Statistical Model Development for Estimating Bicycle Rack Usage at Auburn University

by

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Abstract

The objective of this research was to develop and evaluate statistical models to estimate bicycle rack usage for a university campus environment. An analysis was conducted on bicycle rack usage data, collected in 2008, on the Auburn University campus to develop statistical models to estimate demand at residence halls and academic buildings. Bicycle rack demand for residence halls and academic buildings is a function of number of beds and square footage, and gross square footage, classroom square footage and enrollment, respectively. For this research, spatial locations of all bicycle racks on campus and overall rack usage were collected. The statistical models were used to estimate bicycle rack usage demand, and these results were validated against data collected in 2010. The recommended model for residence halls was the variable 'number of beds' model. The two models recommended for academic buildings were the 'classroom square footage' and 'enrollment' and 'enrollment' models.

Acknowledgments

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CHAPTER 1

INTRODUCTION

1.1 Background

On a national level, few people take advantage of riding a bicycle as a mode of transportation. According to the 2009 National Household Travel Survey (NHTS), bicycling accounted for 0.2 percent of person miles of daily travel and only 1.0 percent of daily trips (USDOT 2009). People that choose to ride a bicycle, do it for a variety of reasons including exercise, the reduced price of riding in comparison to other modes of transportation, and helping reduce their carbon footprint (Litman, 1994). Depending on the trip length and the characteristics of the area, a trip on a bicycle could reduce the commute time for some users (Ryley, 2006). The nationally low percent of miles traveled daily and trips made by bicycle can be attributed to the convenience of personal vehicles, making the vehicle mode dominant (Ryley, 2006).

Certain factors influence whether a user will choose to commute by bicycle. Trip length and weather are the most obvious of those factors, while other factors such as topography, land use and the presence of bicycle facilities (i.e. bicycle lanes, bicycle racks, showers) between the origin and destination of the trip and trip purpose influence a user's choice (Dill and Voros, 2007). Various cities and towns across the United States experience a higher bicycle mode share than the national statistics. College towns in particular have higher rates, sometimes 10% or more of bicycle commuter trips (Dill and Voros, 2007).

Since the development of the *2002 Auburn University Campus Master Plan*, AU has been steadily shifting towards a pedestrian and bicycle friendly campus (Sasaki, 2007). The university has added pedestrian concourses throughout the campus and increased the number of bicycle facilities. AU has made a commitment to creating a pedestrian and bicycle friendly environment on campus by encouraging the use of alternate modes of transportation to and from campus. AU is transitioning into a multimodal campus by offering several modes of transportation that include the use of a personal vehicle, bicycling, walking, Tiger Transit and carpooling. The purpose of this transition is to "to create a stronger, more vibrant community, reduce energy consumption, provide alternative transportation options, preserve water resources and habitats, more efficiently utilize land resources, and support the programmatic improvements required for a vibrant and dynamic institution (Sasaki, 2007).

In 2004 and 2008, AU conducted a mode choice survey questioning faculty and students regarding their individual preferences about the mode of transportation used to commute to and from campus and how the choices have changed over time. Figure 1-1 shows the results of the 2004 and 2008 survey displaying the percent distribution of preferred mode choices among students when traveling to and from campus.

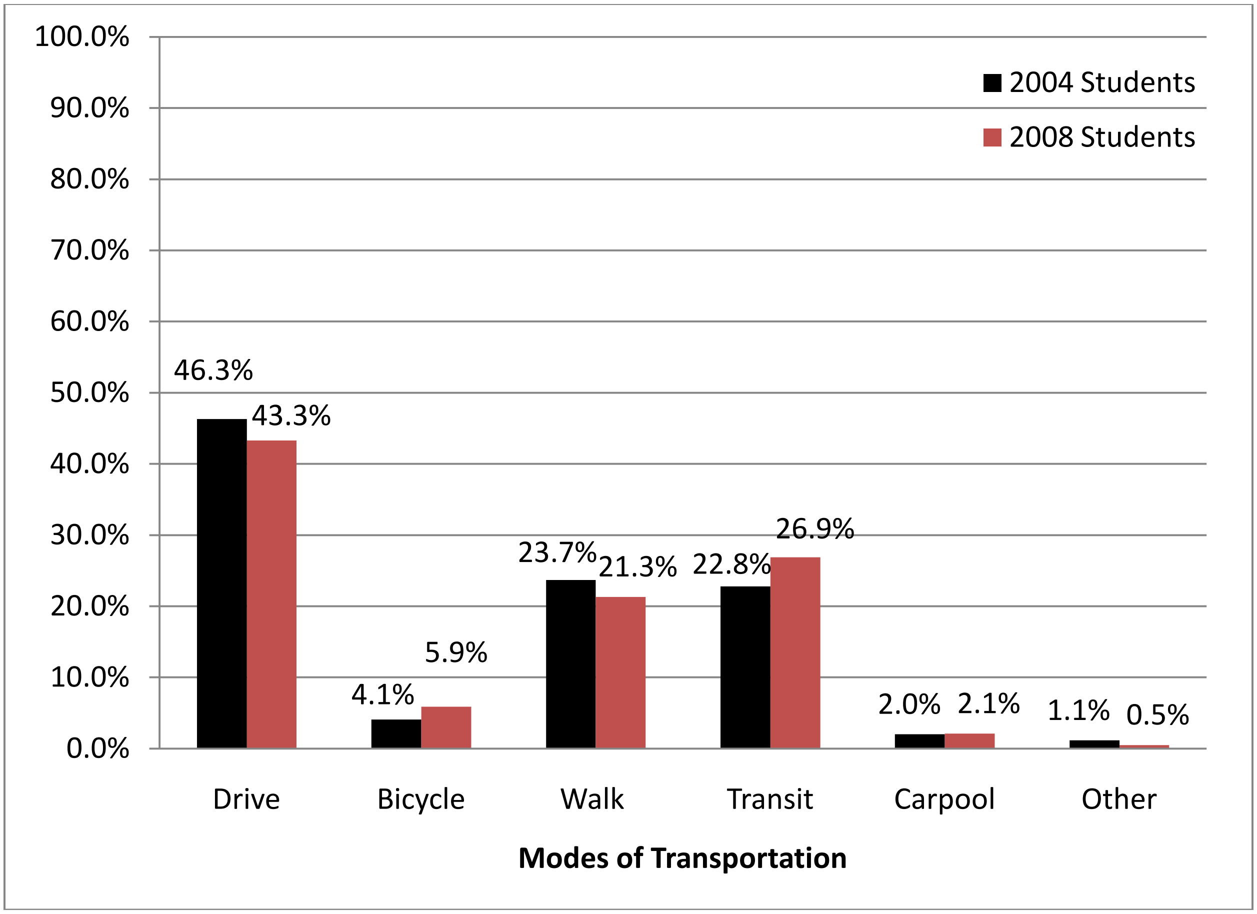

Figure 1-1: Summary of Student Responses to 2004 and 2008 Mode Choice Surveys.

In 2004 there were 22,928 students and 5,298 faculty / staff members at Auburn that participated in the in the mode choice survey and those figures increased to 24,530 students and 5,920 faculty / staff members in the fall of 2008 (AU, 2011a). An unevenly distributed number of faculty and students utilize different mode choices for commuting to and from campus every day. Figure 1-1 shows that less than half of the student body drives to campus while Figure 1-2 displays almost 88% of faculty members prefer commuting by personal vehicle. The high percentage of faculty that drives to campus could be a result of where they live in relation to the university or the availability of parking near their offices.

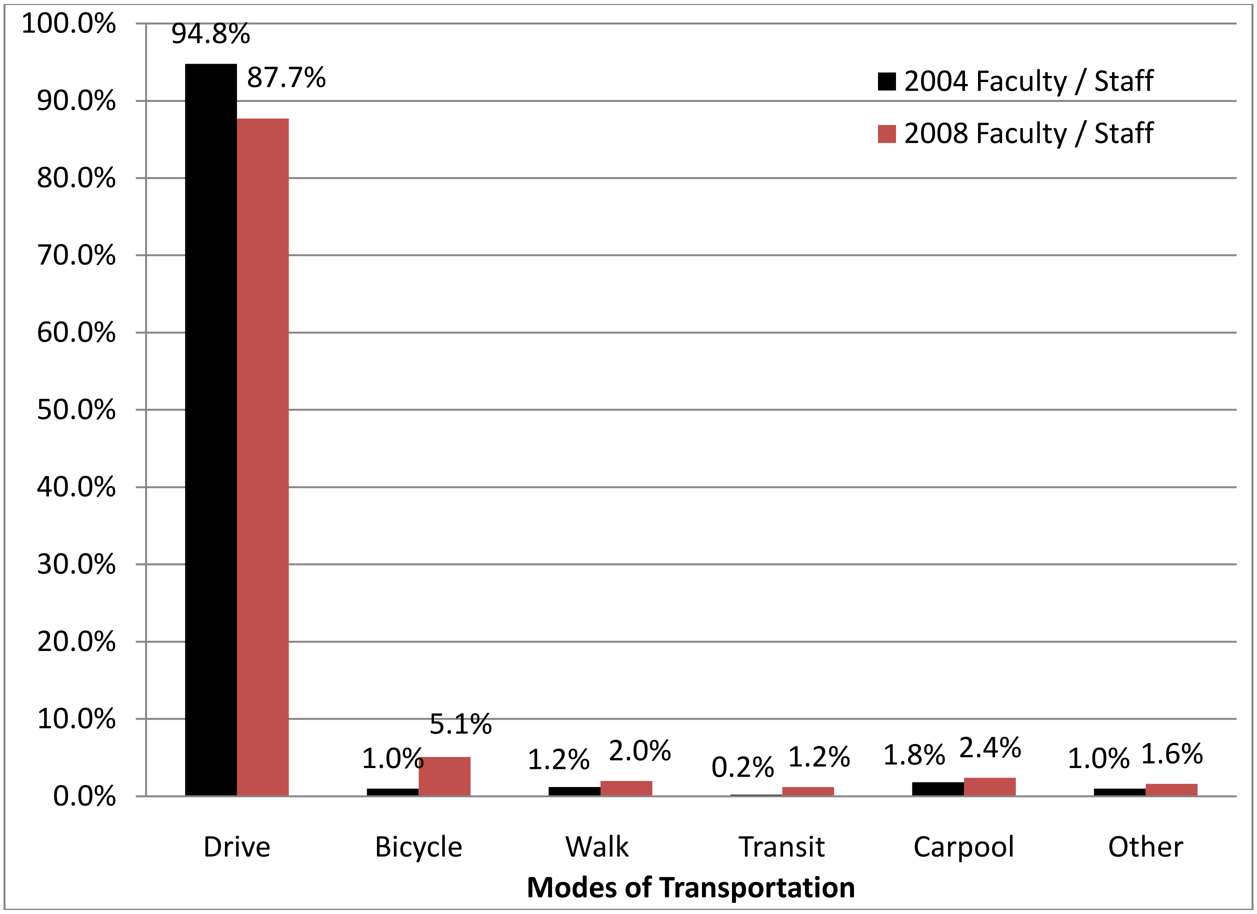

Figure 1-2: Summary of Faculty / Staff Responses to 2004 and 2008 Mode Choice Surveys.

Although students account for over 10,600 commuters by personal vehicle, they exhibit higher percentages for mode choices of walking, riding a bicycle and riding the transit to campus. A possible reason that students exhibit these characteristics is directly related to where they live in relation to the university. In 2008, approximately 11.5% of students (2834 out of 24,530) lived in on-campus residence halls, allowing shorter distances for walking and bicycling (AU, 2011a). Many off-campus housing complexes are close enough to campus that students may walk or ride their bicycles to campus. Others may prefer to ride Tiger Transit, a campus wide transit system, which has routes that pick up and drop off at a large number of apartment complexes throughout Auburn.

A reduction in the percentage of faculty and students that drive to campus was observed from 2004 to 2008, while in almost all other areas increases were experienced. The number of faculty that drive to campus was reduced 7.1%, while students saw a 3.0% decrease. The share of riding a bicycle to campus increased for both faculty and students, with the number of faculty increasing by 4.1% and the number of students increasing by 1.8%. This represents an increase of approximately 250 faculty members and over 500 students choosing cycling to campus as their mode choice. Possible contributions to this increase in bicycle mode share include additions in the number of bicycle lanes, and bicycle racks. Walking to campus experienced an increase for faculty, and a decrease for students and ridership on Tiger Transit increased, as did carpooling for faculty and students.

1.2 Motivation for the Research

AU is committed to improving pedestrian and bicycle safety on campus (Sasaki, 2007). Since 2002, the university has reduced the number of vehicles that travel through campus by closing streets and converting them into pedestrian concourses and bicycle facilities to minimize the interactions with vehicles. Existing streets were developed into shared use paths on which pedestrians and cyclists can use to travel around campus. Thach Ave., from Mell St. to Wire Rd, and Roosevelt Dr., from Mell St. to Duncan Dr., were converted to shared use pathways on campus. Within the general improvements to these areas, the university has expressed interest in developing a technique to assist in determining the better placement of bicycle racks. Currently, bicycle racks are placed around residence halls, academic buildings, and student centers with no specific knowledge of the estimated demand produced by each building. A mathematical model to predict bicycle rack usage demand as a function of the building characteristics currently does not exist. In 2009, AU completed the construction of The Village, an eight building student housing addition to campus. Bicycle racks were placed around these buildings, but an insufficient number is apparent because of the excess number of bicycles at each rack. Evidence of the lack of available space to secure a bicycle to a storage rack can be seen throughout campus, shown in Figure 1-3. Bicycles have been observed secured to railings, trees, fences, etc. around the Student Center and various other buildings on campus. To better serve the faculty and students that commute to campus by bicycle, the university wants a method for determining where to place bicycle racks around campus. AU has a campus bicycle committee made up of faculty, staff and students that want to promote bicycle usage and increase the number of facilities on campus. One of the goals of the bicycle committee is to provide "sufficient bike racks to accommodate peak bike traffic on campus" (AU, 2011b).

(a) Bicycles Chained to Columns and Each Other in The Village

(b) Bicycles Chained to Fence Along the Roosevelt Concourse

Figure 1-3: Evidence Indicating Lack of Bicycle Parking Facilities on Campus.

The motivation for this research began with AU's Office of Campus Planning and Space Management desiring a quantified way to predict the bicycle rack usage at buildings on campus. The purpose of this model would be to allow a planner to determine the bicycle rack capacity needed for each building using some deterministic features of each building.

1.3 Research Objectives

The objective of this research is to develop a statistical model to help AU better understand the capacity needed to accommodate the bicycle parking demand on campus. Presently, when a new building is constructed on campus, bicycle racks are placed with limited quantified knowledge as to how much capacity is required. Racks are placed sparsely around buildings in hopes that they will provide sufficient space. The tasks executed to accomplish the objective of this research are:

- Conduct a literature review, documenting research performed in developing ways to predict bicycle rack usage;
- Collect spatial locations for all bicycle racks including newly installed racks and re-collect usage data for all bicycle racks on campus;
- Develop a statistical model for the residence halls to express peak rack usage as a function of 'building square footage' and the 'number of beds' in each building using bicycle rack usage data collected in October, 2008;
- Develop a statistical model for the academic buildings to express peak rack usage as a function of 'gross square footage,' 'classroom square footage,' and 'class enrollment' using bicycle rack usage data collected in October, 2008;

- Analyze the performance of the statistical models for the residence halls and academic buildings by comparing the collected rack usage from 2010 with the estimated rack usage from the created statistical models; and
- Recommend statistical model(s) for use to forecast bicycle rack usage when new residence halls or academic buildings are constructed.

1.4 Organization of the Thesis

The remainder of this research is divided into five chapters that illustrate the steps taken to complete the tasks necessary to satisfy the overall objective of this research described above. *Chapter 2: Literature Review* includes the relevant information found on bicycle friendly areas, safety, predicting demand, rack placement, and bicycle counting methods. Additionally, the literature review will identify possible variables to be used in the statistical modeling. *Chapter 3: Methodology* will discuss step-by-step, the analysis procedures and analysis methods of bicycle rack usage data collected in 2008 and the development of several statistical models that will be used to estimate bicycle rack usage. *Chapter 4: Data Collection* will examine the data collection effort performed in 2010 and the synthesis of the data. *Chapter 5: Model Application and Results* will discuss the application of the statistical model(s) developed in Chapter 4 and the comparison of estimated peak rack usage with the bicycle rack usage data collected in October 2010. *Chapter 6: Conclusions and Recommendations* will summarize the work performed and make recommendations for the use of the preferred statistical model(s). Furthermore, Chapter 6 will address lessons learned through the course of this research and suggest possibilities for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to satisfy the research tasks and overall objective outlined in the previous chapter, a comprehensive review of literature was completed. Several topics that were researched include:

1. Bicycling at Auburn University
2. Bicycle friendly areas across the United States of America,
3. Bicycle safety techniques and methods being used,
4. Forecasting bicycle demand and travel,
5. Guidelines on the placement of bicycle racks, and
6. Bicycle counting methods

The following sections in this chapter will examine the topics listed above.

2.2 Bicycling at Auburn University

Since the ideas from the *2002 Auburn University Campus Master Plan* have begun to be implemented, many changes have occurred at Auburn University (AU). The university is shifting to a more sustainable design with the encouragement of alternate forms of transportation. Parking within the core of campus has been removed and relocated further away and Tiger

Transit routes to and from these areas were added. Walking and cycling are being encouraged by the restriction of personal vehicles throughout certain areas of campus. The completion of the Thach Concourse and the Roosevelt Concourse were the start of the shift towards a more pedestrian and bicycle friendly campus. Programs such as *Travel With Care* promote safety and awareness among all modes with public service announcements for safety when traveling by personal vehicle, transit, bicycle, walking (City of Auburn, 2011).

The City of Auburn has approximately 34 miles of existing bicycle lanes with a proposed amount of 117 miles. Separate from the city, Auburn University currently has almost 5 miles of on road bicycle lanes and 2 miles off road. Proposed bicycle lanes amount to 2 miles on road and 6 miles off road (AU, 2011b). Within the Office of Sustainability at AU, there is a Campus Bicycle Committee that promotes the use of bicycles as a mode of transportation. The committee is made up of faculty, staff, and students from AU who want to educate the community about cycling. Some of the goals of the committee are to provide "convenient access to central campus for bikes" and provide "sufficient parking racks and shelters" (AU, 2011b).

The Campus Bicycle Committee has developed some design considerations for the university, listed below:

- Complete bicycle loop around the campus core
- Provide bicycle parking as close to each building as possible
- Separate bicycle paths, pedestrians, and automobiles from each other
- Provide bicycle parking for 6 to 10 bicycles at each building (minimum) or every entrance (maximum)

2.3 Prominent Bicycle Friendly Areas

Rising gas prices may be a factor that is encouraging people to seek alternate modes of transportation. Alternates of traveling by personal vehicle include, but are not limited to walking, bicycling, carpooling, and mass transit. Trips that are taken by vehicle that cover less than one mile produce more pollution per mile than longer trips do (FHWA, 2006). According to the 2009 National Household Travel Survey (NHTS), 11.4 percent of all daily trips are made by bicycle or by walking (USDOT, 2009). Examination of person miles of daily travel and daily trips reveals that bicycling accounts for approximately 8.9 billion miles (0.2%) of daily travel and 4.1 billion (1.0%) daily trips (USDOT, 2009). The benefits of riding a bicycle to make any length trip range from reducing traffic congestion and parking demand to alleviating air pollution, decreasing user costs, promoting health and sustaining urban development (Litman, 1994).

This increase in the volume of bicycle transportation is an issue that many college campuses are facing. Students that live on and off campus are more frequently riding their bicycles to class, as seen in the change in mode share from 2004 to 2008 (see Figure 1-1 and 1-2). Riding a bicycle to class not only provides exercise, but can reduce the amount of time it takes to get to class or campus. Riding bicycles also reduces the amount of emissions from cars, by eliminating the contribution completely from those that were left at home. The improvement of quality and quantity of the bicycle infrastructure is an initial step to increasing bicycle transportation.

Examination of other areas can be used to determine techniques used and provide examples of how cycling as a mode of transportation is estimated and modeled. While observing cities that encourage cycling as an alternate mode of transportation to commuting by personal vehicle is significant, identifying colleges and universities that do the same will provide more useful to this study. Colleges and universities across the U.S. that have adopted bicycle plans and encourage cycling amongst the faculty and students were identified and have been examined.

The League of American Bicyclists recognized the City of Davis, California with its highest Bicycle Friendly Community Award in 2005 (Hansen, 2005). The City of Davis has approximately 50 miles of bicycle lanes and 52 miles of bicycle paths. Bicycle paths and bicycle lanes can be found on more than 90 percent of Davis' collector and arterial streets (Moler and Shaw, 2009). The University of California at Davis is a part of that community. The campus at UC Davis has little elevation change and experiences hot summers and mild winters, making it an enjoyable place for transportation by bicycle. Cyclists outnumber pedestrians nearly four to one, averaging between 15,000 and 18,000 trips daily. UC Davis has an extensive bicycle network with 14 miles of paths and 12 miles of shared roadway. The university also has a strong partnership with the City of Davis. This partnership is the main reason why the bicycle program is so successful in the area, with the promotion of various programs for both the city and the university (as referenced in AU, 2006).

