of roadway characteristics, pedestrian facilities, bicyclists facilities, traffic calming devices, transit facilities, and land use. These characteristics best describe the built environment in the area being studied.

The most common data collection method for trip records has been through surveys. These surveys are the best way to collecting detailed trip information along with socio-demographic and preference characteristics [24]. There have been different methods to distribute surveys to households or individuals. Surveys are conducted through questionnaires over the phone, in-person (intercept surveys) or they were handed out in-person and asked to be mailed back [23, 21, 42]. A pro of surveys is they are relatively cheap because they are just a stack of paper handed out or a person interviewing an individual. Surveys can collect a great amount of data over a short period of time. A con about surveys is they require people who are cooperative to complete the survey. The over the phone survey also requires people to have access to a phone and will answer when called. Intercept surveys only survey the people in the area on the day(s) the questionnaire was administered. The surveys that were handed out and asked to be mailed back require people who are willing to complete the survey on their own time and mail it back.

On the other hand, a new method for data collection has become available in recent years. This method is web-based surveys through the use of email. An email is sent out to a large group of individuals asking them to take the questionnaire by providing a link to the survey. Web-based surveys are better than paper or phone surveys because they are easier for the respondent to take [55]. Respondents can easily take web-based surveys on their computer or mobile phone and instantly send their responses to the surveyors [55]. Web-based surveys reduce the probability of self-selection bias because the email is sent out to so many people and there is a large number of respondents [29]. A challenge of web-based surveys is they requires individuals to have internet access [56]. In this day and age there is internet access all over the U.S. so this concern is minimal [57].

For collecting built environment characteristics there have been a number of databases used from the following organizations: US Bureau of the Census, US Department of Transportation, local property tax records, local transit records, local planning office records, and local land inventory system [23, 21, 48]. In more recent years Geographic Information System (GIS) data has been used to create roadway networks [29]. This GIS data can be analyzed in programs such as ArcGIS which is provided by the company ESRI. This GIS data can be used to find the routes individuals are taking when they drive. The number of intersections and major to minor street ratio along the route can be calculated in ArcGIS. While GIS can provide data on the routes individuals use, additional built environment questionnaires are needed to obtain built environment characteristics of the origin area.

Although most built environment data can be collected through databases, a neighborhood's walkability has been determined through the use of surveys. The Pedestrian Environment Data Scan (PEDS) is a tool that catalogs built environment features that have been found to impact walking [58]. Each feature is quantified or scored and a final walkability score is calculated to determine how supportive an area if for walking. The Walkability Survey by

Health by Design [59] is another example where individuals evaluate the built environment characteristics of a neighborhood with the survey. A score is determined to understand the walkability of a neighborhood.

### 2.5 Modeling Physical Activity and Mode Choice

There have mainly been two different types of models used in previous literature for modeling physical activity and mode choice: Binary Logit and Multinomial Logit. While very similar, the biggest difference between these models is that the dependent variable in a Binary Logit model can only have two outcomes while it can have three or more in a Multinomial Logit model.

The first type chosen by researchers was the Binary Logit model [32, 17, 29]. Binary Logit models find an odds ratio of the affect a variable has on a mode choice. The mode choices are not compared against each other. For example, Lundberg et al. [29] used the Binary Logit model to calculate the odds ratio of each travel method. This odds ratio shows how statistically likely it is that the person will use that mode given the variables in the model. Piatkowski et al. [17] used a Binary Logit model to examine if individuals bike to work only on a sponsored bike to work day or all days of the week. The dependent variables in the model was that the individual only biked to work on the sponsored day (0 = yes and 1 = bike to work on all other days). An odds ratio was computed to show how likely it was that an individual with given characteristics biked to work on all other days. Heinen et al. [32] used this type of model to calculate how likely an individual was to commute by bicycle compared to all other modes. Binary Logit models can only compare the affect variables have on a single mode and not the affect that modes have on each other.

The second type of model found in past research was a Multinomial Logit model [30, 27, 23, 36]. In each Multinomial Logit model the utility of different modes was calculated and the mode with the highest utility was assumed to be used. Multinomial Logit models are better than Binary Logit models because they compare mode choices against a set mode. For example, Whalen et al. [30] used a Multinomial Logit model to calculate the utility of walking, high speed rail, and car compared to cycling. The influence a variable had on a mode was shown through the utility that mode had compared to cycling. Schwanen et al. [27] performed this type of model to calculate the utilities of different travel modes by assuming individuals have unobservable preferences for the different modes. These unobservable preferences can been seen in the utility values calculated. Different sets of variables can be used in the model to determine the significance they have on the utility of a mode. For example, Rodríguez et al [23] used three factors in the Multinomial Logit model to calculate utility of different modes: individual, mode particular, and environmental. Multinomial models can discover variables that have significant effects on mode choice utility compared to a base mode.

### 2.6 Summary vis-á-vis This Research

From past research it can be seen that many models focus on mode choice and not physical activity. Also, the majority of the research has been completed on large urban settings instead of university suburban settings. To overcome these limitations, this thesis models mode choice and physical activity in a medium sized university setting.

# CHAPTER 3

# DATA

The mode choice analysis was conducted with data collected from two sources: 2014 University Campus Travel Choices Survey (UCTCS) and our Neighborhood Walkability Survey (NWS) adapted from PEDS [58]. The UCTCS provided information on socio-demographic and individual preference variables. The NWS provided information on the built environment characteristics. The following sections are about the methods used to collect the surveys and summarize the data provided.

## 3.1 2014 University Campus Travel Choices Survey

### 3.1.1 Motivation

Each year, the population of students, faculty and staff at Auburn University and the surrounding city of Auburn, Alabama, changes, generating new mobility demands on the transportation system. In response, engineers and planners within the University Facilities Division, Parking Services, Transit Service and other divisions seek to improve the campus transportation facilities to promote sustainable, efficient, and safe movement to and from campus.

In support of these efforts, campus transportation mode choice surveys are completed every few years. These surveys provide detailed information about the transportation needs and travel behaviors of students, faculty and staff on the main Auburn University campus in Auburn, Alabama. The motivation for conducting these surveys is to provide insights into the travel mode choices on a typical weekday to identify areas on campus and transport policies that are either working well or provide opportunities for improvement.

### 3.1.2 Construction

The survey instrument was funded by the Auburn University Facilities Division and developed by faculty in the Department of Civil Engineering with input from an advisory number of campus decision-makers, including Don Andrae (Parking Services), Rex Huffman (Tiger Transit Service), Benjamin Burmester (Campus Planning and Space Management), Richard Guether (Campus Planning and Space Management), and Amy Strickland (Office of Sustainability). The two most recent campus travel surveys from 2004 and 2008 were reviewed at the beginning of the study, and it was decided that a) additional travel information should be gathered as part of the effort to support more analysis than only mode splits and b) a more representative sample from the campus would be sought. As such, the advisory committee identified a number of current policy topics that would benefit from more campus data (these are outlined and explored later in the report).

With these topic areas in mind, a preliminary version of the survey was created and edited through a number of iterations, including an initial review by the advisory board on October 1, 2014 and a beta test by the advisory board and volunteers from across campus on October 22, 2014. The final web-based Qualtrics version of the survey questionnaire was produced on November 1, 2014 and distributed to the campus community online on November 5, 2014.

The survey consists of five main sections: a) *Getting to and From Campus*, which determined how/when/where the Auburn University student body and employees get to and from campus during a normal school week, b) *Getting Around Campus*, which determine how students and employees moved around campus on an average Wednesday during the school year, c) *Improving Campus Travel*, which identified students' and employees' involvement in transportation programs in the Auburn area, d) *Travel Preferences*, which cataloged participants' motives when deciding which mode of transportation to take to and from campus, and e) *Traveler Information*, which collected socio-demographic information on the participants taking this survey.

One of the goals of this survey was to make it as easy as possible for respondents to take, and one of the main ways this was accomplished was through the use of interactive maps. Different maps were generated that highlighted buildings on campus, parking lots on campus, neighborhoods in the city, and major roadways. These maps were embedded into the survey, and respondents were asked to click on the maps to show where they lived, destinations, parking locations, etc. The image coordinates were then converted to latitude / longitude locations for analysis. This method was successful in collecting spatial information except when participants took the survey on a mobile device. In these situations, the map was resized to a smaller screen and the locations selected on the image were recorded as the upper left corner of the image. These locations had to be removed from the analysis.

Additionally, the survey was designed to be adaptive, meaning that the questions changed based on how a respondent completed certain previous questions. For example, if a respondent did not take Tiger Transit to campus any day during the study week, the questions about pick-ups and drop-offs using transit were omitted from the survey. Additionally, if a respondent did not visit campus on a day (or multiple days) during the survey time period, questions were dropped about those days of travel.


**Figure 1: City of Auburn Map**

### 3.1.3 Sampling Procedure

It was important to collect statistically significant sample sizes in order to generate meaningful conclusions from the campus travel survey. Therefore, the team considered past response rates from different campus population groups and calculated the required sample sizes necessary to have a representative overall sample. The equation used for this process is as follows:

$$X = {}^{S_S}/_{A_R} \qquad (3.1.3.1)$$

where X is the required sample size, $S_S$ is the statistically significant sample size, and $A_R$ is the assumed response rate.

In order to calculate how many people were needed to be invited to complete the survey, the 2010-2011 UC Davis Campus Travel Survey was used as a reference. The statistically significant sample sizes and assumed response rates in Table 1 were taken from the 2010-2011 UC Davis Campus Travel Survey Results [60]. These values were used in Equation 3.1.3.1 to determine the amount of individuals to invite to participate in the survey. Table 1 shows the sampling sizes used for each role at Auburn University.

**Table 1: Sampling Procedure**

| | 2013 Population | Statistically Significant Sample Sizes | Assumed Response Rate | Number Invited | 2014 Eligible Population |
|---|---|---|---|---|---|
| **Students** | ***23710*** | | | | |
| Freshmen | 4522 | 355 | 19% | 1869 | 5476 |
| Sophomores | 4353 | 354 | 12% | 2950 | 4247 |
| Juniors | 4589 | 355 | 15% | 2367 | 4503 |
| Seniors & 5th Yr. | 6334 | 363 | 10% | 3630 | 6403 |
| Graduates | 3912 | 350 | 20% | 1750 | 4071 |
| **Employees** | ***5913*** | | | | **4776** |
| Faculty | 1181 | 290 | 20% | 1450 | 1500 |
| Admin & Profess. | 2103 | 325 | 35% | 929 | 1863 |
| Other Staff | 2629 | 336 | 26% | 1293 | 1413 |
| **Overall Sample** | **29623** | **2728** | | **16238** | **26673** |

### 3.1.4 Survey Administration

The Auburn University Campus Travel Choices Survey was emailed to the 16,238 randomly generated campus emails (based on the statistically representative sample requirements) on November 5, 2014. The recruiting email text can be found in Figure 2.

