Using GPS and Accelerometers to Identify Preferred Locations for Physical Activity Participation and Commuter Mode Choice

by

Scott Seidband

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Approved by

Jeffrey LaMondia, Chair, Assistant Professor of Civil Engineering
Rod Turochy, Associate Professor of Civil Engineering
Huaguo Zhou, Associate Professor of Civil Engineering

Abstract

As cities seek to foster more livable and active communities, much attention is being placed on promoting physical activity through active transport and wellness activities. As such, it is important that city planners and engineers be able to tailor these livable improvements to the interests and needs of their specific residents. More importantly, it is important to understand *where* individuals are most likely to participate in physical activities as well as their *level of interest* in pursuing these activities. This thesis develops a unique GPS and accelerometer-based methodology for collecting and analyzing (through a series of regression models) university students' levels of interest in physical activities that take place at/near home, at a destination or during transportation. It also utilizes a discrete choice model to determine the factors influencing students' commute mode choices. As a result, it was possible to determine where students were most physically active through observed activity data. Both built environment and health/lifestyle variables significantly influenced physical activity as well as mode choice. These methods and the models estimated in this paper can be applied on a larger scale to communities to forecast locations of physical activity participation for use in guiding the development of livable communities.

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List of Abbreviations

AEROS	Aerobic Steps
AU	Auburn University
GIS	Geographic Information System
GPS	Global Positioning System
IID	Independent and Identically Distributed
PAGA	Physical Activity Guidelines for Americans
UCLA	University of California, Los Angeles
UNC	University of North Carolina
USB	Universal Serial Bus

1. **INTRODUCTION**

As cities seek to foster more livable and active communities, much attention is being placed on promoting physical activity through active transport and wellness activities. These efforts generate jobs, reduce medical costs, temper congestion, support the environment, and improve regions' quality of life (American Heart Association 2013; Share the Road Cycling Coalition 2013; Litman 2013). Unfortunately, millions of people do not obtain their recommended amounts of daily physical activity, and obesity continues to grow throughout the United States across all demographics (Frank, *et al.* 2004). As of 2013, 23.9 million children aged 2 to 19 and 154.7 million adults over 20 are overweight or obese, resulting in an anticipated $254 billion healthcare cost (American Heart Association 2013). Many researchers link this inactivity with neighborhood design and the built environment and recommend a) a network of walkways, bicycle lanes and pathways be designed to permit citizens to partake in active transportation safely as well as b) easily accessible destinations that provide opportunities for people to participate in physical activities, such as running trails, gyms, or pools. Fortunately, these improvements fall directly within the realm of livable and active communities, which has the potential to greatly improve communities and their transportation systems.

Still, it is important that city planners and engineers be able to tailor these livable improvements to the interests and needs of their residents. More specifically, it is important to understand *where* individuals are most likely to participate in physical activities as well as their *level of interest* in pursuing these activities (Sallis 2009; Kilpatrick, *et al.* 2005). Most physical activity takes place at specific locations referred to as "environments", including transportation (e.g. walking or bicycling) (Sallis 2009). However, past research is rather limited in addressing the locations of physical activity, especially related to transportation, with a focus on the benefits of participating in physical activity or the dangers of neglecting to do so. In one such study, Andersen, *et al.* examined the relationship between different levels of physical activity during work, cycling to work, sports, and times of leisure and found that individuals developed strong preferences toward participating in physical activities in one specific location (Andersen, *et al.* 2000). By understanding these location needs, development improvements can be made to specifically provide the infrastructure or programs necessary to assist individuals to be physically active.

To help further flesh out the issues of physical activity participation, this thesis also considers active commuter mode choice. Factors such as trip duration, trip purpose, weather, neighborhood safety, traffic safety, cost, personal attitudes, gender, age, etc. all have significant influences on mode choice (Klöckner and Friedrichsmeier 2011; McMillan 2007; Whalen, *et al.* 2013; Zhou 2012). It is important to analyze these factors influencing mode choice because some of them may outweigh an individual's desire to obtain physical activity through transportation. While several studies have been conducted in the past examining physical activity obtained through transportation, most neglect to look at the factors influencing active mode choices.

Two tools can be used to identify locations and measure interest levels of physical activity as well as help to determine active commuter mode choice. First, the Global Positioning System (GPS) can be used through a portable recorder to track an individual's travel and duration at and between specific locations. In addition, the time and distances between logged data can help identify what mode of transportation a person is using. Second, accelerometers are able to record amounts of physical activity obtained by an individual by recording aerobic steps. Based on these different amounts of physical activity, varying levels of physical activity interest can be estimated. Therefore, this study uses a unique GPS and accelerometer-based methodology for collecting and analyzing, through a series of linear regression models, university students' levels of interest in physical activities that take place at/near home, at a destination or during transportation. It also utilizes a discrete choice model to determine the factors influencing students' commute mode choices. As such, these methods and the models estimated in this paper can be applied on a larger scale to communities to forecast locations of physical activity participation for use in guiding the development of livable communities.

The objectives of this thesis are three-fold. First, the research develops and pilots a unique GPS & accelerometer based methodology to collect/analyze locations of and level of interest in physical activity, which will be examined. Second, this research seeks to identify the factors influencing students' choice of physical activity locations. Third, it seeks to also determine the factors influencing of commuter mode choice. Both the second and third objectives involve uses the data collected from the GPS and accelerometers in new ways.

2. LITERATURE REVIEW

This chapter reviews the literature on factors influencing physical activity, locations of physical activity, level of interest in physical activity, physical activity measurements, and factors influencing commuter mode choice of college students.

2.1 Factors Influencing Physical Activity

Much work has been done over the past few decades to study the effect of the built environment on physical activities in the transportation arena. Over that time, it has been shown that many factors within the built environment, from the presence of sidewalks to mixed use development, positively encourage people to take active transport modes and participate in physical activity (Handy, *et al.* 2002; Humphrey 2005). However, most community design over the past century has resulted in a built environment that discourages physical activities such as walking and cycling, thereby contributing to human health issues. New livable design standards are beginning to be implemented but more research is required to understand the complexity of the built environment and how it affects *where* these activities take place (Frank, Engelke, *et al.* 2003).

The relationship between the built environment and physical activity is complex and must be examined through several different variables (Carlson, *et al.* 2012). Some relationships that have been shown to be significant include neighborhood physical attributes and resident perceptions of the neighborhood attributes. Researchers have found that the built environment and health through neighborhood physical activity are not necessarily directly related to each other as predicted in the past, but rather related through complex relationships. Specifically, the existence and proximity of walking trails, sidewalks, and bike lanes have a positive influence on physical activity, while factors such as crime have a negative influence on physical activity (Carlson, *et al.* 2012; Sandy, *et al.* 2013; Fenton 2005). Walking distances to activity opportunities are critical to promoting livable communities, and travel times to physical activity destinations rather should be approached differently than past methods in order to build an environment that promotes walking (Lachapelle 2009). The presence of walking trails near a child's home directly correlates with reduced bodyweights. However, significant weight reductions only took place in areas where crime was low (Sandy, *et al.* 2013). Also, reliance on personal vehicle travel further results in less physical activity, with each additional hour per day spent in a car corresponding to a 6% increase in obesity likelihood, and each additional kilometer walked per day corresponding to a 4.8% decrease in obesity likelihood (Frank, *et al.* 2004).

Although the built environment can have a significant role, an individual must make the decision to be physically active or not. This decision is based on an individual's personal health and lifestyle and *perception* of the built environment, which is another primary consideration of this research. Several studies have been conducted analyzing how health and lifestyle affect physical activity. Andersen, *et al.* examined the relationship between different levels of physical activity during work, cycling to work, sports, and times of leisure and mortality. The researchers found that moderately to highly active sports participants experienced a mortality rate half of non-sports participants. In addition, they found that cycling to and from work reduced the risk of death by about 40% (Andersen, *et al.* 2000). In a more recent study, Ford, *et al.* evaluated the effects of not smoking, a healthy diet, and sufficient physical activity on mortality in adults. The researchers found that the nonsmokers' risk of death was 56% less than the smokers', the physically active participants' risk of death was 47% less than the inactive participants', and the healthy diet participants' risk of death was 26% less than the non-healthy diet participants'. They concluded that not smoking, partaking in physical activity, and eating healthy can greatly reduce the risk of death in adults (Ford, *et al.* 2012). In another study, which was conducted in twelve rural counties in Missouri, residents' knowledge, attitudes, and behaviors of walking were analyzed in order to determine patterns of walking, availability of walking places, walking trail effects on physical activity, and attitudes towards walking trails. The researchers classified about 19.5% of the surveyed participants as regular walkers. They found that approximately 36.5% of respondents had access to a walking trail, and of these, around 38.8% actually used the trails. In addition, the researchers saw that of the respondents who did use the trails, approximately 55.2% increased the amount of walking they did from before using the trails. They concluded that walking trails could be useful in encouraging physical activity, especially among people at the highest risk of being inactive (Brownson, *et al.* 2000). In a third study, researchers found that physical activity obtained during commuting to and from work significantly reduced the risk of heart disease in women but not in men. In addition, they found that moderate and high levels of both leisure and occupational physical activity significantly decreased the chance of heart disease in both men and women (Hu, *et al.* 2007). A fourth study, which was conducted at 24 middle schools, found that parents transported their adolescents to locations of physical activity on average 2.13 times per week. The researchers also found that boys were provided transport more often than girls. In addition, they saw that the parental transportation had a huge influence on girls' total amount of physical activity in the week, where as it only slightly influenced boys' overall physical activity for the week. Overall, they concluded that parental transportation is closely related to the amount of physical activity young students receive outside of school (Hoefer, *et al.* 2001).

2.2 Locations of Physical Activity

A very limited amount of past research identifies where physical activity takes place. In one example, Giles-Corti and Donovan examined the relationship of individual, social and physical environmental factors on recreational physical activity. As expected, recreational facilities located in close proximity to participants' homes were utilized more than those located further from their homes. The researchers found that facilities such as the streets, public open space, and the beach were the most often used instead of places such as a gym. Therefore, they concluded that the environment's physical characteristics were a secondary influence compared to its individual and social factors on physical activity locations (Giles-Corti and Donovan 2002). In a second study, researchers used a mail survey to examine the physical activity preferences of adults at risk of inactivity. They found that over 80% of the participant's preferred physical activity that could be done at/near home (Burton, *et al.* 2012). The researchers of these two studies only used the survey results to assess where physical activity had occurred but did not back up these survey results with the use of GPS devices. As mentioned before, surveys and questionnaires are not always correct, meaning the self-reported data is often biased. Therefore, without the use of GPS devices, the researchers' assessment of locations of physical activity could be inaccurate. In a third study, Quigg, *et al.* used GPS units and accelerometers to examine the amount of children's physical activity taking place at public parks. Using the GPS data, the researchers were able to map park locations of physical activity to make recommendations on park development (Quigg, *et al.* 2010). The researchers did not, however, consider or compare this data to the amount of physical activity the children received through transportation, at/near home, or at places other than the parks. Similarly, a recent study examined physical activity in 24 elementary school children using GPS units and accelerometers. The researchers found that the children spent most of their time at/near home, but equivalent amounts of time partaking in physical activity at/near home and walking in the streets (Oreskovic, *et al.* 2012). In a fifth study, researchers used GPS and accelerometers to identify where joint parent and child physical activity takes place. They found that most of the parent-child respondents participated in physical activity at parks or venues outside of their neighborhood (Dunton, *et al.* 2013).

2.3 Level of Interest in Physical Activity

Past research is also very limited in determining the level of interest individuals have towards physical activity. However, this aspect of physical activity is important as it influences the frequency and likely recurrence of the behavior. In one study, researchers examined the motivation for physical activity of college students. They found that the students participated in sports for enjoyment or to be challenged. However, the researchers discovered that physical activity obtained through non-sport exercise was motivated by factors such as appearance, weight, and stress. Therefore, they concluded that the level of interest in physical activity is much higher when obtaining it through entertainment rather through other types of exercising (Kilpatrick, *et al.* 2005). In a second study, 1131 adolescents from Iceland were surveyed to determine what factors influence their level of interest in physical activity. The researchers found that a significant others' (father, mother, friend, etc.) involvement and a perceived importance of physical activity directly related to a higher interest level in physical activity

(Vilhjalmsson & Thorolfur 1998). In a third study, the researcher studied children's attraction to physical activity. Similarly to the first study, he saw that the level of interest of physical activity was high if the physical activity was a game or sport. Like the second study, he also found that a perceived importance of physical activity related to a higher interest level in physical activity (Brustad 1996). However, none of this past research suggests a good method for actually quantifying the level of interest in physical activity.

2.4 Collecting Data on Physical Activity

Several methods can be used to collect data on where, when, and how much a person participates in physical activity, including travel diaries, questionnaires, accelerometers, and GPS devices. Each has their individual benefits and challenges. For example, surveys can gauge interest in activities but are biased towards recall and optimistic about level of participation; GPS units allow for accurate location data but do not indicate level of participation. Despite this, much of the past research focuses on using just one of these methods (Troiano, *et al.* 2008; Terry, *et al.* 2003).

One of the most common combinations of data collection techniques is the use of questionnaires and accelerometers. For example, in a study done in accordance with the Physical Activity Guidelines for Americans (PAGA), Tucker, *et al.* evaluated the self-reported physical activity of U.S. adults. In addition, the physical activity of a second group of adults was measured using accelerometers, which were worn by participants for seven consecutive days. The researchers found that 62% of the adults who self-reported their physical activity met the PAGA, but only 9.6% of the adults examined using accelerometers met the guidelines. They therefore concluded that the self-reported data was likely inaccurate thereby resulting in the great variability between the self-reported and accelerometer data (Tucker, *et al.* 2011). Others agree that the best way to quantify physical activity was through motion sensors rather than with the questionnaires (Pitta, *et al.* 2006). Due to these biases, it is difficult to accurately determine location and interest.

Another common combination of data collection methods is the use of GPS and accelerometers. Alamanza et al. used GPS devices and accelerometers to track the children's physical activity within a neighborhood (Almanza, *et al.* 2012), and Quigg, *et al.* used them to track their physical activity in playgrounds (Quigg, *et al.* 2010). As mentioned before, Oreskovic, *et al.* and Dunton, *et al.* used this combination to identify locations of elementary children's physical activity, and locations of joint parent and child physical activity, respectfully (Oreskovic, *et al.* 2012; Dunton, *et al.* 2013). This combination was also used by a group of researchers to measure the physical activity of children on their way to school (Cooper, *et al.* 2010). In a study of semipro swimmers, researchers compared the results obtained from GPS and accelerometers with video footage. They found that no significant differences were found between the GPS-obtained velocity and the velocity caught by the video for two of the three types of swim strokes observed and concluded that the combination was an overall accurate tool for quantifying swim strokes (Beanland, *et al.* 2013).

This combination of GPS and accelerometers is a very beneficial tool to researchers; however, the collection of GPS data can be hindered. GPS works by receiving signals from satellites. To accurately determine a position, it requires a continuous signal from a minimum of four satellites. Disruptions in signaling can be produced by obstructions such as trees, buildings, tunnels, etc. (Duncan, *et al.* 2009). When a disruption occurs, several minutes of data may be lost until the signal is obtained again. This can be detrimental to a dataset, especially when collecting travel data (Duncan, *et al.* 2009). Besides the accuracy issues associated with signal loss, some GPS devices also have a very short battery life. This presents a major problem when data collection occurs for several days (Oliver, *et al.* 2010).

2.5 Factors Influencing Active Commuter Mode Choice

Over the past decade, much research has been conducted to determine the factors that influence commuter mode choice. In one study conducted at Ruhr University in Bochum, Germany, researchers analyzed student mode choice for four different types of trips including to the university, to work, to a leisure activity, and to a shop. In order to collect data, the researchers used an online travel survey and weeklong travel diaries. The final dataset included 3,560 students and 26,865 trips. The researchers found that car ownership and trip duration were two of the most influential factors for choosing car over other modes. In addition, they found that other factors such as trip purpose and weather had strong influences on mode choice (Klöckner and Friedrichsmeier 2011). In a second study, University of California, Los Angeles (UCLA) students commuting behaviors were examined. A total of 3,429 students, which represented approximately 10% of the college's student population, were sent online travel surveys via email, and a final dataset of 508 surveys were used in the analysis. The researcher focused on the responses of students who said they lived off campus. He found that student parking permit ownership influenced the use of automobile, while transit pass ownership influenced the use of alternative modes. The researcher also saw that longer travel distances influenced carpooling and telecommuting. In addition, he found that gender, academic status, and age were significantly correlated to alternative modes (Zhou 2012). A third study suggests that the mode choice of college students was found to be predominantly influenced by cost, personal attitudes, and environmental attributes. The researchers of this study also found that travel time positively influenced the use of both bicycles and cars (Whalen, *et al.* 2013). In a fourth study, conducted at the University of North Carolina at Chapel Hill (UNC), researchers examined the relationship between the mode choice of students and faculty members and the local physical environment. Factors such as travel time and cost were also considered. The researchers concluded that physical factors such as sloping terrain negatively influence active modes of transportation (walking and bicycling), while the presence of sidewalks positively influences the use of active modes (Rodríguez and Joo 2004).