The University of California at Santa Barbara was not built for vehicular access. When it was built it followed an urban model, allowing for a pedestrian and transit oriented area. The main campus is only 100 acres, which allows suitable travel by foot and by bicycle. The climate is ideal for walking and bicycling and the topography is relatively flat. Approximately one to two miles from campus is the community where most students live. The proximity to campus coupled with the low number of parking spaces available on campus, influences modes of transportation other than by vehicle. About 15,000 students commute to campus by bicycle daily (as referenced in AU, 2006).

The University of Oregon is another example of a pedestrian and bicycle friendly campus. During the original development of the school's master plan in 1976, students, faculty and staff had a big influence in creating a campus they wanted, thus developing the bicycle/pedestrian friendly campus that remains today. Much like the City of Davis, the City of Eugene, where the University of Oregon is located, supports the pedestrian/bicycle friendly environment. The University of Oregon offers alternatives to driving a vehicle to campus. They provide bicycle racks on transit buses, and more bicycle parking spaces than vehicle parking spaces (as referenced in AU, 2006).

The City of Berkeley, California has long been supportive of bicycling as a mode of transportation, but adopted its first bicycle plan in 2000. The plan aims at encouraging bicycling as an environmentally friendly, healthy form of transportation. This plan allowed for the consideration of cyclists to be integrated into the road systems of the city. Five years after the adoption of the bicycle plan, the City of Berkeley had spent approximately $2,000,000 on programs to support cycling and the infrastructure (Wilbur Smith Assoc., 1998).

Some European countries such as Germany, Denmark and the Netherlands exhibit much higher percentages for bicycle ridership than the United States (US) does (Pucher and Buehler, 2008). Approximately 1% of daily trips in the US are made by bicycle (USDOT 2009) while Germany, Denmark, and the Netherlands experience 9%, 19%, and 27% of daily trips, respectively (Pucher and Buehler, 2008). This increase in bicycling in European countries comes from the use of bicycles for more trip purposes. Cycling in the US is mainly recreational, while some European countries experience more trips for work, school, shopping, etc (Pucher and Buehler, 2008).

2.4 Transportation System Management for Bicycle Safety

Various programs and policies are needed to make cycling safe for users. Some of the facilities and techniques that can be implemented are bicycle paths/lanes, traffic calming, intersection modifications, bicycle parking, integration with public transport, training and education. Bicycle paths and lanes allow for an area for cyclists to ride, separating them from the flow of traffic. Between 1976 and 1996, Germany tripled the length of its bicycle path network from 12,911 to 31,236 km (Pucher and Buehler, 2008). This increase was from the off-street shortcuts between streets, allowing travel across city blocks giving cyclists the most direct route possible.

Ideas for creating and/or improving bicycle safety can be gathered from the Netherlands. Techniques such as road narrowing, raised intersections and crosswalks, zigzag routes, automobile-free city centers, and artificial street closures can be implemented to create a safer environment for cyclists (Pucher and Buehler, 2008). Narrow streets can be given lower speeds for vehicular traffic and priority to cyclists is provided.

More and more students, on and off campus, are using bicycles to get around campus. With this trend increasing, safety is an important issue. As an example, the University of Illinois has developed a bicycle path management system that allows segments to be monitored, inspected, and repaired when needed in a timely manner. Bicycle paths on Illinois campus consist of approximately 5.7 miles of concrete and asphalt paths. There are a total of 50 paths throughout the campus which encounter volumes between 500 and 1000 bicycles that use any given path on a good weather day. The paths are separated into two types: paths that are strictly for bicycle use and paths that are part of the street separated by pavement markings or a barrier.

The only type not integrated into the Illinois campus path network is the shared path on which bicycles and cars share the street (Gharaibeh et al., 1998).

Another example of college campuses trying to increase the safety of pedestrians and cyclists is at UC Davis and Stanford. These two campuses have installed roundabouts for pedestrians and bicycles on shared use paths. The roundabout is becoming more popular at roadway intersections in the US, and transportation agencies are using its ability to improve safety and traffic flow on college campuses. This application of a roundabout decreases the number of conflicts between pedestrians and bicycles by slowing down those entering the roundabout and yielding to those already there. Pedestrians tend to feel intimidated by bicyclists when they encounter them on a path or at an intersection. Installing roundabouts can help alleviate that problem and reduce the number of incidents (Moler and Shaw, 2009).

2.5 Forecasting Demand

"Studies have shown time and safety to be the greatest determinants on a cyclists route choice…" (Ryley, 2006). When trying to estimate the demand for a proposed bicycle facility the current methods available can be grouped into these categories (Porter et al., 1999):

- Aggregate methods,
- Surveys,
- Discrete choice models, and
- Regional travel models.

Aggregate methods are used to predict the number of trips based on area characteristics for a bicycle facility and can be accomplished through studies and surveys. Comparing the usage of a facility before and after an improvement can be used to access the impact of facility updates to the areas mode choice (Porter et al., 1999). Surveys that directly ask someone about various aspects of cycling and their habits can be performed. Government departments from cities that want to improve the bicycle facilities or add new ones can ask respondents if they would ride a bicycle if new facilities were constructed, or if they would ride more frequently if certain areas were improved. Asking questions like this could be used to develop a priority list of improvements that could be made (Porter et al., 1999).

Discrete choice and regional travel models can be used to predict travel patterns. Discrete models can include variables like facility improvements and policy changes. Two types of discrete models include route choice and mode choice (Ryley, 2006). Regional models examine past travel patterns and areas such as transportation network characteristics to predict travel in the future. These models can be used to predict multiple travel decisions such as mode and route choice (Porter et al., 1999).

One issue to decide upon when trying to determine bicycle demand is to think about what types of questions the model will be used to answer. Questions such as: "How many people will use the new facility? How much will total demand increase given an improved facility or network? How does bicycling affect public objectives such as congestion and air quality?" (Barnes and Krizek, 2005) There are at least two perspectives on how to estimate bicycling demand. The first is using unmeasured factors like cultural or historical factors and the second is to use known information about cycling. Traditional approaches to demand modeling come from the forecasting of vehicle travel. This is done by examining the people and the environment and using them in some way to predict the amount of travel. Bicycle demand can be described as a function of some basic factors such as demographics, policy, and facility variables. However, the models may have limited transferability between different areas (Barnes and Krizek, 2005).

Factors associated with the physical environment affect the use of bicycle facilities. Schwartz discusses the impact of bicycling to rail stations in Chicago showing that promoting *Bike and Ride* programs can extend the reach of transit networks with a lower cost to provide bicycle parking than to actually extend the network. In a survey conducted by the Chicago Transportation Authority more than 50% of respondents said they rode between ½ mile and 1 mile to the station. Schwartz's results showed that bicycle parking usage increased at rail stations when there was higher station boarding, more bicycle parking, lower residential density and crime, and fewer bus options (Schwartz, 2008).

2.6 Placement of Bicycle Racks

The availability or unavailability of a bicycle rack influences whether people ride their bicycles to specific destinations (APBP, 2010). The promotion of bicycling for transportation and recreation can be accomplished by having a strategy in place for supplying bicycle parking. Parking facilities for bicycles can be viewed as two types, short term and long term (APBP, 2010). Short term parking includes racks located on the sidewalk or street in front of a possible destination. Long term parking includes lockers, cages, and bicycle rooms and is designed to be out of the way and emphasizes security. The Association of Pedestrian and Bicycle Professionals (APBP) has developed recommended rates of bicycle parking for various types of buildings. In the 2nd Edition of its publication *Bicycle Parking Guidelines*, APBP provides a minimum number of spaces for colleges and universities. Table 2-1 outlines the recommended number of spaces suggested (APBP, 2010).

Table 2-1: APBP Guidelines for Long and Short Term Bicycle Parking Spaces at Colleges and Universities (Source: APBP, 2010)

	Long Term Bicycle Parking	Short Term Bicycle Parking
Minimum Suggested Requirement	1 space per 10 employees plus 1 space per 10 students of planned capacity; or 1 space for each 20,000 s.f. of floor area, whichever is greater	1 space per 10 students of planned capacity. Minimum of 2 spaces
Suggested for Mode Shares Over 5%	1.5 spaces per 10 employees plus 1 space per 10 students of planned capacity; or 1 space for each 20,000 s.f. of floor area, whichever is greater	1 space per 10 students of planned capacity. Minimum of 2 spaces

Although the APBP guidelines do not directly address criteria for residence halls, multi-family dwellings are addressed. Table 2-2 outlines the recommendations.

Table 2-2: APBP Guidelines for Long and Short Term Bicycle Parking Spaces at Multi-Family Dwellings (Source: APBP, 2010)

	Long Term Bicycle Parking	Short Term Bicycle Parking
Minimum Suggested Requirement (without private garage)	0.15 spaces for each bedroom. Minimum 2 spaces	0.05 spaces for each bedroom. Minimum of 2 spaces
Suggested for Mode Shares Over 5% (without private garage)	0.20 spaces for each bedroom. Minimum 2 spaces	0.10 spaces for each bedroom. Minimum of 2 spaces

2.7 Bicycle Counting Methods

There are several ways to count bicycles and determine the volumes traveling around a specific area. One of the most common ways to count bicycles is to do a traffic count (Lovejoy and Handy, 2011). This can be done in the same manner as for vehicles, by manually counting bicycles passing a certain place or intersection or by using an automated bicycle counter. Other methods for counting bicycles are to perform rack counts and travel surveys. Some of the information that these methods produce can include, gender, whether the rider is wearing a helmet, and if the rider is traveling the wrong way on a path (Lovejoy and Handy, 2011).

The San Francisco County Transportation Authority developed a smartphone application that is free to download for the iPhone and Android brands of cellular telephones. With the ease of access to smartphones with GPS enabled capabilities, this opens a new avenue for data collection. The “app” called CycleTracks is used to collect routes traveled by cyclists. With a simple tap on the screen, recording of the trip would start or stop, automatically uploading the trip to a central database. Options such as gender and trip purpose were optional inputs and the “app” records details of the trip such as slope and the presence of bicycle lanes (Charlton et al., 2011).

2.8 Lessons Learned

Through the research performed for this project certain ideas and methods have been selected for the modeling of bicycle rack usage at AU. The ideas suggested in the *2010 APBP Bicycle Parking Guidelines* of providing a specific amount of bicycle parking spaces at colleges and universities can be developed into the provision of bicycle parking based on the number of students enrolled in classes in each academic building. The use of square feet of floor area could also be incorporated as another possible predictor of bicycle rack usage.

Using the APBP guidelines for multi-family dwellings, a method for modeling the residence halls could be developed using the number of bedroom to denote the number of spaces needed. For the residence halls at AU, each bedroom can have one or two residents, so instead of directly applying the APBP guidelines in the form of bicycle parking per bedroom, it will be examined per bed.

In *Chapter 3, Methodology*, the 2008 bicycle rack usage dataset, collected as part of a previous study, will be examined. The possible independent variables will be discussed and the development of statistical models based on these variables will be examined.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The intention of this chapter is establish and describe a methodology for the development of a statistical model to be used for the estimation of bicycle rack usage at Auburn University (AU). For modeling purposes, the buildings on AU's campus being included in the model were separated into residence halls and academic buildings.

Data collected in 2008 prior to this study included the spatial location of each bicycle rack on campus and the rack usage for the residence halls prior to classes beginning for the day. In that study, the assumption was made that peak rack usage would occur for racks located at the residence halls during that time. The 2008 bicycle rack usage was collected for the academic buildings during scheduled class times. Analysis of the 2008 bicycle rack usage will be performed by separating the original dataset into two datasets: rack usage for the residence halls, and rack usage for the academic buildings. Using the rack usage data for each group of buildings, statistical models will be developed with the objective of estimating bicycle rack usage.

The independent variables examined as possible predictors of bicycle rack usage for the residence halls were 'number of beds' and 'building square footage.' These two candidate independent variables were selected based on ideas gathered from the Association of Pedestrian and Bicycle Professionals (APBP) publication, *Bicycle Parking Guidelines 2nd Edition* (APBP, 2010). The independent variables examined as potential predictors of bicycle rack usage for the academic buildings were 'gross square footage,' 'classroom square footage' and 'enrollment.' These candidate independent variables were selected based on direct recommendation from the APBP guidelines. The dependent variable for both groups of buildings on campus was the 'peak rack usage.' The 'peak rack usage' value was selected as the dependent variable because developing a model that designs for the peak usage will be able to handle all other levels of rack usage. The Campus Bicycle Committee would also like to provide "sufficient bike racks to accommodate peak bike traffic on campus" (AU, 2011b).

3.2 Data Management

In the fall of 2008, bicycle rack data were collected at AU. The data collected included the spatial location of each bicycle rack, capacity, the usage during peak times, the type of rack and the current condition of each rack (Wood, 2009). The spatial location of each rack on campus and the bicycle rack usage were retrieved from this dataset to be used in the development of statistical models to estimate bicycle rack usage on AU's campus. The data used in the development of the following statistical models were collected by a group of faculty and students from the Department of Civil Engineering at Auburn University during the fall of 2008 (Wood, 2009). Other data were required for the development of the statistical models and were obtained from various offices at AU.

Based on the review of available literature, potential independent variables were identified for both the residence hall and the academic building model. In the *APBP Bicycle Parking Guidelines 2nd Edition*, recommendations were made for the provision of bicycle parking based on characteristics of the area in question (APBP, 2010). Although residence halls were not specifically addressed, multifamily dwellings were. The recommendation for the amount of bicycle parking for multifamily dwellings is based on the number of bedrooms in each dwelling; however, the 'number of beds' in each residence hall was selected as a candidate independent variable for the residence hall model. 'Building square footage' was as selected as a candidate variable because rack usage may be related to the building area. The data for the residence hall model were obtained from two offices on campus at AU. The 'number of beds' in each residence hall was obtained from the Office of Housing and Residence Life and the 'building square footage' was received from the Facilities Division.

Adhering to the recommendations provided by the *APBP Bicycle Parking Guidelines 2nd Edition*, independent variables were selected based on the suggested bicycle parking for colleges and universities. Bicycle parking is suggested based on the number of students of planned capacity and, or square footage of floor area (APBP, 2010). Therefore, the candidate variables selected for examination were 'gross square footage,' 'classroom square footage' and 'enrollment.' The 'gross square footage' and 'classroom square footage' values for each academic building on AU's campus were obtained from the Facilities Division. The enrollment data for the fall of 2008 was obtained from the Office of the Registrar in order to determine how many students were enrolled in classes in each academic building.

3.3 Background of Residence Hall Model

There are three distinct residence hall areas on AU's campus: The Hill, The Quad, and The Caroline Draughon Village (CDV) Extension. The spatial locations of each bicycle rack and the buildings associated with each residence hall area were examined in order to assign bicycle racks to certain buildings. A combination of various criteria were utilized in assignment of bicycle racks to specific residence halls. The *1st Edition of the APBP Bicycle Parking Guidelines* suggests that “The rack area should be no more than a 30-second walk (120 feet) from the entrance it serves and should preferably be within 50 feet” (APBP, 2002). Using this recommendation, knowledge of AU’s campus, and the researcher’s personal experience from bicycling around campus for six years, racks were assigned to individual or multiple buildings.

The dataset that was obtained from the fall of 2008 had bicycle rack usage data for the three residence hall areas on campus: The Hill, The Quad and The CDV Extension. Data were collected for the bicycle racks around the residence halls between 6:00 am and 7:00 am, Monday through Thursday. This time frame in the early morning was selected because the ‘peak rack usage’ of these bicycle racks will occur when the residents are most likely to be in their rooms (Wood, 2009).

The Hill consists of twelve residence hall buildings, with 34 bicycle racks in the area. The bicycle racks and the buildings in The Hill are shown in Figure 3-1. Two buildings in The Hill were removed from the development of the residence hall model: Burton Hall and Terrell Dining Hall. Terrell is a dining hall that serves The Hill and Burton Hall is used by the Office of Housing and Residence Life. Two of the racks, numbered 73 and 74, were eliminated from the data set because they were located in front of Terrell Dining Hall.

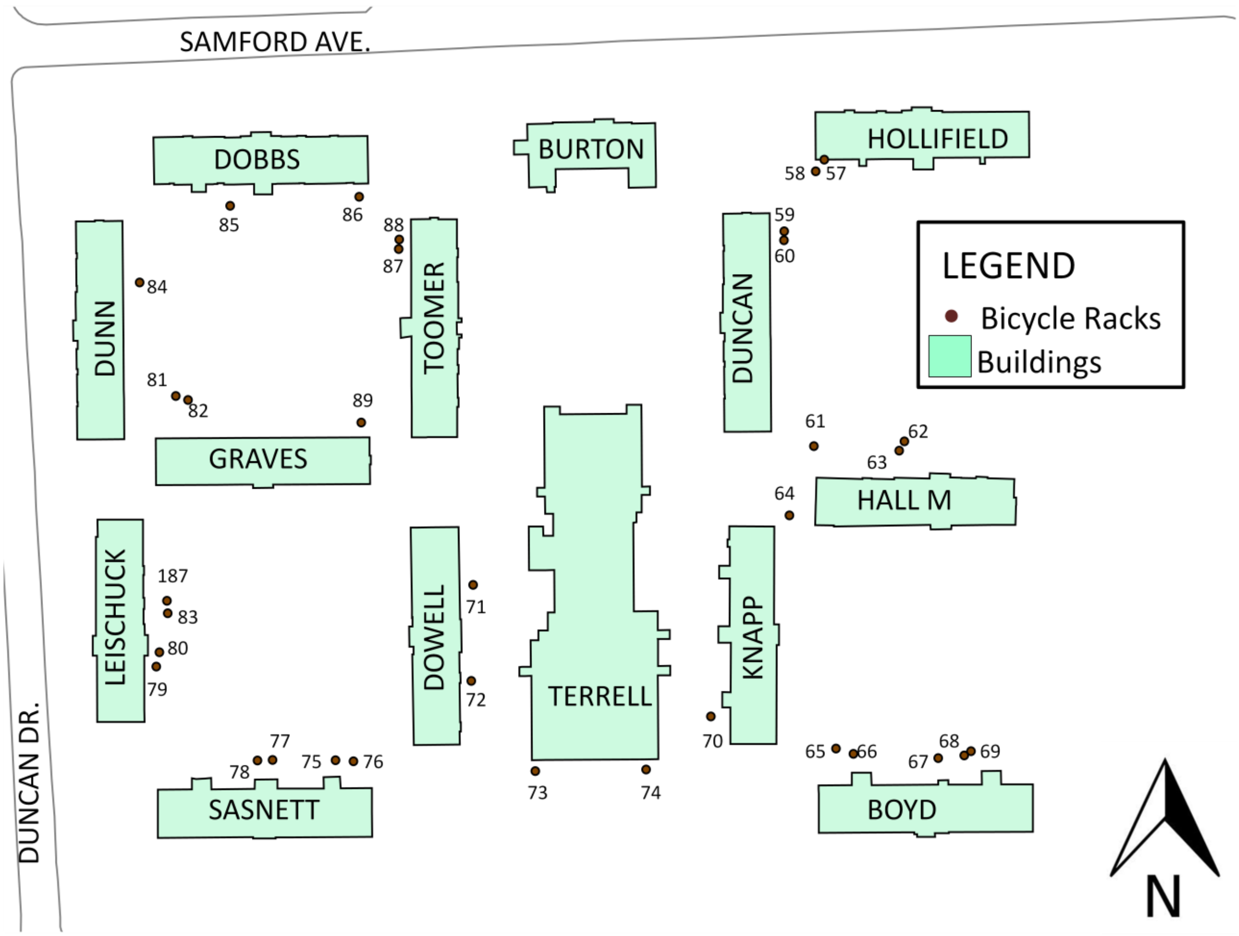

Figure 3-1: Bicycle Rack Locations at The Hill Residence Halls

It was observed that some bicycle racks were in locations that could result in them being assigned to more than one building. For racks such as 61 near Hall M and Duncan Hall, its location is between 50 feet and 120 feet from entrances of both buildings in accordance with the APBP guidelines. The bicycle rack usage for racks such as 61 was divided between multiple buildings based on the idea that residents of both Hall M and Duncan Hall could utilize the available space. Without observing each individual rack in question, it was unable to be determined which residence hall rack users lived in. The collected rack usage was divided between multiple buildings based on the number of beds per residence hall using the following equation.

$$\%Bldg_A = \frac{\#\ of\ Beds\ in\ Bldg_A}{\#\ of\ Beds\ in\ Bldg_A + \#\ of\ Beds\ in\ Bldg_B} \tag{1}$$

Using the criteria previously discussed, the racks were assigned to the buildings in The Hill as displayed in Table 3-1.