Participants had until November 13, 2014 to complete the survey and all participants were eligible to win a $100 gift card to the Ariccia restaurant, provided by the Office of Sustainability. So as not to bias responses, the email was signed by all three main supporting entities and a generic university email address (campustravelsurvey@auburn.edu) was used as the sender. The survey was available online through the Qualtrics survey software and able to be completed on desktop / laptop computers as well as mobile devices, such as smartphones or tablets. Based on beta testing and data collected from the survey responses, the average time individuals spent on the survey was 12 minutes. No questions or complaints were received during the administration of the survey. Additionally, the Office of Institutional Research and Assessment did not allow the team to send follow up reminder emails.

**2014 Auburn University Campus Travel Choices Survey**
**RECRUITING EMAIL**

You have been selected as part of a small group of students, faculty, and staff to participate in the **2014 Auburn University Campus Travel Choices Survey**. This survey provides campus planners with valuable feedback on how people get to campus and their experiences with transportation programs. They will use this information to improve our campus transportation options, parking opportunities and traffic congestion. It should take less than 10 minutes to complete this survey.

As a token of our appreciation, *anyone who completes the survey is eligible to win a $100 giftcard to the Ariccia restaurant, in the Auburn Hotel and Conference Center.*

You may access the survey until November 12th here: https://auburn.qualtrics.com/SE/?SID=SV_9sifbEPRDN4Rzcp

Your participation in the study does not involve any risk, is completely voluntary, and all reported results will be summarized/generalized. No individual information will be retained or shared. You may skip questions in the survey or withdraw at anytime by closing the survey. If you would like to know more information about the survey, please feel free to contact us at campustravelsurvey@auburn.edu.

Thanks for participating!

Sincerely,
Auburn University Facilities
Auburn University Office of Sustainability
Auburn University Civil Transportation Engineering

**Figure 2: Recruitment Email**

### 3.1.5 Response Rate

The survey was available for slightly more than one week, but as Figure 3 shows, the majority of responses were received within the first two days. This highlights the fact that most respondents completed the survey when they first opened the recruiting email. In total, the team received 2,099 responses.

However, not all of the groups responded with similar vigor. The response rate reflects how many people within their particular role responded to the survey while the "Unidentified" response rate is a percentage from the overall number of responses. The response rates differed greatly from the 2010-2011 UC Davis Campus Travel Survey. The best response rate was from the faculty and staff: between 20% and 29% among the employee categories of those emailed replied. Students were less interested in the survey: between 3% and 12% among the class levels of those emailed replied. Interestingly, graduate students had the highest response rate among the students, with freshmen having the lowest response rate. Responses were biased by self-selection, so it is possible younger campus students opted out of the survey because they did not have enough significant (positive or negative) experience with the transportation systems on campus to care about the survey. The Auburn University Campus Travel Choices Survey response rate can be seen in Table 2.

**Table 2: Auburn University Campus Travel Choices Survey Response Rate**

| | 2014 Population | Number Invited | Number of Responses | Actual Response Rate |
|---|---|---|---|---|
| **Students** | **24700** | | | |
| Freshmen | 5476 | 1869 | 57 | 3% |
| Sophomores | 4247 | 2950 | 164 | 6% |
| Juniors | 4503 | 2367 | 156 | 7% |
| Seniors & 5th Yr. | 6403 | 3630 | 278 | 8% |
| Graduates | 4071 | 1750 | 211 | 12% |
| **Employees** | **4776** | | | |
| Faculty | 1500 | 1450 | 347 | 29% |
| Admin & Profess. | 1863 | 929 | 244 | 26% |
| Other Staff | 1413 | 1293 | 261 | 20% |
| **Unidentified** | | | 381 | 18% |
| **Overall Responses** | **29623** | **16238** | **2099** | |

Fortunately, the majority of responses were complete and thorough. Figure 4 details the number of respondents that completed at least part of each of the 5 sections of the survey. Clearly, if individuals completed the beginning sections, they made it through the entire survey. Those incomplete surveys were removed from all analysis.

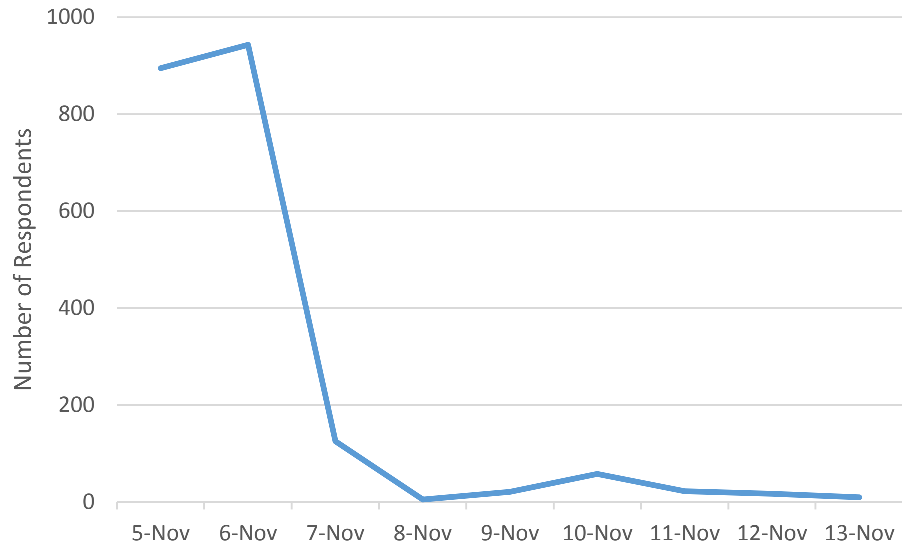


**Figure 3: Responses by Date**

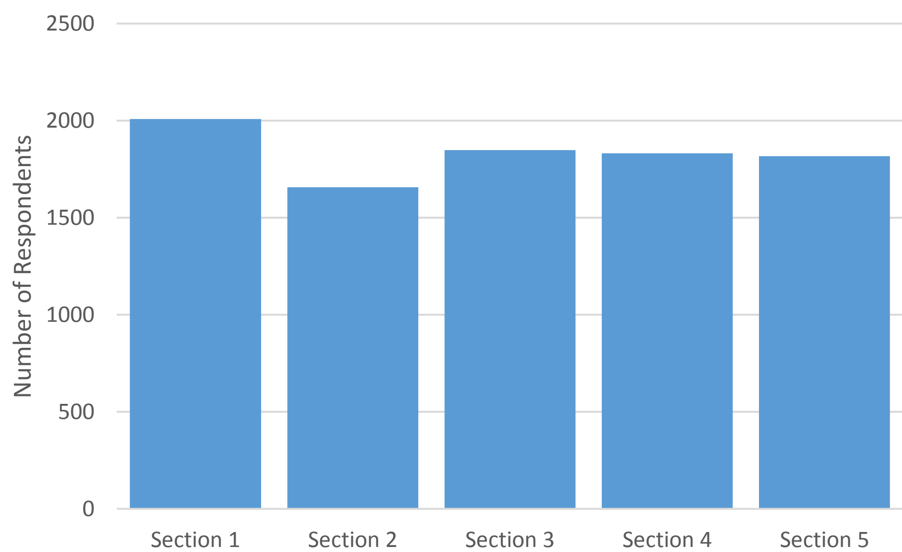


**Figure 4: Number Completed at Least Part of Each Section**

### 3.1.6 Reference Week

The weekdays asked about in the survey, October 27, 2014 through October 31, 2014, were selected because they were as typical as possible, without any football games or significant events occurring during that time. The high during that time was 82°F and the low was 37°F, and Auburn saw only 0.01" of precipitation on Wednesday October 29, 2014. The full graph of temperature throughout the week compared to the historical high and low can be seen below in Figure 5. Additionally, there were no major interruptions with Tiger Transit service, but there were 9 minor incidents where a Tiger Transit vehicle was quickly replaced with a new vehicle. Because of how fast the Tiger Transit buses were switched out there was no downtime. There was also no road construction or maintenance in the City of Auburn during the reference week. Auburn University did have an away football game on Saturday, November 1, 2014 in Oxford, MS at 6:00 PM. It would also be useful to consider administering a spring version of the survey to observe any differences in mode splits.

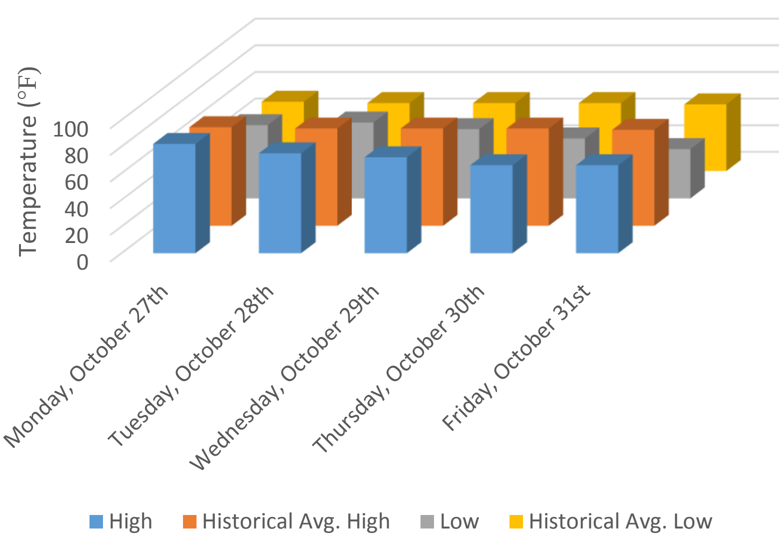


**Figure 5: Reference Week Temperature**

### 3.1.7 Respondent Demographics

The Traveler Information section was an important piece of the survey to gauge how representative the responses were, beyond the role at the university. Participants who completed the Traveler Information section created data on the socio-demographic composition of the survey. For example, Auburn University's students and employees are made up of 49.5% female and 50.5% male. The breakdown for participants taking this survey was 52.3% female, 33.4% male, 0.4% other, and 13.9% non-response. Although there were more females than males that completed the survey, the results for gender represent Auburn University as a whole. The average age of respondents was 26-30 years old and this does represent the average age of Auburn University's students and employees combined.

## 3.2 Neighborhood Walkability Survey

The NWS was developed in order to gather information about the livability of highly populated neighborhoods in the Auburn area. The survey was administered because there was a lack of information regarding active transportation access in neighborhoods surrounding campus. The NWS collected critical data on roadway characteristics, pedestrian facilities, bicycle facilities, transit facilities, and land uses where the majority of Auburn University students, faculty and staff lived. The NWS was adapted from PEDS in order to measure built environment characteristics that related to walking and biking in neighborhoods. PEDS is a very detailed survey that measures a great amount of built environment characteristics but some were not relevant to this research. These included condition of the road, sidewalk obstructions, sidewalk distance from curb, off-street parking spaces, presence of curb cuts, sidewalk lighting, sidewalk amenities, number of trees shading walk area, degree of enclosure, overall cleanliness, building setbacks from sidewalks, building height, presence of power lines along segment and articulation in building designs.  Also, new survey questions were added based off of the UTCTS and its findings.  These included travel purpose, route feasibility, and destination distance.  Connectivity characteristics were also added including the number of 4-way intersections along the route and major to minor street ratio along the route.  These measures especially showed the walkability and bikeability for individuals.  Figure 6 displays the questionnaire portion of the NWS.