2.6 Past Research in Relation to the Current Research

The issues of physical activity participation intensity, location, and methods of collecting data on this behavior are critical topics for study. While many studies have considered singular aspects of this behavior, the combined effects of built environment, health/ lifestyle characteristics, and physical activity are rarely considered together. Some papers have been written on the locations where physical activity takes place; however, most only discuss one location, and the majority of them neglect physical activity obtained through transportation outright. Many papers have been written on the motivation behind physical activity, but none suggest a good method of quantifying the level of interest in physical activity. Finally, many studies have used GPS and accelerometers to obtain data, but few have used them along with a questionnaire to examine physical activity and commuter mode choice.

For this study, *both* built environment and health and lifestyle characteristics are examined to determine the extent to which influence college students to partake in physical activities. Furthermore, this research seeks to identify where the physical activity, if any, is taking place. Unlike past research, this thesis divides up physical activity locations into three categories, including during transportation (either through walking or biking), at/near home, and somewhere else away from home but not during transportation (for future brevity, away from home). This thesis also seeks to quantify the students' level of interest in physical activity through thresholds of aerobic steps. These goals are accomplished through the combined use of GPS and accelerometers as well as a questionnaire as discussed in further detail in the following chapter.

3. METHODOLOGY

College students are a critical group to reach regarding physical activity because they are at the stage in their lives where they begin to form independent behaviors that will carry through much of their adult lives. It is important for them to understand their physical activity needs, and they are more susceptible to be influenced by changes in their built and social environments (Dyck, *et al.* 2011).

Therefore, this study focused on collecting a unique set of data from students at Auburn University (AU) during the fall 2012 academic semester. Student volunteers were recruited (with the incentive of receiving a personal physical activity summary) through engineering and kinesiology classes (as well as by word of mouth). They carried with them, either on their person or in their bag, a QSTARZ BT-Q1000XT GPS Travel Recorder and an Omron HJ-720ITC Pocket Accelerometer constantly between a Monday and Thursday. The GPS Travel Recorders used a vibration sensing technique to detect movement (QSTARZ, 2013). Similarly, the pocket accelerometer utilized a specialized movement technology with double sensors. With these advanced technologies, carrying the devices in a bag worked just as effectively as carrying them on person. As soon as the participants were given the devices, the units began logging location and physical activity information. The accelerometer devices measured vertical acceleration and recorded it as “counts”. Therefore, essentially every step taken by an individual was counted by the accelerometer he or she was wearing. Specifically, the devices were able to record the number of anaerobic, or non-physically active, and aerobic, or physically active steps, per hour once calibrated. To evaluate the intensity of an activity, aerobic-only (i.e. high intensity) counts were examined over a time interval. A large amount of steps or counts over a short time period indicated an intense physical activity. In order to calibrate the accelerometers, the weights and natural walking strides of the participants were obtained using a scale and a ten-foot stride-measuring distance, respectively. With these measurements plugged into the accelerometers, the units were able to distinguish between the two types of steps for each participant. These physically active steps were an unbiased method for observing physical activity data. In this study, the exact number of aerobic steps was not important; rather, the higher the number of aerobic steps, the more of an observed interest the participant had in physical activity in that location. Since both the GPS and accelerometer included timestamps, these pieces of technology could be combined for an intensity- location analysis. After the devices were returned, the corresponding GPS and accelerometer data was recorded.

Of the four days of data collection, only the data from Tuesday and Wednesday were used in this analysis. This was done to eliminate any anomalies due to the novelty of the devices on the first day (Monday) of data collection and to disregard the partial day data collected on the return day (Thursday). In addition, Tuesday and Wednesday each represent one of the two types of typical school days at Auburn University. At the University, most classes are either offered on Monday, Wednesday, and Friday or Tuesday and Thursday. Monday, Wednesday, and Friday classes meet for 50 minutes, while Tuesday and Thursday classes meet for 75 minutes. The specific dates of the data collection are provided on the following page in Table 3.1.

Table 3.1: Dates of Data Collection

Start Day	End Day
September 17th	September 20th
September 24th	September 27th
October 1st	October 4th
October 22nd	October 25th
October 29th	November 1st
November 5th	November 8th

As mentioned before, the collection of GPS data can be hindered by signal dropouts or loss of battery life. In the collected data, very few signal drops were detected. However, in order to adjust the data for when a signal drop did occur, the last point of data before a signal drop was assumed to be constant throughout the gap up until the first point after the signal drop. To avoid dead batteries, participants were given a USB cord to charge the GPS units with a computer overnight. A text or email reminder was sent to each participant to remind him or her to charge their unit once at home for the night.

Much of the dataset creation was done through a geographic information system (GIS) analysis. First, the students' addresses were geocoded to road layers from Lee County, Alabama. Next, the distance from each home location to the centroid of the university campus was calculated. To do this, the average x-coordinate and average y-coordinate were determined for each of the academic buildings within the core of the AU campus, which is surrounded by four main roads: Samford Avenue, College Street, Magnolia Avenue, and Donahue Drive. An average of these x and y coordinates was then computed to provide an x and y coordinate location for the campus centroid. With the addresses correctly geocoded and with the location of the campus centroid, the distances from each address to the centroid of campus were calculated using the distance formula:

$$D = \sqrt{(x_i - X)^2 + (y_i - Y)^2}$$

Where D is the distance, x_i is the x-coordinate of address i, y_i is the y-coordinate of address i, X is the x-coordinate for the campus centroid, and Y is the y-coordinate for the campus centroid. Home locations were then overlaid with census block groups and land use designations collected from the city of Auburn. Census block group data from the American Community Survey and the 2010 census were also added to the layers. Finally, the GPS collected location points for each respondent were added along with building footprints and locations of interest. This GPS data was then matched with the corresponding accelerometer data to identify where physical activity took place. Places of physical activity were broken down into three categories: during transportation, at/near home, or away from home. Physical activity occurring during transportation was clearly recognizable from the GIS map, as it showed data points in a trail pattern. With the addresses on the map, the physical activity data recorded at/near the students' home was also easily identifiable. All other points of physical activity fell into the final category, away from home.

In addition to the GPS and accelerometer data collected, the student participants were asked to complete a questionnaire about their travel and physical activity behaviors. In order to gauge the students' health and lifestyle characteristics, they were asked several questions pertaining to their past and present physical activities. To examine travel behaviors, the students were asked to provide how many days per week they traveled to and from campus by each mode (walk, bicycle, car, Tiger Transit – the name of AU's bus transit service, or other). The students also described how walkable they observed their neighborhood to be. Perceived distances to many destination types were also collected. In addition, students were asked to provide their local address for the GIS analysis. From the questionnaire data, the questions were coded into variables, and two types of statistical analyses were performed. First, linear regression was used to examine the significance of the variables on physical activity. Second, a discrete choice model was utilized to determine the significance of the variables on mode choice. The specifics of these analyses and the results are discussed in greater detail in Chapters 5 and 6, respectively.

4. SAMPLE

After removing incomplete surveys, GPS recordings, or accelerometer errors, the final data set included physical activity interest levels (characterized by aerobic step counts) across the three locations for 77 students. Of the 77 students in this final dataset, 12% were grad students, 88% were undergraduate students, 47% participated through the Civil Engineering department, and 53% participated through the Kinesiology department. One concern was that with a self-selected panel that each person would be predisposed to physical activities. However, 13 participants did not record any physical activities (no aerobic steps were logged) over their two study days. Table 4.1 provides the percentage of participating students and the average activity in steps for each of the three locations as well as for combinations of the three. As one can see, many people participated in physical activities in multiple locations. Interestingly, the largest percentage of students obtained their physical activity during transportation. However, the highest average activity was found to take place at/near home.

Table 4.1: Percentage of Students and Average Activity by Location

Location of Physical Activity Interest			Percentage of Records	Average Number of Active Steps
During Transportation	At/Near Home	Away From Home		
√			23%	3484
	√		17%	4126
		√	9%	2887
√	√		14%	3805
√		√	8%	3186
	√	√	4%	3507
√	√	√	7%	3499
			17%	0

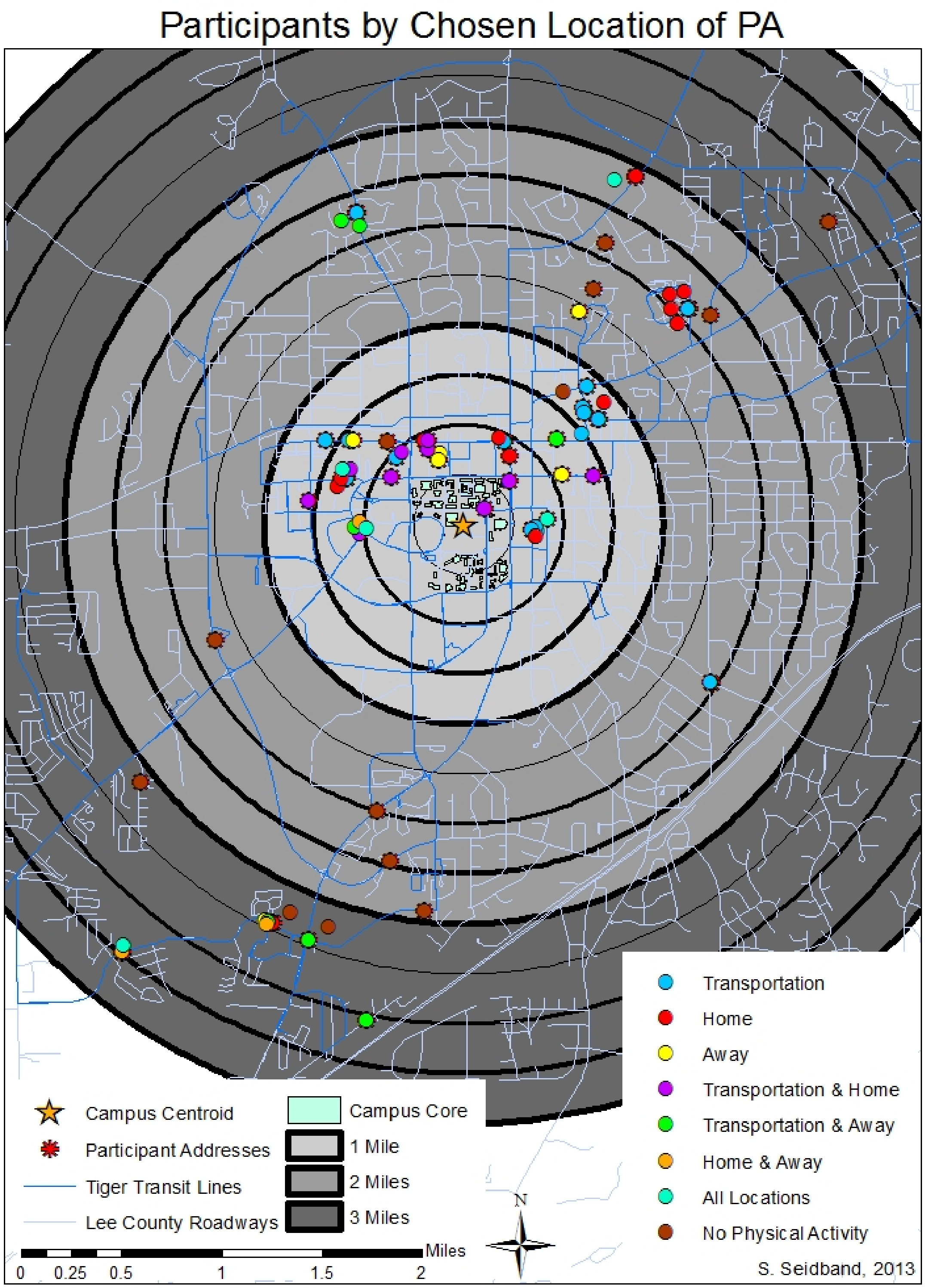

Figure 4.1: Map of Participants by Chosen Location of Physical Activity

As seen in Table 4.1, the participants could fall into 1 of 8 physical activity categories by location. Figure 4.1 on the previous page provides a map of the participants based on these categories. As seen in the map, each category is represented by a different colored circle displayed on or around each participant's address. Interestingly, all of the participants who only did physical activity during transportation (represented by the blue circles) live within 1.75 miles of the campus centroid. This suggests that these participants got their physical activity traveling to and from campus. Participants who only did physical activity at home (represented by the red circles) live a wide range of distances from the campus centroid from less than a half mile to more than two miles. This suggests that many people prefer to obtain physical activity at home regardless of their home distance. Most of the participants who did not record any physical activity (represented by the brown circles) live further than a mile from the campus centroid. This suggests that many of these people lived too far to obtain their physical activity traveling to campus, and therefore, they did not obtain any physical activity.

All of the remaining symbols on the first map remain constant for every map provided in this paper. First, each ring around the campus core represents a quarter-mile radius distance. To distinguish the distances, each mile is shaded differently, from light to dark. Within each mile, the ring for each half-mile is outlined differently, from thin to thick. Second, the buildings of the campus core are outlined around the campus centroid, which is denoted by the star. Finally, the heavy lines represent all Tiger Transit routes, and the lighter lines represent all Lee County Roadways.

Looking at the physical activity data, some important trends were found by collection day for each of the three locations of physical activity. Several charts showing participant aerobic steps versus hour of the day were created to illustrate these trends. First, comparing the during transportation activity for Tuesday, which is displayed in Figure 4.2, to Wednesday, which is displayed in Figure 4.3, more physical activity took place on Wednesday. However, higher amounts of aerobic steps were recorded on Tuesday. Second, comparing the at/near home physical activity for Tuesday, which is displayed in Figure 4.4, to Wednesday, which is displayed in Figure 4.5, similar amounts of physical activity took place on both days. However, as with the during transportation physical activity, higher amounts of aerobic steps were recorded on Tuesday. Third, comparing the away from home physical activity for Tuesday, which is displayed in Figure 4.6, to Wednesday, which is displayed in Figure 4.7, similar amounts of physical activity took place on both days as with the at/near home physical activity. As with the previous two locations of physical activity, higher amounts of aerobic steps were recorded on Tuesday. Figures 4.8 and 4.9 provide all of the collected physical activity for Tuesday and Wednesday, respectively. It can be seen clearly in these two charts that higher amounts of aerobic steps were recorded on Tuesday. This suggests that the participants were much more interested in the physical activity they were obtaining on Tuesday than the physical activity they were obtaining on Wednesday. For a final illustration, Figures 4.10 and 4.11 were created to compare each individual participant's Tuesday and Wednesday physical activity. As seen in these Figures, each participant who recorded physical activity data is represented by one row in the z-axis.