Table 3-1: Rack Assignment for The Hill

Residence Halls	Racks
Dunn	81, 84
Leischuck	79, 80, 83, 187
Dobbs	85, 86
Graves	82, 89
Sasnett	75, 76, 77, 78
Toomer	87, 88
Dowell	71, 72
Duncan	59, 60, 61
Knapp	64, 70
Hollifield	57, 58
Hall M	61, 62, 63, 64
Boyd	65, 66, 67, 68, 69

The Quad, located near the center of campus, consists of ten residence halls, with ten bicycle racks in the area, shown in Figure 3-2.

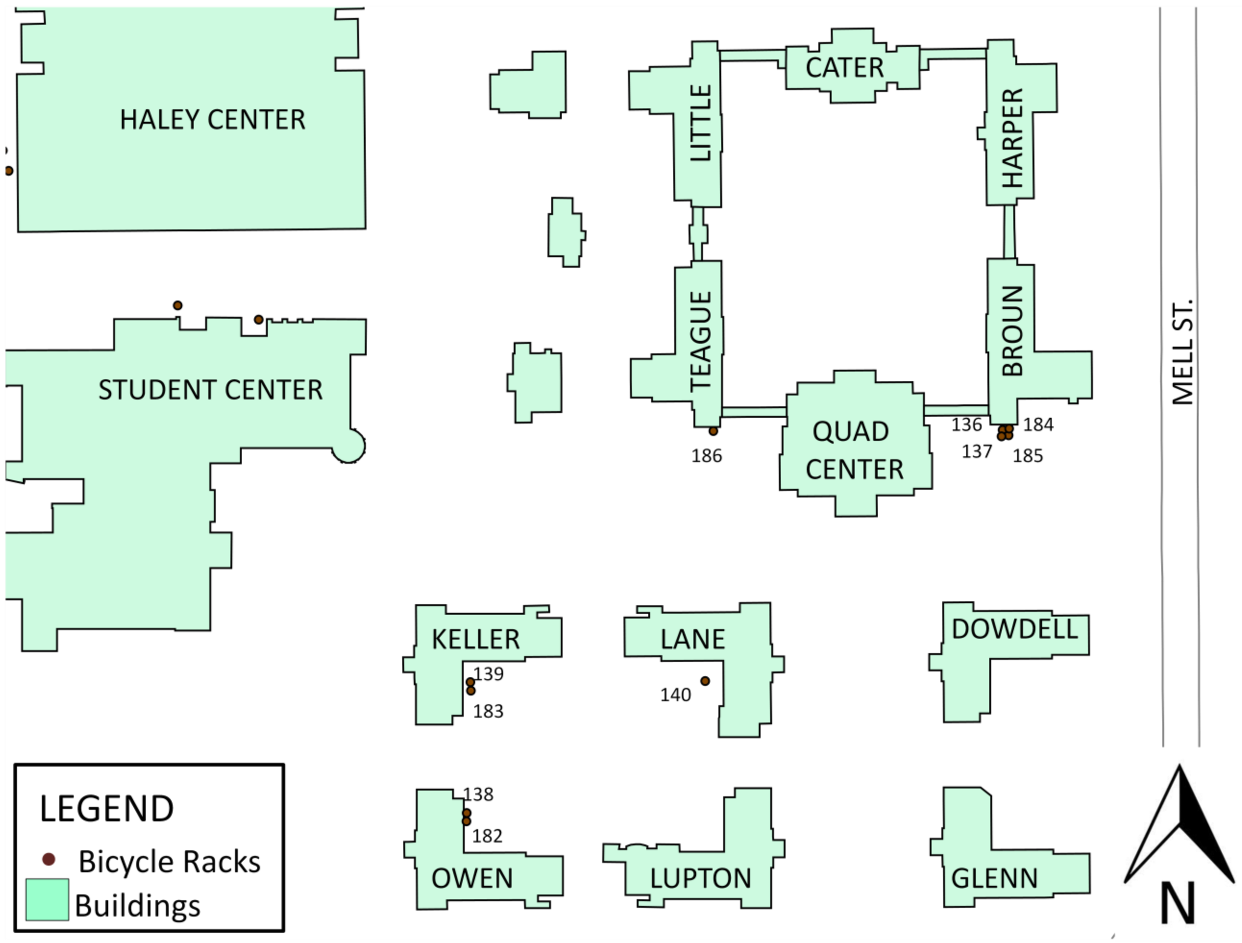

Figure 3-2: Bicycle Rack Locations at The Quad Residence Halls

Unlike The Hill, The Quad has some buildings that have no bicycle racks near them. The racks that are located in The Quad provide nearby bicycle parking to only five of the residence halls, a list of which is shown in Table 3-2.

Table 3-2: Rack Assignment for The Quad

Residence Halls	Racks
Little	-
Harper	-
Teague	186
Broun	136, 137, 184, 185
Keller	139, 183
Owen	138, 182
Lane	140
Lupton	-
Dowdell	-
Glenn	-

3.3.1 Development of Residence Hall Model

The development of the residence hall model included the 'peak rack usage' from The Hill and The Quad. Before creating the statistical model, the data that were collected in 2008 had to be sorted. At this point, the available data included the name and 'building square footage' of each residence hall, the number of beds in each hall, the racks that were assigned to each building, and the rack usage data. The data was sorted in different ways to examine which would be the best method to analyze the data. Table 3-3 shows an example of how the data were organized for The Hill.

Table 3-3: 2008 Data Organization for The Hill

The Hill		Bldg Sq. Footage	Rack#	Bicycle Rack Usage				Avg	Peak	Bldg Total	Peak Rack Usage
Hall	# of Beds			Mon	Tues	Wed	Thur				
Hollifield	107	29896	57	6	7	7	7	6.75	7	13	13
	107	29896	58	6	6	6	6	6.00	6	-	-
Duncan	107	30226	59	5	5	4	4	4.50	5	11	11
	107	30226	60	6	6	6	5	5.75	6	-	-
Toomer	107	30160	87	6	6	6	6	6.00	6	8	8
	107	30160	88	2	2	2	2	2.00	2	-	-
Dobbs	107	30213	85	3	3	3	3	3.00	3	9	9
	107	30213	86	6	6	4	4	5.00	6	-	-
Dunn	107	30536	84	10	10	8	8	9.00	10	19	19
	107	30536	81	9	9	7	7	8.00	9	-	-
Graves	107	35521	82	8	8	8	8	8.00	8	15	15
	107	35521	89	7	7	6	7	6.75	7	-	-
Dowell	107	36378	71	0	0	0	0	0.00	0	4	4
	107	36378	72	4	4	3	3	3.50	4	-	-
Knapp	107	36512	64	3.6	3.6	3.6	3.6	3.60	3.6	3.6	3.6
	107	36512	70	0	0	0	0	0.00	0	-	-
Boyd	212	61981	65	5	6	5	5	5.25	6	41	39
	212	61981	66	5	5	5	6	5.25	6	-	-
	212	61981	67	11	11	12	11	11.25	12	-	-
	212	61981	68	7	9	7	7	7.50	9	-	-
	212	61981	69	7	8	7	8	7.50	8	-	-
Sasnett	212	61561	75	7	7	8	8	7.50	8	38	37
	212	61561	76	9	9	8	9	8.75	9	-	-
	212	61561	77	10	10	9	9	9.50	10	-	-
	212	61561	78	8	9	11	11	9.75	11	-	-
Leischuck	101	31193	187	-	-	2	2	2.00	2	8	6
	101	31193	83	3	3	1	1	2.00	3	-	-
	101	31193	80	0	0	0	0	0.00	0	-	-
	101	31193	79	2	2	3	3	2.50	3	-	-
Hall M	101	31182	61	0	0	0	0	0.00	0	17.4	17.4
	101	31182	62	7	7	7	7	7.00	7	-	-
	101	31182	63	7	7	7	7	7.00	7	-	-
	101	31182	64	3.4	3.4	3.4	3.4	3.4	3.4	-	-

In Table 3-3, the four columns labeled 'Avg,' 'Peak,' 'Bldg Total,' and 'Peak Rack Usage' were created from the data collected in 2008 to be considered as the possible dependent variable in the model development. The 'Avg' column is the average usage for each rack across all four observed days and the 'Peak' column is the peak rack usage for each rack across all four observed days of data collection. The column labeled 'Bldg Total' is the sum of the peak values for each rack, but not corresponding to one particular day for each building. Finally, the column labeled 'Peak Rack Usage' represents the peak rack usage across all racks associated with an individual residence hall building for a single day. An example of how the 'Peak Rack Usage' values were obtained is shown in Table 3-4.

Table 3-4: Explanation of How Peak Rack Usage Term was Obtained

The Hill		Bldg Sq. Footage	Rack	Bicycle Rack Usage				Peak Rack Usage
Hall	# of Beds		#	Mon	Tues	Wed	Thur	
Sasnett	212	61561	75	7	7	8	8	37
Sasnett	212	61561	76	9	9	8	9	-
Sasnett	212	61561	77	10	10	9	9	-
Sasnett	212	61561	78	8	9	11	11	-
			TOTAL:	34	35	36	37	

The 'peak rack usage' represents the most bicycles present at the racks associated with one residence hall for a particular day throughout the data collection period. This value was chosen because it gives a more accurate count of the number of bicycles at each residence hall than the other variables by eliminating the possibility of counting the same bicycle twice. The data for The Quad was sorted in the same manner, and can be found in Appendix A, Table A-1 for further inspection.

From the 2008 rack usage data, the ‘peak rack usage’ was determined for each building in The Hill and The Quad. In total, there were 17 data points, one for each building, used in the creation of the model for the residence halls. The data points created for each building are located in the Peak Usage column of Table 3-5.

Table 3-5: Data Set Used for Creation of Residence Hall Model

Residence Halls		Bldg Sq.	Rack	Bicycle Rack Usage				Peak Rack
Hall	# of Beds	Footage	#	Monday	Tuesday	Wednesday	Thursday	Usage
Hollifield	107	29896	57	6	7	7	7	13
Hollifield	107	29896	58	6	6	6	6	-
Duncan	107	30226	59	5	5	4	4	11
Duncan	107	30226	60	6	6	6	5	-
Duncan	107	30226	61	0	0	0	0	-
Toomer	107	30160	87	6	6	6	6	8
Toomer	107	30160	88	2	2	2	2	-
Dobbs	107	30213	85	3	3	3	3	9
Dobbs	107	30213	86	6	6	4	4	-
Dunn	107	30536	84	10	10	8	8	19
Dunn	107	30536	81	9	9	7	7	-
Graves	107	35521	82	8	8	8	8	15
Graves	107	35521	89	7	7	6	7	-
Dowell	107	36378	71	0	0	0	0	4
Dowell	107	36378	72	4	4	3	3	-
Knapp	107	36512	64	3.6	3.6	3.6	3.6	3.6
Knapp	107	36512	70	0	0	0	0	-
Boyd	212	61981	65	5	6	5	5	39
Boyd	212	61981	66	5	5	5	6	-
Boyd	212	61981	67	11	11	12	11	-
Boyd	212	61981	68	7	9	7	7	-
Boyd	212	61981	69	7	8	7	8	-
Sasnett	212	61561	75	7	7	8	8	37
Sasnett	212	61561	76	9	9	8	9	-
Sasnett	212	61561	77	10	10	9	9	-
Sasnett	212	61561	78	8	9	11	11	-
Leischuck	101	31193	187	-	-	2	2	6
Leischuck	101	31193	83	3	3	1	1	-
Leischuck	101	31193	80	0	0	0	0	-
Leischuck	101	31193	79	2	2	3	3	-
HallM	101	31182	61	0	0	0	0	17.4
HallM	101	31182	62	7	7	7	7	-
HallM	101	31182	63	7	7	7	7	-
HallM	101	31182	64	3.4	3.4	3.4	3.4	-
Harper	78	21390	-	-	-	-	-	-
Broun	101	26340	136	8	7	7	8	28
Broun	101	26340	137	6	7	5	4	-
Broun	101	26340	184	3	6	7	-	-
Broun	101	26340	185	4	8	8	-	-
Little	90	27295	-	-	-	-	-	-
Teague	90	27041	186	12	-	-	-	12
Dowdell	104	30168	-	-	-	-	-	-
Glenn	104	25163	-	-	-	-	-	-
Lane	104	24370	140	12	11	11	11	12
Lupton	88	24349	-	-	-	-	-	-
Keller	104	23896	139	3	6	2	4	9
Keller	104	23896	183	6	-	3	4	-
Owen	104	23777	138	2	5	3	3	9
Owen	104	23777	182	7	-	2	3	-

The statistical analysis was performed using Statistical Analysis Software (SAS) version 9.1. SAS is a statistical analysis program that can be used to perform various functions. To complete the process of creating statistical models for this dataset, SAS was used for data entry and retrieval, multiple forms of regression analysis, and determination of statistical significance to the model.

Two methods of analysis were used when deriving a statistical model regression formula. Linear regression analysis and backward elimination were used in the development of the statistical models. Linear regression is a way of modeling the relationship between one observed variable (dependent variable) and one or more predictor variables (independent variable). Backward elimination is process of testing variables to determine their significance to the model by the examination of their corresponding p-value. If the p-value is greater than the selected significance level, then it is removed from the model. Three statistical values were also examined during this process, the p-value, R^2, and the r value. The p-value is the probability that the test statistic would take a value as extreme as or more extreme than that actually observed. The significance level, alpha, is the largest p-value tolerated, in this case 5% or 0.05, as is common practice in statistical modeling in this field. R^2, also known as the coefficient of determination, is calculated in the regression analysis, can range from zero to one and measures the goodness of fit of the plotted data. When performing linear regression, R^2 represents how well the data fit a line (i.e. y=mx+b) that has a constant slope. The closer the value of R^2 to one, the better the fitted model explains variability. The r value is the correlation coefficient between two variables. The closer the correlation coefficient r is to negative one or positive one, the higher the correlation between the variables.

The first method used was multiple linear regression. The residence hall data was analyzed in SAS and a model was created using the dependent variable 'peak rack usage' and the independent variables 'building square footage' and 'number of beds' in each residence hall. From this point on for the residence hall model, the independent variable building square footage will be referred to as 'SqFeet' and number of beds as 'Beds.' The linear regression formula developed is shown below.

$$PeakRackUsage = -13.162 + 0.3599*Beds - 0.0004182*SqFeet \quad \textbf{(2)}$$

In order to determine if both of the independent variables were statistically significant contributors to the model, the second method of analysis, backward elimination, was used. If a variable has a p-value greater than 0.05, then the variable is deemed statistically insignificant. During backward elimination the variable 'SqFeet' was eliminated from the analysis because it displayed a p-value of 0.36, shown in Table 3-6. The correlation coefficient between the two variables was examined, r = 0.9725, and it was determined that the variables 'Beds' and 'SqFeet' are correlated.

Table 3-6: SAS Output from Backward Elimination on Residence Hall Model (2)

Number of Observations Read	49	
Number of Observations Used	17	
Number of Observations with Missing Values	32	
All Variables Entered: **R-Square = 0.6731**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	-13.162	0.030
Beds	0.3599	0.022
SqFeet	-0.0004182	0.36

After removing the square footage term, simple linear regression was performed using the dependent variable 'peak rack usage,' and the independent variable, 'number of beds' in each building, to obtain the regression formula shown below.

$$\text{PeakRackUsage} = -12.708 + 0.2358*\text{Beds} \qquad \textbf{(3)}$$

Examination of the p-value for the number of beds reveals that it is statistically significant ($p < 0.0001$) shown in Table 3-7.

Table 3-7: SAS Output from Backward Elimination on Residence Hall Model (3)

Number of Observations Read	49	
Number of Observations Used	17	
Number of Observations with Missing Values	32	
All Variables Entered: **R-Square = 0.6523**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	-12.708	0.033
Beds	0.2358	<.0001

3.4 Development of Academic Building Model

During the fall of 2008, there were 42 buildings on AU's campus where classes were being held. Of these 42 buildings, 28 had bicycle racks that were associated with them. In 2008, there was a total of 188 bicycle racks on AU's campus, 112 of which were assigned to academic buildings. Bicycle racks were assigned to academic building using the same criteria as for the residence halls (Sec 3.3). Much like some bicycle racks for the residence halls, some racks for the academic buildings were assigned to more than one building. When this occurred, bicycle rack usage was divided between the buildings during each scheduled class period on each day that data were collected. The rack usage was divided using Equation (1), using the enrollment in each building during the scheduled class time to determine the percentage of rack usage to assign to each building.

Bicycle rack usage data were collected for the bicycle racks around the academic buildings during scheduled class times on Monday through Thursday. On Monday and Wednesday usage data were collected during the following times: 9:00-9:50am, 10:00-10:50am, 11:00-11:50am, 12:00-12:50pm, and 1:00-1:50pm. On Tuesday and Thursday usage data were collected from 9:30-10:45am, 11:00-12:15pm, and 12:30-1:45pm. These time periods coincide with the scheduled class times on their respective days. These collection times were chosen based on analysis of when the majority of students are registered for classes on Monday through Thursday (Wood, 2009).

AU has not developed a method for the placement of bicycle racks on campus and this can be seen when examining the position of these bicycle racks. The bicycle racks are scattered throughout campus, with most buildings having at least one bicycle rack assigned to it. However, some areas on campus are underserved and no bicycle racks are present. A map of campus with the spatial locations of all 112 racks in the academic building model is shown in Figure 3-3.

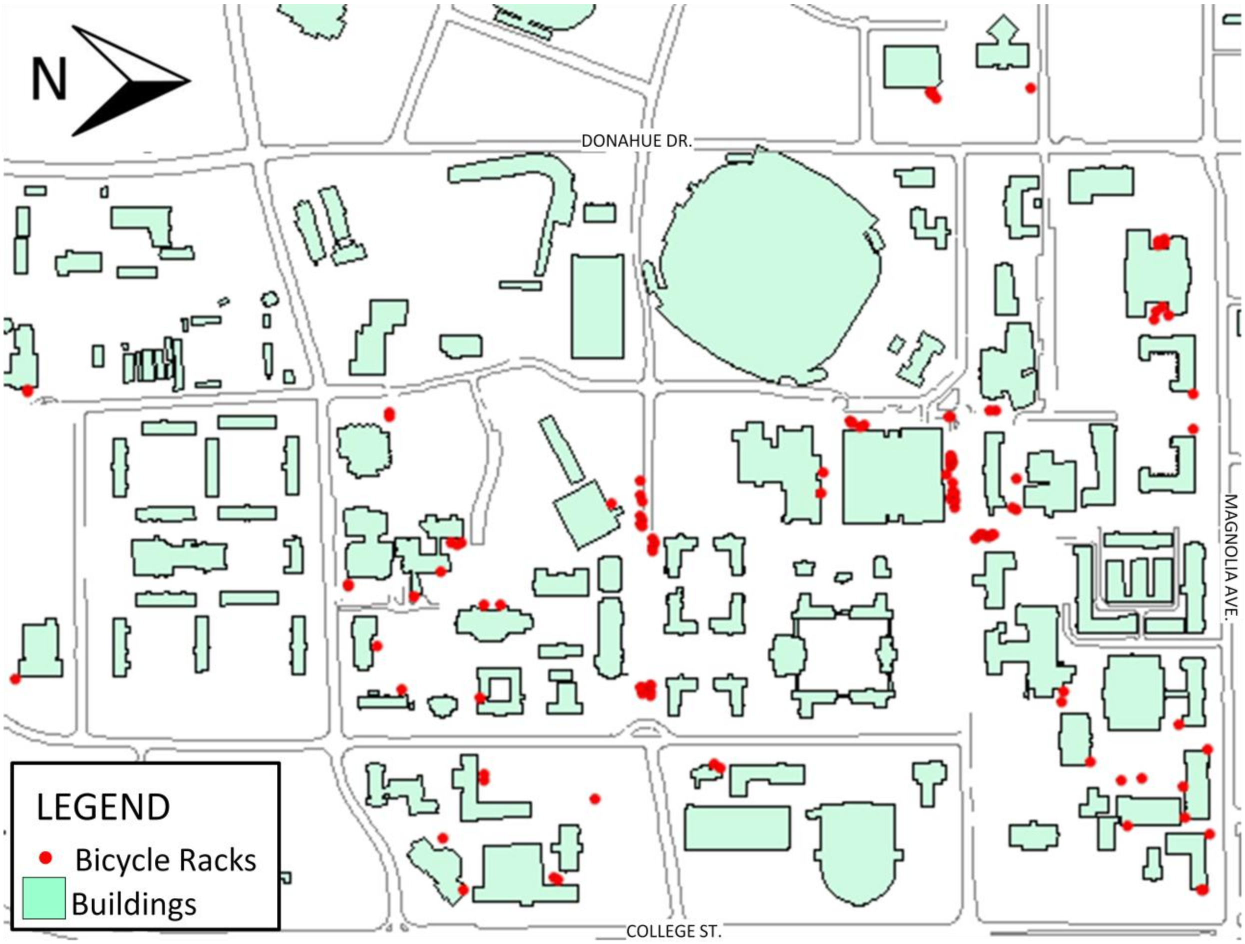

Figure 3-3: 2008 Auburn University Campus with All Bicycle Racks Assigned to Academic Buildings

The entire campus was examined, assigning bicycle racks to their corresponding building(s), and dividing the rack usage among multiple buildings when needed. Some bicycle racks were eliminated from the academic model because the building they were next to did not hold classes and therefore had no enrollment data. The following list presents reasons why bicycle racks were removed from the model.