Name:________________ Date:__________ Study Area:____________

Segment Number:_________ Time:__________ Weather:______________

**A. Roadway**

**1. Route Traffic**
- Low volume road (local or collector)
- High volume road (arterial or highway)

**2. Lane Attributes**
- Width of outside lane (feet) ______
- Maximum number of lanes ______

**3. Posted Speed Limit**
- Speed limit (mph) ______

**4. Topography**
- Flat (no perceived hill; 0%-1% grade)
- Slight hill (perceived hill but not difficult to walk; 2%-6% grade)
- Steep hill (perceived hill that is difficult to walk; 7%+ grade)

**5. Traffic Calming Devices** *(check all that apply)*
- Traffic circles (not roundabouts)
- Speed bumps
- Chicanes
- Raised intersection

**6. Presence of Driveways**
- Presence of medium to high volume driveway(s)

**B. Bicycle Facilities**

**7. Bicycle Facilities** *(check all that apply)*
- Route sign (sign for bicyclists)
- Bicycle lanes (lane on roadway solely for bicyclists)
- Pathway (path for bikes and pedestrians)

**C. Pedestrian Facilities** *(skip if none present)*

**8. Pedestrian Facilities** *(check all that apply)*
- Sidewalk complete and good repair
- Siddewalk incomplete and good repair
- Sidewalk complete and poor repair
- Sidewalk incomplete and poor repair

**9. Sidewalk Width**
- < 4 feet
- Between 4 and 8 feet
- > 8 feet

**10. Crosswalks**
- Visible crosswalks and complete
- Visible crosswalks and incomplete

**11. Crossing Aids (all that apply)**
- Pedestrian crossing warning sign (yellow diamond sign)
- Pedestrian Signal (push to walk button with signal head)
- Median/Traffic Island (median for pedestrians)
- Raised Crosswalk (crosswalk on rasied speed hump)

**D. Land Uses**

**12. Bus Stop Density**
- Length of time for bus to arrive
- Number of bus stops ______

**13. Land use entropy** *(check all that apply)*
- Houses (single family)
- Apartments
- Mobile homes
- Office/Campus (offices, churches, or Auburn University buildings)
- Restaurant/Commercial (restaurants or shops)
- Industrial (factories, mills, industrial complexes)
- Vacant/Undeveloped (cleared off lots, natrual vegetation, rivers, or lakes)
- Recreation (parks, golf courses, or sport areas)

**E. Connectivity**

**14. Street Connectivity**
- Number of 4-way intersections on route to campus

**15. Major Streets en-route to destination**
- Number of major streets en-route to destination

**16. Bikeway Connectivity**
- Complete bikeway connectivity to campus
- Incomplete bikeway connectivity to campus

**F. Respondent Characteristics**

**17. Travel Purpose**
- Work
- Meeting
- Class
- Studying
- Campus activities
- Visiting friends/family
- Personal reasons

**18. Route Feasibility** *(check all that apply)*
- Reasonable distance to walk
- Reasonable time to walk
- Reasonable distance to bike
- Reasonable time to bike
- Use a personal vehicle for work during the day

**19. Shortest Travel Time to Campus**
- By car
- By bike
- By walking

**20. Destination Distance**
- Distance to destination on campus (miles)

**Figure 6: Neighborhood Walkability Survey Questionnaire**

Using the home location data gathered from the 2014 Auburn University Campus Travel Choices Survey, 40 neighborhoods of 0.5 mile diameter were determined based on the highest populations.  These neighborhoods contained 73.2% of the respondents' home locations.  The other 26.8% of respondents' home locations were not captured mainly due to an error in recording these locations.  This error was believed to be caused by respondents completing the survey on a mobile device instead of a desktop computer.  Figure 7 displays the 40 highest populated neighborhoods in Auburn.

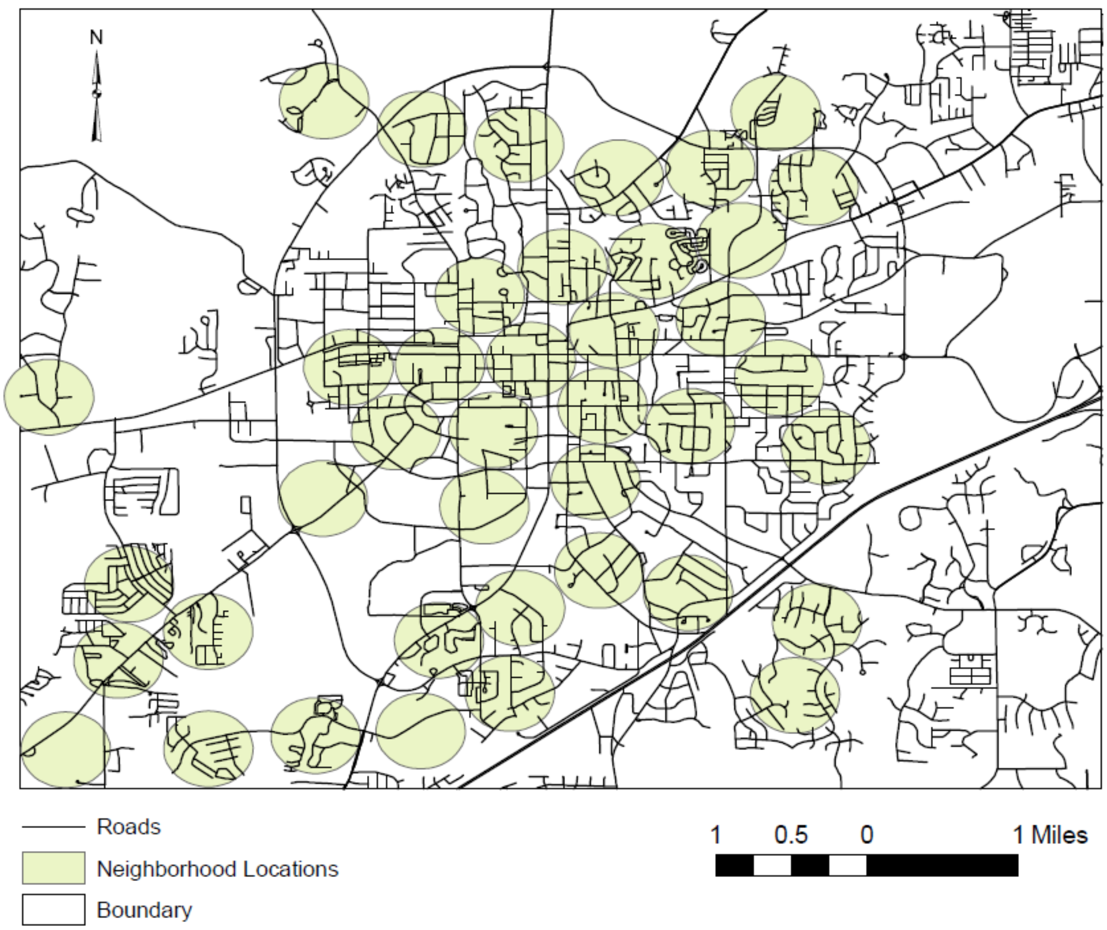


**Figure 7: Neighborhood Locations**

Collecting the NWS data on every street in each neighborhood would be both costly and redundant. Therefore, 25% of the segments in each neighborhood were randomly selected to collect the NWS. This percentage was determined based on past built environment characteristic analysis research, which found that a random sample of 25% of street segments accurately represented the full set of neighborhood streets [62].

First, an Auburn streets GIS layer was used in ArcGIS to identify the total number of street segments located across the neighborhoods (i.e. 1,364 segments). Second, each segment was assigned a randomly generated number. Third, each neighborhood was considered in turn, and the segments present in each neighborhood were ranked by their random number. Finally, the lowest valued 25% of segments in each neighborhood were selected to be evaluated.

Once all the segments were selected to be analyzed, GIS maps were created to show where they were located within the neighborhoods. Figure 8 shows the front page of the NWS with the segments highlighted and numbered.

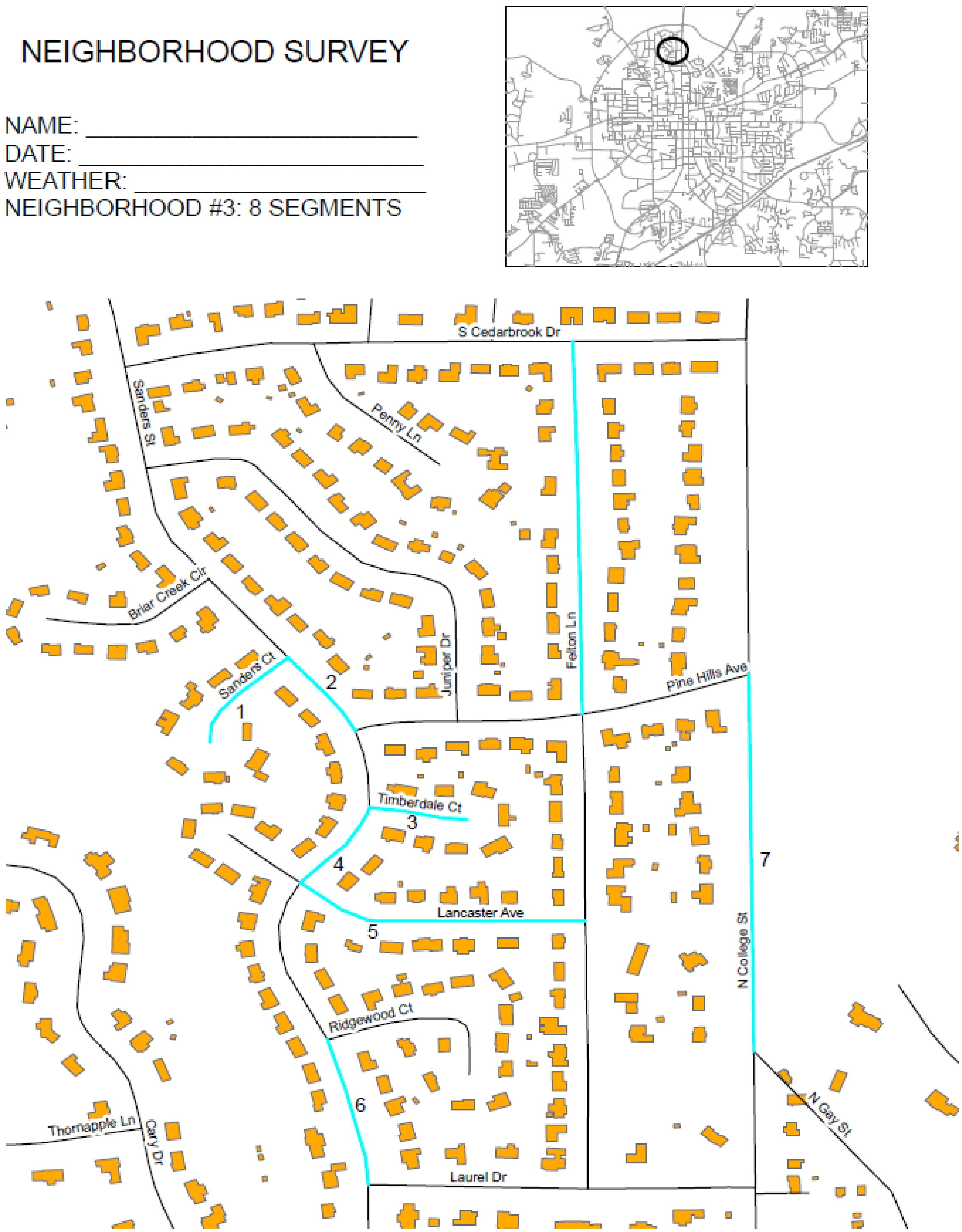


**Figure 8: Neighborhood Survey Map**

These maps were given to seven volunteers in order to identify which segments to survey. Four volunteers were graduate research assistants from the Auburn University Civil Engineering Transportation group and the other three volunteers were from the Auburn University Office of Sustainability. The NWS was conducted on different dates from April 3, 2015 through May 5, 2015. Volunteers were instructed to locate the highlighted segments within their assigned neighborhoods and fill out the NWS. The NWS had a certain technique for volunteers to understand what to write down.