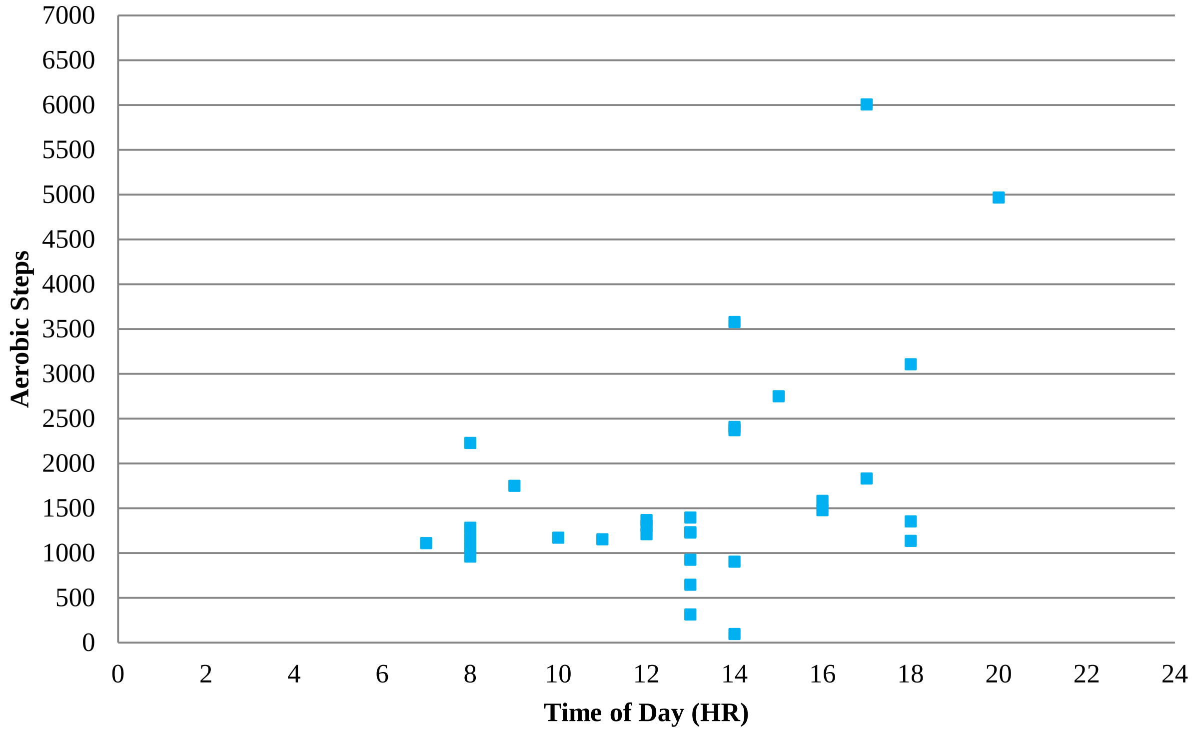

Figure 4.2: Tuesday During Transportation Physical Activity Data

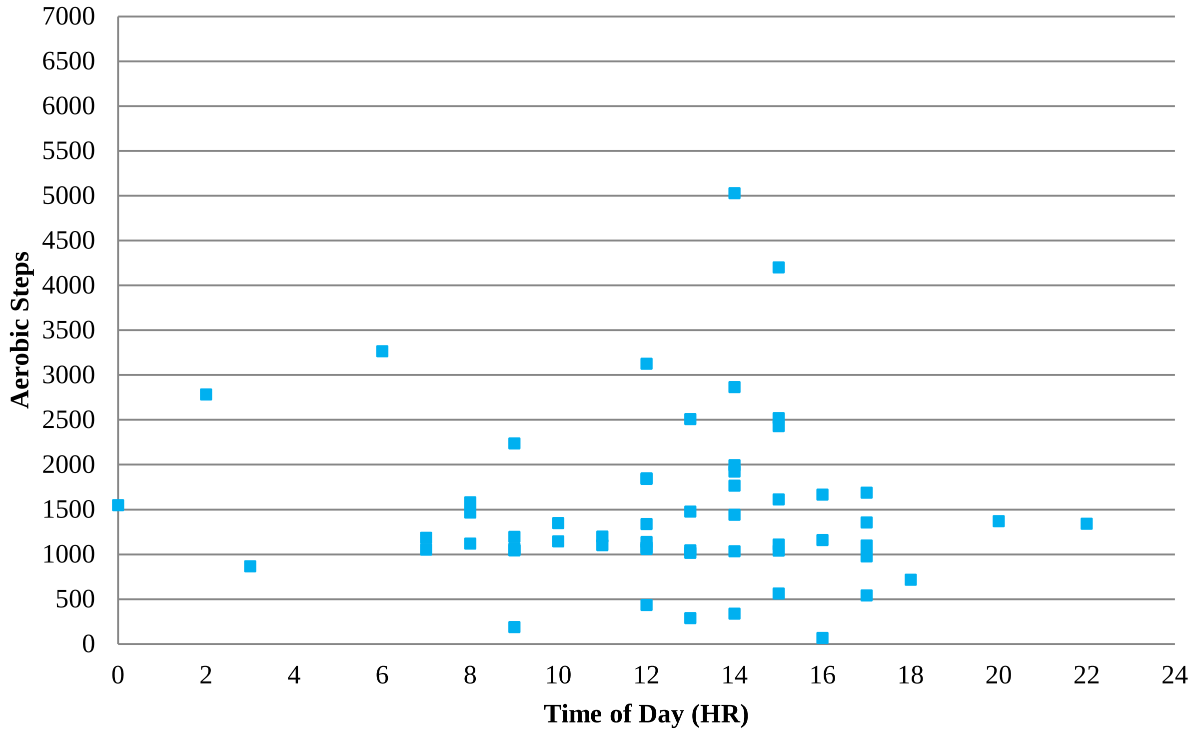

Figure 4.3: Wednesday During Transportation Physical Activity Data

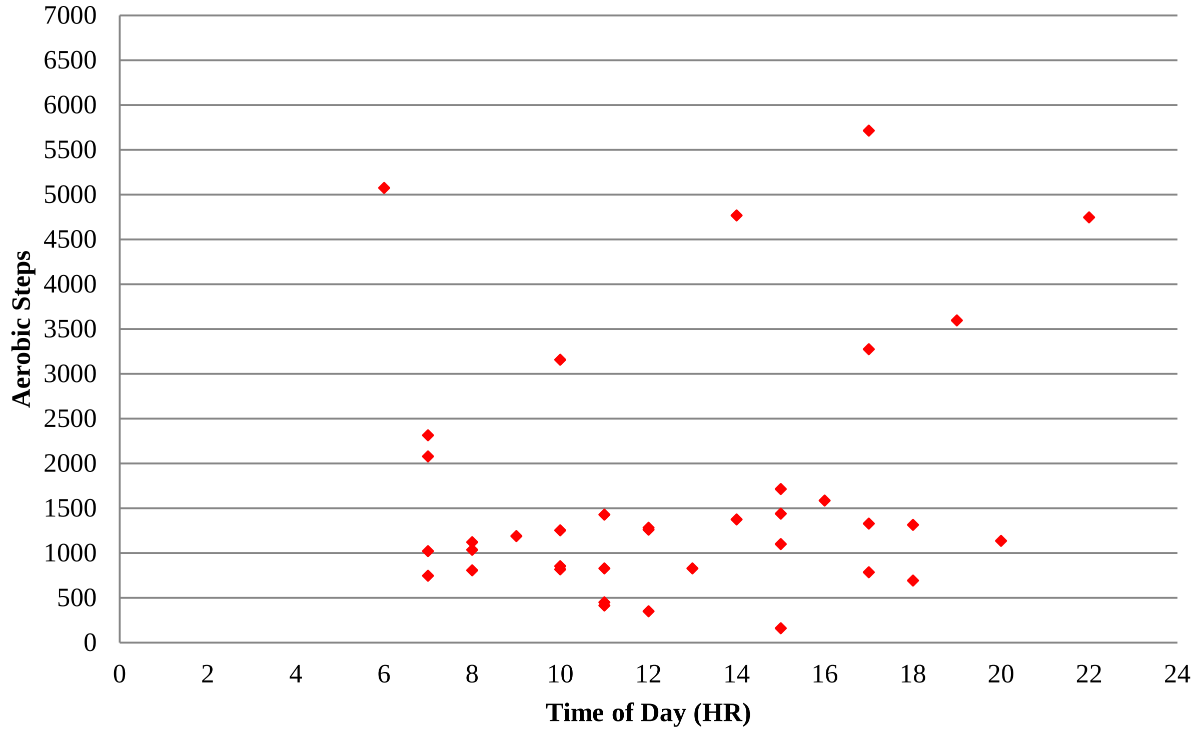

Figure 4.4: Tuesday At/Near Home Physical Activity Data

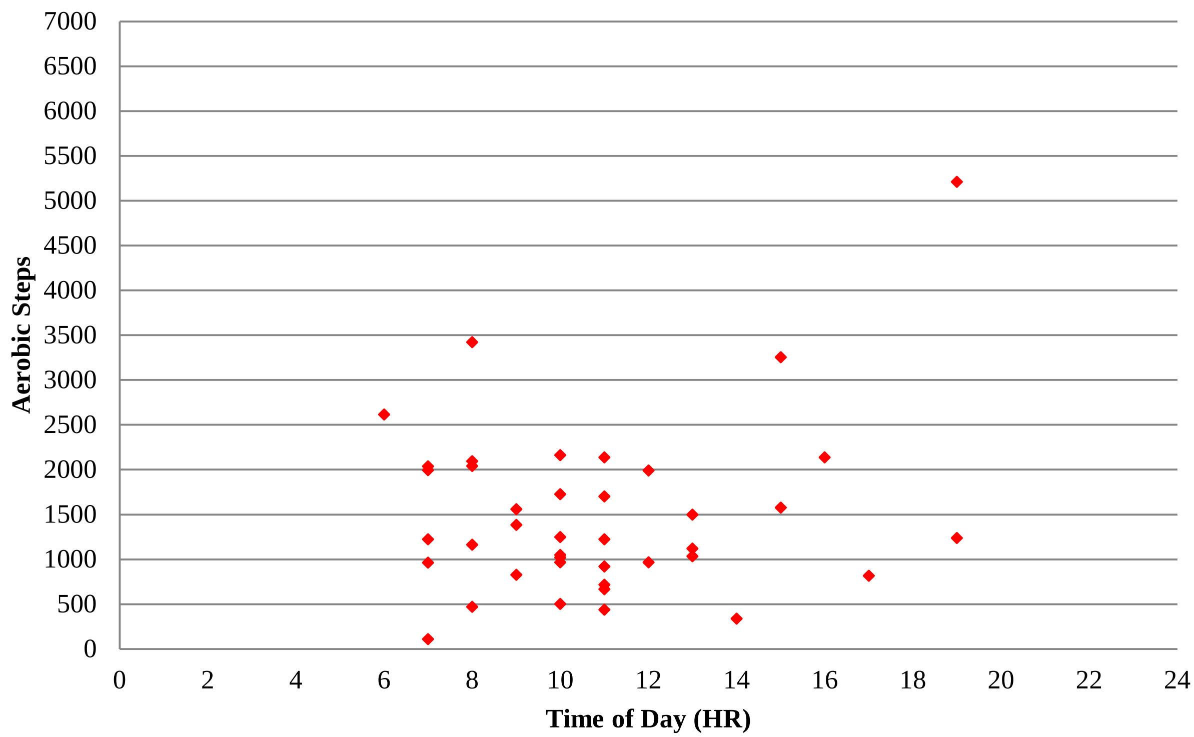

Figure 4.5: Wednesday At/Near Home Physical Activity Data

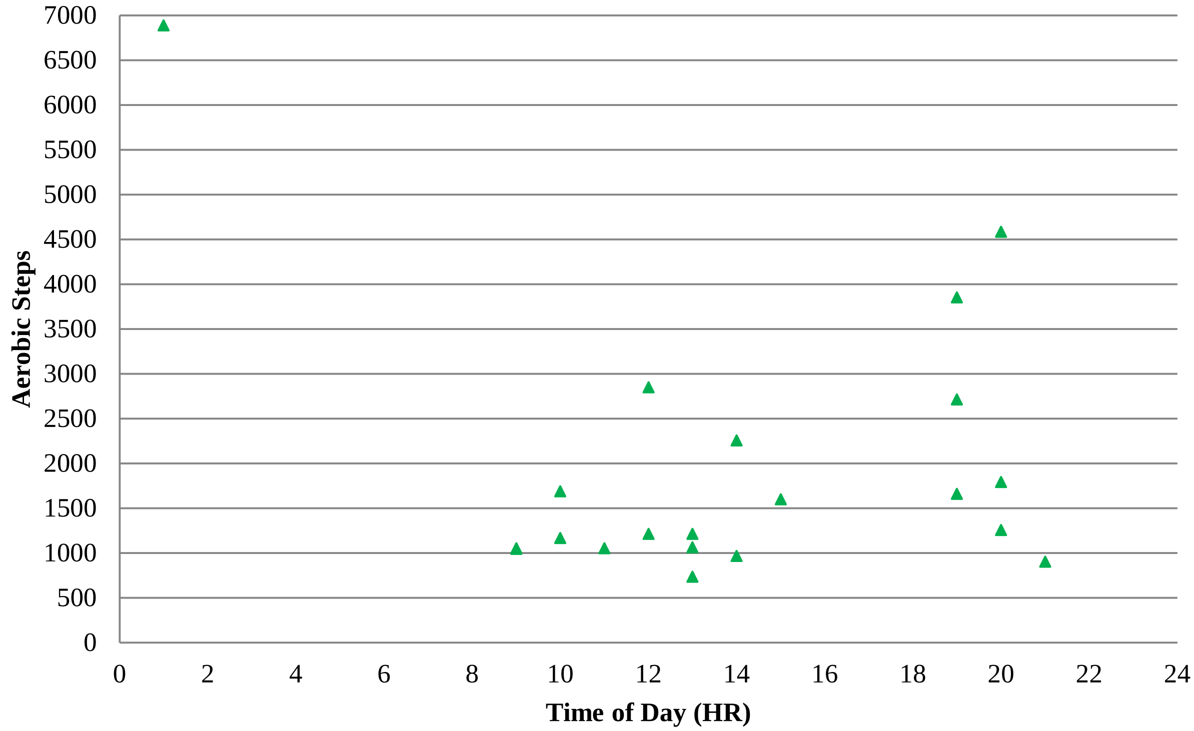

Figure 4.6: Tuesday Away From Home Physical Activity Data

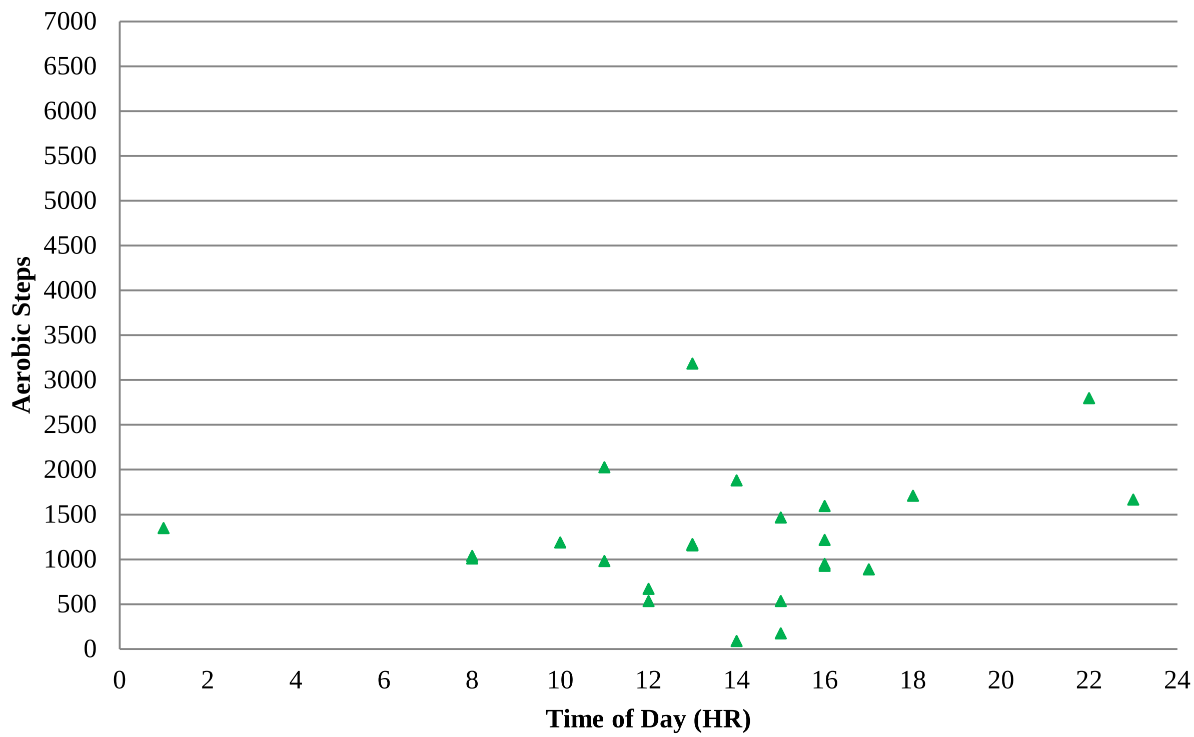

Figure 4.7: Wednesday Away From Home Physical Activity Data

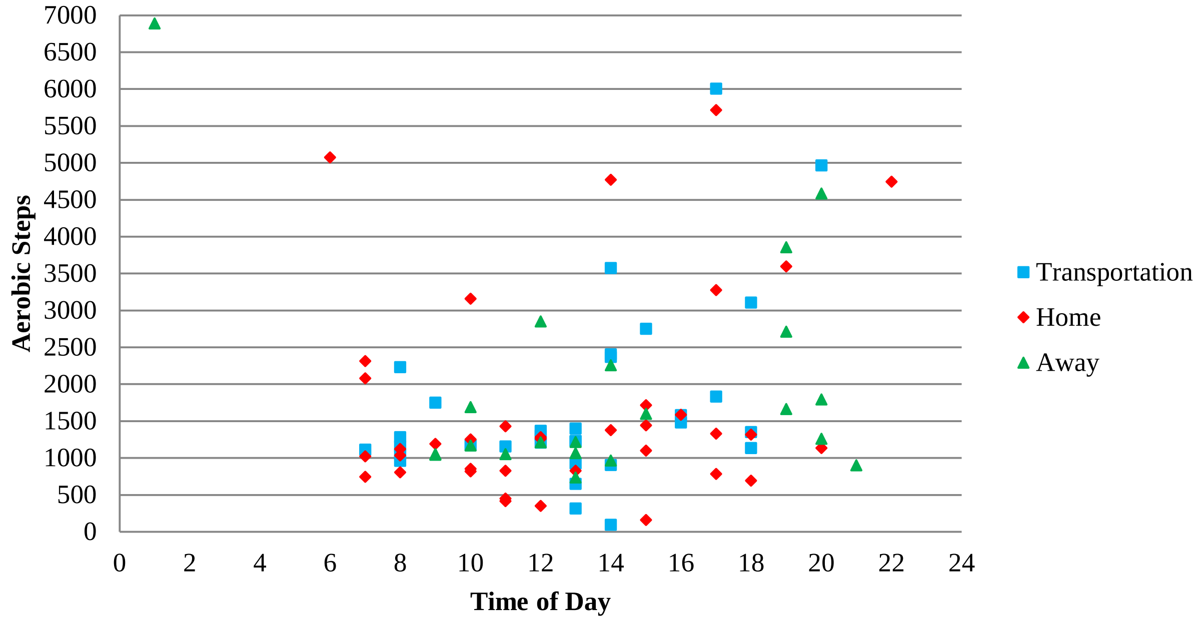

Figure 4.8: Tuesday Physical Activity Data

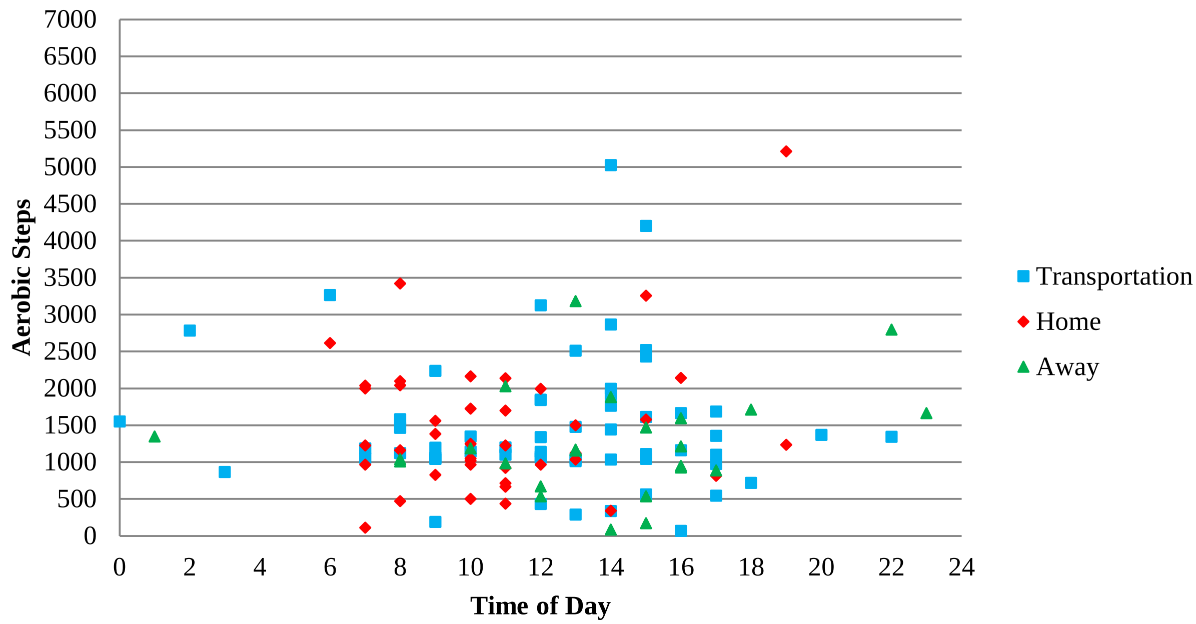

Figure 4.9: Wednesday Physical Activity Data

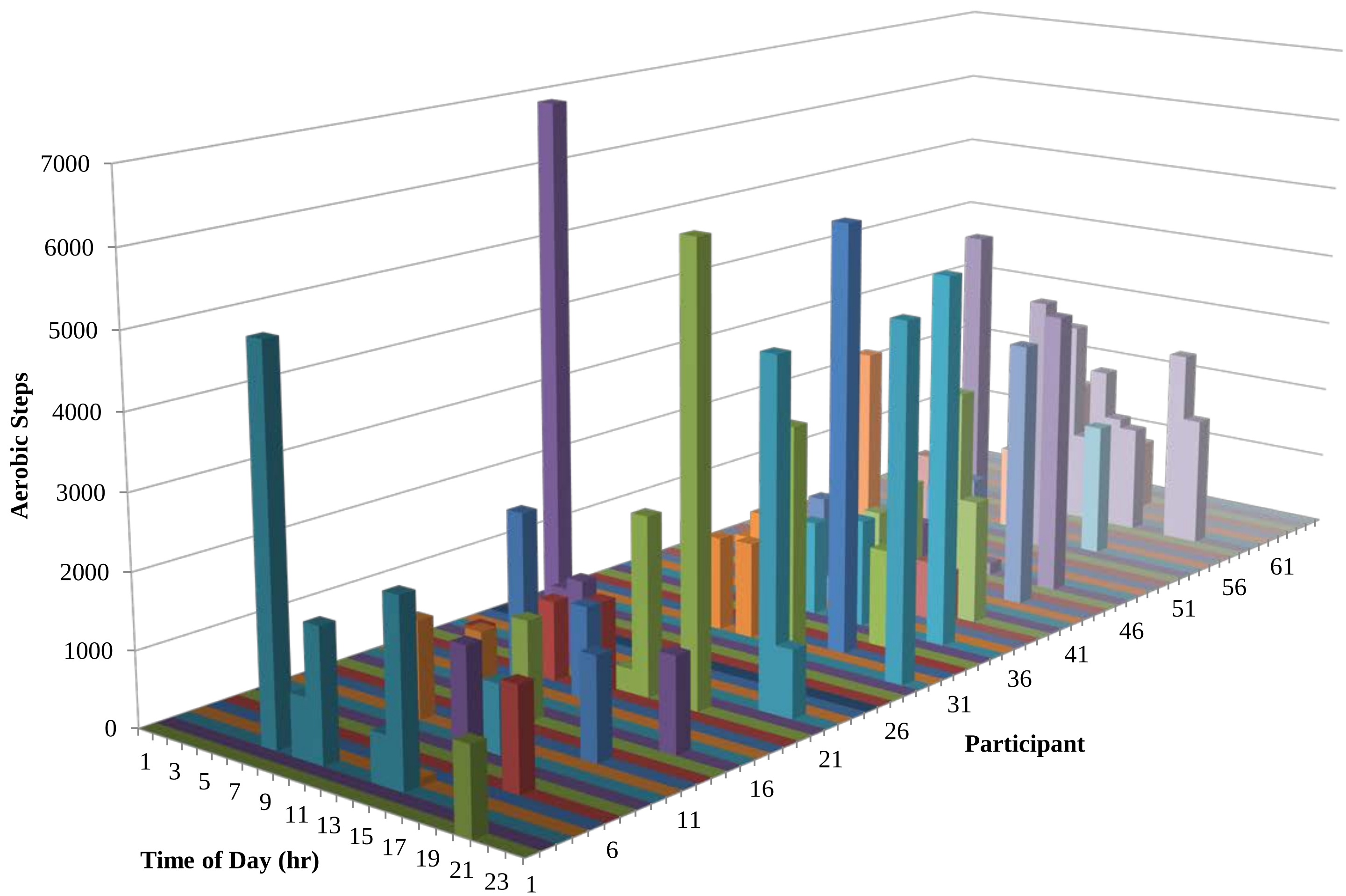

Figure 4.10: Participant Tuesday Aerobic Steps by Hour

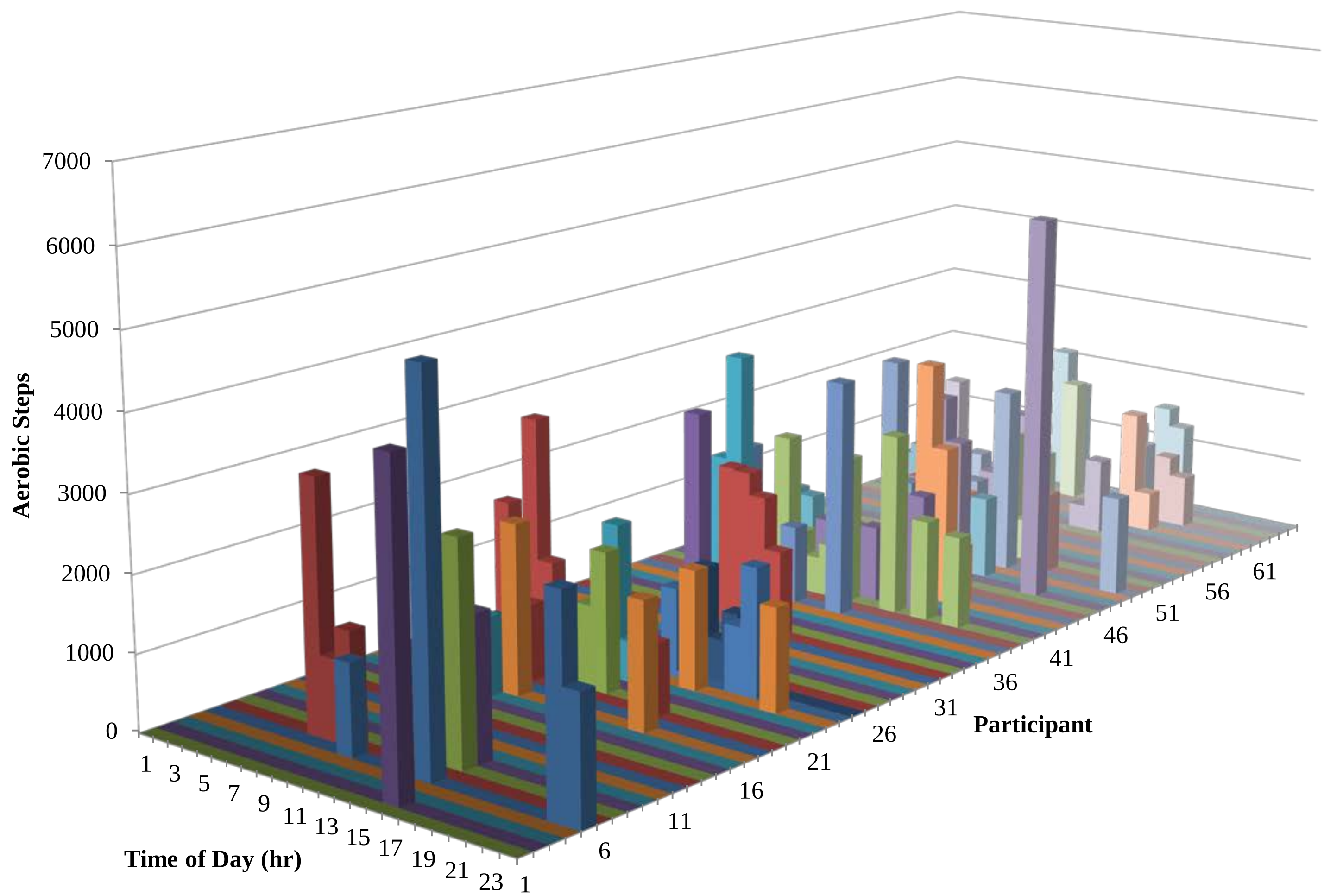

Figure 4.11: Participant Wednesday Aerobic Steps by Hour

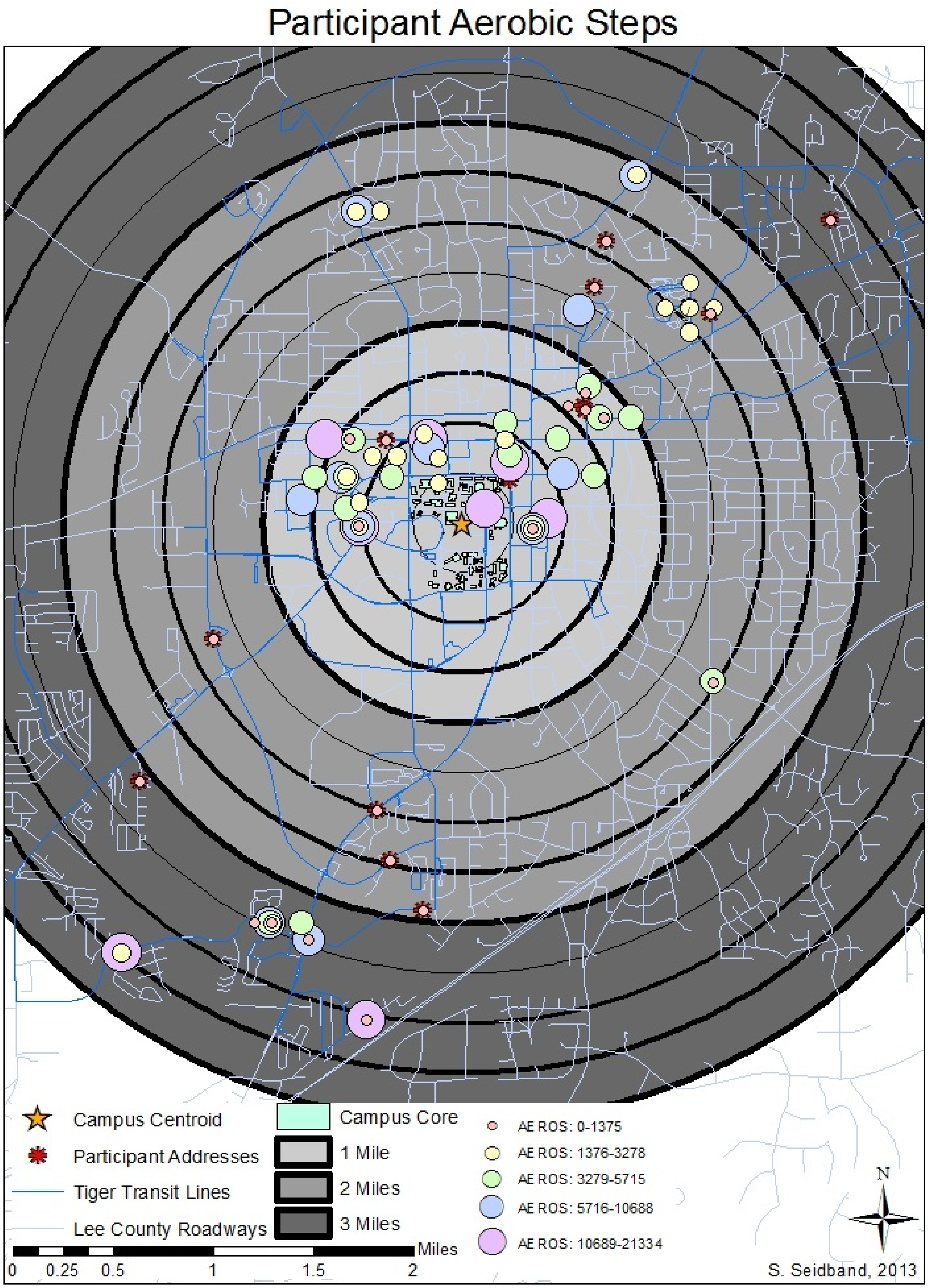

Figure 4.12: Map of Participants Comparing Aerobic Steps to Distance from Campus

A very important observation to be made in this research is the comparison of student participants' aerobic step levels to students' home distances from campus. Figure 4.2 on the previous page provides a map of the participants based on the amount of aerobic steps they did during the data collection period. These data points are displayed as circles on or around the students' addresses, shown as large asterisks, to allow for a comparison of aerobic steps to home distances from campus. As seen in the map, the participant aerobic steps are broken down into five threshold levels: 1) 0 – 1375 aerobic steps, 2) 1376 – 3278 aerobic steps, 3) 3279 – 5715, 4) 5716 – 10688 aerobic steps, and 5) 10689 – 21334 aerobic steps. Also, note on the map that the circles grow from small to large based on the threshold level of the aerobic steps.

These levels were determined by a "natural break" histogram (provided in Figure 4.2 below), which was created in GIS. The program picks the natural break points by minimizing the variance within each threshold and maximizing the variance between the thresholds. As seen in Figure 4.2, the distance between breaks grows as the number of aerobic steps increases. This is due to fewer people having higher levels of aerobic steps.