- Rack 122 was removed because it is near Samford Hall, which is not an academic building. It houses offices for the President, Vice President, Provost, and other administrative offices.

- Racks 132 and 133 were removed because Wilmore Laboratories showed no enrollment for the fall of 2008.
- Rack 135 was removed because it was next to Foy Student Union, which is not an academic building. Foy contains student organization offices and dining areas.
- Racks 123, 124, 149-153, and 179-181 were removed because they are next to the Ralph Brown Draughon Library (RBD). The RBD Library serves few classes, with the majority of students at the library there to study.
- Racks 107-112 were removed because they are next to the Student Activities Center which has few classes, with the majority of students there for recreational purposes.

The racks around the RBD Library serve more than just students attending the classes that are held there. The racks are utilized by the students that visit the library each day to complete class work and to study; this makes the usage data for the racks around the RBD Library inconsistent with the number of students enrolled in classes there. The Student Activities Center, Beard-Eaves Memorial Coliseum, and Martin Aquatics Center are similar to the library in that the number of students that travel there for recreation is assumed to be greater than that of the number of students enrolled in classes there.

3.4.1 Academic Model by Individual Building

Once the racks had been assigned to specific academic buildings, the method of how to model enrollment and rack usage was determined. Several different ways were examined before the selection of the preferred method was made. The first option analyzed was comparing the average rack usage for each building with the average enrollment for a single data collection day.

This technique was rejected because averaging the values distorts the actual behavior of the data. Averaging the rack usage and enrollment provides a value lower than the peak, which would underrepresent the actual peak demand. The second option explored was to compare the total peak rack usage for each building on a single day with the peak enrollment for the same day. This option was discarded because the peak rack usage did not always coincide with the peak enrollment, creating a misrepresentation of what the actual demand. The final option was to compare the peak rack usage for each building with the associated enrollment for that time period. This technique was chosen because it provides a more accurate representation of the usage by relating it to the actual number of students enrolled.

The usage data for all the racks that were assigned to one building for each day were summed up to get the totals for each of the collection periods across all four days, shown in Table 3-8. The corresponding enrollment for the peak rack usage value from all four days was the enrollment value that was used in the model development.

Table 3-8: Description of How Enrollment Data was Chosen Based on Rack Usage

					Rack Usage on Monday				
Building Name	**Day, Time**	**Enrollment**		**RACK #**	**9-950**	**10-1050**	**11-1150**	**12-1250**	**1-150**
Biggin Hall	**M 9-950**	48							
	M 10-1050	112		114	2	1	0	2	2
	M 11-1150	86		115	2	5	4	4	5
	M 12-1250	129		117	1	1	1	1	1
	M 1-150	115		118	0.00	0.46	0.46	0.23	0.23
				Total	5	7.46	5.46	7.23	8.23

The table above, Table 3-8, displays how the enrollment values and the bicycle rack usage values were chosen. Once the total rack usage for all racks associated with one building was obtained, shown in the bottom row labeled 'Total', the peak value was determined. For Biggin Hall on

Monday, the collected peak rack usage was 8.23 bicycles. This usage value is in the column for Monday, 1:00-1:50pm. The enrollment value associated with the Monday time slot of 1:00-1:50pm is 115 students. The usage for rack number 118 was divided between Biggin Hall and Charles E. Davis Aerospace Hall. Instead of rounding the decimal created by the division, the true values were left in the data. Although it is not possible to have a fraction of a bicycle, having that level of precision within the data provides a better representation of the true bicycle rack usage. Table 3-9 below shows which buildings some of the racks on campus were assigned to. A complete list of which racks were assigned to each building can be found in Appendix A in Table A-2.

Table 3-9: Bicycle Racks Assigned to Academic Buildings (Partial Table)

Academic Building	Rack #
Biggin Hall	114, 115, 117, 118
Harbert Center	119, 156
Ramsay Hall	141
Charles E. Davis Aerospace Hall	116, 118, 120, 121
Ross Hall	131, 134

Figure 3-4 provides a visual display of the buildings and racks provided in Table 3-9, as used in the fall 2008 data collection effort (Wood, 2009).

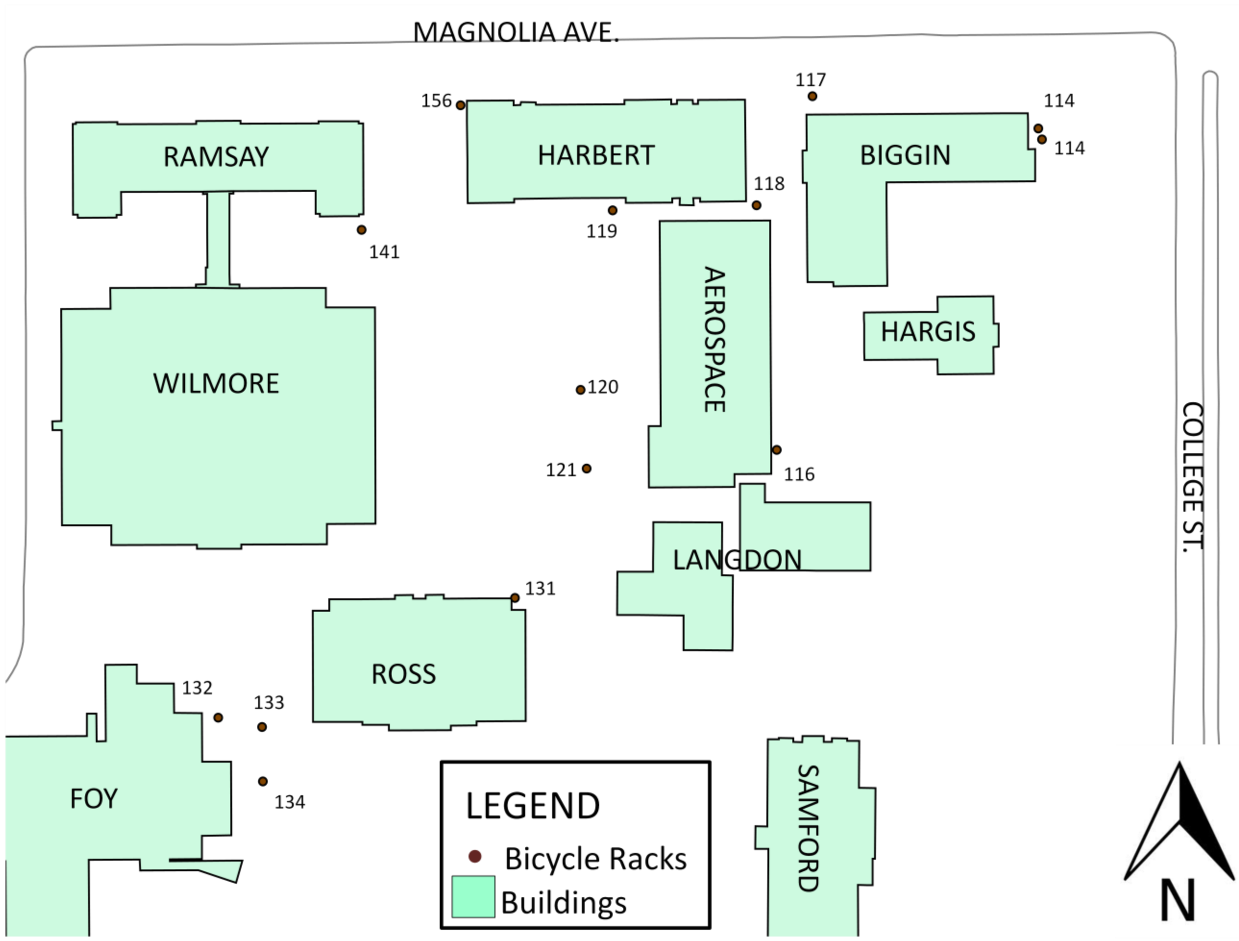

Figure 3-4: Buildings and Racks Displayed in Table 3-9

Rack usage was divided between buildings based on the maximum number of students enrolled in classes for each collection day. For example, rack number 118 was divided between Aerospace and Biggin. For Monday, the collected rack usage is shown in Table 3-10 below.

Table 3-10: Collected Rack Usage for Rack 118 on Monday

RACK #	M 9-950	M 10-1050	M 11-1150	M 12-1250	M 1-150
118	0	2	2	1	1

The maximum enrollment for Biggin Hall on Monday was 129 and for Aerospace it was 432. Following the same equation used for the division of rack usage for the residence hall model, Equation 1, the following calculations were made.

Table 3-11: Rack Usage Assignment for Rack 118 Between Aerospace and Biggin

Academic Building	Collected Usage (10-1050)	%	Assigned Usage
Biggin	2	0.23	0.46
Aero		0.77	1.54

Table 3-10 and Table 3-11 show only a portion of all the calculations made to develop the academic building data. For a list of all the racks that were divided between multiple buildings and the full dataset refer to Appendix A, Tables A-3 and A-4, respectively.

Once the full dataset was complete, it was imported into SAS. In SAS, linear regression and backward elimination were performed to determine which variables would be used in the model to predict bicycle rack usage. The dependent variable for the model was the 'peak rack usage,' and the independent variables under consideration were total building square footage (GrossSqFt), total classroom square footage (ClassSqFt), and 'Enrollment.' There were 28 buildings in this model that had bicycle racks assigned to them. There were 112 observations (N=112) because each building had one data point for each of the four days (Monday-Thursday). However, the first model was created using only 108 observations because one of the buildings, the Science Center Laboratories, did not have a classroom square footage reported by the University. Multiple linear regression was performed including all three independent variables in the model. The resulting regression formula is shown below.

$$\text{PeakRackUsage} = 1.9853 + 0.00006521 * \text{GrossSqFt} - 0.0005616 * \text{ClassSqFt} + 0.04755 * \text{Enrollment} \quad \textbf{(4)}$$

To determine the statistical significance of the variables in the model, backward elimination was used. It was determined that all the variables were significant (P-value < 0.05). The correlation coefficient r was analyzed for the variables in model (4). The variables 'Enrollment' and 'GrossSqFt' had an r value of 0.8038, 'Enrollment' and 'ClassSqFt' had an r value of 0.9483 and

'ClassSqFt' and 'GrossSqFt' had an r value of 0.8758. The output from SAS is shown in Table 3-12.

Table 3-12: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (4)

Number of Observations Read	112	
Number of Observations Used	108	
Number of Observations with Missing Values	4	
All Variables Entered: **R-Square = 0.8360**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	1.9853	0.134
GrossSqFt	0.00006521	0.00470
ClassSqFt	-0.0005616	0.0283
Enrollment	0.04755	<.0001

All the variables in model (4) are statistically significant and therefore the model will be incorporated into *Chapter 5: Model Application and Results*.

Three other models were also created to further expand the analysis of the academic model for each individual building. The first model included 'Enrollment' and 'ClassSqFt' as the independent variables. The second model included 'Enrollment' and 'GrossSqFt' as the independent variables. The third model included only 'Enrollment' as the independent variable. These models were created to help determine which independent variables, regardless of significance, could be used as predictors of the peak rack usage. The statistical significance of the variables changes when the dataset is reduced to include combinations of the three candidate independent variables.

The first model examined included the 'ClassSqFt' and 'Enrollment' as the independent variables. Multiple linear regression was performed with the two independent variables, and the dependent variable 'peak rack usage.' The model equation shown below is the result of the analysis performed in SAS and Table 3-13 displays the SAS output data.

PeakRackUsage = 4.4271 + 0.04470*Enrollment - 0.0001243*ClassSqFt **(5)**

Table 3-13: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (5)

Number of Observations Read	112	
Number of Observations Used	108	
Number of Observations with Missing Values	4	
All Variables Entered: **R-Square = 0.8228**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	4.427	<.0001
ClassSqFt	-0.0001243	0.554
Enrollment	0.04470	<.0001

Backward elimination was performed to determine the significance of the independent variables. The p-value of the 'Enrollment' term showed that it was statistically significant ($p < 0.0001$). The correlation coefficient r for the independent variables in this model is 0.9483, displaying a strong correlation between variables. However, the classroom square footage variable was determined to be insignificant ($p = 0.554$), so model (5) will not be carried into the model application process.

The second model analyzed was created using the independent variables 'Enrollment' and 'GrossSqFt.' The regression formula developed for is shown below, accompanied by the backward elimination output from SAS in Table 3-14.

PeakRackUsage = 3.0395 + 0.03631*Enrollment + 3.751×10^{-5}*GrossSqFt **(6)**

Table 3-14: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (6)

Number of Observations Read		112
Number of Observations Used		112
Number of Observations with Missing Values		0
All Variables Entered: **R-Square = 0.8252**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	3.0395	0.0175
GrossSqFt	0.00003751	0.0420
Enrollment	0.03631	<.0001

Even though the coefficient for gross square footage was very small, after completing backward elimination it showed significance to the model (p=0.0420). This significance can be explained by the values of gross square footage that range from 10^4 to 10^6 square feet. Both 'Enrollment' and 'GrossSqFt' are statistically significant predictors to the model and have a correlation coefficient r=0.8038. Model (6) will be applied and the results will be compared to the newly collected 'peak rack usage' values from 2010 in *Chapter 5*.

The final model created using this dataset with 112 data points included only the independent variable 'Enrollment.' The regression formula produced by comparing the enrollment to the peak rack usage is shown below.

$$\text{PeakRackUsage} = 4.6051 + 0.04140*\text{Enrollment} \qquad \textbf{(7)}$$

Table 3-15: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (7)

Number of Observations Read		112
Number of Observations Used		112
Number of Observations with Missing Values		0
All Variables Entered: **R-Square = 0.8184**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	4.6051	<.0001
Enrollment	0.04140	<.0001

As expected, the p-value for the enrollment variable in this model showed that it was significant ($p<0.0001$). Model (7) will be examined in model application to determine its validity.

One more avenue of model development was explored. In the previous models, each building had four data points; one for each data collection day (Monday, Tuesday, Wednesday, and Thursday). The model was reduced from 112 observations, to only 28. The dataset was compressed by examining the peak rack usage and enrollment for each building on each day and selecting the peak usage from these four values.

Table 3-16: Data Set for All Four Days

Building Name	Monday		Tuesday		Wednesday		Thursday	
	Peak Rack Usage	Enrollment	Peak Rack Usage	Enrollment	Peak Rack Usage	Enrollment	Peak Rack Usage	Enrollment
Biggin	8.23	115	14.00	221	7.23	129	11.43	221
Broun	12.31	121	18.96	197	14.15	175	17.54	299
Aero	26.54	432	15.00	303	26.77	432	16.57	295
ChemBldg	25.00	412	15.00	367	21.00	426	20.00	430

For example, the 'Peak Rack Usage' and 'Enrollment' for Broun Hall on Monday through Thursday are shown in Table 3-16. Broun Hall has a 'peak rack usage' of 18.96 across all four days, so the rack usage and the corresponding enrollment of 197 were used in the creation of a reduced data set. The completely reduced data set is shown in Appendix A, Table A-5.

This group of models will be referred to as the peak day models. The independent variables that were considered in this form of the model are the same as in the previous model: 'ClassSqFt,' 'GrossSqFt' and 'Enrollment'. The dependent variable 'peak rack usage' has not changed.

The initial peak day model that was created included all three independent variables. Linear regression and backward elimination were again performed using SAS. During the first step of backward elimination, gross square footage was removed from the model because it was deemed not significant (p=0.4909).

Table 3-17: SAS Output from Backward Elimination for Academic Building Model Variables

Number of Observations Read	28	
Number of Observations Used	27	
Number of Observations with Missing Values	1	
All Variables Entered: **R-Square = 0.9107**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	4.8619	0.0461
Enrollment	0.07456	<.0001
GrossSqFt	0.00002759	0.4909
ClassSqFt	-0.00105	0.0193

Once the variable 'GrossSqFt' was removed, backward elimination was performed again. After the second step was completed, no more variables were eliminated, producing the following equation. The results from the SAS output are shown in Table 3-18.

$$PeakRackUsage = 5.8818 + 0.07458*Enrollment - 0.0009045*ClassSqFt \quad \textbf{(8)}$$

Table 3-18: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (8)

Number of Observations Read	28	
Number of Observations Used	27	
Number of Observations with Missing Values	1	
All Variables Entered: **R-Square = 0.9088**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	5.8818	0.0028
Enrollment	0.07458	<.0001
ClassSqFt	-0.0009045	0.0188

'ClassSqFt' and 'Enrollment' were left in the model because they were significant at the p<0.05 level. The independent variables have a correlation coefficient r of 0.9494 showing a strong relationship between the variables. Model (8) will be carried through to analysis because of the significance (p-value) of the two variables.

To further provide more models to analyze new usage data, two more models were developed: ‘Enrollment’ and ‘GrossSqFt’ and only ‘Enrollment.’ When ‘ClassSqFt’ is replaced with ‘GrossSqFt’ the square footage term becomes insignificant (p>0.05). The regression model is shown below with the SAS output for the process of backward elimination in Table 3-19.

PeakRackUsage = 6.1853 + 0.05264*Enrollment - 2.086E-5*GrossSqFt **(9)**

Table 3-19: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (9)

Number of Observations Read	28	
Number of Observations Used	28	
Number of Observations with Missing Values		
All Variables Entered: **R-Square = 0.8863**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	6.1853	0.0168
Enrollment	0.05264	<.0001
GrossSqFt	-0.00002086	0.5799

Since the ‘GrossSqFt’ variable was not significant, model (9) will not be analyzed against the data collected in 2010. The final model created for the analysis of the usage for the peak day includes on the independent variable ‘Enrollment.’ This model equation is shown below, along with the SAS output in Table 3-20.

PeakRackUsage = 5.3632 + 0.04964*Enrollment **(10)**

Table 3-20: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (10)

Number of Observations Read	28	
Number of Observations Used	28	
Number of Observations with Missing Values	0	
All Variables Entered: **R-Square = 0.8849**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	5.3632	0.0088
Enrollment	0.04964	<.0001

Two models from the group of peak day models will be examined in *Chapter 5: Model Application and Results.* The results from model (8) with the independent variables 'ClassSqFt' and 'Enrollment' and model (10) with only "Enrollment' will be compared to the 2010 collected rack usage data.

During the development of the academic building models, the residence hall model was being analyzed with new observed bicycle rack usage data that was collected during the fall of 2010. The collection of new data will be explained in *Chapter 4*. During this analysis process, it was determined that the residence hall model predicted rack usage better when each area was examined as a group, instead of individual buildings. Therefore, the academic building model was re-examined and zones were created to analyze the academic buildings as groups instead of individual buildings. The following section will explain this process and the models created.

3.4.2 Academic Building Model by Zone

Examining the academic model using zones instead of individual buildings was a result of analysis that was being performed on the residence hall model and new data collected in 2010. The residence hall model produced much better results when they were grouped into zones. The same approach was applied to the academic building model after the discovery of this idea. The academic buildings on campus were grouped together into 15 zones. The delineation of these zones was determined by the use of engineering judgment, knowledge about the campus layout and the locations of bicycle racks around campus, shown in Figure 3-5. There is some potential for bias in the creation of the zones on campus. The researcher used personal experience from attending Auburn University and commuting by bicycle for six years as an influential factor in the delineation of each zone. Each zone was created by examining natural groups of buildings and groups of bicycle racks. Some zones contain only one building, while others contain three or four. Refer to Figure 3-4 for an illustration of a created zone.