- Each question had a blank space or check box next to it to indicate to the volunteer what kind of answer they needed to write down.
    - A blank indicated that a numerical answer was required while a check box denoted a check was required if the facility was present.
- The blanks with a slash through them showed the volunteers that they should not mark anything there. These were calculated from different sources.
    - Route traffic was determined from the City of Auburn GIS website. An interactive GIS map was able to show what type of roadway (local, collector, arterial, or highway) each segment was.
    - Bus headways were found on the Auburn University Tiger Transit website.
    - The number of intersections was calculated in ArcGIS by using the tool Network Analyst. This tool projects the route from each neighborhood individuals would take to get to campus. The campus destination point was marked as the stadium parking deck.
    - Major to minor street ratio and destination distance were also calculated from the Network Analyst tool.

- Neighborhood travel purpose was computed by finding each reason's percentage within the neighborhood.
- To determine route feasibility, a buffer of 0.5 mile radius from the Haley Center was created for walking and 2 miles for biking was created in ArcGIS. Previous research has shown that the median distance an individual will walk is 0.5 miles and 2 miles for biking [61, 62]. Segments that intersected or within the buffer were considered walkable or bikeable. The Student Center was chosen as the center of campus because it is speculated to be the most popular place for Auburn University students, faculty, and staff to visit. It is also very close to many other campus buildings which makes it known as the center of campus.

### 3.3 Final Dataset

The final dataset was made up of respondents' ID numbers, neighborhood ID number, mode choice, socio-demographic variables, respondent preference variables, and built environment characteristics. Tuesday, October 28, 2014 was selected to be analyzed because it had the largest amount of respondents visiting campus. Figure 9 displays the mode choice by each day of the reference week. The final dataset started with 848 cases because this was the number of people that had selected their home location within one of the 40 neighborhoods. Cases were deleted from the dataset because they were missing answers to questions from the 2014 Auburn University Campus Travel Choices Survey. Table 3 portrays the number of cases deleted and reason for deleting. The final dataset contained 759 cases.

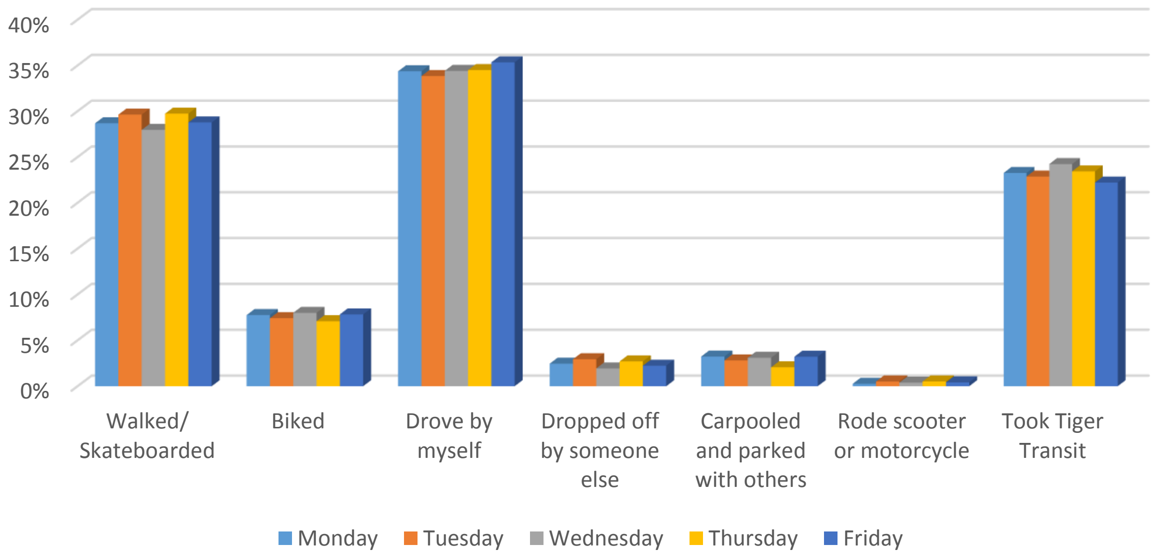


**Figure 9: Mode Choice by Day**

**Table 3: Log of Deleted Cases**

| Reason for Deleting | Number Deleted |
|---|---|
| Respondent did not choose a… | |
| …mode | 65 |
| …arrival time | 4 |
| …gender | 1 |
| …household income | 17 |
| …living arrangement | 2 |

Socio-demographic variables were gathered from the section Traveler Information in the UCTCS. Table 4 displays the socio-demographic variables. These variables were used because previous research has found them to be significantly related to mode choice and physical activity. Table 5 exhibits the proportions and standard deviations of the socio-demographic variables. The proportion of undergraduate students is 64% but this can be related to the fact that the map of home locations used in the survey only covered an area of about 4 miles from campus. Faculty and staff are more likely to live farther from campus than students.

## Table 4: Socio-Demographic Variables

| Living Arrangement… | Age… | Income… | Gender… | Role at Auburn University… |
|---|---|---|---|---|
| … Alone | … 18 to 20 | … Less than $15,000 | … Male | … Undergraduate Student |
| … One roommate | …21 to 25 | … $15,000 to $64,999 | … Female | … Graduate Student |
| … Spouse/partner | … 26 to 40 | … $65,000 to $115,000 | … Other | … Faculty |
| … Family Members | … 41 to 50 | | | … Staff |
| … Two or more roommates | … Older than 50 | … More than $115,000 | | |

## Table 5: Socio-Demographic Statistics

| | Proportion | Std. Deviation |
|---|---|---|
| **Living Arrangement** | | |
| Alone | 0.19 | 0.39 |
| One roommate | 0.22 | 0.42 |
| Two or more roommates | 0.37 | 0.48 |
| Spouse/partner | 0.16 | 0.37 |
| Family members | 0.12 | 0.32 |
| **Age** | | |
| 18 to 20 | 0.31 | 0.46 |
| 21 to 25 | 0.39 | 0.49 |
| 26 to 40 | 0.14 | 0.35 |
| 41 to 50 | 0.07 | 0.25 |
| Older than 50 | 0.09 | 0.28 |
| **Income** | | |
| Less than $15,000 | 0.45 | 0.50 |
| $15,000 to $64,999 | 0.19 | 0.40 |
| $65,000 to $115,000 | 0.16 | 0.37 |
| More than $115,000 | 0.19 | 0.40 |
| **Gender** | | |
| Male | 0.42 | 0.49 |
| Female | 0.58 | 0.49 |
| Other | 0.01 | 0.07 |
| **Role at Auburn** | | |
| Undergraduate Student | 0.64 | 0.48 |
| Graduate Student | 0.14 | 0.34 |
| Faculty | 0.13 | 0.34 |
| Staff | 0.09 | 0.28 |

Preference variables obtained from the UCTCS can be viewed in Table 6. Likert style questions were inserted into the final dataset as a binomial variable. If a respondent answered agree, strongly agree, important, or extremely important to any of these questions they received a 1 in the final dataset. If a respondent answered neutral, disagree, strongly disagree, somewhat important, or not at all important to any of these questions they received a 0. This showed the respondents preferences when traveling. Table 7 shows the proportions and standard deviations of the preference variables. The majority of these proportions can be attributed to the amount of undergraduate students that were analyzed. For example, 74% of respondents visited campus for class. Auburn has an active group of students, faculty, and staff that enjoy physical activity and this can be seen by the proportion of respondents that agreed that they enjoy walking.

**Table 6: Preference Variables**

| **Do you…** | **Importance of…** | **Reason for visiting campus…** | **Time arriving on campus…** | **Time leaving campus…** |
|---|---|---|---|---|
| … enjoy walking | … travel time | … work | … before 6:00 am | … before 6:00 am |
| … enjoy driving | … convenience | … meeting | … 6:00 to 7:59 am | … 6:00 to 7:59 am |
| … try to limit driving | … traffic | … class | … 8:00 to 9:59 am | … 8:00 to 9:59 am |
| … pick up/drop off kids or run errands on the way/leaving campus | … weather | … studying | … 10:00 to 11:59 am | … 10:00 to 11:59 am |
| | … cost | … campus activities | … 12:00 to 1:59 am | … 12:00 to 1:59 am |
| | … environmental impacts | … friends/family | … 2:00 to 3:59 pm | … 2:00 to 3:59 pm |
| | | … personal reasons | … 4:00 to 6:00 pm | … 4:00 to 6:00 pm |
| | | | … after 6:00 pm | … after 6:00 pm |

**Table 7: Preference Statistics**

| | Proportion | Std. Deviation |
|---|---|---|
| **Reason for Visiting Campus** | | |
| Work | 0.41 | 0.49 |
| Meeting | 0.13 | 0.33 |
| Class | 0.74 | 0.44 |
| Studying | 0.28 | 0.45 |
| Campus Activities | 0.12 | 0.33 |
| Friends/Family | 0.03 | 0.16 |
| Personal Reasons | 0.03 | 0.17 |
| **Time Arriving on Campus** | | |
| Before 6am | 0.04 | 0.19 |
| 6:00-7:59am | 0.36 | 0.48 |
| 8:00-9:59am | 0.39 | 0.49 |
| 10:00-11:59am | 0.14 | 0.34 |
| 12:00-1:59pm | 0.06 | 0.23 |
| 2:00-3:59pm | 0.02 | 0.13 |
| 4:00-5:59pm | 0.00 | 0.05 |
| After 6pm | 0.00 | 0.06 |
| **Time Leaving Campus** | | |
| Before 6am | 0.00 | 0.06 |
| 6:00-7:59am | 0.00 | 0.05 |
| 8:00-9:59am | 0.01 | 0.11 |
| 10:00-11:59am | 0.05 | 0.21 |
| 12:00-1:59pm | 0.10 | 0.30 |
| 2:00-3:59pm | 0.20 | 0.40 |
| 4:00-5:59pm | 0.37 | 0.48 |
| After 6pm | 0.26 | 0.44 |
| **Travel Mode Preferences** | | |
| Enjoy walking | 0.90 | 0.31 |
| Enjoy driving | 0.66 | 0.48 |
| Try to limit driving during the day | 0.60 | 0.49 |
| Pick up kids/drop off or run errands on way/leaving campus | 0.38 | 0.48 |
| **Importance of** | | |
| Travel time | 0.94 | 0.25 |
| Convenience | 0.94 | 0.23 |
| Environmental impacts | 0.32 | 0.47 |
| Traffic | 0.67 | 0.47 |
| Weather | 0.75 | 0.43 |
| Cost | 0.54 | 0.50 |

Built environment variables in the final dataset represented the average segment in each neighborhood. To do this the median of each neighborhood's built environment characteristic was calculated. This had to be done because each individual in the dataset had to be assigned to a neighborhood. Only one line of built environment characteristics from the neighborhood could be assigned to the individual and thus the median was used to represent the average segment within the neighborhood. Table 8 displays the built environment variables used in the final dataset. Table 9 and Table 10 show the binomial and numerical built environment statistics, respectively. It should be noted that the median number of bike lanes, traffic circles, chicanes, raised intersections, multi-use paths, traffic islands, raised crosswalks, industrial land use, and recreation land use were zero so they are excluded from the analysis. This is concerning because it is believed that most livable neighborhoods should have bike lanes, traffic calming devices, raised crosswalks, and recreation land use. It is understandable that an industrial land use is excluded (given that this is a medium sized university setting), but not having the other characteristics that promote safety and comfort when using active modes show that these neighborhoods could improve their livability.