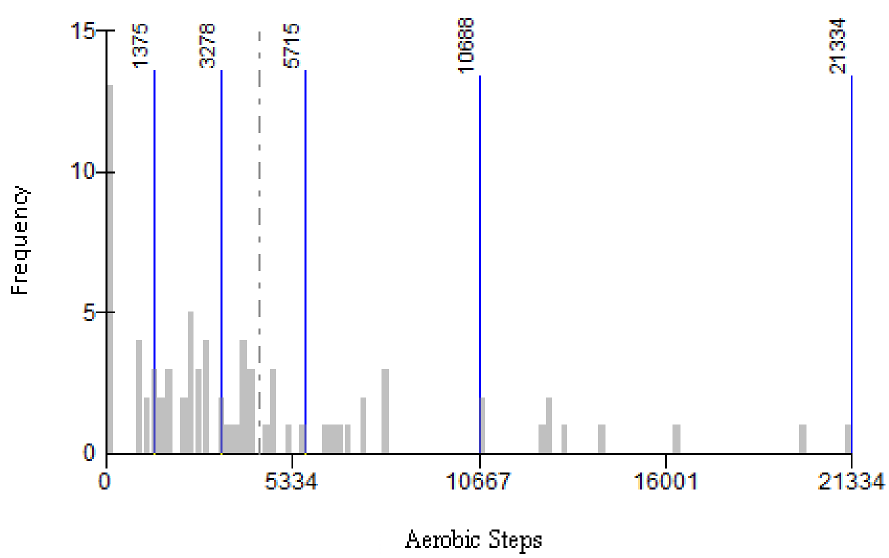

Figure 4.13: Histogram of Participant Aerobic Steps

Table 4.2: Mode Choice Frequencies and Percentages

Mode	Frequency	Percent
Walk	36	47
Bike	6	8
Car	15	19
Tiger Transit	16	21
Other	4	5
Total	77	100

In order to observe student mode choices in relation to home address distances from campus, a map has been provided displaying participants by each mode choice: walk, bicycle, car, Tiger Transit, and other. The average distances to the campus centroid from the participants' home addresses were 0.88 miles, 0.77 miles, 1.45 miles, 1.43 miles, and 1.76 miles for walk, bicycle, car, Tiger Transit, and other, respectively. Each participant observation, displayed on the map as a circle on or around the student's address, is represented only once on 1 of the 5 maps based on which mode the student said he or she used most to get to and from campus on a normal week. First, Figure 4.3 provides a map of the participants who said they walk to and from campus. As seen in Table 4.2 above, this group of participants represents 47% of the sample. Looking at the map, 29 of the 36 students who walk to and from campus live within a mile of the campus centroid, and only 3 of the 36 who walk live further than two miles from the campus centroid. Second, Figure 4.4 provides a map of the participants who said they bike. As seen in Table 4.2, this group of students represents 8% of the sample. Looking at the map, 5 of the 6 students who bike to and from campus live within a mile of the campus centroid, and none of them live further than a mile and a half from the campus centroid. Third, Figure 4.5 provides a map of the participants who said they drive to and from campus on a normal week. As seen in Table 4.2, this group of participants represents 19% of the sample. Looking at the map, 12 of the 15 students who drive to and from campus live further than a mile from the campus centroid, and none of them live within a half-mile of the campus centroid. Fourth, Figure 4.6 provides a map of the participants who said they took Tiger Transit. As seen in Table 4.2, this group of students represents 21% of the sample. Looking at the map, 10 of the 16 students who take Tiger Transit live further than a mile from the campus centroid, and none of them live within a quarter-mile of the campus centroid. Finally, Figure 4.7 provides a map of the participants who said they used a mode of transportation other than walking, biking, car, or Tiger Transit to get to and from campus on a normal week. Although the participants who selected other as their mode choice were not asked to specify what exactly they used to get to and from campus, it is assumed that they drove a motorcycle or motorized scooter. This is because the parking for these vehicles is very abundant on the AU campus, unlike the parking availability for cars. As seen in Table 4.2, this group of participants represents 5% of the sample. Looking at the map, 3 of the 4 students who use another mode to get to and from campus live further than a mile and a half from the campus centroid, and all of them live further than a mile from the campus centroid. Therefore, based on these maps alone, it can be seen that distance from campus plays a major role in student commuter mode choice. If a student lives within a mile of the campus centroid, he or she likely walks or bikes to campus. However, if a student lives further than a mile from campus, he or she likely drives, takes the Tiger Transit, or uses a mode other than the four mentioned.