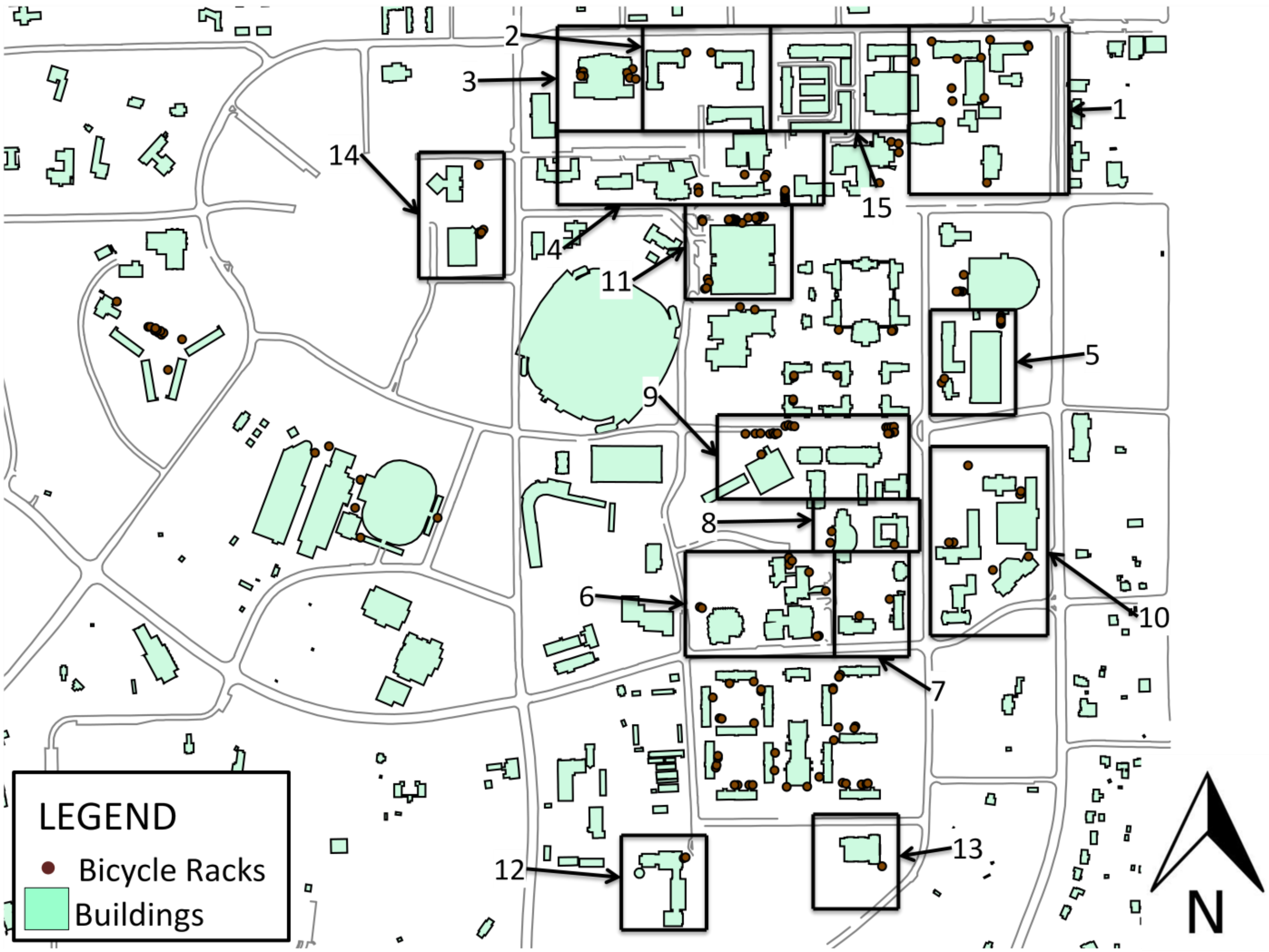

Figure 3-5: Auburn University Campus with Zone Delineation

Once the zones were created, the bicycle rack usage data collected from 2008 was sorted to represent the usage for each zone. By using this method to divide up the campus, racks do not need to be divided between buildings; therefore a more accurate representation of the demand can be portrayed. The racks assigned to each zone were then organized in order to calculate the peak rack usage for each zone on Monday, Tuesday, Wednesday, and Thursday. The same technique for data organization was used for the zone analysis as was for the individual building analysis. The rack usage for each zone was summed up according to their collection times. The peak usage was determined from the totals of the all racks in each zone. The enrollment value associated with the peak rack usage time period served as one of the independent variables.

Fifteen zones were delineated that contain all the bicycle racks on campus that were associated with academic buildings. Four zones, zones 12-15 in Table 3-21, were eliminated from the development of the model because rack usage data was not available from the 2008 data.

Table 3-21: Academic Buildings and their Respective Zones

Zone	Building Name
1	Biggin Hall, Harbert Center, Aerospace, Ramsay Hall, Ross Hall
2	Shelby Center
3	Lowder Business Building
4	Walker Building, Broun Hall, Thach Hall
5	Spidle Hall
6	Peet Theatre, Goodwin Hall, Dudley Hall
7	Miller Gorrie Center, Swingle Hall
8	Chemistry Building, Corley
9	Parker, Science Center Auditorium, Science Center Laboratory, Science Center Classroom
10	Upchurch Hall, Rouse Life Sciences, Funchess Hall, Comer Hall
11	Haley Center
12	Forestry and Wildlife Sciences
13	Poultry Science Building
14	Nichols Center, Wallace Center
15	Textile Building, Engineering Shops

The initial model tested contained the dependent variable peak rack usage and the three independent variables, classroom square footage, gross square footage, and enrollment. The number of observations for this model was 44. Each of the eleven zones had four data points corresponding to Monday through Thursday. The first step of backward elimination removed classroom square footage from the model (p=0.7625) and then gross square footage was removed second because it was not statistically significant (p=0.2907). The results of backward elimination are shown in Table 3-22.

Table 3-22: SAS Output from Backward Elimination for All Academic Building Model Variables

Number of Observations Read	44	
Number of Observations Used	44	
Number of Observations with Missing Values	0	
All Variables Entered: **R-Square = 0.6416**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	5.5553	0.4459
Enrollment	0.0467	0.0008
ClassSqFt	-0.0001629	0.7625
GrossSqFt	0.00004498	0.2907

The resultant model contained only the variable 'Enrollment' for the independent variables. The regression formula derived is shown below.

$$PeakRackUsage = 11.263 + 0.0464*Enrollment \quad \textbf{(11)}$$

Table 3-23: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (11)

Number of Observations Read	44
Number of Observations Used	44
Number of Observations with Missing Values	0

All Variables Entered: **R-Square = 0.6298**

Variable	Parameter Estimate	Pr > F
Intercept	11.263	0.0343
Enrollment	0.04644	<.0001

The second model was the peak day model. It had only eleven observations, one data point for each building. This data point represented the peak rack usage for all four collection days, across all collection periods, for each zone. Table 3-24 shows the dataset for the peak day model.

Table 3-24: Peak Day Academic building Model Data

ZONE	Total Zone Gross Square Footage	Classroom Square Footage	PEAK DAY	
			Peak Rack Usage	Enrollment during peak rack usage
1	278024	20375	59	667
2	198169	10315	19	239
3	161848	38635	49	1155
4	274430	28651	43	491
5	50843	5469	7	297
6	160495	9208	49	392
7	67521	3935	9	101
8	95858	9348	29	450
9	135711	27978	135	1356
10	339158	12186	39	444
11	414651	62278	118	2120

Backward elimination removed gross square footage (p=0.4372) in step one and classroom square footage (p=0.1947) in step two. Enrollment was the only significant term that was tested for this model (p=0.0005). The regression formula produced is shown below.

$$\text{PeakRackUsage} = 8.8121 + 0.05953*\text{Enrollment} \qquad \textbf{(12)}$$

Table 3-25: SAS Output from Backward Elimination for Academic Building Model Variables in Equation (12)

Number of Observations Read	11	
Number of Observations Used	11	
Number of Observations with Missing Values	0	
All Variables Entered: **R-Square = 0.7605**		
Variable	**Parameter Estimate**	**Pr > F**
Intercept	8.8121	0.4059
Enrollment	0.05953	0.0005

3.5 Summary of Created Statistical Models

All the statistical models developed in this chapter were derived from bicycle rack usage data that were collected in 2008, and the building data for the residence halls and the academic buildings. The model that will be carried through to analysis for the residence halls is shown below.

$$PeakRackUsage = -12.708 + 0.2358*Beds \quad \textbf{(3)}$$

Model (3) contains the only statistically significant independent variable that was analyzed.

The models that will be carried through to analysis for the academic buildings are listed below.

$$PeakRackUsage = 1.9853 + 0.00006521*GrossSqFt - 0.0005616*ClassSqFt + 0.04755*Enrollment \quad \textbf{(4)}$$

$$PeakRackUsage = 3.0395 + 0.03631*Enrollment + 3.751 \times 10^{-5}*GrossSqFt \quad \textbf{(6)}$$

$$PeakRackUsage = 4.6051 + 0.04140*Enrollment \quad \textbf{(7)}$$

$$PeakRackUsage = 5.8818 + 0.07458*Enrollment - 0.0009045*ClassSqFt \quad \textbf{(8)}$$

PeakRackUsage = 5.3632 + 0.04964*Enrollment	**(10)**
PeakRackUsage = 11.263 + 0.0464*Enrollment	**(11)**
PeakRackUsage = 8.8121 + 0.05953*Enrollment	**(12)**

Model (4), (6), and (7) for the individual building, all four days analysis, will be carried through for comparison to the 2010 collected rack usage data. These models were selected by analyzing the statistical significance of each variable and the correlation between variables. Models (8) and (10) were selected for the individual building, peak day analysis to be carried through to the analysis process for the same reasons. Model (11) and (12) were chosen to represent the zone analysis, for all four days and peak day respectively, based on 'Enrollment' being the only significant independent variable.

The spatial locations of all bicycle racks on campus were collected in 2010, which will be discussed in *Chapter 4: Data Collection*. A new set of data were collected in the fall of 2010, and the regression formulas in this section will be examined to determine how closely they estimate the rack usage that was collected. The rack usage estimates calculated from the statistical models developed in this chapter will be compared to the collected rack usage from October 2010, as discussed in *Chapter 4: Data Collection*.

CHAPTER 4

DATA COLLECTION

4.1 Introduction

Once the models had been developed from the 2008 data, new bicycle rack usage data needed to be collected. The new bicycle rack usage data would be used to determine the accuracy of the predicted rack demand, based on the 2008 rack usage data, as described in *Chapter 3*, by the created linear regression models. Auburn University's (AU) campus has undergone changes since the data collection effort in 2008; therefore the locations of each bicycle rack had to be collected so that rack usage data could be collected to test the models. The spatial locations of bicycle racks were collected using a Trimble Geo Xt receiver and imported into ArcMap. A computer aided design (CAD) file of all the buildings on campus was also imported into ArcMap and the rack position data were overlaid onto the map. For the data collection effort, campus was divided in half because of its size and the limited number of data collectors. Week 1 consisted of data collection for the north half of campus and the residence halls and week 2 consisted of the south half of campus. These data were then entered into a spreadsheet and organized so that analysis of the created models could take place.

4.2 Changes to Campus

Since the collection of bicycle rack data during 2008, many changes have taken place at Auburn University. A new residence hall area, The Village, was opened to students in 2009. The new residence area provided bicycle racks that were not previously included or collected in the data. New bicycle racks were installed near Parker Hall, increasing the number of racks and the overall capacity. The Haley Concourse was refinished and bicycle racks were placed on it near Haley Center. The following list presents the locations where more bicycle racks were added, or new locations of bicycle racks (between 2008 and 2010):

- Davis Aerospace Building
- Shelby Center
- Lowder Business Building
- Parker Hall
- Chemistry Building
- Funchess Hall
- Haley Center
- Walker Pharmacy Building
- Cary Hall
- The Village
- The Quad

4.3 Equipment Used

Throughout the process of collecting the spatial location of bicycle racks on campus, some hardware and certain software programs were utilized. AutoCAD 2010, ArcGIS 9.3, Pathfinder Office and a Trimble Geo Xt receiver were used during the data collection process.

The spatial locations of all the bicycle racks on campus were collected using a Trimble Geo Xt receiver, borrowed from the Biosystems Engineering department at AU. The receiver is a handheld global positioning system (GPS) with the ability to collect multiple forms of data. The unit was operated as a handheld GPS device, accessing satellites' positions above to determine the position of each bicycle rack on the ground. In conjunction with the Geo Xt receiver, software called Pathfinder Office was used to create a data dictionary that was used during the collection of bicycle rack positions. Pathfinder Office can be used for post processing to improve the accuracy of the data collected in the field. A campus map containing the CAD drawings and spatial locations of all the buildings, roads, sidewalks and multiple other features was obtained from the Office of Campus Planning. AutoCAD was used to reduce the file to the necessary features needed for use during data collection. Once a new file had been created in AutoCAD that contained the buildings, roads and sidewalks, it was imported into ArcMap. ArcMap is the main component in ESRI's software package ArcGIS. ArcMap is a geospatial processing program used to view, edit, create, and analyze geospatial data. ArcMap was used to create a campus wide map that included all the buildings and locations of the bicycle racks. These maps were used in the collection of rack usage data.

4.4 Geo-Location of Bicycle Racks

The Trimble Geo Xt receiver is a handheld GPS data collector that was used to collect the spatial location of the bicycle racks on campus. Prior to collecting bicycle rack position data, a data dictionary was created in Pathfinder Office. The data dictionary contained information that was used to assist in the data collection and provided a file to upload onto the Geo Xt receiver for the creation and storage of shape files when collecting in the field. There are three different types of shape files that can be collected: point, line, and polygon. For the purpose of collecting bicycle rack positions in this research, point files were created at each location. The entire campus was covered during the location and collection of each rack on campus. At each bicycle rack a new point file was created. To collect the location a sufficient number of satellites was necessary, and a minimum number of registered points were needed. The minimum number of satellites needed to collect latitude, longitude and altitude is four. When collecting point features with the Geo Xt receiver with a logging interval of one second, a minimum of 90 collected positions logged is suggested to obtain an accurate point. Pathfinder Office allows for increased accuracy of collected features by differentially correcting the position information. After the locations of all the bicycle racks were collected, the data were uploaded into Pathfinder Office. Using a permanently fixed base station, called a CORS (Continuously Operating Reference Station), the data was differentially corrected. CORS are used to correct collected data because its location is known to a high degree of certainty. The CORS station in Auburn, AL is located at the City of Auburn Information Technology office was used to differentially correct the collected rack locations. Differential correction is a process used to decrease the errors that affect the accuracy of GPS. The data is corrected by obtaining the location of the nearest CORS and calculating the error for each position feature collected.

Once the spatial locations of the collected bicycle racks had been differentially corrected they were imported into ArcGIS. In ArcGIS, the spatial locations of the bicycle racks was combined with the campus map imported from AutoCAD to create a complete map of AU with all the bicycle racks on campus.

4.5 Data Collection Effort

In 2010 the spatial locations of 269 bicycle racks were collected, up from 188 in 2008. The total of 269 bicycle racks includes all racks around the residence halls, the RBD Library, Foy Hall, the Student Center, and the academic buildings. The data collection effort was divided into two, week long periods and the campus was divided into two sections of racks, the northern half and the southern half. Week 1 was October 4-7, 2010 and Week 2 was October 11-14, 2010. The collection took two weeks because of the size of campus, the distance to some areas where racks were located and the number of data collectors available to help. Fellow graduate students and some faculty members from the Civil Engineering Department participated in the collection of the bicycle rack usage data. During Week 1, the usage data for the northern part of campus along with the usage data for the residence hall areas were collected. Week 2 consisted of data collection for the southern part of campus. Each portion of campus was further subdivided into smaller components so that data collection could be made more manageable and collected by one person in each component within the designated time period.

The usage data were collected at the same time intervals as the data from 2008. The bicycle rack usage for the residence halls was collected from 6:00am to 7:00am on Monday through Thursday. The rack usage for the academic buildings was collected during times when classes were scheduled to be in session, but the actual collection time intervals included a buffer of ten minutes after the class started and before the class ended. The collection times that the data collectors recorded usage for are listed below.

- Monday and Wednesday: 9:10-9:40am, 10:10-10:40am, 11:10-11:40am, 12:10-12:40pm, and 1:10-1:40pm
- Tuesday and Thursday: 9:40-10:35am, 11:10-12:05pm, and 12:40-1:35pm

These collection times were chosen to allow the maximum number of students to be present in class. The ten minute buffer after class begins allows for students running late to make it to class and the ten minute buffer before class ends for students who leave early to still be counted in the rack usage.

During Week 1, Monday October 4 to Thursday October 7, 2010, usage data were collected for the residence hall areas and the zones in the northern portion of campus and during Week 2, Monday October 11 to Thursday October 14, usage data were collected for the southern portion of campus. Figure 4-1 shows the delineation of the zones for the northern half of campus. The zone boundaries have no relation the zone delineation previously performed on the existing data from 2008. A map of the locations of the residence halls and a map of the southern half of campus can be found in Appendix B, Figures B-1 and B-2, respectively.

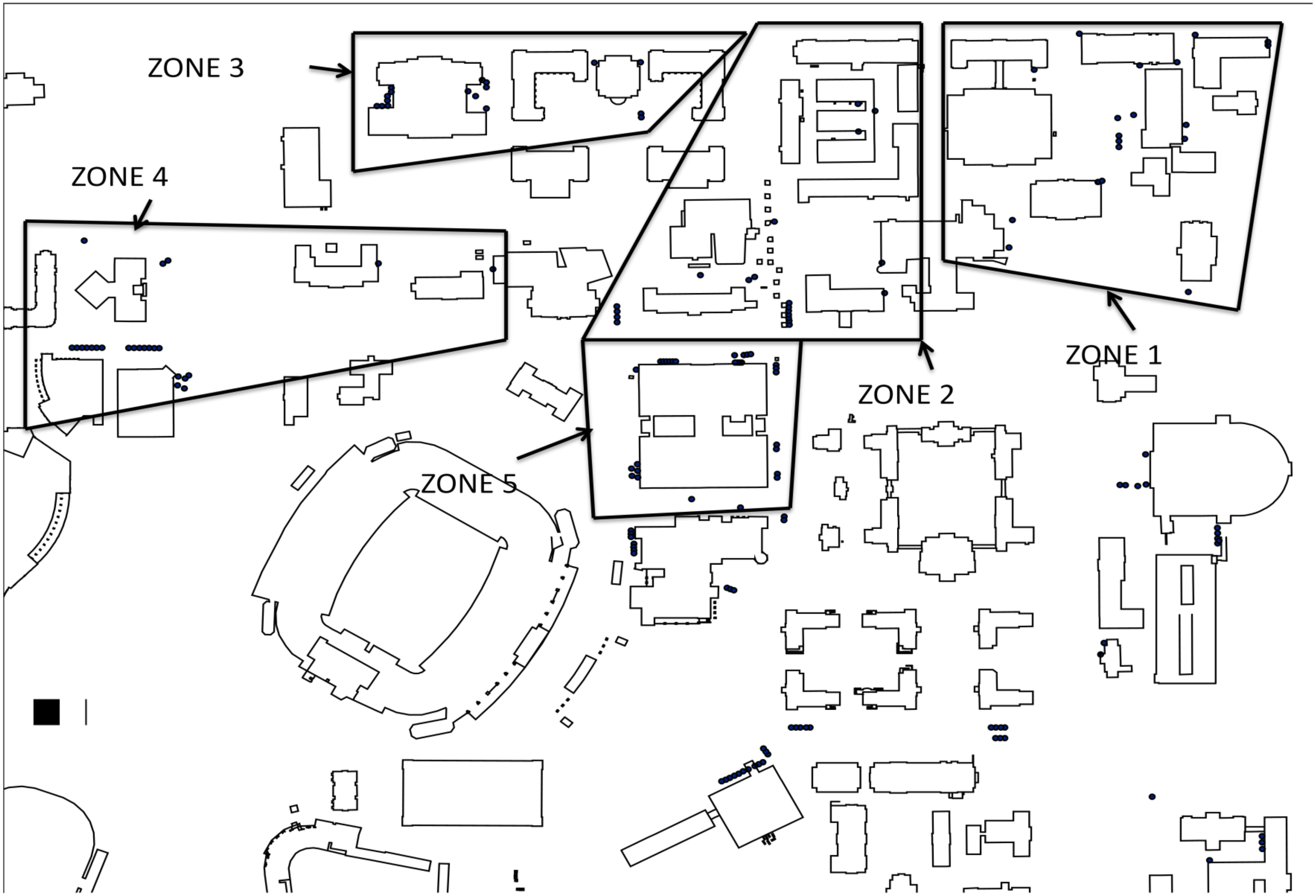

Figure 4-1: Northern Portion of Campus with Delineated Zones Collected During Week 1

Data collectors signed up for time slots in which they would record the rack usage data for particular zones all over campus. For both the residence hall areas and the academic building zones the data collectors were each given two maps and a data collection sheet for each time slot they signed up for. The first map was a map of campus, with their specific collection area displayed. This map was intended to show the location of their collection zone in relation to the rest of campus. The second map showed a detailed representation of the collection area. This map was intended to provide the locations of all the bicycle racks in which they were supposed to collect usage data for. Examples of maps and data collection sheets for the residence halls can be found in Appendix B, Figures B-3 and B-4, and for the academic buildings in Appendix B, Figures B-5 and B-6.

4.5.1 The Residence Halls

The usage data for the residence hall areas were only collected on Monday and Tuesday. This decision to eliminate the collection of usage data on Wednesday and Thursday was made because the data was similar on Monday and Tuesday, if not exact in some cases. A comparison of the data collected for the Village is shown in Table 4-1.