## Table 8: Built Environment Variables

| **Roadway Characteristics** | **Bicycle Facilities…** | **Land Use…** |
|---|---|---|
| Major to minor street ratio | … bike lanes | … single family homes |
| Number of intersections along the route | … route sign | … apartments |
| All low volume roads | … multi-use path | … mobile homes |
| Mostly low volume roads | **Sidewalk Width…** | … office/campus |
| Mostly or all high volume roads | … less than 4 feet | … restaurant/commercial |
| Lane width | … greater than 4 feet | … industrial |
| Number of lanes | **Pedestrian Facilities…** | … vacant |
| Speed limit | … cross sign | … recreation |
| Presence of driveways | … pedestrian signal | **Neighborhood's Reason for Visiting Campus…** |
| **Topography…** | … traffic island | … work |
| … easy to ride | … raised crosswalk | … meeting |
| … not easy to ride | **Transit Facilities** | … class |
| **Traffic Calming Devices…** | Transit headway | … studying |
| … traffic circle | Number of transit stops | … campus activities |
| … speed bumps | **Neighborhood Location** | … friends/family |
| … chicanes | … walkable | … personal reasons |
| … raised intersection | … bikeable | |
| | Distance to Student Center | |

**Table 9: Binomial Built Environment Statistics**

| | Proportion | Std. Deviation |
|---|---|---|
| **Route Traffic** | | |
| All low volume roads | 0.31 | 0.46 |
| Mostly low volume roads | 0.50 | 0.50 |
| Mostly or all high volume roads | 0.19 | 0.39 |
| **Roadway Characteristics** | | |
| Driveways | 0.09 | 0.26 |
| Speed bumps | 0.01 | 0.12 |
| **Topography** | | |
| Easy to ride | 0.62 | 0.48 |
| Not easy to ride | 0.38 | 0.48 |
| **Sidewalks** | | |
| Mostly <4ft wide | 0.12 | 0.32 |
| All or mostly >4ft wide | 0.48 | 0.50 |
| **Pedestrian and Bicyclist Facilities** | | |
| Pedestrian Cross Sign | 0.02 | 0.09 |
| Pedestrian Signal | 0.01 | 0.07 |
| Bicycle Route sign | 0.03 | 0.16 |
| **Crosswalks** | | |
| Mostly visible and complete | 0.21 | 0.41 |
| Mostly visible and incomplete | 0.04 | 0.20 |
| **Land use** | | |
| Houses (single family) | 0.47 | 0.49 |
| Apartments | 0.40 | 0.49 |
| Mobile Homes | 0.04 | 0.19 |
| Office/campus | 0.17 | 0.32 |
| Restaurant/commercial | 0.07 | 0.23 |
| Vacant/undeveloped | 0.11 | 0.30 |
| **Neighborhood Reason for Visiting campus** | | |
| Recreation | 0.02 | 0.14 |
| Work | 0.25 | 0.14 |
| Meeting | 0.07 | 0.04 |
| Class | 0.43 | 0.11 |
| Studying | 0.15 | 0.05 |
| Campus Activities | 0.07 | 0.03 |
| Friends/Family | 0.01 | 0.02 |
| Personal Reasons | 0.02 | 0.02 |
| **Neighborhood Location** | | |
| Walkable | 0.41 | 0.49 |
| Bikeable | 0.74 | 0.44 |

**Table 10: Numerical Built Environment Statistics**

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| **Route** | | | | |
| Street Ratio | 0.00 | 11.87 | 2.60 | 2.85 |
| Number of Intersections | 4.00 | 32.00 | 14.62 | 8.33 |
| **Roadway Characteristics** | | | | |
| Lane Width | 8.00 ft | 14.00 ft | 11.93 ft | 1.01 ft |
| Number of lanes | 2.00 | 3.00 | 2.06 | 0.22 |
| Speed limit | 15.00 mph | 40.00 mph | 26.35 mph | 3.74 mph |
| **Transit Facilities** | | | | |
| Transit time | 0.00 min | 27.50 min | 10.28 min | 8.66 min |
| Number of transit stops | 0.00 | 1.00 | 0.03 | 0.15 |
| **Neighborhood Location** | | | | |
| Distance | 0.40 mi | 3.65 mi | 1.77 mi | 0.90 mi |

The statistics from the final dataset can be compared to the most recent campus travel surveys from 2004 and 2008. Figure 10 displays the results of mode splits among students from each campus travel survey. It can be seen that walking, biking, and Tiger Transit ridership have increased while driving has decreased among students. An increase in walking and biking may be due to the fact that the amount of pedestrian and bicyclist facilities have increased around campus since 2004. Also, more apartment complexes have been built within a walkable distance to campus since 2004. Tiger Transit ridership has increased and this may be attributed to the fact that the Tiger Transit system has grown since the 2004 campus travel survey. There are additional Tiger Transit stops and smaller transit headways making Tiger Transit riding more convenient. Figure 11 shows the results of mode splits among faculty and staff from each campus travel survey. Although the majority of faculty and staff drive to campus, the overall percent of faculty and staff driving has decreased since 2004. Walking, carpooling, and using other modes of transportation have slightly increased. An increase in walking could again be related to the fact that new pedestrian facilities have been built around campus since 2004.

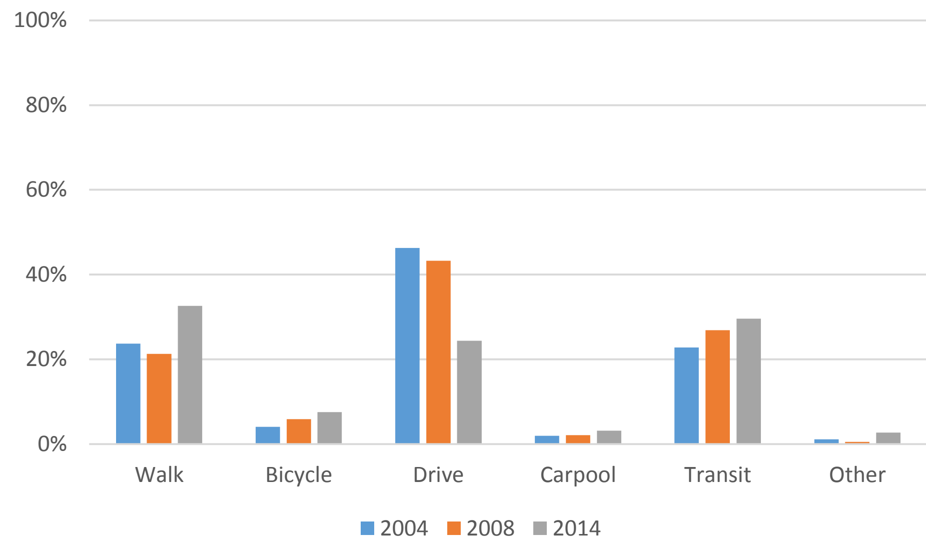


**Figure 10: Comparison of Mode Splits among Students**

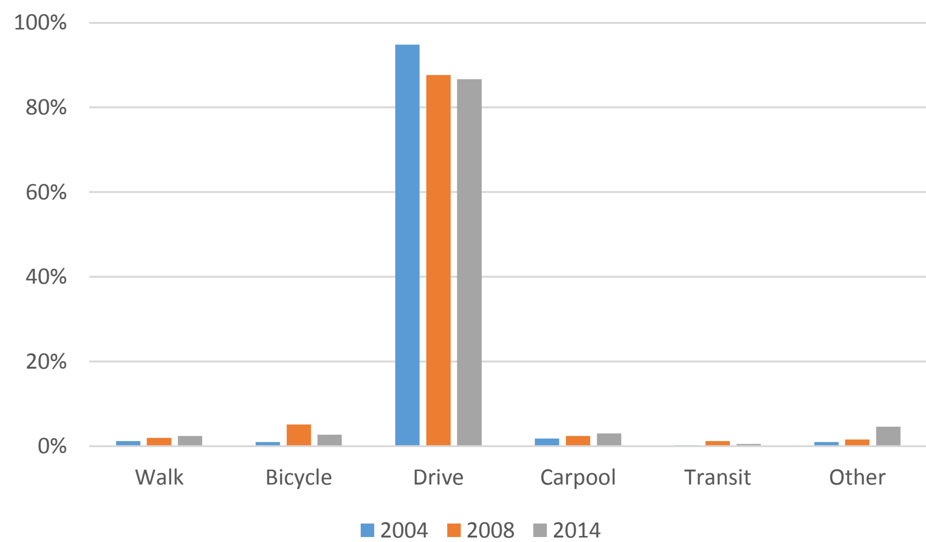


**Figure 11: Comparison of Mode Splits among Faculty and Staff**

**CHAPTER 4**

**METHODOLOGY**

## 4.1 Mode Choice Model Selection

A Multinomial Logit Model (MNL) was chosen to model the mode choices in the research. The MNL is a discrete-choice model that uses utility maximization to calculate utilities of each mode alternative. Utilities are unit-less measures of how much perceived benefit an individual receives from various chosen options. These utilities are compared to each other to calculate the probability that an individual will select a specific alternative, and the alternative with the maximum utility (and therefore probability) is the most likely to be selected. MNL models have been used in a variety of individual travel choice analyses, such as mode, home location, vehicle ownership, and destination [63]. The MNL Model is based on a number of assumptions, which are: 1) alternatives are independent from each other; 2) individuals' choice error terms are independent and identically distributed; and 3) the error associated with each individual is assumed to be normally distributed [63].

## 4.2 Multinomial Logit Regression Formulation

A multinomial logistic regression was used to decide the likelihood of each mode choice based on independent variables. First, the utility function for each mode *i* was defined as:

$$U_{i,q} = \beta x_{i,q} + \varepsilon_{i,q} \tag{4.2.1}$$

where $U_{i,q}$ is the net utility of alternative *i* to individual $q$, $x_{i,q}$ is a set of demographic, preference and built environment variables associated with individual $q$, $\beta$ is the set of coefficient weights on these independent variables, and $\varepsilon_{i,q}$ is the error term.