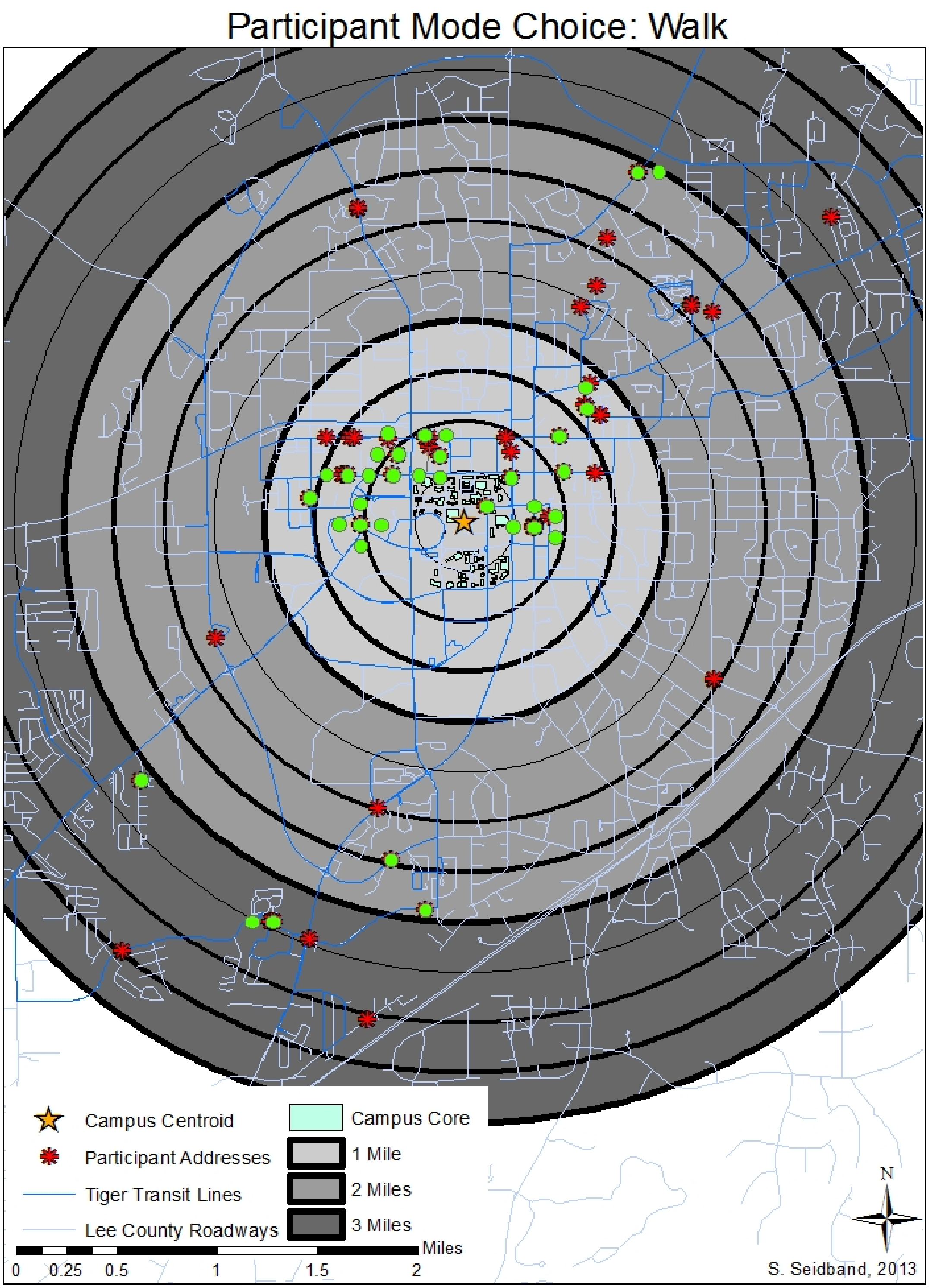

Figure 4.14: Map of Participants Who Walk to/from Campus

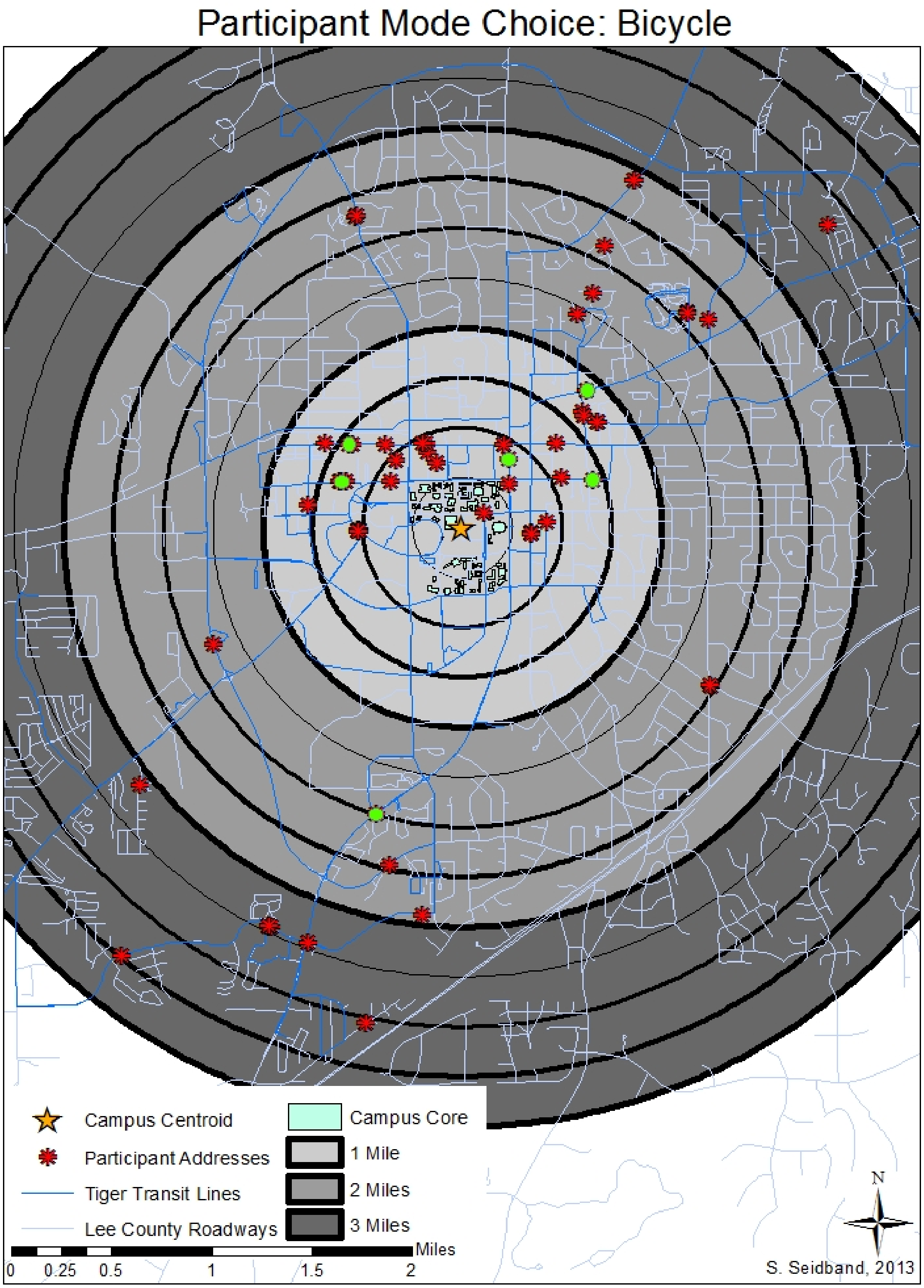

Figure 4.15: Map of Participants Who Bike to/from Campus

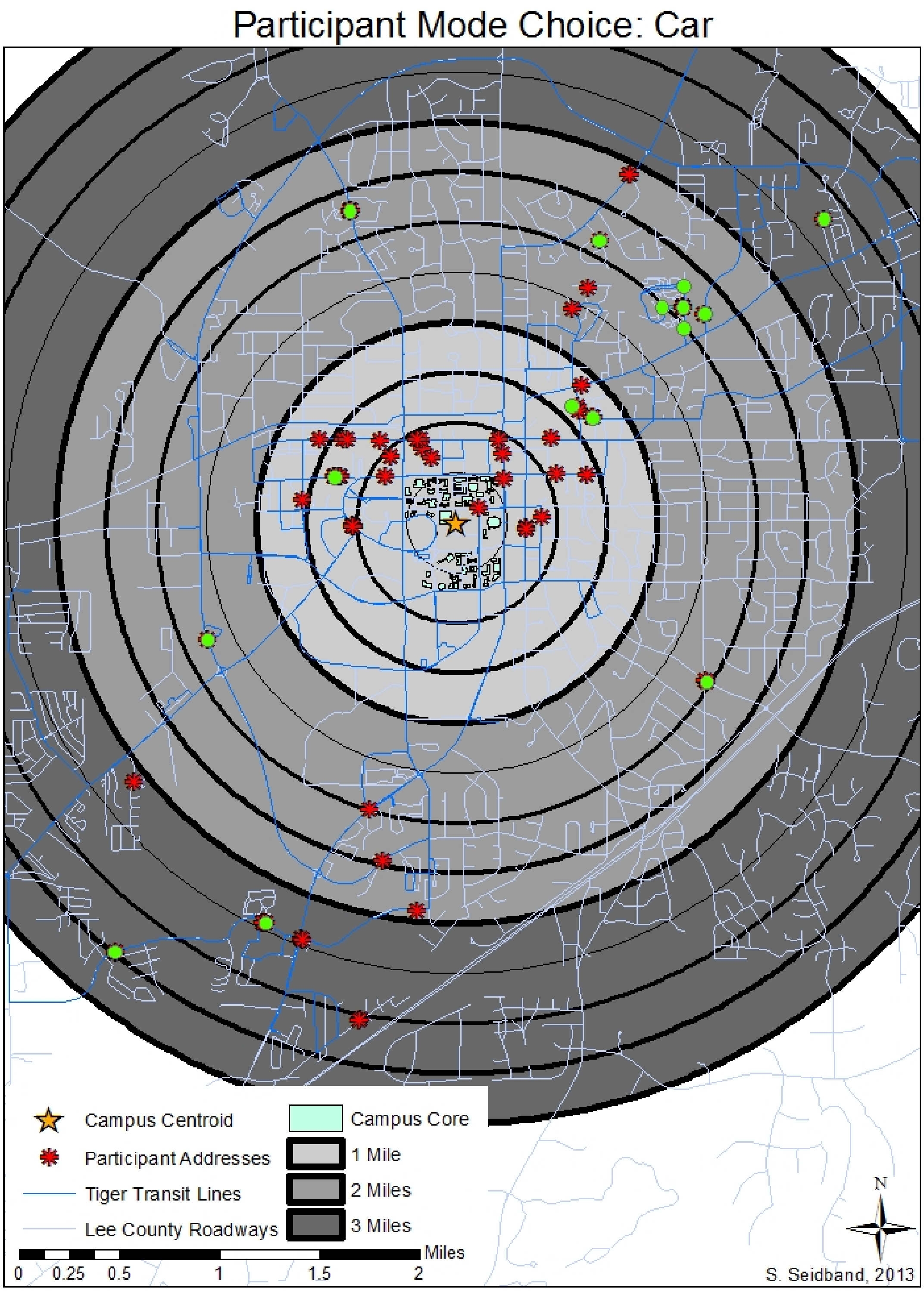

Figure 4.16: Map of Participants Who Drive to/from Campus

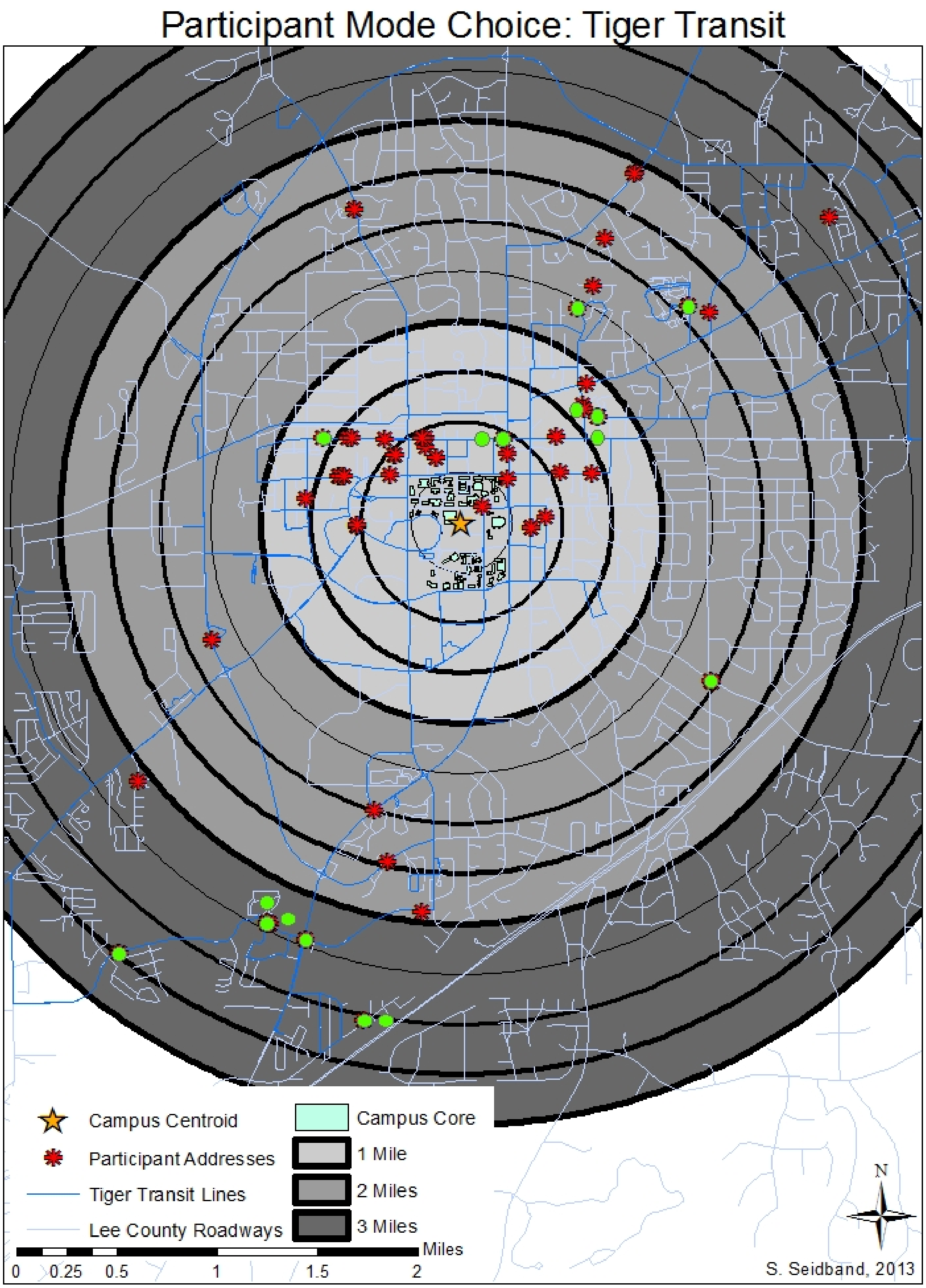

Figure 4.17: Map of Participants Who Take Tiger Transit to/from Campus

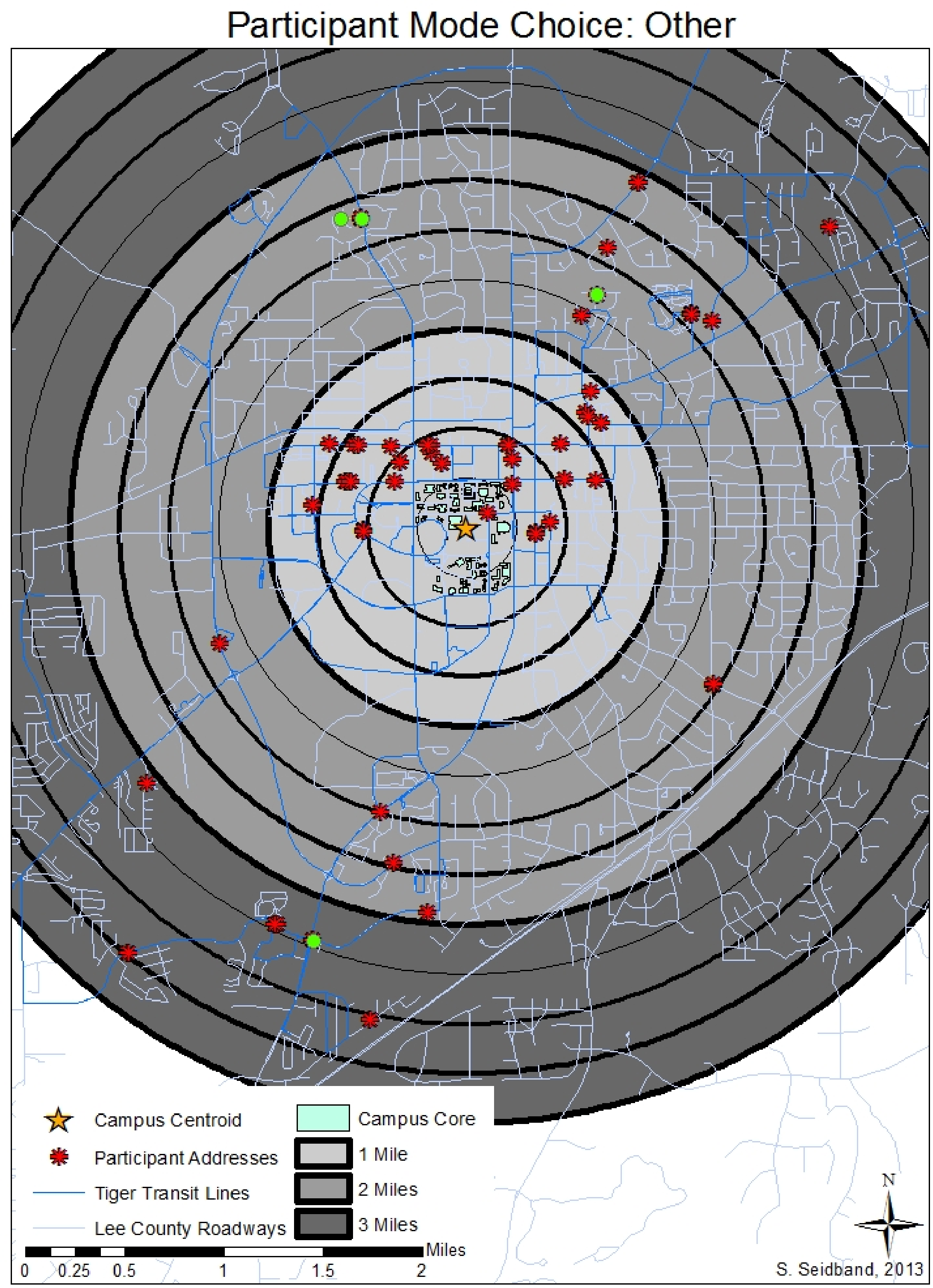

Figure 4.18: Map of Participants Who Use Other Modes to/from Campus

In addition to the mode choice maps, two charts were created for a graphical representation of the participants compared to distance from campus by mode. The first of these, Figure 4.8, is a line chart that compares the cumulative percentage of participants by distance from campus for each mode. As seen in the chart, the line representing students who walk to and from campus sharply rises to about 75% within the first mile and then steadily climbs to 100% from 1 to 2.25 miles. Similarly, the line representing students who bike quickly increases to 75% within three quarters of a mile and then reaches 100% by 1.5 miles. The line for car begins to rise after a half-mile, sharply increases from 30% at 1.5 miles to 80% at 1.75 miles, and then gradually continues up to 100%. The line for Tiger Transit progressively grows from 0% at the centroid of campus to 100% at two and three-quarters miles. The line for other remains at 0% through 1.25 miles and then increases up to 100% within the next mile. Therefore, as concluded from the maps, distance from campus plays a major role in student commuter mode choice. Specifically, a one-mile distance appears to be the cut-off point between walking or biking and using another mode, as this is where their cumulative probabilities level off and the other modes start to dramatically increase.

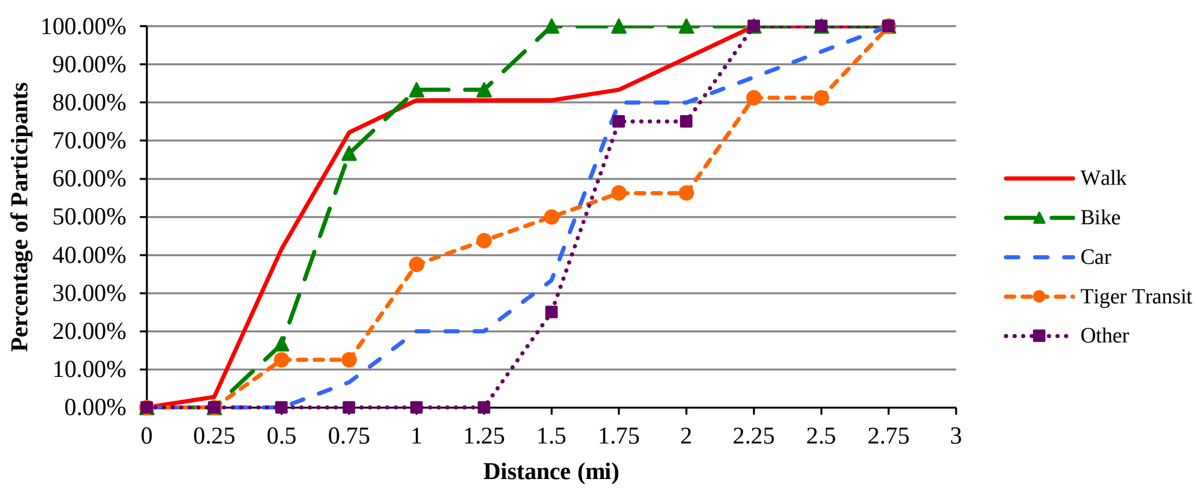

Figure 4.19: Cumulative Percentage of Participants by Distance from Campus

The second graphical representation, Figure 4.9, displays the same information as Figure 4.8 but does so through a column chart instead of a line chart. As seen in the chart, each mode is represented as an individual column, and the distances are displayed using a gray scale, where the color becomes lighter as the distance increases. The columns representing walk and bike are much darker than the other three, as the majority of students who chose these modes live close to campus. Contrarily, the columns representing car, Tiger Transit, and other modes are much lighter than the other two, as the majority of students who chose these modes live further away from campus. The shade representing one-mile from campus (the fourth darkest gray) appears close to the top of the walk and bike columns and towards the bottom of the car and Tiger Transit columns. As mentioned before, this one-mile distance seems to be the point where students opt to drive, take Tiger Transit or use another mode rather than walk or bike to campus.

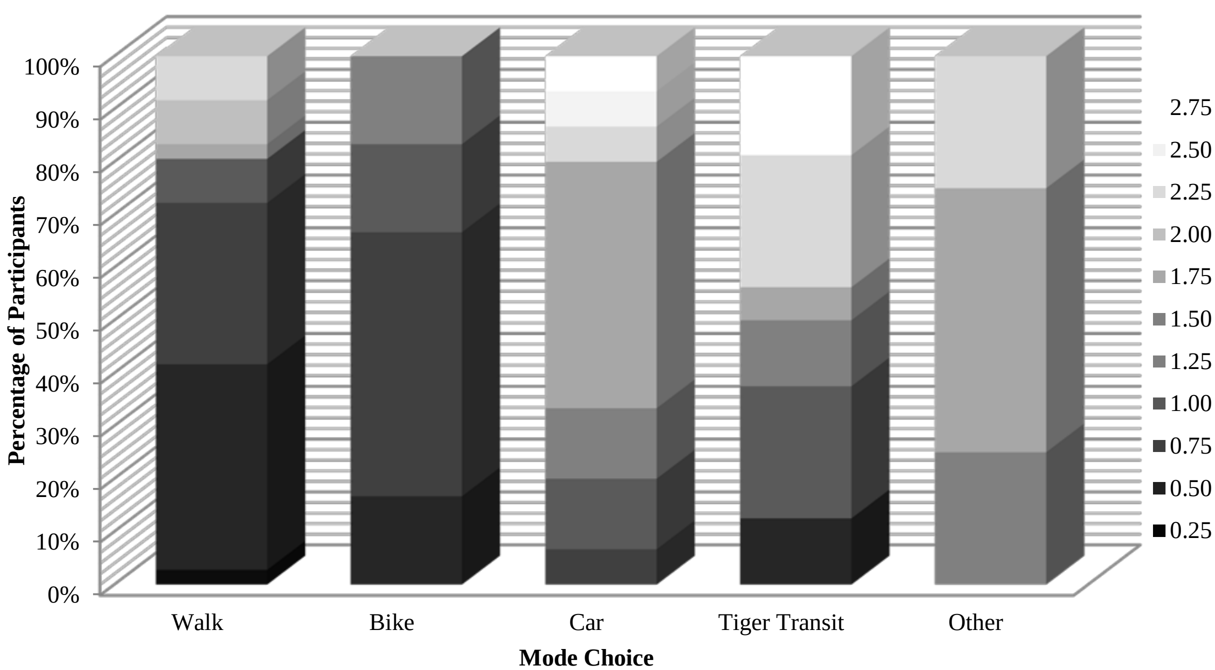

Figure 4.20: Cumulative Percentage of Participants by Mode per ¼ Mile from Campus

5. LINEAR REGRESSION MODEL ESTIMATION

In order to compare the dependent variables, aerobic steps (an observed surrogate for interest level) at/near home, during transportation, and away from home, with the independent variables, including participant physical activity information and neighborhood perceptions obtained from the questionnaires as well as demographic data acquired from the U.S. Census Bureau, three linear regressions were estimated. This method was preferred because it provided the relative importance of each of the different factors on the three locations of physical activity. The relationships between interest level and participant characteristics were assumed to be linear, and the variables followed relatively normal distributions. For physical activity during transportation, at/near home, and away from home, the R^2 value was calculated to be 0.57, 0.91, and 0.55, respectively. These regressions are relatively good fits as at least half of the variability is accounted for in each model. The results are presented in Table 5.1 at the end of this chapter and discussed in detail in the following sections.

5.1 Factors Influencing Physical Activity Done During Transportation

This first model predicts the level of interest in participating in physical activity during transportation, such as walking or cycling. In most cases this activity was done over short distances with high intensity and accumulated over the day. This category can be interpreted as either the most dedicated physical activity (e.g. the cyclists who commutes to work/class) or the most passive (e.g. the person who gets activity in walking throughout the day). Regardless, this behavior is important, as it emphasizes the need to build infrastructure to support both conscientiously and inadvertently active people.

Overall, built environment variables are more influential on transport-based physical activity than health and lifestyle variables. A participant's home being within walking distance of shops, stores, and markets, had a positive influence on physical activity done during transportation. A person would likely walk to these places rather than drive if he or she lives close enough to them. Alternatively, if a participant lives within walking distance of a transit stop, he/she would be less interested in transport-based physical activity. A student would likely utilize the transit service instead of walking or bicycling if a stop is conveniently located near his or her residence. The time it takes to walk from home to the nearest elementary school, fast food restaurant, bank, park, or to a job all had a negative influence on physical activity done during transportation. This is likely due to these places being too far away to travel from home by walking or biking. Contrarily, the time it takes to walk from home to the nearest pharmacy or recreational center both had a positive influence on physical activity done during transportation meaning that these places are likely located within a close enough proximity to the home to allow an individual to walk or bike if they so choose. Interestingly, as the distance from home to the core of campus increases, so does interest in physical activity done during transportation. Perhaps this indicates a level of residential self-selection, where those that want to pursue transport-activity select a home location further away that allows them to do so.

In the neighborhood, parked cars between the sidewalks and roadway and traffic along nearby streets negatively influenced physical activity during transportation. Both of these factors would discourage walking or bicycling in and around the neighborhood. However, the existence of low-cost recreational facilities in the neighborhood, sidewalks, and interesting things to look at while walking all positively influenced physical activity during transportation. These factors would influence walking or bicycling around the neighborhood (Carlson, *et al.* 2012; Fenton 2005; Dyck, *et al.* 2011).

A few health and lifestyle characteristic variables were significant as well. Smoking (Ford, *et al.* 2012) had a negative influence on transport-based activity, mainly due to the fact that this limits aerobic abilities. Physical activity in the past six months also had a negative influence on physical activity during transportation, which likely indicated that it was being done other than during transportation. The more days per week individuals took a vehicle other than a car or transit bus to campus, the less they participated in transport-activities. However, encouragement from family to be physically active and walking to work both had a positive influence on physical activity obtained through transportation. A person is more likely to do something if they are encouraged, and walking to work is, by definition, a form of physical activity during transportation.

5.2 Factors Influencing Physical Activity Done At/Near Home

This second model predicts the level of interest in participating in physical activity done at/near home, such as a home gym or doing strenuous housework. Additionally, these could happen near or around the home location. Here, the activities were for dedicated periods of time. Again, this category could be for dedicated athletes or for individuals who are getting exercise by doing their normal routine. This behavior is important because it emphasizes the livability around the home.

Similar to the previous regression, built environment variables significantly influenced physical activity done at/near home more than health and lifestyle variables. Again, if a participant's home was within walking distance of shops, stores, and markets they were more interested in pursuing physical activity at/near home. This is likely due to the convenience of these places allotting a person more time to partake in physical activity at/near home. Alternatively, the time it takes to walk from home to the nearest convenience store, non-elementary school, bank, non-fast food restaurant, park, or to a job all had a negative influence on physical activity done at/near home. However, the time it takes to walk from home to the nearest grocery store, laundry/dry cleaners, post office, bookstore, fast food restaurant, and gym or fitness facility all had a positive influence on physical activity done at/near home. Clearly a good mix of land uses is not wholly conducive to physical activity being pursued at/near home. In addition, the distance from home to the core of campus had a positive influence on physical activity done at/near home. People who lived further from campus do not have easy access to the campus recreation center, so they will do their exercise at/near home to compensate.