Table 4-1: A Comparison of the Usage Data Collected for The Village on Monday October 4, 2010 and Tuesday October 5, 2010

Rack FID #	Monday	Tuesday
88	5	3
89	1	0
90	0	0
91	0	0
92	0	0
93	0	0
94	0	0
95	0	0
96	0	0
97	0	0
98	0	0
99	1	1
100	2	4
101	6	7
102	14	15
103	15	15
104	15	15
105	11	10
106	6	7
107	5	5
108	8	7
109	29	20
110	18	21
111	13	16
112	17	14
113	8	8
114	9	10
115	19	18
116	19	19
117	23	21
118	29	29
119	30	28
120	17	19
121	15	15
122	15	18
123	15	13
124	12	11
125	15	10
126	12	15
127	0	3

When all the data for the residence halls had been collected, each rack was assigned to a particular residence hall. This process had to be repeated for the 2010 data because of the relocation of some racks and the addition of new racks. For the 2010 residence hall data, no racks were required to be divided between multiple buildings. The locations of the racks clearly displayed which residence hall they were primarily used by.

The decision to discontinue collection on Wednesday and Thursday around the residence halls was reinforced when the rack usage by building was analyzed, displaying minimal fluctuation of usage at the racks associated to a particular building. The comparison between the building totals on Monday and Tuesday is shown in Appendix B, Tables B-1 through B-3.

4.5.2 The Academic Buildings

After both weeks of data collection were complete, the task of sorting the new data began. The 2010 rack usage data was sorted so that it would be easy to extract the necessary data for model validation. The complete data set was manipulated to represent both types of models that were created: Individual building analysis model and zone analysis model.

The individual building analysis required each rack to be assigned to a building or multiple buildings. The location of each rack in relation to the academic buildings around it determined which building it was assigned to. The general knowledge of the layout of campus and the trends of where students park their bicycles when attending classes in certain buildings is also important. Once each rack had been assigned to its respective building(s), the enrollment for each academic building had to be obtained. The enrollment data for 2010 was obtained from the Office of the Registrar. The rack usage data was then paired with the enrollment data for each building on campus that had bicycle racks associated with it.

The data that was required for analysis of the regression model included the peak rack usage and the corresponding enrollment. Each building was analyzed individually. The total number of bicycles parked at all the racks for one building was determined for each collection time slot on Monday through Thursday. The maximum value for each collection day represents the peak rack usage value for that day. The corresponding enrollment value for that building during the time in which the peak rack usage occurs is the value that will be used for the 'Enrollment' term. For example, if the peak rack usage occurs during the time slot of 9:00am - 9:50am, then the enrollment used will be for the same time slot. This process was completed for all 34 buildings that had racks associated with them. Once this had been completed for each building, on each day, a spreadsheet was created with these values and can be found in Appendix B, Tables B-4 to B-7.

Once the values for 'Peak Rack Usage' and 'Enrollment' had been gathered for each building on all four data collection days, the next dataset was created. The next dataset was used for the individual building analysis as well, but represents only the peak usage for the whole week. Each building was analyzed, and the peak usage across all four days and the corresponding enrollment was extracted from the previous dataset. This dataset can also be found in Tables B-9 through B-12 in Appendix B.

The zone analysis did not require racks to be assigned to individual buildings, but to specific zones and the zones that were used were discussed in Chapter 3. Having the previous dataset with racks assigned to buildings made assigning racks to zones a much quicker process. The racks associated with an individual building before now became associated to a particular zone. The dataset was simply rearranged to create a new one. Once the buildings and racks had been divided into their respective zones, the peak rack usage for each zone could be calculated. The same process was followed. The total number of bicycles for each time slot from all the racks in a zone was determined. The maximum value was selected from each day to represent the peak rack usage. The corresponding enrollment was also selected, and a spreadsheet of the 'Peak Rack Usage' and 'Enrollment' was created.

The same process as before was followed for the creation of the peak day spreadsheet. The peak rack usage from Monday through Thursday was extracted along with its enrollment value to create a second spreadsheet.

All the spreadsheets created from the collection of rack usage data in 2010 can be found in Appendix B.

4.6 Data Collection Summary

Two new datasets were collected during this research process. The spatial locations of 269 bicycle racks were collected, displaying a 43% increase in the number of racks on Auburn's campus from 2008. Bicycle rack usage data was collected for the residence halls and the academic buildings in 2010 so that the models created from the 2008 usage data could be tested. The following chapter discusses the analysis of each model and its performance when comparing the rack usage estimates with the collected data from 2010.

CHAPTER 5

MODEL APPLICATION AND RESULTS

5.1 Introduction

As previously discussed in *Chapter 3: Methodology*, several statistical models were created from the 2008 bicycle rack usage data and the residence hall and academic building data. These models were applied to the new bicycle rack usage data that were collected in 2010. Each model was separately analyzed and the results will be discussed in the following sections.

5.2 Residence Hall Model

The first step in the analysis process was to separate out the data necessary to examine the residence halls on Auburn University's campus from the 2010 dataset. Using the bicycle rack usage data collected in the fall of 2008, a statistical model was created using linear regression. The statistically significant variable used to estimate the demand for bicycle rack usage was the number of beds in each residence hall. The linear regression formula derived from the statistical analysis, as described in Section 3.3.1, is shown below.

$$\text{PeakUsage} = -12.708 + 0.2358*\text{Beds} \qquad \textbf{(3)}$$

This equation is used to estimate the 2010 usage by using the number of beds from each residence hall and model (3) to obtain the estimated peak rack usage. The estimated value for each building was then compared to the rack usage data collected in the fall of 2010. The 'peak rack usage was calculated the same way for the 2010 data as it was for the 2008 data, as discussed in Section 3.3.1, and bicycle racks were assigned to individual residence buildings in the same manner. Once the 2010 data had been formatted similarly to that of the 2008 data, it was compared to the results of the created regression model. Two measures of error were computed to analyze the accuracy of the model, the model error and percent error. These two forms of error were calculated by using the following formulas:

$$Model\ Error = Estimated - PeakDay\ Collected \quad \textbf{(13)}$$

$$Percent\ Error = \left(\frac{Estimated - PeakDay\ Collected}{PeakDay\ Collected}\right) * 100 \quad \textbf{(14)}$$

All three of the residence areas on campus were analyzed, but detailed analysis for The Village will be shown here and the analyses for the other two areas can be found in Appendix C, Table C-1 and C-2. The Village is a new residence area that Auburn University opened to students during the fall of 2009. Table 5-1 shows the analysis of the estimated data using the created regression model and the collected data from 2010.

Table 5-1: Analysis Results for The Village Residence Halls

The Village					
Name	**Beds**	**Estimated Peak Usage**	**Collected Peak Rack Usage**	**Model Error**	**% Error**
Aubie	298	57.56	128	-70.44	-55.03%
Plainsman	160	25.02	47	-21.98	-46.77%
Willow	246	45.30	30	15.30	51.00%
Oak	246	45.30	18	27.30	151.66%
Magnolia	233	42.23	38	4.23	11.14%
Talon	160	25.02	52	-26.98	-51.88%
Tiger	150	22.66	47	-24.34	-51.78%
Eagle	150	22.66	33	-10.34	-31.33%
			Average	-13.41	-2.87%

The negative numbers in the model error column represent instances where the model formula underestimated the rack usage for The Village. The lower model error values represent cases where the collected peak rack usage data is larger than the estimated rack usage. The larger model error values represent cases where the estimated rack usage is greater than the peak usage collected data from 2010. The closer the model error value is to zero (0), the closer the linear regression formula was to predicting the actual rack usage collected in 2010. The percent error column should be interpreted similarly. A negative percent error represents an underestimation by the regression model, while a positive percent represents an overestimation.

On average, the model for The Village underestimates by only 2.87%, but the error for each individual building fluctuates greatly. The % error ranges from to -55.03% (Aubie) to 151.66% (Oak). The regression model underpredicts bicycle rack usage for five of the eight buildings in The Village. Willow and Oak residence halls represent the highest overestimations because of the locations of the bicycle racks. The racks that correspond to these two buildings are racks 111 – 114. The location of each rack is shown in Figure 5-1.

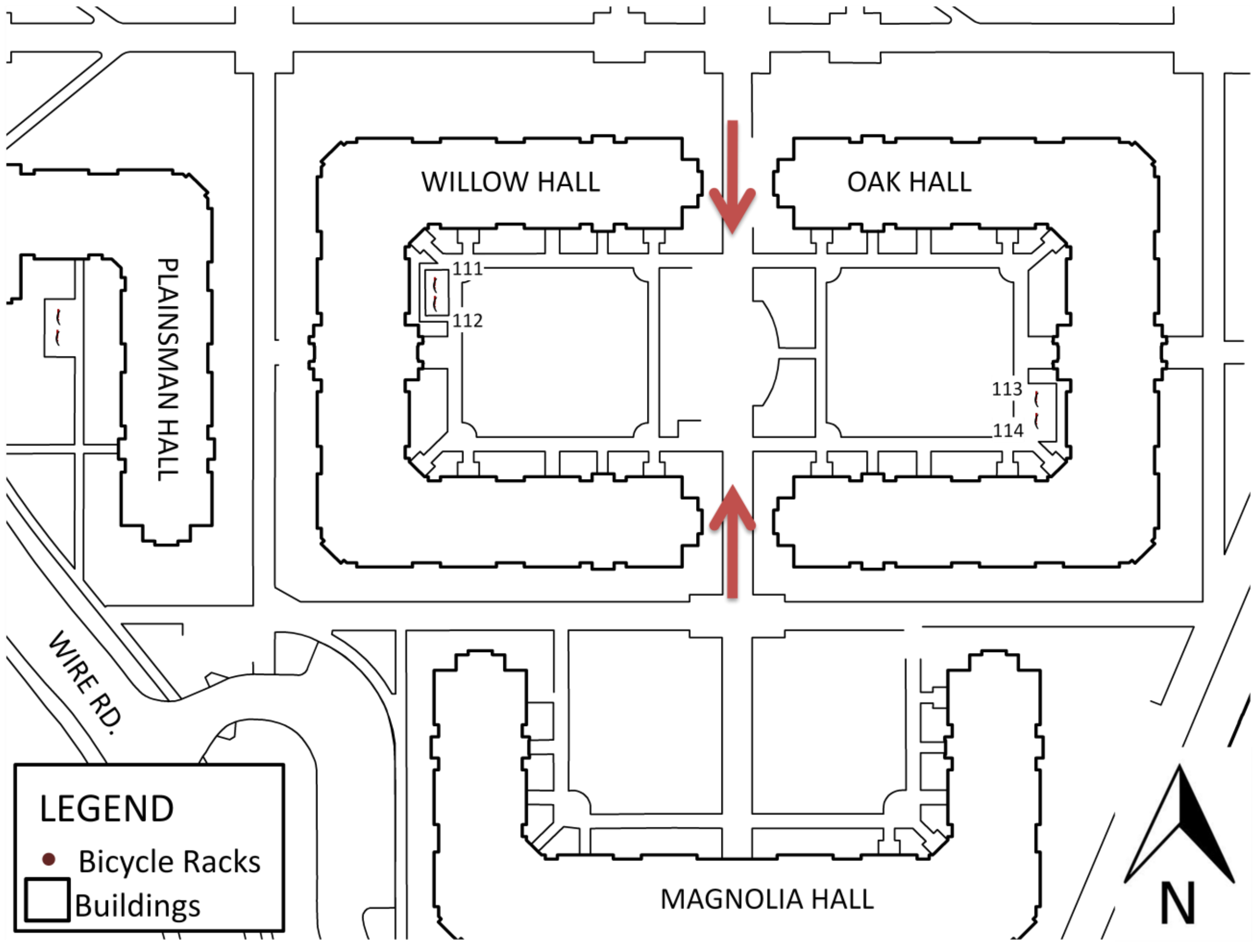

Figure 5-1: Bicycle Rack Locations for Oak and Willow Hall

A possible reason as to why the racks at Willow Hall (111 and 112) and Oak Hall (113 and 114) experience low usage is because of the restricted access to these racks. It can be seen in Figure 5-1 that Willow Hall and Oak Hall create an internal courtyard, where the racks are located. There are only two points of access to this area, denoted by the arrows in the figure. Once a cyclist enters the courtyard area, there is only one route that can be taken to the racks at each building. Although there are two routes shown, one of those routes has a set of stairs that hinders the ability of cyclists to utilize it.

The average errors were analyzed for all three groups of residence halls to see how well the model performed overall, shown in Table 5-2.

Table 5-2: Average Model and Percent Error for All Residence Areas on Campus

Average	Model Error	Percent Error
The Hill	-10	-18.17%
The Quad	-13	-33.29%
The Village	-13	-2.87%

The percent error shown for The Village could be considered negligible, while The Hill and The Quad are not. Even though the average error for The Village is close to zero, the percent error for each building is not. This is consistent with the percent error for individual buildings in The Hill and The Quad as well.

When examining the residence halls it is important to remember that they are a group of buildings, not just individual buildings. When new residence halls are needed, they are not built one at a time, but are built in groups. After the individual building analysis of each area of residence halls was completed, the analysis of each area as a group was performed. Instead of assigning bicycle racks to buildings, the racks were assigned to each group, The Hill, Quad, and Village. The number of beds was no longer for each individual building, but the total number of beds in each residence area, shown in Table 5-3.

Table 5-3: The Total Number of Beds in Each Residence Area

Residence Area	# of Beds
The Hill	1482
The Quad	1057
The Village	1643

To compare the estimated peak usage for the racks in each area with the collected peak usage, a new value for the peak usage had to be determined. The peak usage values changed because now the usage represented the peak rack usage for a particular collection day across all the racks in each area. The same regression formula as before, model (3) was used to perform the analysis. The results of this method of analysis are shown in Table 5-4.

Table 5-4: Results of Residence Halls Analyzed in Groups

Residence Area	# of Beds	Estimated Peak Usage	Collected Peak Usage	Model Error	% Error
The Hill	1482	336.75	306	30.75	10.05%
The Quad	1057	236.53	224	12.53	5.59%
The Village	1643	374.71	389	-14.29	-3.67%

Even though model (3) was created by analyzing the individual buildings in each residence hall areas, it was applied to each residence area. The reason a model was not created for the zone approach with the residence halls is because the model would only have three observations. A model created with only three observations does not create a model that can be used to accurately.

The results of the analysis by area are closer to the actual data collected in 2010. Although an overestimation is shown for The Hill and Quad, this is an acceptable outcome. A minor underestimation is not grounds for rejection of the model, and the same goes for an overestimation. An overestimation may be preferable because supplying more capacity than needed is better than not supplying enough. However, the approach of supplying more capacity than needed may result in expenditures that could be viewed as unnecessary. Ultimately, this becomes a policy issue that would have to be decided upon by the appropriate offices at the university.

5.3 Academic Building Model

Several linear regression models were created using the data that were collected in 2008. Once the data that were collected in 2010 were organized, an analysis of how each model performed could be completed. Each model was observed individually, and then all the results were compared.

5.3.1 Analysis by Individual Building

The first model type developed contained the entire dataset, with all three of the independent variables (ClassSqFt, GrossSqFt, and Enrollment). This dataset included four data points for each of the 28 academic buildings (one data point per building per day for all four days). During the development of the regression models, the independent variables in this model were determined to all be significant. This model analyzes the academic buildings individually, predicting the rack usage based on the total building square footage, the square footage of classroom space, and the total enrollment for each collection day (Monday through Thursday). The first model equation derived in Section 3.3.1 is shown below followed by the analysis results for Monday shown in Table 5-6.

$$\text{PeakRackUsage} = 1.9853 + 0.0006521*\text{GrossSqFt} - 0.0005616*\text{ClassSqFt} + 0.04755*\text{Enrollment} \qquad \textbf{(4)}$$

Table 5-6: Individual Building Analysis Results for Equation (4) on a Monday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	164	11.05	9.83	1.21	12.33%
Broun Hall	101459	4820	293	19.83	22.27	-2.44	-10.95%
Charles E. Davis Aerospace Hall	72899	9981	501	24.96	80.95	-56.00	-69.17%
Chemistry Bldg	72179	7148	360	19.80	37.00	-17.20	-46.50%
Comer Hall	45625	2790	95	7.91	15.86	-7.95	-50.11%
Corley Hall	23679	2201	10	2.77	3.00	-0.23	-7.70%
Dudley Hall	56286	3952	146	10.38	22.00	-11.62	-52.82%
Forestry and Wildlife Science Bldg	112067	8027	124	10.68	27.00	-16.32	-60.44%
Funchess Hall	151454	4402	182	18.04	12.20	5.84	47.85%
Goodwin Hall	49766	4580	118	8.27	12.00	-3.73	-31.09%
Gorrie Center	37278	3181	141	9.33	9.00	0.33	3.71%
Haley Center	414651	62278	2163	96.90	191.00	-94.10	-49.27%
Harbert Center	46446	1432	33	5.78	6.14	-0.36	-5.93%
Lowder Hall	161848	38635	1357	55.37	64.00	-8.63	-13.49%
Miller Hall	25347	2692	76	5.74	4.00	1.74	43.50%
Nichols Center	33709	4332	22	2.80	13.86	-11.06	-79.82%
Parker Hall	90660	18558	859	38.32	94.00	-55.68	-59.23%
Pharmacy Bldg -Walker Building	130100	20371	28	0.36	4.00	-3.64	-91.00%
Ramsay Hall	47963	3365	100	7.98	8.00	-0.02	-0.27%
Ross Hall	57320	1646	22	5.85	7.00	-1.15	-16.50%
Rouse Life Sciences Bldg	71384	1847	123	11.45	18.00	-6.55	-36.38%
Sciences Center Auditorium	10809	5373	269	12.46	33.00	-20.54	-62.23%
Shelby Center	198169	10315	223	19.72	26.00	-6.28	-24.16%
Spidle Hall	50843	5469	362	19.44	16.00	3.44	21.51%
Swingle Hall	30243	754	5	3.77	1.00	2.77	277.20%
Telfair Peet Univ Theatre	54444	676	10	5.63	3.00	2.63	87.71%
Textile Engineering Bldg	51446	2539	19	4.82	3.00	1.82	60.58%
Thach Hall	42871	3460	241	14.30	26.26	-11.96	-45.55%
Upchurch Hall	70695	3147	61	7.73	6.00	1.73	28.81%
Wallace Center	42134	2919	34	4.71	30.14	-25.43	-84.37%
					AVERAGE:	-11.31	-10.46%

The complete spreadsheet of results for this regression model can be found in Tables C-3 through C-5 in Appendix C. Although the data for Monday only shows an average percent error of -10.46%, the averages for the other days underestimated more. For the remaining three days, the average model error was close to zero, and the average percent error underestimated the observed rack usage. The values for average model error and percent error are shown in Table 5-7.

Table 5-7: Analysis Results for Monday Through Thursday for Equation (4)

Model (4)	Average Model Error	Average % Error
Monday	-11.31	-10.46%
Tuesday	-8.67	-14.53%
Wednesday	-10.34	-16.31%
Thursday	-6.89	-10.63%

The next model created contained the independent variables ‘Enrollment’ and ‘GrossSqFt’ from Section 3.4.1, and were both found to be significant to the model ($p<0.05$).

$$PeakRackUsage = 3.0395 + 0.03631 * Enrollment + 3.751E\text{-}5 * GrossSqFt \quad \mathbf{(6)}$$

The complete results can be found in Appendix C, Tables C-6 through C-9 and the average model error and percent error can be found in Table 5-8.

Table 5-8: Analysis Results for Monday Through Thursday for Equation (6)

Model (6)	Average Model Error	Average % Error
Monday	-10.95	1.79%
Tuesday	-8.07	21.93%
Wednesday	-9.98	18.28%
Thursday	-6.34	27.65%

Although it can be expected that when the model error underestimates the usage that the percent error will also underestimate the observed usage, Table 5-8 shows that model (6) does not concur with this idea. The positive average percent error for each day can be attributed to the high overestimation of certain buildings because of the high value of 'GrossSqFt' compared to the low value of 'Enrollment' and collected peak rack usage.

The final model explored with the dataset for all four days included only the 'Enrollment' variable, Equation 7, from Section 3.4.1

$$\text{PeakRackUsage} = 4.6051 + 0.04140 * \text{Enrollment} \quad \textbf{(7)}$$

The complete results for this model can be found in Appendix C, Tables C-10 through C-13. The results from the analysis of this regression formula display an overestimation of average percent error and an underestimation of average model error for each data collection day, shown in Table 5-9. The negative model errors and positive percent errors can be attributed to buildings with low enrollment and low observed rack usage, creating a high individual percent error that distorts the average of all the errors.