In this analysis, there are 4 mode-alternatives: walk, bike, drive, and transit. The independent variables in the model include: socio-demographic, individual preference, and built environment factors as seen in Table 11, Table 12, and Table 13, respectively.

The probability of an individual choosing a mode is calculated using:

$$P_{i,q} = \frac{e^{V_{i,q}}}{\sum_{i=1}^{J} e^{V_{i,q}}}, \tag{4.2.2}$$

where $P_{i,q}$ is the probability that alternative $i$ is selected by individual $q$, $V_{i,q}$ is the utility of alternative $i$ calculated in Equation 4.2.1, and $J$ is the total number of alternatives (in this case 4).

## Table 11: Socio-Demographic Independent Variables

| Living Arrangement… | Age… | Income… | Gender… | Role at Auburn University… |
|---|---|---|---|---|
| … Alone | … 18 to 20 | … Less than $15,000 | … Male | … Undergraduate Student |
| … One roommate | …21 to 25 | … $15,000 to $64,999 | … Female | … Graduate Student |
| … Spouse/partner | … 26 to 40 | … $65,000 to $115,000 | … Other | … Faculty |
| … Family Members | … 41 to 50 | | | … Staff |
| … Two or more roommates | … Older than 50 | … More than $115,000 | | |

## Table 12: Individual Preference Independent Variables

| Do you… | Importance of… | Reason for visiting campus… | Time arriving on campus… | Time leaving campus… |
|---|---|---|---|---|
| … enjoy walking | … travel time | … work | … before 6:00 am | … before 6:00 am |
| … enjoy driving | … convenience | … meeting | … 6:00 to 7:59 am | … 6:00 to 7:59 am |
| … try to limit driving | … traffic | … class | … 8:00 to 9:59 am | … 8:00 to 9:59 am |
| … pick up/drop off kids or run errands on the way/leaving campus | … weather | … studying | … 10:00 to 11:59 am | … 10:00 to 11:59 am |
| | … cost | … campus activities | … 12:00 to 1:59 am | … 12:00 to 1:59 am |
| | … environmental impacts | … friends/family | … 2:00 to 3:59 pm | … 2:00 to 3:59 pm |
| | | … personal reasons | … 4:00 to 6:00 pm | … 4:00 to 6:00 pm |
| | | | … after 6:00 pm | … after 6:00 pm |

**Table 13: Built Environment Independent Variables**

| **Roadway Characteristics** | **Bicycle Facilities…** | **Land Use…** |
|---|---|---|
| Major to minor street ratio | … bike lanes | … single family homes |
| Number of intersections along the route | … route sign | … apartments |
| All low volume roads | … multi-use path | … mobile homes |
| Mostly low volume roads | **Sidewalk Width…** | … office/campus |
| Mostly or all high volume roads | … less than 4 feet | … restaurant/commercial |
| Lane width | … greater than 4 feet | … industrial |
| Number of lanes | **Pedestrian Facilities…** | … vacant |
| Speed limit | … cross sign | … recreation |
| Presence of driveways | … pedestrian signal | **Neighborhood's Reason for Visiting Campus…** |
| **Topography…** | … traffic island | … work |
| … easy to ride | … raised crosswalk | … meeting |
| … not easy to ride | **Transit Facilities** | … class |
| **Traffic Calming Devices…** | Transit headway | … studying |
| … traffic circle | Number of transit stops | … campus activities |
| … speed bumps | **Neighborhood Location** | … friends/family |
| … chicanes | … walkable | … personal reasons |
| … raised intersection | … bikeable | |
| | Distance to Student Center | |

**Table 14: Mode Choice Dependent Variables**

| **Mode Choice…** |
|---|
| … Walk |
| … Bike |
| … Drive |
| … Transit |

## 4.4 Multinomial Logit Estimation Process

The MNL coefficient weights are calculated using the Maximum Likelihood Estimation process. This process uses the observed records in the dataset to calculate the set of coefficient weights that most accurately reproduce the observed mode choices for each individual (and their set of independent variables). As the name implies, this process is done by maximizing the log-likelihood function:

$$logL(\theta|x) = \sum P_q(x|\theta) \tag{4.4.1}$$

where *logL* is the log likelihood of set of parameters $\theta$ given outcome x and P is the probability of the observed outcome choice x given the set of parameters $\theta$ for the set of observed individuals $q$. The final coefficient weights are calculated by iteratively updating the values and determining whether the log-likelihood function has been maximized. This process continues until no changes to the coefficients result in a larger log-likelihood value.

A 90% confidence level was used to accept or reject the inclusion of different variable coefficients. This means that there is a 90% probability that the true coefficient is not equal to zero. The 90% confidence level corresponds to a 10% significance level, which is the standard in research when exploring a new set of variables [64].

R Studio was the software used to estimate the final model. R Studio is a software package for statistical computing and graphics. The Log-likelihood value from the final model was -602.48. This value can be compared to other models to determine its likelihood.

# CHAPTER 5

# RESULTS

## 5.1 Model Results

### 5.1.1 Multinomial Regression Model Results

This chapter examines the results of the multinomial logistic regression model that was created. The variables that were incorporated into the model are displayed in Table 15 as well as their coefficients and t-statistic. This final model contains built environment characteristics, socio-demographic characteristics, and preference characteristics. The mode choices in the final model are compared to a base of transit. The variables were estimated at a confidence level of 90% with only the significant ones still shown.

**Table 15: Model Results**

| Explanatory Variables | Walk | | Bike | | Drive | |
|---|---|---|---|---|---|---|
| | *Coeff.* | *T-Stat* | *Coeff.* | *T-Stat* | *Coeff.* | *T-Stat* |
| **Built Environment Characteristics** | | | | | | |
| ***Roadway Attributes (Median)*** | | | | | | |
| Speed Limit | | | 0.176 | 2.81 | | |
| Driveways | | | -3.319 | -2.47 | | |
| ***Bicycle Facilities (Median)*** | | | | | | |
| Route Sign | -3.744 | -2.32 | | | | |
| ***Pedestrian Facilities (Median)*** | | | | | | |
| Pedestrian Cross Sign | | | -8.891 | -2.11 | | |
| Pedestrian Signal | | | 14.472 | 2.46 | 8.305 | 1.80 |
| ***Transit Facilities (Median)*** | | | | | | |
| Transit Headway | | | | | -0.051 | -2.21 |
| Number of Transit Stops | | | 3.257 | 1.98 | | |
| ***Land Use (Median) (base of single family homes)*** | | | | | | |
| Apartments | | | 1.039 | 1.72 | | |
| Recreation/Commercial | | | 4.263 | 2.44 | | |
| ***Neighborhood Reason for Visiting Campus (Median) (base of work)*** | | | | | | |
| Meeting | | | 40.863 | 3.86 | 17.940 | 2.38 |
| Class | -3.647 | -1.71 | -5.689 | -1.68 | | |
| Studying | 5.973 | 1.70 | | | | |
| ***Neighborhood Location (Median) (base of bikeable)*** | | | | | | |
| Walkable | | | -3.027 | -2.73 | | |
| ***Distance from Center of Campus (Median)*** | | | | | | |
| Distance | -0.953 | -1.98 | -2.185 | -2.98 | | |
| **Socio-Demographic Characteristics** | | | | | | |
| ***Age (base of 18 to 20)*** | | | | | | |
| Age 21 to 25 | | | | | 0.806 | 2.94 |
| ***Income (base of less than $15,000)*** | | | | | | |
| $15,000 to $64,999 | | | -1.620 | -2.71 | | |
| $65,000 to $114,999 | | | | | 1.323 | 3.16 |
| $115,000 or more | 1.246 | 3.08 | | | 1.382 | 3.09 |
| ***Gender (base of male)*** | | | | | | |
| Female | | | -1.337 | -3.55 | | |
| ***Role at Auburn University (base of undergraduate student)*** | | | | | | |
| Graduate Student | | | | | 0.870 | 2.20 |
| Faculty | | | 2.857 | 2.21 | 2.845 | 2.62 |
| ***Living Arrangements (base of living alone)*** | | | | | | |
| Partner/Spouse | | | | | 1.138 | 2.48 |
| Family Members | -1.589 | -2.31 | | | | |
| **Preference Characteristics** | | | | | | |
| ***Reason for Visiting Campus*** | | | | | | |
| Work | | | | | 1.443 | 4.63 |
| Friends/Family | 1.288 | 1.65 | | | | |
| Personal Reasons | | | | | -1.892 | -2.23 |
| ***Do you…*** | | | | | | |
| Enjoy Walking | 1.051 | 2.37 | -0.862 | -1.67 | -0.678 | -1.68 |
| Pick up/drop off kids on the way/run errands | | | | | 2.148 | 7.12 |
| ***Importance of…*** | | | | | | |
| Environmental Impacts | | | | | -0.673 | -2.17 |
| Traffic | | | | | -0.580 | -1.91 |
| Cost | -0.540 | -2.06 | | | -1.096 | -3.84 |

#### 5.1.1.1 Built Environment Characteristics

The initial set of independent variables used in the model was built environment characteristics. From the multinomial regression it can be seen that many variables had a significant relationship with mode choice. The median speed limit had a positive impact on biking over taking the transit. This makes sense for biking because people are more likely to bike to their destination when speeds are higher. Driveways had a negative impact on biking and this can be alluded to the fact that people do not enjoy biking in busy areas where cars are pulling in and out of driveways.

Only one bicycle facility feature was found to be significantly related to a mode choice. Route signs were seen to have a negative effect on walking compared to transit. This was not expected but it can be hypothesized that bicycle route signs are in busier areas where walking is not ideal.

Two pedestrian facility features were found to have a significant impact on biking and driving compared to taking the transit. Pedestrian cross signs were discovered to have a negative impact on biking while pedestrian signals were found to have a positive relationship with driving and biking. Pedestrian cross signs could be in places where taking the transit is a more feasible option than biking. Also, pedestrian signals could be located in areas where driving or biking is preferred over taking the transit.

Both transit features were found to have a significant impact on mode choice. The transit headway is seen to have a significant negative impact on driving. This makes sense because the less time it takes for a transit to arrive at a stop, the higher the utility is to ride that transit. The amount of transit stops had a positive impact on biking compared to taking the transit. This might sound surprising but can be related to the fact that the most transit stops that were recorded were very close to campus where the distance is bikeable.

Two land uses were found to be significantly related to mode choice: apartments and recreation/commercial compared to single family homes. Apartments were found to have a positive impact on biking compared to taking the transit. This makes sense because most transit stops are located at apartment complexes that are a bikeable distance. Recreation/commercial land use also had a significant positive impact on biking compared to taking the transit. This can be explained because recreation/commercial land use promotes active travel behavior and people are more likely to bike than take the transit.