Within the neighborhood, street lighting at night, crosswalks at busy corners, traffic along nearby streets, and crime rates (Sandy, *et al.* 2013) that makes it unsafe to walk at night all negatively influence physical activity at/near home. These characteristics make for an unpleasant environment that would encourage individuals to pursue all activities, and not just physical ones elsewhere. Fortunately a number of perceived facilities in the area encourage physical activity at/near home as well: low-cost recreational facilities, alternative routes, sidewalks (Carlson, *et al.* 2012), visibility of walkers and bikers, trees, and attractive buildings/homes all have a positive influence on physical activity at/near home. This is expected, as all of these factors are typically inviting and would therefore encourage someone to stay at/near home or within their neighborhood to do physical activity. Crime rate during the day also had a positive influence on physical activity at/near home. This could likely be caused by a person not wanting to leave their home unless they needed to because of the dangerous crime rate. Therefore, they chose to partake in physical activity at/near home.

Being currently physically active and days per week traveled to and from campus by walking all had a positive influence on physical activity at/near home. It is expected that factors such as these would promote physical activity in general. Being physically active for the past six months and intending to become more physically active within the next six months oddly had a negative influence on physical activity at/near home. This is likely do to physical activity being obtained elsewhere in the past and expected to occur elsewhere in the future.

5.3 Factors Influencing Physical Activity Done Away From Home

This third model predicts the level of interest in participating in physical activity away from home, most likely at a gym or during a long distance run. Of the three options, this physical activity type was the most repetitive and even across days. Individuals had to specifically seek out this type of physical activity and typically did so once per day. Regardless, this behavior is important, as it emphasizes the need to provide destination opportunities for people to have access.

Unlike the regression results for physical activity obtained during transportation and at/near home, the amount of built environment variables found to have a significant influence on physical activity done away from home was slightly less than the amount of health and lifestyle variables found to have a significant influence on physical activity done away from home. A participant's home being within walking distance of shops, stores, and markets had a negative influence on physical activity done away from home. This is likely due to the convenience of these places allotting a person more time to partake in physical activity at/near home, thereby not having to obtain physical activity elsewhere. The time it takes to walk from home to the nearest convenience store and elementary school had a positive influence on physical activity done away from home. This is likely due to these places being located near a place where physical activity could also be done, thereby allowing an individual to trip chain. The time it takes to walk from home to the nearest clothing store and recreational center had a negative influence on physical activity done away from home. This is likely due to these places being close enough to home that the person could partake in physical activity by walking or biking there or at the house.

For the neighborhood specifically, the existence of low-cost recreational facilities and drivers speeding had a negative influence on physical activity done away from home. If low-cost recreational facilities exist in a person's neighborhood, they have no reason to go somewhere else to do physical activity. The speeding drivers likely had a negative influence because their danger discourages an individual from leaving their home to do physical activity.

Several health and lifestyle characteristics variables had a significant influence on physical activity obtained away from home. Academic classification as a junior or senior, being physically active for the past six months, being encouraged by family to be physically active, and participating in competitive sports in high school all had a positive influence on physical activity away from home. For academic classification, this likely demonstrates that upperclassmen prefer to obtain physical activity away from their homes. This could also be due to an increased work load requiring them to stay on campus for extended periods of time, thereby influencing them to obtain their physical activity in their limited free time on campus. The other three variables were expected to produce a positive influence on physical activity away from home simple because they demonstrate physically active characteristics in an individual. However, participation in competitive sports in elementary school, participation in competitive sports in college, days per week traveled to and from campus by car, and days per week traveled to and from campus by bicycle all had a negative influence on physical activity away from home. The participation in both competitive sports in elementary school and college has a negative influence on physical activity away from home because the physical activity is likely obtained through transportation or possibly at/near home instead. The days per week traveled to and from campus by car variable negatively influences physical activity away from home because the physical activity is likely obtained at/near home. The days per week traveled to and from campus by bicycle variable negatively influences physical activity away from home because the physical activity is likely obtained during transportation.

Table 5.1 provides the results of these three physical activity location linear regressions. The columns on the right of the Table each represent 1 of the 3 linear regressions. The column on the far left contains all of the variables that were significant in at least one of the models. A blank space in one of the regression-specific columns indicates that the variable was not significant in that regression. Within each regression-specific column, there is a column for coefficient values and a column for t-statistic values. Positive t-statistic values imply that the variable positively influences physical activity in the given location, and negative t-statistic values imply that the variable negatively influences physical activity in the given location.

From these linear regressions, there are many key takeaway points. As seen in Table 5.1 many more built environment variables were found to be significant than health and lifestyle variables for both physical activity during transportation and at/near home. This emphasizes the fact that infrastructure should be built to support physical activity through transportation to accommodate individuals who obtain their physical activity this way. This also emphasizes the need for active and livable communities to accommodate those who choose to obtain physical activity at/near home. Also seen in Table 5.1, more health and lifestyle variables were found to be significant than built environment variables for physical activity away from home. This emphasizes the fact that physical activity destinations should be built to accommodate individuals who prefer to obtain their physical activity away from the home.

Table 5.1: Physical Activity During Transportation, At/Near Home & Away From Home

Activity Occurred:	**During Transportation**		**At/Near Home**		**Away From Home**	
	Coef.	**t-stat.**	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**
BUILT ENVIRONMENT						
HOME WITHIN WALKING DISTANCE OF						
Shops, stores, & markets	1464.56	1.96	4092.96	6.95	-2043.74	-4.06
Transit stop	-880.34	-3.05				
Many places			2494.21	7.08		
IF WALKING, TIME FROM HOME TO						
Nearest convenience store			-1039.12	-3.76	310.37	1.72
Nearest clothing store					-344.86	-1.96
Nearest grocery store			1457.53	5.72		
Nearest laundry/dry cleaners			403.48	3.22		
Nearest post office			1096.12	5.96		
Nearest elementary school	-686.98	-3.67			207.89	1.78
Nearest other/non-elementary school			-1354.39	-8.01		
Nearest book store			912.23	3.39		
Nearest fast food restaurant	-470.73	-1.31	785.38	2.55		
Nearest bank	-862.02	-3.08	-1996.80	-6.01		
Nearest pharmacy	1175.76	3.94				
Nearest non-fast food restaurant			-1059.90	-3.66		
Job	-508.02	-3.63	-457.90	-4.15		
Nearest park	-304.51	-1.44	-467.84	-3.28		
Nearest gym or fitness facility			525.49	2.82		
Nearest recreational center	1200.57	4.26			-212.89	-1.27
IN NEIGHBORHOOD						
There exists free or low-cost recreation facilities	2031.76	3.45	3378.17	6.84	-863.40	-2.05
Many alternative routes exist for getting from place to place			822.50	3.41		

Most streets have sidewalks	1006.53	2.36	1096.75	3.18		
Parked cars separate sidewalks from road/traffic	-639.28	-2.75				
Streets are well lit at night			-1112.77	-3.77		
Many interesting things to look at while walking	653.38	2.25				
Walkers/Bikers can be easily seen by people in homes			1133.52	4.12		
Crosswalk/pedestrian signals help walkers cross busy streets			-3070.61	-8.32		
Trees along streets			2949.25	7.33		
Attractive buildings/homes			1006.11	3.94		
Traffic on nearby streets makes it difficult/unpleasant to walk	-1122.21	-3.25	-2654.90	-8.35		
Most drivers exceed posted speed limits					-737.06	-2.89
Crime rate makes it unsafe to walk during day			7096.64	4.34		
Crime rate makes it unsafe to walk at night			-2247.89	-5.58		
Distance from home to campus core	0.42	3.23	0.82	6.29		
HEALTH & LIFESTYLE CHARACTERISTICS						
Smoke	-4361.60	-2.73				
Academic classification: Junior					1504.11	2.41
Academic classification: Senior					1950.49	3.47
Growing up, encouraged by family to be physically active	1283.21	1.72			1562.06	2.56
Currently physically active			7876.25	5.69		
Intend to be more physically active within next six months			-5071.92	-7.19		
Physically active for the past six months	-2947.45	-3.61	-2674.41	-5.13	1438.11	2.88
Participated in competitive sports in elementary school					-1804.81	-2.95
Participated in competitive sports in high school					1195.21	2.16
Participated in competitive sports in college					-708.51	-1.42
Days/week traveled to/from campus by walking			344.22	2.69		
Days/week traveled to/from campus by bicycle					-336.12	-2.15
Days/week traveled to/from campus by car					-289.13	-2.24
Days/week traveled to/from campus by other vehicle	-443.85	-1.39				
Traveled to work by walking	15.73	1.93				

6. DISCRETE CHOICE MODEL ESTIMATION

A discrete choice model can be used to explain individuals' choices between alternatives. In order to use a discrete choice model, however, the set of alternatives evaluated must display three required characteristics. First, the alternatives must be mutually exclusive, meaning that only one alternative may be chosen. By choosing this one alternative, the other alternatives may not be chosen. Second, the set must be exhaustive, meaning that all of the possible alternatives have been included in the set. Third, the set must be made up of a finite number of alternatives (Train 2009). In addition to the set of alternatives meeting these characteristics, the variables are assumed to be independent and identically distributed (IID). This means that all variables are independent of each other, and they all follow the same distribution (Train 2009). All of the variables in this study were assumed to follow a normal distribution.

To determine if a model is decent, a goodness of fit test must be conducted. This is done by examining the log-likelihood of the restricted model, which is a model consisting only of the independent variable and no predictors, compared to the log-likelihood of the unrestricted model, which is the model consisting of the independent variable and the predictors. The value obtained from this comparison is then compared to values in an F-distribution based on the specified confidence interval. If the calculated value is greater than the value found in the table (the critical value), then the unrestricted model is a better fit than the restricted model, and therefore, the model is good.

For this research, a binary logistic regression, which is a specific type of discrete choice model with only two alternatives, was used to analyze student transportation mode choice. The two alternatives were active modes of transportation, including walking and biking, and inactive modes of transportation, including car, Tiger Transit, and other. The alternative for inactive modes of transportation was used as the base; therefore, all coefficients were calculated to show the likelihood of using active transportation modes instead of inactive transportation modes. Comparing this model to the restricted model, the calculated F value was 53.793. Based on a 99% confidence interval, the critical F value was 3.02. Therefore, this is a good model based on the goodness of fit test.

As seen in Table 6.1, five variables were found to be significant based on the results of the binary logistic regression. First, living a half-mile or less from campus positively influenced the use of active modes of transportation over inactive modes. This is expected because by living close to campus, there is no need to drive, take Tiger Transit, or use another mode of transportation besides walking or biking to get to and from campus. Also, longer travel distances (living further away from campus) influenced the use of automobile (Zhou 2012). Second, living within walking distance of many places positively influenced the use of active transportation. Similarly to living close to campus, one does not need to drive, take Tiger Transit, or use another mode to get to a place if it is within walking distance of home. Third, neighborhood crosswalks and pedestrian signals on busy streets positively influenced active transportation over inactive transportation. This is also expected as these features make walking and biking safer, thereby encouraging people to use those modes. Fourth, being physically active for the past six months negatively influenced the use of active modes of transportation. This is because participants who have been physically active likely have a routine location such as home or a gym where they obtain their physical activity and do not need to use active modes of transportation. Finally, currently participating in regular physical activity positively influenced the use of active modes over inactive modes. This is because being physically active leads to active commuting. Factors such as gender, academic status, age, personal attitudes, and environmental attributes other than neighborhood crosswalks and pedestrian signals were not found to be significant as seen in past research (Zhou 2012; Whalen, *et al.* 2013). Weather, which was found to be significant in one study (Klöckner and Friedrichsmeier 2011), was not considered in this research.

Table 6.1: Mode Choice Influential Variables

Variable	Coefficient	t-stat
Home is half-mile or less from campus	3.19	2.50
Home is within walking distance of many places	1.26	3.13
In neighborhood, crosswalks and pedestrian signals help walkers cross busy streets	1.37	3.01
Physically active for the past six months	-2.79	-2.36
Currently participate in regular physical activity	5.34	2.01

Before arriving at the final binary logistic regression model, several iterations were run using various sets of all of the independent variables to come up with the five significant variables. Through these iterations, it was discovered that the variables physically active for the past six months and currently participate in regular physical activity were not significant when individually used in the final model with the other three remaining variables. However, as seen in Table 6.1, these variables were found to be significant when in the final model together. Therefore, a cross-tabulation was conducted to evaluate this phenomenon, and the results are provided in Table 6.2. As seen in Table 6.2, all but one of the participants who said they were physically active for the past six months said they also participate in regular physical activity.

This group of participants represents 71% of the sample. Because this is such a large percentage of the sample, the combination of the two variables becomes significant.

Table 6.2: Evolution of Active Mode Choices

Cross-Tabulation		Physically active for the past six months		Total
		No	Yes	
Currently Participate in Regular Physical Activity	No	7	1	8
	Yes	14	55	69
Total		21	56	77

Using the information provided in Tables 6.1 and 6.2, coefficient values are given to each of the four groups of participants broken down by past and current physical activity. These coefficient values are 0.00, -2.79, 5.34, and 2.55 for participants who were not and are not physically active, participants who were but currently are not physically active, participants who were not but now are physically active, and participants who were and still are physically active, respectively. Therefore, the participants who said they were not physically active the past six months but are currently physically active have the greatest influence on active transportation based on their coefficient value of 5.34. This means that individuals' likelihood of using active modes is at its greatest during the first 6 months of being active after not being active previously. Individuals' likelihood for physically active modes drops off slightly after this 6-month introductory period, but is also positive. Contrarily, the likelihood of using active modes decreases as participants who were physically active become inactive. In addition, people who were inactive and remain inactive do not have an influence on the likelihood of active modes.

For a visual comparison of the two alternatives observed in the binary logistic regression, two maps are provided. First, Figure 6.1 displays a map of all of the participants who chose an active mode of transportation (walk or bicycle) to get to and from campus. As seen in the map, 34 of the 42 students who chose an active mode live within a mile of the campus centroid. Second, Figure 6.2 displays a map of all of the participants who chose an inactive mode of transportation (car, Tiger Transit, or other) to get to and from campus. As seen in the map, 26 of the 35 students who chose an inactive mode live further than a mile from the campus centroid.