Table 5-9: Analysis Results for Monday Through Thursday for Equation (7)

Model (7)	Average Model Error	Average % Error
Monday	-10.26	1.05%
Tuesday	-7.85	11.31%
Wednesday	-9.57	8.30%
Thursday	-6.10	31.44%

The second model type based on the peak day of rack usage, which was reduced from 112 to 28 data points. This was done by selecting the peak rack usage across all four days for each building. This analysis process was completed to provide a model that represented the busiest day of the week from the 2008 data. The model was analyzed with the complete data set of 'ClassSqFt', 'GrossSqFt' and 'Enrollment'. The product of completing backward analysis in Section 3.4.1 was the following equation.

$$\text{PeakRackUsage} = 5.8818 + 0.07458*\text{Enrollment} - 0.0009045*\text{ClassSqFt} \quad \textbf{(8)}$$

The results from comparing the estimated rack usage and the collected usage from 2010 are shown in Table 5-10. Model (8) underestimates rack usage when the average percent error and average model error are examined, but fluctuates between overestimation and underestimation for each individual building.

Table 5-10: Individual Building Analysis Results for the Peak Day Analysis of Equation (8)

PEAK DAY						
Building Name	**ClassSqFt**	**Enrollment**	**Estimated**	**Collected**	**Model Error**	**% Error**
Biggin Hall	3951	214	18.27	14.96	3.31	22.15%
Broun Hall	4820	319	25.31	30.48	-5.17	-16.95%
Charles E. Davis Aerospace Hall	9981	501	34.22	82.14	-47.92	-58.34%
Chemistry Bldg	7148	360	26.27	37.00	-10.73	-29.01%
Comer Hall	2790	30	5.60	17.16	-11.56	-67.39%
Corley Hall	2201	9	4.56	3.00	1.56	52.09%
Dudley Hall	3952	166	14.69	24.00	-9.31	-38.80%
Forestry and Wildlife Science Bldg	8027	124	7.87	27.00	-19.13	-70.85%
Funchess Hall	4402	182	15.47	19.43	-3.96	-20.36%
Goodwin Hall	4580	118	10.54	12.00	-1.46	-12.17%
Gorrie Center	3181	141	13.52	9.00	4.52	50.22%
Haley Center	62278	2163	110.87	191.00	-80.13	-41.95%
Harbert Center	1432	88	11.15	8.13	3.02	37.12%
Lowder Hall	38635	1332	70.28	76.00	-5.72	-7.53%
Miller Hall	2692	28	5.53	6.00	-0.47	-7.75%
Nichols Center	4332	64	6.74	19.83	-13.09	-66.02%
Parker Hall	18558	859	53.16	94.00	-40.84	-43.45%
Ramsay Hall	3365	50	6.57	9.00	-2.43	-27.03%
Rouse Life Sciences Bldg	1847	123	13.38	18.00	-4.62	-25.64%
Sciences Center Auditorium	5373	269	21.08	33.00	-11.92	-36.11%
Shelby Center	10315	308	19.52	38.00	-18.48	-48.62%
Spidle Hall	5469	357	27.56	18.00	9.56	53.11%
Swingle Hall	754	5	5.57	2.00	3.57	178.66%
Telfair Peet Univ Theatre	676	30	7.51	6.00	1.51	25.13%
Textile Engineering Bldg	2539	30	5.82	4.00	1.82	45.56%
Thach Hall	3460	241	20.73	26.26	-5.53	-21.06%
Upchurch Hall	3147	61	7.58	6.00	1.58	26.41%
Wallace Center	2919	34	5.78	30.14	-24.36	-80.83%
				AVERAGE:	**-10.23**	**-8.19%**

Two other forms of this model were explored, one with ‘Enrollment’ and GrossSqFt’, and the other with only ‘Enrollment’. When the process of backward elimination was performed on the model with ‘GrossSqFt’ and ‘Enrollment’, it was determined that ‘Enrollment’ was the only significant variable. This model was not analyzed with the new data that were collected in 2010. The model with 'Enrollment', Equation 10 from Section 3.4.1, was analyzed and the average model error and percent error values are shown in Table 5-11.

$$PeakRackUsage = 5.3632 + 0.04964*Enrollment \qquad \textbf{(10)}$$

Table 5-11: Individual Building Analysis Results for the Peak Day Analysis for Model (10)

	PEAK DAY	
	Model Error	**% Error**
AVERAGE:	-12.53	-11.81%

The complete data sets for all the statistical models analyzed in this chapter can be found in Appendix C.

5.3.2 Analysis by Zone

The following models were developed using the data that were created by delineating zones of academic buildings. These zones were created by grouping buildings and bicycle racks together. The zones represent areas where a group of bicycle racks could be utilized by students attending classes at multiple buildings. Two separate models were created using this data in Section 3.3.2. The first model included the data from all four collection days, model (11). The second model included only the peak day for the entire collection period (12).

$$PeakRackUsage = 11.263 + 0.04644*Enrollment \qquad \textbf{(11)}$$

$$PeakRackUsage = 8.8121 + 0.05953*Enrollment \qquad \textbf{(12)}$$

The estimated peak rack usage from model (11) originally had 15 zones from the 2010 data to be compared to. The final dataset however, had only 13 zones. Zone 2 and Zone 8 were removed from the analysis because of a small enrollment value for the building(s) in these zones created an undesirable over estimation of rack usage. The complete dataset of the results can be found in Tables C-14 through C-16 in Appendix C and the results for Tuesday are shown in Table 5-13.

Table 5-12: Analysis Results from Zone Analysis on a Tuesday Using Equation (11)

Tuesday					
ZONE	**Collected Peak Rack Usage**	**Enrollment**	**Estimated Peak Rack Usage**	**Model Error**	**% Error**
1	67	531	35.92	-31.08	-46.38%
3	26	210	21.02	-4.98	-19.17%
4	76	1332	73.12	-2.88	-3.79%
5	46	146	18.04	-27.96	-60.78%
6	85	509	34.90	-50.10	-58.94%
7	18	357	27.84	9.84	54.68%
9	15	167	19.02	4.02	26.79%
10	31	171	19.20	-11.80	-38.05%
11	6	52	13.68	7.68	127.96%
12	23	404	30.02	7.02	30.54%
13	176	1526	82.13	-93.87	-53.33%
14	44	259	23.29	-20.71	-47.07%
15	175	2194	113.15	-61.85	-35.34%
AVERAGE				**-21.28**	**-9.45%**

Model (12), was applied to all 15 zones. Zone 2 and 8 were left in the analysis for this model because each zones peak day did not produce the large percent errors that the other days did in the previous model. The results of comparing the estimated rack usage to the actual collected usage from 2010 are shown in Table 5-14.

Table 5-13: Analysis Results from Zone Analysis for the Peak Day Using Model (12)

PEAK DAY					
ZONE	**Collected Peak Rack Usage**	**Enrollment**	**Estimated Peak Rack Usage**	**Model Error**	**% Error**
1	113	813	57.21	-55.79	-49.37%
2	4	30	10.60	6.60	164.95%
3	40	223	22.09	-17.91	-44.78%
4	76	1332	88.11	12.11	15.93%
5	46	146	17.50	-28.50	-61.95%
6	85	509	39.11	-45.89	-53.98%
7	18	357	30.06	12.06	67.02%
8	4	28	10.48	6.48	161.97%
9	27	124	16.19	-10.81	-40.02%
10	39	432	34.53	-4.47	-11.46%
11	10	160	18.34	8.34	83.37%
12	39	373	31.02	-7.98	-20.47%
13	155	1104	74.53	-80.47	-51.91%
14	52	319	27.80	-24.20	-46.53%
15	191	2163	137.58	-53.42	-27.97%
			AVERAGE	**-18.92**	**5.65%**

5.4 Summary of Analysis Results

Multiple models developed with the 2008 rack usage data and residence hall and academic building data. These models were tested to determine the accuracy of the estimated peak rack usage values by comparing the model estimates to the collected rack usage data in 2010. Each model had its positives and negatives. A summary of the residence hall model is shown in Table 5-14 and all the academic building models performance is shown in Table 5-15. The following chapter will discuss selection of models that are recommended for use for the residence halls and the academic buildings.

Table 5-14: Summary of Results for the Residence Hall Models Tested

	Individual Buildings		Residence Hall Groups		Model Equation
	Model Error	% Error	Model Error	% Error	
The Hill	-10	-18.17%	31	10.05%	3
The Quad	-13	-33.29%	13	5.59%	
The Village	-13	-2.87%	-14	-3.67%	

Table 5-15: Summary of Results for the Academic Building Models Tested

	ALL 4 DAYS								PEAK DAY		
	MONDAY		TUESDAY		WEDNESDAY		THURSDAY				
	Model Error	% Error	Model Error	% Error	Model Error	% Error	Model Error	% Error	Model Error	% Error	MODEL EQUATION
By Building											
All 4 Days	-11.31	-10.46%	-8.67	-14.53%	-10.34	-16.31%	-6.89	-10.63%	-	-	4
	-10.95	1.79%	-8.07	21.93%	-9.98	18.28%	-6.34	27.65%	-	-	6
	-10.26	1.05%	-7.85	11.31%	-9.57	8.30%	-6.10	31.44%	-	-	7
Peak Day	-	-	-	-	-	-	-	-	-10.23	-8.19%	8
	-	-	-	-	-	-	-	-	-12.53	-11.81%	10
By Zone											
All 4 Days	-28.07	-20.81%	-21.28	-9.45%	-25.28	-5.65%	-15.09	2.89%	-	-	11
Peak Day	-	-	-	-	-	-	-	-	-18.92	5.65%	12

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

While completing the analysis described in this report several models were created using data collected in 2008 to examine bicycle rack usage at Auburn University (AU). These models expressed bicycle rack usage as a function of the number of beds in the residence halls and square footage of each hall, and the total and classroom square footage of each academic building and the student enrollment in classes in each building. As part of this study, during the fall of 2010, new data were collected for the spatial locations of each rack on campus and the rack usage experienced on Monday through Thursday. The newly collected usage data were then compared to the estimated demand produced by the statistical models. The following paragraphs provide conclusions and recommendations regarding which models should be applied in various situations including the construction of new residence halls and academic buildings.

The completion of this research was dependent on determining the factors, if any, that influence bicycle rack usage. A literature review was conducted in order to establish knowledge of any previous work done and possible factors that affect rack usage. Using the bicycle rack usage data collected in 2008, linear regression models were created to represent the rack usage at the residence halls and the academic buildings. The independent variables tested for the residence halls were total building square footage and the number of beds in each hall. The variables examined for the academic building model were total building square footage, classroom square footage, and enrollment. Several models were developed for two types of analysis, individual building analysis and zone analysis. The spatial location of all the bicycle racks was collected in 2010, so that the usage data for each rack could be re-collected. The peak rack usage from the collected data was compared to the estimated peak rack usage produced by the regression models to test the accuracy of each model.

6.1 Overall Conclusions

Once the data collection and analyses were completed for this report, many observations about the factors that influence rack usage were developed. Possibly the most influential of these factors is the placement of bicycle racks in relation to the intended building of service. While conducting the collection of the spatial location of each bicycle rack, it was observed that the placement of each rack did not always coincide with the easiest point of access to the building. Some racks were placed outside of doors that are primarily used by faculty and staff entering from a parking lot while others were not even placed beside an entrance. The placement of the bicycle racks influences the usage.

The accessibility of a bicycle rack is also a determining factor for its usage. If there is only one route that a cyclist can take to get to a particular rack, then that rack is likely to experience lower usage than those that have multiple paths of access. An example of a factor that affects the accessibility is terrain. It appears that a bicyclist is less likely to ride up a hill or traverse stairs to a rack when they can park their bicycle at a different rack on level grade and still get into the same building.

Building characteristics such as location, purpose, and size are also influencing factors for rack usage. If a building is at the core of campus, with several surrounding academic buildings, then the usage of bicycle racks is expected to be high. The size of the building and the amount of classroom space affect the number of students that commute to and from the building. Buildings that house multiple disciplines such as the Haley Center create a higher demand because of the amount of classroom space and the number of classes being held there on a daily basis. Although it was not discussed in this report, buildings such as the RBD Library and the Student Center create high demands for bicycle racks. The distinctive nature of the use of these buildings makes the general model for academic buildings not applicable. Students travel to these types of buildings to eat and study at inconsistent times throughout the day. The estimation of rack demand is difficult for the RBD Library and Student Center because of the unpredictable times of travel to these buildings and the lack of similar buildings to develop a predictable model to represent them.

6.2 Recommendations for the Residence Hall Model

The residence halls are unlike the academic buildings on campus because regardless of the time of day or day of week, the same number of students lives in each residence hall. The peak demand is assumed to occur when the students have returned to their rooms for the night. During the statistical analysis of the residence halls, the number of beds was determined to be a statistically significant feature of the buildings. Linear regression analysis produced the model formula from Section 3.3.1 shown below.

$$\text{PeakRackUsage} = -12.708 + 0.2358*\text{Beds} \quad \textbf{(3)}$$

The number of beds from each individual residence hall should be added together to obtain the total number of beds for each group. The use of this model formula is recommended, but reliance on it alone is not. During the analysis of the rack usage data collected in 2010, it was determined that the residence halls should be examined as a group and not as individual buildings. This also followed suit with the general idea that residence halls are in fact built in groups and not one by one. The use of this model formula will provide an estimation of the number of bicycle parking spots necessary for the entire group of residence halls. The goodness of fit, as measured by R^2, for this model is 0.652. Implementing this model for The Hill, The Quad and The Village, using the data collected in 2010 as a part of this study, resulted in an average model error of 31, 13, -14, and percent error of 10.1%, 5.59% and -3.67%, respectively.

Other tools that should be employed along with the use of this model formula include engineering judgment, and knowledge about the area. Engineering judgment must be used to determine the best placement for the bicycle racks throughout the area. It is recommended that the racks be observed a short time after placement, to ensure that they have been placed in the optimal position and relocation of some of the racks might be necessary. Knowledge about the area such as the terrain, entrances and exits for each building is also essential in the determination of the optimal location for each bicycle rack.

6.3 Recommendations for the Academic Building Model

Several models were created to estimate the bicycle rack usage for the academic buildings on campus. The factors that were included in development of these models were total building square footage, classroom square footage, and class enrollment. Regression models were created using data from all four days and the peak day for each individual academic building and for zones of academic buildings. Two models were selected for recommended use in estimating the bicycle rack usage around academic buildings: one model from the individual building analysis and one model from the zone analysis. Both models selected for recommendation were from the peak day analysis. The peak day analysis incorporates the peak rack usage for Monday through Thursday at each building or in each zone. The peak day for one building or zone may fall on a Monday while for another it may be Thursday. The number of bicycle parking spots present at any given academic building is not going to change from day to day, therefore the peak day models were selected. It was also assumed that a campus planner would most likely want to design for the peak rack usage at each academic building, regardless of what day of the week it is.

The model formula recommended for use when analyzing individual academic buildings developed in Section 3.4.1 has an R^2 value of 0.909 and is shown below.

$$PeakRackUsage = 5.8818 + 0.07458*Enrollment - 0.0009045*ClassSqFt \qquad \textbf{(8)}$$

The analysis of individual academic buildings shows an average model error and percent error of -10.2 and -8.19%, respectively. In order to analyze each building individually, the class enrollment for each class time for all the classes being held in that building and the total classroom square footage was obtained. This model attempts to predict the peak rack usage for each building. The enrollment value that must be entered into this formula is the peak enrollment for Monday through Thursday during all of the specified class times for each day.

The other recommended model for use when observing academic buildings incorporates the use of zones. The implementation of engineering judgment is necessary for the delineation of the zones when using this method. Each zone must be defined using knowledge about which racks are used by an academic building or multiple buildings. The model formula developed in Section 3.3.2 that is recommended when implementing the zone approach is shown below.

$$PeakRackUsage = 8.8121 + 0.05953*Enrollment \qquad \textbf{(12)}$$

Using this model with an R^2 of 0.761 resulted in an average model error and percent error of -18.9 and 5.65%, respectively. This model will predict the peak rack usage for each zone based on each zone's peak enrollment value. This value represents the peak enrollment for each zone across all the scheduled class times for all the buildings in each zone for Monday through Friday.

When implementing these formulas, it is important to have knowledge of the campus that includes information about the academic buildings and the location of the bicycle racks. When utilizing the formula to analyze individual buildings, judgment must be incorporated into the placement of the racks around each building. Locating the high traffic entrances to each individual building should be completed in order to place bicycle racks where they will be most used. Also, the position chosen for each rack should allow for multiple paths of accessibility so that bicyclists do not have to travel out of their way to secure their bicycle to a rack. When the zone approach is used, engineering judgment must also be used in locating a centralized area for the bicycle racks. The zone approach incorporates the idea that a rack or group of racks can be used by several of the surrounding buildings. The racks should be placed in such a manner that students traveling to a specific zone will have easy access to any one building in that zone.

The selection of which model to be used is up to the individual. The following are simply recommendations for which model to use in certain situations:

- When a new academic building is being built and there are few or no academic buildings near, the individual building model should be used.
- When a new academic building is being built close to a group of buildings or other individual buildings that can be made into a group, the zone approach model should be used.

6.4 Recommendations for Further Research

After the completion of this research several ideas for further avenues of research within this topic were developed. These possibilities include the re-collection of rack usage data at another point in time, surveying cyclists on campus, and other forms of data collection.

It is recommended that bicycle rack usage data be collected again for the purpose of further validating the models to evaluate how well the model estimates represent the new usage data. This could be done one or two years from the time that this data was collected in October 2010. This process could also be repeated every year for multiple years to generate a new variable to include in the statistical models. This variable would be an average growth percentage applied to the estimates if an increase in demand is observed.

The statistical models developed during this research effort examine the bicycle rack usage as a function of the students. Although students make up the large majority of users, employees also commute by bicycle. A future study of bicycle rack usage could include the employees at Auburn. The number of employees could be examined as another independent variable in the statistical modeling of bicycle rack usage.

This research could also be applied at other university campuses to determine how suitable the models are for use outside of Auburn. Data would need to be obtained about the total building and classroom square footage for the academic buildings and the number of beds and square footage of each residence hall. The spatial location of each bicycle rack and the rack usage data would need to be collected in order to produce the estimated rack usage from the statistical models.

Another opportunity to further this research includes the collection of different forms of data. Surveying students who ride their bicycles on campus could be completed. Data collected from this could include gender, if the bicycle remains on campus overnight, the frequency of riding on campus, and the distance covered to travel to campus. Another option that could be explored is the use of CycleTracks developed by the San Francisco County Transportation Authority. CycleTracks is an application for the iPhone and Android that tracks the routes of cyclists (Charlton et al., 2010). This "app" could be used to determine where students live and the routes they chose to utilize on their trip.