Three neighborhood's reasons to visit campus compared to work were found to be positively related to mode choice. The neighborhood's proportion of going to a meeting was found to promote biking and driving compared to taking the transit. It can be hypothesized that a neighborhood with a greater proportion of individuals visiting campus for a meeting do not have a feasible way to take transit. This could be attributed to the assumption that these neighborhoods are mainly comprised of faculty and staff. In general, neighborhoods with a majority of faculty and staff residents are located a farther distance from campus than neighborhoods with student residents. Also, it can be hypothesized that Tiger Transit does not have stops at these neighborhoods. This equates to a higher likelihood of biking and driving among residents. The neighborhood's proportion of going to campus for class was found to have a negative impact on walking and biking compared to taking the transit. It can be hypothesized that individuals going to class have an easier access to transit than walking or biking. Studying was found to have positive impact on walking compared to taking transit. This too can be hypothesized that a neighborhood with a greater proportion of people visiting campus for studying live closer to campus than individuals that would rather study at home.

A neighborhood's location was found to have a significant relationship with mode choice compared to taking the transit. Compared to being bikeable, a neighborhood that is walkable was seen to have a negative relationship with biking compared to taking the transit. This again can be attributed to the fact that many neighborhoods located within a mile from the center of campus have many transit stops and shorter headways which makes taking transit easy and convenient. The distance a neighborhood is located from the center of campus was found to have a negative impact on walking and biking compared to taking the transit. This makes sense for walking and biking because people do not want to walk long distances to get to campus.

#### 5.1.1.2 Socio-Demographic Characteristics

The second set of variables used in the model were socio-demographic characteristics of the UCTCS respondents. The first variable found to be significant to mode choice was the age of the respondent. Compared to an age of 18 to 20, being 21 to 25 was found to have a significant relationship with driving compared to taking the transit. This could be related to the fact that this age group has a greater access to parking permits for on campus parking and finds there to be a higher utility for driving than taking the transit. Also, it has been seen that the utility of cycling decreases the longer a student is enrolled at Auburn University. It was found that 8.77% of freshman biked to campus while only 7.28% of seniors biked to campus. This could possibly be related to the fact that 95.41% of seniors agreed that convenience of the travel mode was important to their mode choice decision while only 85.77% of freshman agreed. It is interesting to note that older age groups were not significantly related to driving compared to taking the transit. This is surprising because the main Tiger Transit ridership is comprised of students.

Each household income interval was found to have a significant impact on mode choice compared to making less than $15,000. Having a household income of $15,000 to $64,999 was found to decrease the likelihood of biking to campus compared to taking the transit. This makes sense because taking the transit is free and owning a bike has initial and upkeep costs. A household income of $65,000 to $114,999 was found to have a positive impact on driving compared to taking the transit. This was expected because this income group can afford to own and operating a personal vehicle. A household income of $115,000 or more was found to have a positive relationship with walking and driving compared to taking the transit. Again this was expected for driving because persons in this income group are more likely to afford to own and operating a personal vehicle. It is surprising that this income group has a positive impact on walking but this could possibly related to the fact that the higher income groups may live in livable neighborhoods which promote walking.

Gender was found to have a significant relationship with biking compared to transit riding. Females are seen to be less likely to bike compared to males. This relationship has also been found to be significant in past research [26].

Another socio-demographic characteristic that was found to be significantly related to mode choice was the role of the individual. Using a base of undergraduate student, graduate students and faculty were found to be significantly related to mode choice. Graduate students and faculty were discovered to have a positive impacts on driving compared to transit riding. This makes sense because graduate students and faculty are more likely to own parking permits than undergraduate students. Also, faculty was found to have a positive relationship with bicycle riding compared to taking the transit. This can be explained because there is a much higher percentage of faculty that bike than take the Tiger Transit.

Using a base of living alone, two living arrangements were found to be significantly related to mode choice. Having a partner/spouse increased the likelihood of driving compared to taking the transit. This has been seen in previous research [22] and makes sense because people that have a partner/spouse may have more responsibilities that need to be taken care of with a personal vehicle. Living with family members was also found to have a negative impact on walking compared to transit riding. This could be due to the fact that most people that live with family members live in single family homes or apartments that are located farther from campus than walkable neighborhoods.

#### 5.1.1.3 Preference Characteristics

The final set of variables that have a relationship with mode choice are preference characteristics. The individual's reason for visiting campus was found to have a significant impact on mode choice. Respondents who visited campus for work had a positive relationship with driving compared to taking the transit. This makes sense because individuals visiting campus for work are mainly faculty that need the flexibility of a personal vehicle. Individuals who visited campus to see friends/family were seen to have a positive impact on the likelihood of walking compared to transit riding. Past research has also seen this reason as having a significant impact on walking [65]. Individuals that visited campus for personal reasons were found to have a negative impact on driving compared to taking the transit. This is an interesting finding because little to no research has been completed on this in the past. It can be hypothesized that individuals traveling to campus for personal reasons do not have a concern with travel time and can take extra time to wait on a transit.

Individuals who enjoy walking were seen to have a positive relationship with walking and a negative relationship with biking and driving compared to taking the transit. This is self-explanatory because people that enjoy walking are more likely to walk. Individuals that have to pick up/drop off kids or run errands on the way/leaving campus were found to have a positive impact on driving compared to transit riding. This makes sense because individuals need a car to perform these activities.

The importance of certain variables to respondents was found to play a significant role with mode choice. The importance of environmental impacts was seen to have a negative relationship with driving compared to taking the transit. This makes sense because people that have a passion for minimizing environmental impacts are more likely to use an active mode choice and will try to limit their personal vehicle use [22, 27]. The importance of traffic and costs also had negative relationships with driving compared to transit riding. Previous research has found that traffic can change an individual's mode choice from driving to transit [39]. Cost also had a negative impact on walking compared to taking the transit. Past research has shown that one of the main reasons people choose to walk is because of the trip cost [28, 29]. While the relationship between cost and driving makes sense because taking the transit is free and driving is not, the relationship between cost and walking compared to transit does not. Both walking and riding transit are free so there must be an underlying variable that causes cost to have a negative relationship with walking compared to transit.

### 5.2 UCTCS Results

This section displays a couple interesting results from the UCTCS. Figure 12 displays the mode splits of respondents by their reason visiting campus. To interpret this graph it can be read as the percentage of individuals who used a certain mode visited campus for a certain reason. For example, by looking in the lower left corner of the graph it can be seen that 19% of respondents who walked were visiting campus for work. The percentages will not add up to 100% because respondents could have selected more than one reason for visiting campus. As seen in the figure, individuals that are visiting campus for class, studying, or campus activities are mainly using active modes of travel or transit. Individuals that are visiting campus for work are mainly driving or using a non-active travel mode. This shows that students are being active while employees are mainly driving to campus. It can be hypothesized that this is because of a number of reasons. First, faculty and staff may live a farther distance from campus than students and thus are more likely to drive. Second, faculty and staff might have a greater access to campus parking permits than students causing it to be more convenient and easy to park near their office. Third, it can be hypothesized that faculty and staff have a higher income than students and this has been shown to have increase the likelihood of driving. Finally, in general faculty and staff have more life responsibilities than students and thus need the flexibility of a personal vehicle. These life responsibilities could possibly include having to pick up or drop off children when traveling to or from campus.

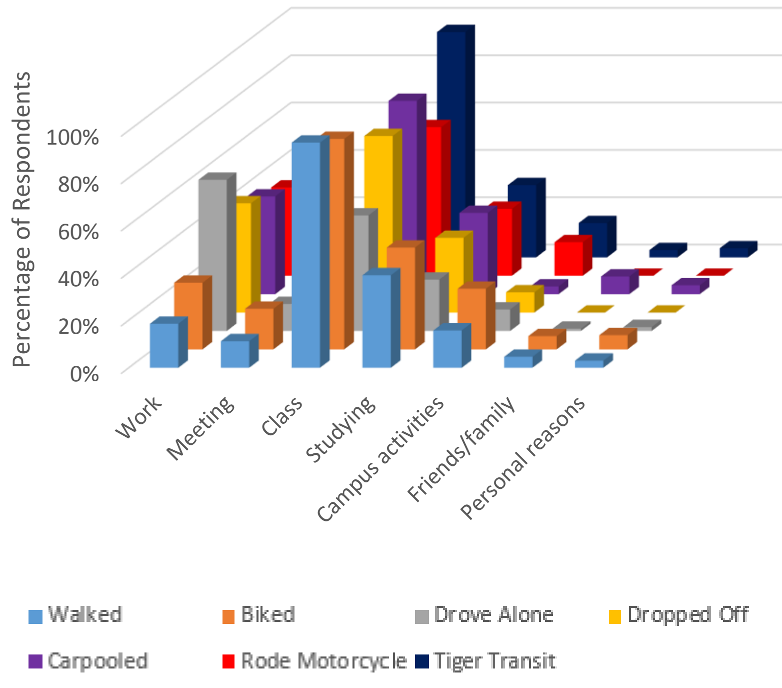


**Figure 12: Mode Splits by Reason Visiting Campus**

Another interesting finding from the UCTCS is the mode splits by arrival period. Figure 13 shows the mode splits of respondents by their arrival period on campus. These can be interpreted as the percentage of individuals who arrived at a certain time period used a certain mode. For example, 31% of individuals who arrived before 6:00 AM walked to campus. It can be seen that respondents are mainly driving to campus early in the morning or late in the evening while respondents are walking to campus all throughout the day. It can be assumed that individuals who are driving to campus in the morning are faculty and staff that are arriving on campus for work. Also, it can be hypothesized that individuals driving to campus in the evening are students and staff. Many of the parking regulations on campus end at 5:00 PM and because of this students or other individuals who normally do not have access to many parking areas are allowed to park in them. Some staff members can be assumed to arrive on campus later in the evening because they work at night. Also, transit ridership increases from the morning to 3:59 PM. This can be attributed to the fact that the main ridership of Tiger Transit is students. In general, classes and other campus activities take place throughout the middle of the day. The largest amount of respondents biking happens from 2:00 to 3:59 PM. There is no reasonable explanation for this but it could possibly be due to the fact of the lower amount of respondents who biked to campus. The highest percentage of individuals who walked to campus also occurred throughout the middle of the day. This can too be related to the assumption that classes and other campus activities occur throughout the middle of the day. These findings are very interesting to note and can be used in a planning process when determining when individuals will be arriving to campus by each mode.