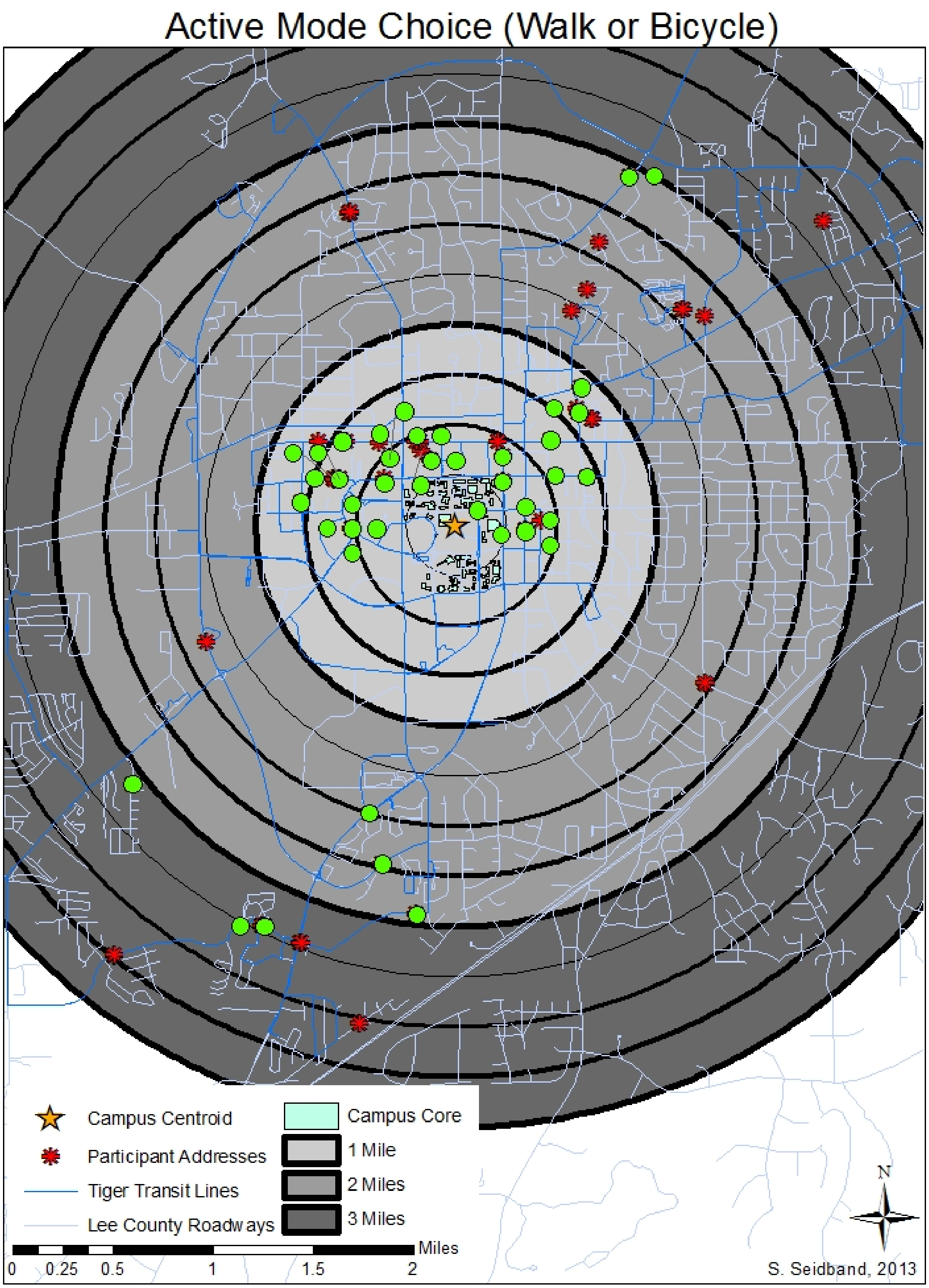

Figure 6.1: Map of Participants Who Use Active Modes to/from Campus

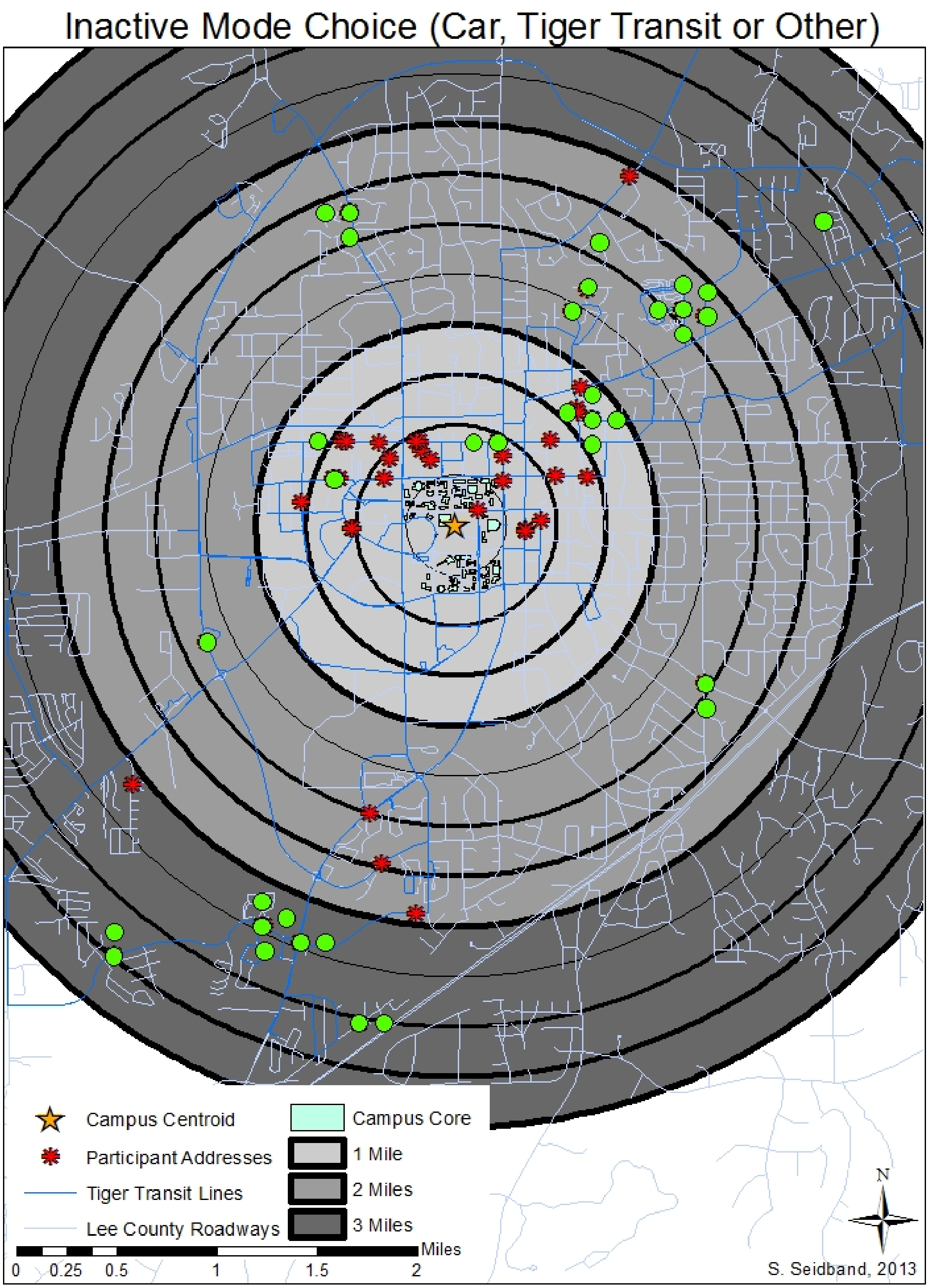

Figure 6.2: Map of Participants Who Use Inactive Modes to/from Campus

7. SUMMARY AND CONCLUSIONS

This study utilizes a unique GPS and accelerometer based methodology for measuring and predicting locations where students' are mostly interested in participating in physical activities. This methodology focused on having participants carry synced GPS and accelerometers to track where and how much physical activity was done over a two-day period. As a result, it was possible to determine where individuals were most physically active: during transportation, at/near home or away from the home. The methodology proved to be successful at collecting unbiased observed activity data, which is often difficult to accomplish. 77 respondents completed a questionnaire about their perceptions of the built environment, travel patterns, and background. These results were used in three linear regressions to determine the factors influencing participation in physical activities at different locations. The results were also used in a discrete choice model to identify what factors influenced student mode choice.

For both physical activities during transportation and at/near home, more built environment variables were found to be significant than health and lifestyle characteristics variables. Specifically, the walking distance and time to get to certain places were most influential. In addition, several neighborhood characteristics had an influence on the physical activity obtained during transportation or while at/near home. Alternatively, for physical activities away from home, more health and lifestyle characteristics variables were found to be significant than built environment variables, as these describe more of a dedicated behavior to visit a specific destination. In this case, participation in competitive sports at all age levels proved to be most influential.

For student mode choice, active transportation was positively influenced most by current participation in regular physical activity as well as home proximity to campus. Living close to many places as well as pedestrian safety features such as crosswalks and signals also positively influenced the use of active transportation modes.

Therefore, livable neighborhood built environments need to accommodate all types of physical activity participation (from dedicatedly active people to those who unintentionally get exercise). In fact, the built environment is especially important for the latter group as it may be the only way for them to get physical activity. If the built environment can provide even a little natural physical activity, it will assist in promoting healthy lifestyles. The most promising recommendations include building mixed use development (especially with nearby activity centers) with amenities (e.g. sidewalks, bike paths) and encouraging residents to live closer to their work locations. Policies may offer another means of influencing physical activity participation, including active programs for students, children, and even adults.

City planners and engineers may be able to apply these models to other areas and neighborhoods to determine the potential specific interests and needs of the people living there (if they have a sense of those individuals' characteristics). Once they understand the aggregated levels of interest in transportation-based activity, at /near home activity, and destination-based activities, they can provide the requisite opportunities to pursue these activities. This may include building new health centers, adding neighborhood amenities or developing new activity policies to encourage livable behaviors.

Of course, this work was done based on data collected from college students so it would be recommended that this methodology be expanded to comprise more populations. First, different age groups should be studied from young children to elderly adults. This is important to study because different age groups require unique amounts of physical activity and likely have varying preferences of where to obtain physical activity. Second, urban and rural settings should be studied to compare the physical activity interest and location preferences of individuals who live in cities to those who live in the country. Finally, a wider variety of neighborhood characteristics should be studied. Because this research observed physical activity in college students, the neighborhoods that were examined only included apartment complexes, trailer parks, and dorms. It is important to expand this research to include other types of communities such as family neighborhoods and transit-oriented developments.

As discussed before, aerobic step counts from accelerometers were used to quantify interest levels in physical activity. Future research could expand on this methodology to include physical activity diaries filled out by participants after each workout to get a better idea of their interest in the physical activity rather than just relying on the aerobic step counts. Questions in the diaries should gauge ideas such as toughness of the workout and the entertainment level of the workout.

For data collection methodologies, the combination of GPS, accelerometers, and questionnaires is highly recommended for future studies. To expand on this project, future research should aim to collect weeklong data, thereby including physical activity and mode choice patterns on weekends. It should also collect datasets over longer periods of time for each participant. Finally, future research should collect data at different times throughout the year to identify differences in physical activity patterns and mode choice based on the seasons.

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APPENDIX 1

Questionnaire

1. Date of Birth:_____________

2. Height:__________________

3. Weight:__________________

4. Do you smoke? ☐Yes ☐No

5. Have you been diagnosed with high blood pressure? ☐Yes ☐No

6. Have you been diagnosed with diabetes? ☐Yes ☐No

7. How often do you visit a physician?

☐Once a year ☐Twice a year ☐Three times a year ☐Once a month ☐Other_________

8. Do you have or have you had any disease or condition requiring medication, regular physician's care, surgery, or other treatment? ☐Yes ☐No

If yes, please list: ____

____

9. Do you take any medication(s) on a regular, on-going basis? ☐Yes ☐No

If yes, please list: ____

____

10. Major:____

11. Current Rank: Freshman Sophomore Junior Senior

12. Place of Employment:____________________

13. Average number of hours/week at work:______________________

14. Spouse/Partner: ☐Yes ☐No

15. Do you have children: ☐Yes ☐No
If Yes: How Many? ________ Ages:___________________

16. Childcare (Mark all that apply): ☐ N/A ☐ Within your home ☐ Childcare Facility

☐ After school program ☐Other:______________________

17. Current Address in Auburn:____

Is this address a dorm on campus? ☐ Yes ☐ No

18. In which group do you consider yourself?

☐ White, Non-Latino
☐ Asian, Pacific Islander
☐ Black, African-American
☐ Native American (American Indian)
☐ Hispanic, Latino
☐ Other (specify) _________________________________

19. Were you encouraged by your family to be active while growing up?

☐ Never ☐ Rarely ☐ Sometimes ☐ Often

20. Did you participate in **recreational** sports/activity programs during **elementary school** years? (For example: Ballet, Gymnastics, and Swimming)

☐ Never ☐ Rarely ☐ Sometimes ☐ Often

If Yes, please list the sports/activities: ____
____

21. Did you participate in **competitive** sports/activity programs during **elementary school** years? (For example: Soccer, Baseball, Softball, Tennis)

☐ Never ☐ Rarely ☐ Sometimes ☐ Often

If Yes, please list the sports/activities: ____
____

22. Did you participate in **recreational** sports/activity programs during **high school**?

☐ Never ☐ Rarely ☐ Sometimes ☐ Often

If Yes, please list the sports/activities: ____
____

23. Did you participate in **competitive** sports/activity programs during **high school**?

☐ Never ☐ Rarely ☐ Sometimes ☐ Often

If Yes, please list the sports/activities: ____
____

24. Did you participate in **recreational** sports/activity programs during **college**?

☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐Not Applicable

If Yes, please list the sports/activities: ____
____

25. Did you participate in **competitive** sports/activity programs during **college**?

☐ Never ☐ Rarely ☐ Sometimes

☐ Often ☐Not Applicable

If Yes, please list the sports/activities: ____
____

26. Do you currently exercise at a facility outside of home? ☐ Yes ☐ No

If Yes, what is the name of the facility? ___________________________________

27. Do you use exercise equipment at home? ☐ Yes ☐ No

If Yes, please list the exercise equipment you use at home:

____
____

28. Do you use exercise videos/DVDs at home? ☐ Yes ☐ No

29. What forms of transportation do you use to get to and from classes? (mark all that apply) and how many days per week do you use each?

☐ car /auto _______ days

☐ walk _______ days

☐ bicycle _______ days

☐ Tiger Transit _______ days

☐ other please specify __________ _______ days

30. If you drive to campus what parking lot do you utilize (Please list all that apply)

____

30. Shops, stores, and markets are within easy walking distance of my home:

☐ Yes ☐ No

31. My **neighborhood** has free or low-cost recreation facilities, such as parks, walking trails, bike paths, recreation centers,

☐ Yes ☐ No

32. Auburn University has free or low-cost recreation facilities, such as walking trails, bike paths, fitness facilities, recreation centers, etc.

☐ Yes ☐ No

33. There are sidewalks on most of the streets in my neighborhood:

☐ Yes ☐ No

34. The crime rate in my neighborhood makes it unsafe to walk at night:

☐ Yes ☐ No

35. Do you own.... (check all that apply):

☐ Smartphone ☐ Car ☐Bicycle ☐ Scooter/ Motorcycle

36. How many hours per day do you spend on your phone (talking/texting/apps)?

_____________hours

For each of the following questions, please mark Yes or No. Physical activity or exercise includes activities such as walking briskly, jogging, bicycling, swimming, or any other activity in which the exertion is at least as intense as these activities.

37A. I am currently physically active. ☐ Yes ☐ No

37B. I intend to become more physically active in the next six months. ☐ Yes ☐ No

For activity to be **regular**, it must add up to a total of 30 minutes or more per day and be done at least five days per week. For example, you could take one 30-minute walk or take three 10-minute walks for a total of 30 minutes.

38A. I currently engage in **regular** physical activity. ☐ Yes ☐ No

38B. I have been **regularly** physically active for the past six months. ☐ Yes ☐ No

We would like to find out more information about the way that you perceive or think about your neighborhood, where you live when you are attending classes at Auburn University. Please answer the following questions about your neighborhood and yourself. Please answer as honestly and completely as possible and provide only one answer for each item. There is no right or wrong answer and your information is kept confidential.

Part 1. Stores, facilities, and other things in your neighborhood

About how long would it take to get from your home to the nearest businesses or facilities listed below if you **walked** to them? Please put only one check mark (√) for each business or facility.

	1-5 min	6-10 min	11-20 min	21-30 min	31+ min	don't know
example: gas station				√		
convenience/small						
grocery store						
supermarket						
laundry/dry cleaners						
hardware store						
clothing store						
fruit/vegetable market						
post office						
library						
elementary school						
other schools						
book store						
fast food restaurant						
coffee place						
bank/credit union						
non-fast food restaurant						
video store						
pharmacy/drug store						
your job						
park						
recreation center						
gym or fitness facility						

Access to services: Please mark the answer that best applies to you and your neighborhood. Both local and within walking distance mean within a 10-15 minute walk from your home.

	1	2	3	4
	strongly disagree	somewhat disagree	somewhat agree	strongly agree
Stores are within easy walking distance of my home.	□	□	□	□
There are many places to go within easy walking distance of my home	□	□	□	□
The streets in my neighborhood are hilly, making my neighborhood difficult to walk in.	□	□	□	□
Streets in my neighborhood: Please mark the answer that best applies to you and your neighborhood.				
	1	2	3	4
	strongly disagree	somewhat disagree	somewhat agree	strongly agree
The distance between intersections in my neighborhood is usually short (100 yards or less; the length of a football field or less).	□	□	□	□
There are many alternative routes for getting from place to place in my neighborhood. (I don't have to go the same way every time.)	□	□	□	□
Places for walking and cycling: Please mark the answer that best applies to you and your neighborhood.				
	1	2	3	4
	strongly disagree	somewhat disagree	somewhat agree	strongly agree
There are sidewalks on most of the streets in my neighborhood.	□	□	□	□
My neighborhood streets are well lit at night.	□	□	□	□
Sidewalks are separated from the road/traffic in my neighborhood by parked cars.	□	□	□	□
There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood.	□	□	□	□
Neighborhood surroundings: Please mark the answer that best applies to you and your neighborhood				
	1	2	3	4
	strongly disagree	somewhat disagree	somewhat agree	strongly agree
There are trees along the streets in my neighborhood.	□	□	□	□
There are many interesting things to look at while walking in my neighborhood.	□	□	□	□
My neighborhood is generally free from litter.	□	□	□	□
There are many attractive natural sights in my	□	□	□	□

neighborhood (such as landscaping, views).				
There are attractive buildings/homes in my neighborhood.	□	□	□	□

Safety from traffic: Please mark the answer that best applies to you and your neighborhood.

	1	2	3	4
	strongly disagree	somewhat disagree	somewhat agree	strongly agree
There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my Neighborhood	□	□	□	□
The speed of traffic on most nearby streets is usually slow (30 mph or less).	□	□	□	□
Most drivers exceed the posted speed limits while driving in my neighborhood.	□	□	□	□
There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.	□	□	□	□

Safety from crime: Please mark the answer that best applies to you and your neighborhood.

	1	2	3	4
	strongly disagree	somewhat disagree	somewhat agree	strongly agree
There is a high crime rate in my neighborhood.	□	□	□	□
The crime rate in my neighborhood makes it unsafe to go on walks during the day.	□	□	□	□
The crime rate in my neighborhood makes it unsafe to go on walks at night.	□	□	□	□