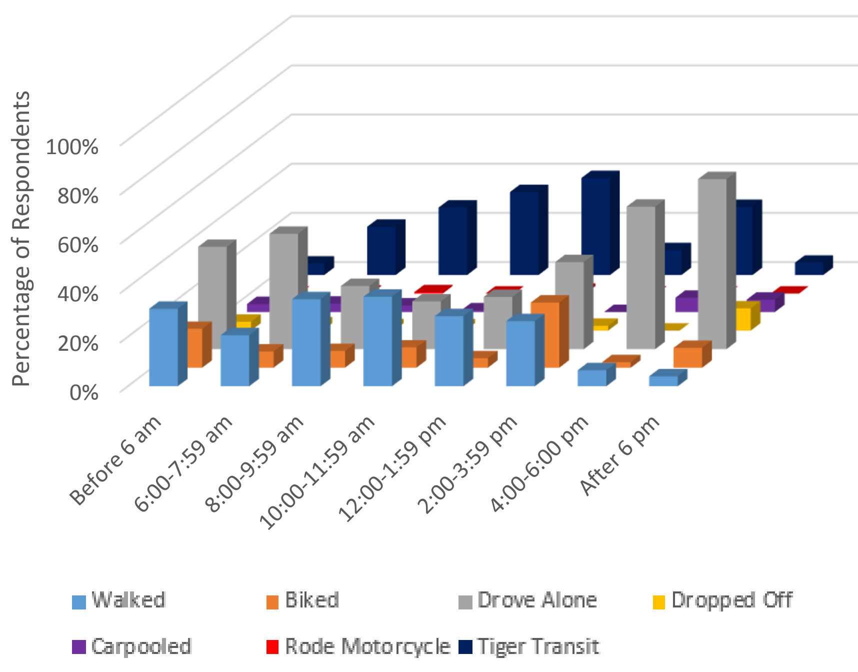


**Figure 13: Mode Splits by Arrival Period**

Survey participants were asked if there were any improvements to cycling that would allow them to ride a bicycle on campus (or ride more frequently). Figure 14 displays the breakdown of preferred cycling improvements by mode choice. This graph can be interpreted as the percentage of individuals who selected a certain mode selected a certain improvement. For example, 60% of respondents who walked answered that no improvements would allow them to ride a bicycle on campus. Also, the percentages will not add up to 100% because respondents could have selected more than one improvement. It can be seen that the majority of individuals using modes other than bicycling believed no improvements would promote them to bicycle on campus. It can be hypothesized that improvements to bicycling would not raise the utility high enough for the majority of individuals to switch to that mode. Respondents who drove alone or were dropped off believed that off-campus infrastructure and on-campus infrastructure would promote them to bike, respectively. This could be because the respondents who are driving are most likely living the farthest from campus and would travel on off-campus infrastructure the most. Respondents who were dropped off may live closer to campus but possibly find it inconvenient to bike while on campus. Respondents who cycled to campus believed that on-campus infrastructure, off-campus infrastructure, and covered bike parking would promote their bicycle use on campus.

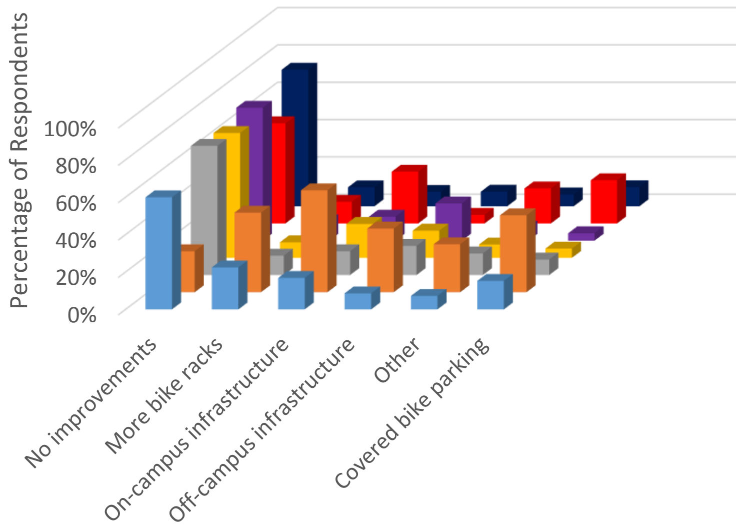


**Figure 14: Preferred Cycling Improvements by Mode Choice**



Finally, survey participants were asked if there were any improvements that would allow them to use Tiger Transit on or to campus (or use it more frequently). Figure 15 shows the breakdown of preferred Tiger Transit improvements by mode choice. This graph can be interpreted as the percentage of individuals who selected a certain mode selected a certain improvement. For example, 40% of respondents who walked answered that no improvements would promote them to use Tiger Transit to or from campus. Also, the percentages will not add up to 100% because respondents could have selected more than one improvement. Clearly, respondents would like to use Tiger Transit if improvements are made. Respondents who walked, biked, drove alone, or carpooled indicated that shorter travel times would inspire them to select campus transit as their mode choice. This could be because these respondents value travel time and are already using modes that get them to campus in the shortest amount of time. Respondents who were dropped off or rode a motorcycle selected transit stops closer to their home as the main improvement. These respondents may live in areas where it is inconvenient to walk to a transit stop.

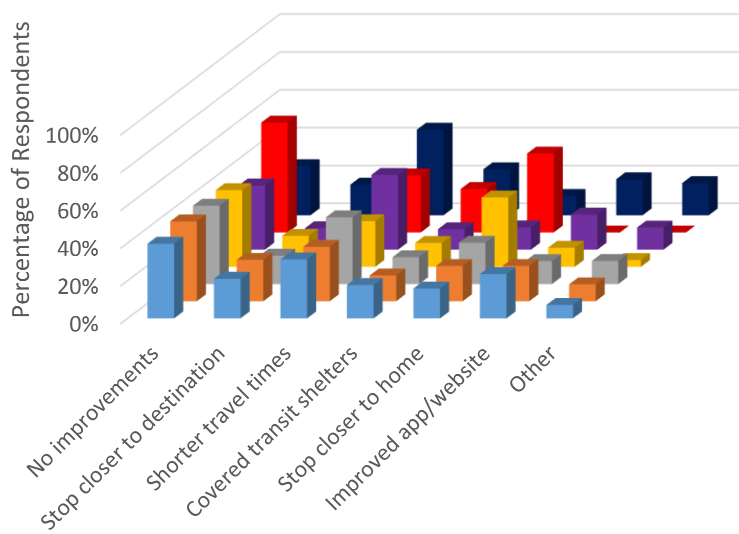


**Figure 15: Preferred Campus Transit Improvements by Mode Choice**

## CHAPTER 6

## CONCLUSIONS

### 6.1 Summary

This analysis used unique data collected from the 2014 University Campus Travel Choices Survey and the Neighborhood Walkability Survey in order to model the likelihood of a mode being chosen using a multinomial logistic regression model. The sample consisted of students, faculty, and staff living in the Auburn area that completed the UCTCS and visited campus on Tuesday October 28, 2014 and the characteristics of the neighborhoods they live in. A number of variables were discovered to be significantly related to mode choice including built environment characteristics, socio-demographic characteristics, and preference characteristics.

The model found that many built environment characteristics such as speed limit, speed bumps, driveways, bicycle route sign, pedestrian cross sign, pedestrian signal, transit headway, number of transit stops, land use, neighborhood's reason for visiting campus, and neighborhood location were significantly related to mode choice and physical activity. Speed limit, number of transit stops, and neighborhood's reason for visiting campus: meeting, class, and studying were found to have a positive relationship with walking compared to transit. Driveways, bicycle route sign, transit headway, land use: apartments, walkable neighborhood location, and distance to the center of campus all had a negative relationship with walking compared to transit. Pedestrian cross sign, transit headway, and walkable neighborhood location were found to have a negative relationship with walking compared to taking the transit while neighborhood's reason for visiting campus: meeting had a positive relationship with biking compared to transit riding. The model estimated that speed limit, speed bumps, pedestrian cross signal, number of transit stops, and neighborhood's reason for visiting campus: meeting, class, studying, and campus activities had a positive impact on driving compared to transit riding. Driveways, transit headway, walkable neighborhood distance, distance to center of campus, and land use: office/campus and recreation/commercial were seen to have a negative relationship with driving compared to transit riding.

The model estimated that socio-demographic characteristics such as age, income, gender, role at Auburn University, and living arrangements were significantly related to mode choice and physical activity. Income of $115,000 or more was seen to have a positive impact on walking compared to transit riding while living with family members was calculated to have a negative relationship. The model found that being a faculty member had a positive impact on biking compared to transit riding while having a household income of less than $115,000 and females had a negative relationship. Individuals of the age 21 to 25, household income of $65,000 or more, graduate students, faculty, and living with a partner/spouse had a positive impact on driving compared to taking the transit.

The model found some preference characteristics that had a significant relationship with mode choice: reason for visiting campus, enjoy walking, pick up/drop off kids or run errands on the way/leaving campus, importance of environmental impacts, traffic, and costs. Individuals that enjoy walking and visited campus for friends/family had a positive relationship with walking compared to transit while individuals that believed cost was very important when traveling and visited campus for personal reasons had a negative impact. Individuals that had to pick up/drop off kids on the way/leaving campus and visited campus for work were found to have a positive significant relationship with driving compared to taking the transit. Individuals that believed environmental impacts, traffic, and costs were important and visited campus for personal reasons had a negative relationship with driving compared to transit riding.

These results can be applied in other areas than medium sized university settings. Areas that do not have a university population but still have livable built environment infrastructure can apply these results. Auburn has been awarded a bronze medal in the Bicycle Friendly Communities Campaign which shows that it provides a safe and encouraging environment for cyclists [16]. The League of American Bicyclists gives this award to communities across the nation [66]. Any community that has received a level of this award can use the results from this thesis to better understand individuals' mode choice. Also, these results can be applied to communities in the U.S that have a local transit. One limitation of this work is that it only included individuals that had ties to Auburn University. It would be plausible to include all individuals in the community if possible. Also, it only looked at neighborhoods within four miles from the campus center. It would be interesting to examine neighborhoods outside of this four mile buffer and see if the results stayed the same.

### 6.2 Application

The research presented in this thesis can help further the study of physical activity and livable neighborhoods by discovering factors that affect mode choice. The model generated is important because it compares the utilities of using a travel mode to transit riding. This research is also significant because the data is from a medium sized university community.

The findings in this thesis can be used by city planners to help design more livable neighborhoods in three major ways:

1) City planners could input their existing communities' socio-demographic, preference, and built environment characteristics in the model to determine mode choices. These results could

be used to help city planners understand what features need to be constructed to help promote a livable community.

2) When designing new communities, city planners can refer to this research to identify variables that promote livability. This research found that when designing a new livable community, features such as the greater number of transit stops and recreation/commercial or office/campus land use should be constructed within a walkable distance from a neighborhood. Also, reducing the amount of driveways and transit headways will promote modes other than driving.

3) Apartment planners can use this research as a parking model to project the number of parking spaces needed in an apartment complex. Planners can input the proposed neighborhood's socio-demographic, preference, and built environment characteristics into the model and forecast the mode splits. By viewing these mode splits, apartment planners can project the number of parking spaces that will be needed at the apartment complex based off the amount of individuals living there.

The model can be utilized to help understand what built environment characteristics can be constructed to promote active travel and transit. Understanding the variables that affect mode choice and physical activity can help engineers and planners construct neighborhood designs that encourage a healthy lifestyle.

To further understand the relationship between mode choice and the built environment, future work could be completed on the routes individuals choose to take to campus. To accomplish this work, GPS could be used to track the routes individuals take and the mode choice they use. Also, the Neighborhood Walkability Survey could be administered on the routes individuals take. Looking into the routes used can give further understanding on why individuals choose a mode of transportation. Future research could look into the routes individuals take to get to their destination. This could show if individuals go out of their way to use routes with livable built environment characteristics. Also, future research could survey a greater number of individuals along with individuals that do not have ties with Auburn University. Finally, future research can investigate areas that do not have a university.

# CHAPTER 7

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