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APPENDIX A

TABLES CREATED FOR THE ORGANIZATION OF 2008 BICYCLE RACK USAGE DATA

Table A-1: 2008 Data Organization for The Quad

The Quad		Bldg Sq. Footage	Racks	Bike Rack Usage				Avg	Peak	Bldg Total	Peak Day
Hall	Capacity		#	M	T	W	Th				
Harper	78	21390	-	-	-	-	-	-	-	-	-
Broun	101	26340	136	8	7	7	8	7.50	8	30	28
	101	26340	137	6	7	5	4	5.50	7	-	-
	101	26340	184	3	6	7	-	5.33	7	-	-
	101	26340	185	4	8	8	-	6.67	8	-	-
Little	90	27295	-	-	-	-	-	-	-	-	-
Teague	90	27041	186	12	-	-	-	12.0	12	12	12
Dowdell	104	30168	-	-	-	-	-	-	-	-	-
Glenn	104	25163	-	-	-	-	-	-	-	-	-
Lane	104	24370	140	12	11	11	11	11.3	12	12	12
Lupton	88	24349	-	-	-	-	-	-	-	-	-
Keller	104	23896	139	3	6	2	4	3.75	6	12	9
	104	23896	183	6	-	3	4	4.33	6	-	-
Owen	104	23777	138	2	5	3	3	3.25	5	12	9
	104	23777	182	7	-	2	3	4.00	7	-	-

Table A-2: Bicycle Racks Assigned to Academic Buildings

Academic Building	Rack #
Biggin Hall	114, 115, 117, 118
Broun Hall	142 - 144, 159 - 166
Charles E. Davis Aerospace Hall	116, 118, 120, 121
Chemistry Bldg	106, 113
Comer Hall	125 - 127
Corley Building	103
Dudley Hall	96 - 100
Funchess Hall	126, 127
Goodwin Hall	94, 95
Miller Gorrie Center	101
Haley Center	26 - 49, 157 - 166
Harbert Center	119, 156
Lowder Business Building	0 - 7
Parker Hall	8 - 14, 105
Peet Theatre	55, 56
Petrie Hall	43, 44
Ramsay Hall	141
Ross Hall	131, 134
Rouse Life Sciences	104, 128
Sciences Center Auditorium (SCA)	11, 12, 13-18
Sciences Center Classroom (SCC)	11, 12, 13, 14
Science Center Laboratory (SCL)	19 - 25
Shelby Center	147, 148, 4 - 7
Spidle Hall	129, 130
Swingle Hall	102
Thach Hall	142 - 146, 159 - 166
Upchurch Hall	154, 155
Walker Building	43, 44, 145, 146

Table A-3: Bicycle Racks Assigned to Multiple Academic Buildings

118	Biggin Hall, Charles E. Davis Aerospace Hall
142, 143, 144	Broun Hall, Thach Hall
159 - 166	Broun Hall, Thach Hall, Haley Center
126, 127	Comer Hall, Funchess Hall
43, 44	Walker Building, Petrie Hall
145, 146	Walker Building, Thach Hall
11, 12, 13, 14	SCA, SCC

Table A-4: Rack Usage Splits for All Racks Assigned To Multiple Buildings

Rack	Academic Building	M 9-950	M 10-1050	M 11-1150	M 12-1250	M 1-150	T 930-1045	T 11-1215	T 1230-145	W 9-950	W 10-1050	W 11-1150	W 12-1250	W 1-150	R 930-1045	R 11-1215	R 1230-145
118	Biggin Hall	0.00	0.46	0.46	0.23	0.23	0.00	0.42	0.00	0.00	0.23	0.23	0.23	0.00	0.43	0.43	0.43
	Charles E. Davis Aerospace Hall	0.00	1.54	1.54	0.77	0.77	0.00	0.58	0.00	0.00	0.77	0.77	0.77	0.00	0.57	0.57	0.57
142	Broun Hall	4.34	5.79	5.79	-	-	7.67	6.28	9.07	4.83	6.27	6.27	6.76	6.27	6.28	7.67	6.98
	Thach Hall	4.66	6.21	6.21	-	-	3.33	2.72	3.93	5.17	6.73	6.73	7.24	6.73	2.72	3.33	3.02
143	Broun Hall	2.41	2.90	3.38	-	-	4.19	4.19	4.88	2.90	3.86	2.90	3.86	4.34	3.49	4.19	2.09
	Thach Hall	2.59	3.10	3.62	-	-	1.81	1.81	2.12	3.10	4.14	3.10	4.14	4.66	1.51	1.81	0.91
144	Broun Hall	2.41	2.90	2.41	-	-	4.19	4.88	4.19	2.41	2.90	3.38	2.90	2.41	3.49	4.19	2.79
	Thach Hall	2.59	3.10	2.59	-	-	1.81	2.12	1.81	2.59	3.10	3.62	3.10	2.59	1.51	1.81	1.21
159	Broun Hall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
↓		0.16	0.16	0.24	0.08	0.08	0.14	0.14	0.14	0.16	0.16	0.16	0.16	0.16	0.27	0.54	0.14
↓		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
↓		0.08	0.08	0.08	0.08	0.08	0.14	0.27	0.27	0.16	0.08	0.16	0.08	0.16	0.41	0.41	0.14
↓		0.08	0.08	0.16	0.08	0.08	0.14	0.00	0.14	0.08	0.08	0.08	0.00	0.08	0.14	0.27	0.14
↓		0.08	0.08	0.08	0.08	0.08	0.14	0.14	0.14	0.08	0.08	0.08	0.08	0.08	0.14	0.14	0.14
↓		0.08	0.00	0.08	0.08	0.08	0.00	0.14	0.00	0.08	0.08	0.08	0.08	0.08	0.14	0.14	0.14
166		0.00	0.08	0.08	0.16	0.16	0.27	0.27	0.14	0.08	0.16	0.16	0.24	0.24	0.14	0.00	0.00

Table A-4: Rack Usage Splits for All Racks Assigned To Multiple Buildings (Cont'd)

Rack	Academic Building	M 9-950	M 10-1050	M 11-1150	M 12-1250	M 1-150	T 930-1045	T 11-1215	T 1230-145	W 9-950	W 10-1050	W 11-1150	W 12-1250	W 1-150	R 930-1045	R 11-1215	R 1230-145
159	Thach Hall	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0.17	0.17	0.26	0.09	0.09	0.06	0.06	0.06	0.17	0.17	0.17	0.17	0.17	0.12	0.24	0.06
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0.09	0.09	0.09	0.09	0.09	0.06	0.12	0.12	0.17	0.09	0.17	0.09	0.17	0.18	0.18	0.06
		0.09	0.09	0.17	0.09	0.09	0.06	0.00	0.06	0.09	0.09	0.09	0.00	0.09	0.06	0.12	0.06
		0.09	0.09	0.09	0.09	0.09	0.06	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.06	0.06	0.06
		0.09	0.00	0.09	0.09	0.09	0.00	0.06	0.00	0.09	0.09	0.09	0.09	0.09	0.06	0.06	0.06
166		0.00	0.09	0.09	0.17	0.17	0.12	0.12	0.06	0.09	0.17	0.17	0.26	0.26	0.06	0.00	0.00
159	Haley Center	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		1.66	1.66	2.50	0.83	0.83	0.80	0.80	0.80	1.67	1.67	1.67	1.67	1.67	1.61	3.22	0.81
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0.83	0.83	0.83	0.83	0.83	0.80	1.61	1.61	1.67	0.83	1.67	0.83	1.67	2.42	2.42	0.81
		0.83	0.83	1.66	0.83	0.83	0.80	0.00	0.80	0.83	0.83	0.83	0.00	0.83	0.81	1.61	0.81
		0.83	0.83	0.83	0.83	0.83	0.80	0.80	0.80	0.83	0.83	0.83	0.83	0.83	0.81	0.81	0.81
		0.83	0.00	0.83	0.83	0.83	0.00	0.80	0.00	0.83	0.83	0.83	0.83	0.83	0.81	0.81	0.81
166		0.00	0.83	0.83	1.66	1.66	1.61	1.61	0.80	0.83	1.67	1.67	2.50	2.50	0.81	0.00	0.00
126	Comer Hall	3.19	1.99	2.39	1.20	1.60	2.57	2.57	2.57	3.59	2.79	2.39	1.20	1.20	2.57	3.00	3.00
	Funchess Hall	4.81	3.01	3.61	1.80	2.40	3.43	3.43	3.43	5.41	4.21	3.61	1.80	1.80	3.43	4.00	4.00
127	Comer Hall	5.18	4.79	5.18	3.59	3.99	5.57	5.14	5.57	5.18	5.58	5.58	4.39	5.18	5.14	5.57	5.14
	Funchess Hall	7.82	7.21	7.82	5.41	6.01	7.43	6.86	7.43	7.82	8.42	8.42	6.61	7.82	6.86	7.43	6.86
43	Walker Building	0.09	-	0.09	-	-	0.23	0.23	0.12	0.11	0.11	0.05	0.11	0.11	0.14	0.14	0.14
	Petrie Hall	0.01	-	0.01	-	-	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03
	Haley Center	0.90	-	0.90	-	-	1.74	1.74	0.87	1.86	1.86	0.93	1.86	1.86	1.83	1.83	1.83

Table A-4: Rack Usage Splits for All Racks Assigned To Multiple Buildings (Cont'd)

Rack	Academic Building	M 9-950	M 10-1050	M 11-1150	M 12-1250	M 1-150	T 930-1045	T 11-1215	T 1230-145	W 9-950	W 10-1050	W 11-1150	W 12-1250	W 1-150	R 930-1045	R 11-1215	R 1230-145
44	Walker Building	0.28	0.38	0.09	-	-	0.35	0.47	0.47	0.11	0.05	0.05	0.11	0.05	0.07	0.14	0.07
	Petrie Hall	0.03	0.03	0.01	-	-	0.05	0.06	0.06	0.03	0.02	0.02	0.03	0.02	0.02	0.03	0.02
	Haley Center	2.69	3.59	0.90	-	-	2.60	3.47	3.47	1.86	0.93	0.93	1.86	0.93	0.91	1.83	0.91
145	Walker Building	2.00	1.50	1.00	-	-	0.91	0.91	0.60	1.43	1.43	1.08	1.08	0.72	0.07	0.14	0.07
	Thach Hall	2.00	1.50	1.00	-	-	1.18	1.18	0.79	2.57	2.57	1.92	1.92	1.28	1.96	0.98	1.47
146	Walker Building	5.01	4.51	4.01	-	-	0.00	0.00	0.65	0.36	0.36	0.36	0.36	0.00	1.53	1.02	1.02
	Thach Hall	4.99	4.49	3.99	-	-	0.00	0.00	0.39	0.64	0.64	0.64	0.64	0.00	1.47	0.98	0.98
11	SCA	2.19	2.58	2.19	0.99	1.79	1.77	1.77	1.97	2.19	2.39	1.59	1.79	1.59	1.69	1.48	1.27
12		1.19	1.39	1.19	1.79	0.60	0.79	0.59	0.59	0.99	1.39	1.39	0.80	1.79	0.84	1.05	0.84
13		0.99	1.19	0.80	1.39	0.80	0.79	0.79	0.79	0.40	1.39	0.99	1.19	0.60	0.42	0.84	0.63
14		0.80	1.59	1.39	0.99	1.39	0.39	0.79	1.18	0.99	1.19	1.19	1.19	0.99	1.27	1.05	1.05
11	SCC	1.25	1.48	1.25	0.57	1.02	1.09	1.09	1.21	1.25	1.36	0.91	1.02	0.91	1.04	0.91	0.78
12		0.68	0.80	0.68	1.02	0.34	0.48	0.36	0.36	0.57	0.80	0.80	0.45	1.02	0.52	0.65	0.52
13		0.57	0.68	0.45	0.80	0.45	0.48	0.48	0.48	0.23	0.80	0.57	0.68	0.34	0.26	0.52	0.39
14		0.45	0.91	0.80	0.57	0.80	0.24	0.48	0.73	0.57	0.68	0.68	0.68	0.57	0.78	0.65	0.65
11	Parker Hall	7.56	8.94	7.56	3.44	6.19	6.14	6.14	6.82	7.56	8.25	5.50	6.19	5.50	5.28	4.62	3.96
12		4.13	4.81	4.13	6.19	2.06	2.73	2.05	2.05	3.44	4.81	4.81	2.75	6.19	2.64	3.30	2.64
13		3.44	4.13	2.75	4.81	2.75	2.73	2.73	2.73	1.38	4.81	3.44	4.13	2.06	1.32	2.64	1.98
14		2.75	5.50	4.81	3.44	4.81	1.36	2.73	4.09	3.44	4.13	4.13	4.13	3.44	3.96	3.30	3.30
4	Lowder Business Building	2.56	4.27	5.13	5.98	3.42	5.24	5.24	3.49	4.44	5.33	4.44	3.55	4.44	4.36	4.36	3.49
5		2.56	2.56	2.56	5.13	3.42	2.62	2.62	5.24	4.44	2.67	3.55	2.67	5.33	4.36	4.36	4.36
6		6.84	5.13	8.55	9.40	5.98	6.98	7.85	4.36	6.22	8.00	9.78	5.33	8.00	6.11	5.24	5.24
7		4.27	2.56	3.42	5.13	1.71	3.49	3.49	3.49	2.67	2.67	4.44	6.22	0.89	1.75	0.87	1.75

Table A-4: Rack Usage Splits for All Racks Assigned To Multiple Buildings (Cont'd)

Rack	Academic Building	M 9-950	M 10-1050	M 11-1150	M 12-1250	M 1-150	T 930-1045	T 11-1215	T 1230-145	W 9-950	W 10-1050	W 11-1150	W 12-1250	W 1-150	R 930-1045	R 11-1215	R 1230-145
4	Shelby Center	0.44	0.73	0.87	1.02	0.58	0.76	0.76	0.51	0.56	0.67	0.56	0.45	0.56	0.64	0.64	0.51
5		0.44	0.44	0.44	0.87	0.58	0.38	0.38	0.76	0.56	0.33	0.45	0.33	0.67	0.64	0.64	0.64
6		1.16	0.87	1.45	1.60	1.02	1.02	1.15	0.64	0.78	1.00	1.22	0.67	1.00	0.89	0.76	0.76
7		0.73	0.44	0.58	0.87	0.29	0.51	0.51	0.51	0.33	0.33	0.56	0.78	0.11	0.25	0.13	0.25

Table A-5: Data Compression from 4 Data Points per Building to 1 Data Point Per Building

Building Name	Gross Area	Room Area	PEAK DAY	
			Peak Rack Usage	Enrollment
Biggin	53395	3951	14.00	221
Broun	101459	4820	18.96	197
Aero	72899	9981	26.77	432
ChemBldg	72179	7148	25.00	412
Comer	45625	2790	12.78	117
Corley	23679	2201	5.00	48
Dudley	56286	3952	36.00	173
Funchess	151454	4402	13.23	197
Goodwin	49766	4580	12.00	132
MillerGorrieCenter	37278	3181	5.00	92
Haley	414651	62278	112.36	2198
Harbert	46446	1432	6.00	43
Lowder	161848	38635	44.64	1155
Parker	90660	18558	78.38	944
TelfairPeet	54444	676	3.00	62
Petrie	21970	624	0.09	18
Ramsay	47963	3365	11.00	75
Ross	57320	1646	11.00	42
RouseLifeSciences	71384	1847	14.00	111
SCA	10809	5373	18.35	269
SCC	34242	4047	3.86	143
SCL	106609	NoData	28.81	521
Shelby	198169	10315	21.68	239
Spidle	50843	5469	7.00	29
Swingle	30243	754	5.00	30
Thach	42871	3460	18.93	234
Upchurch	70695	3147	6.00	94
Walker	130100	20371	6.39	133

APPENDIX B

DATA COLLECTION MAPS, USAGE SHEETS AND 2010 BICYCLE RACK USAGE DATA

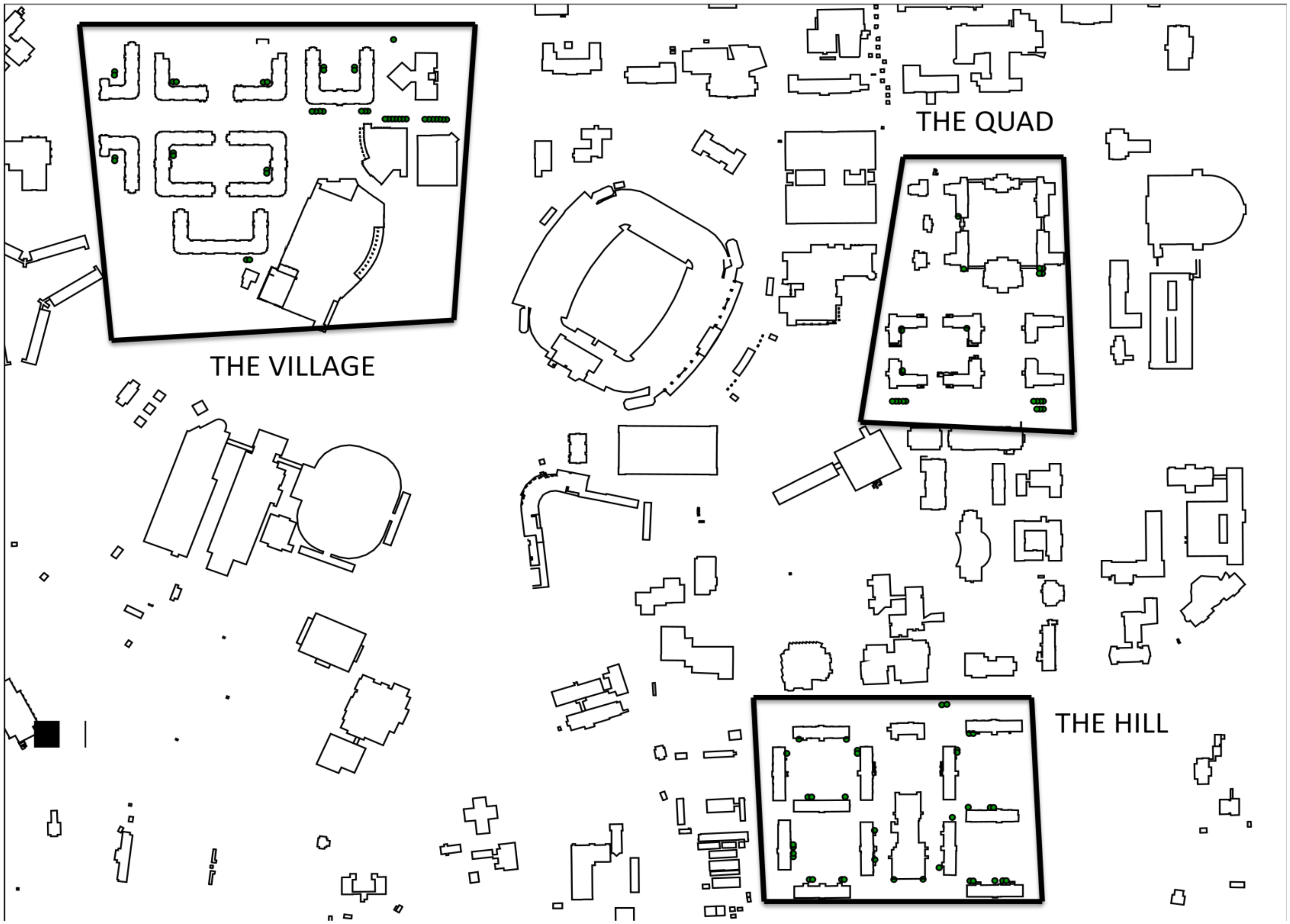

Figure B-1: Auburn University Campus Map with the Locations of each Residence Hall Area

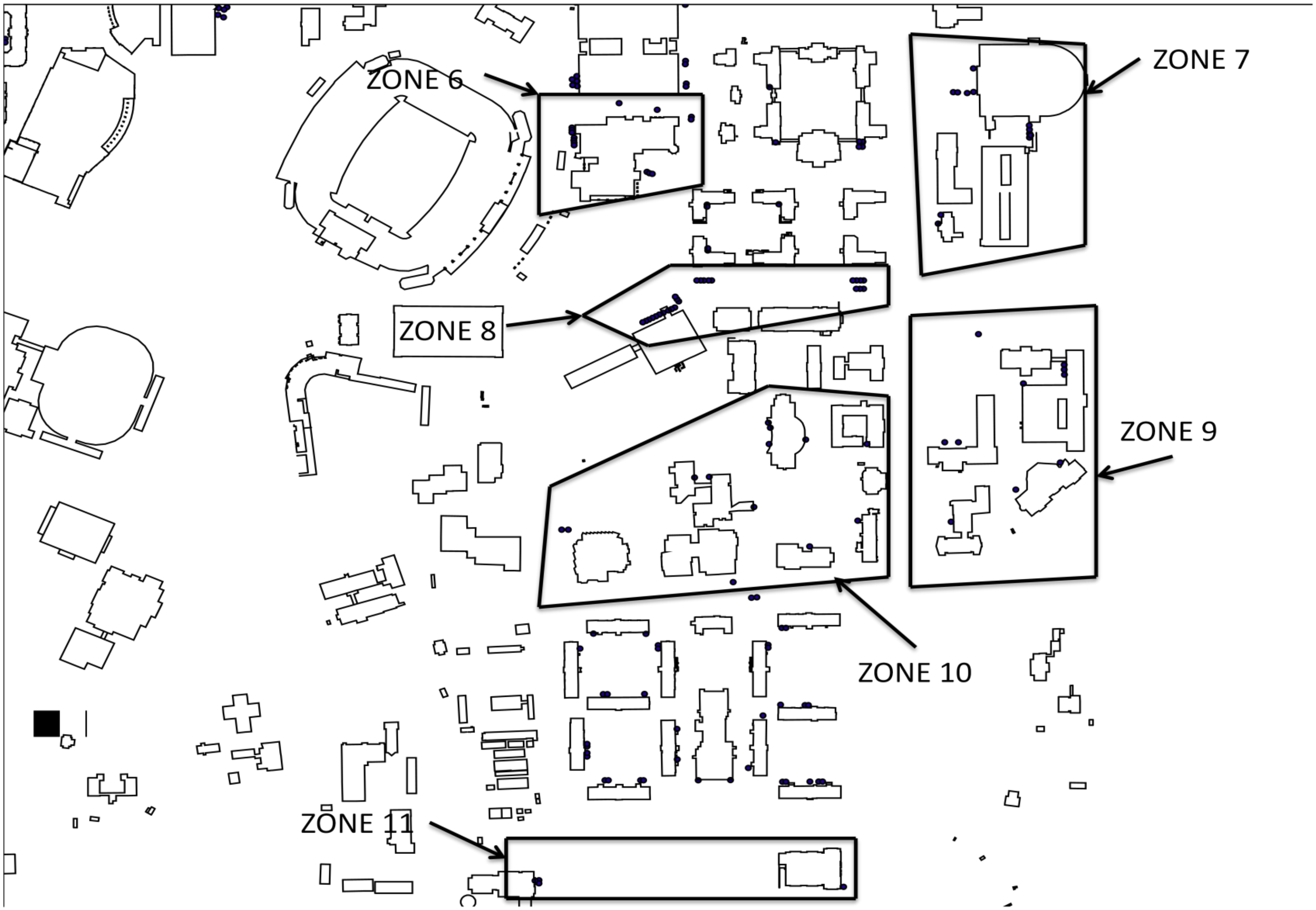

Figure B-2: Southern Portion of Campus with Delineated Zones Collected During Week 2

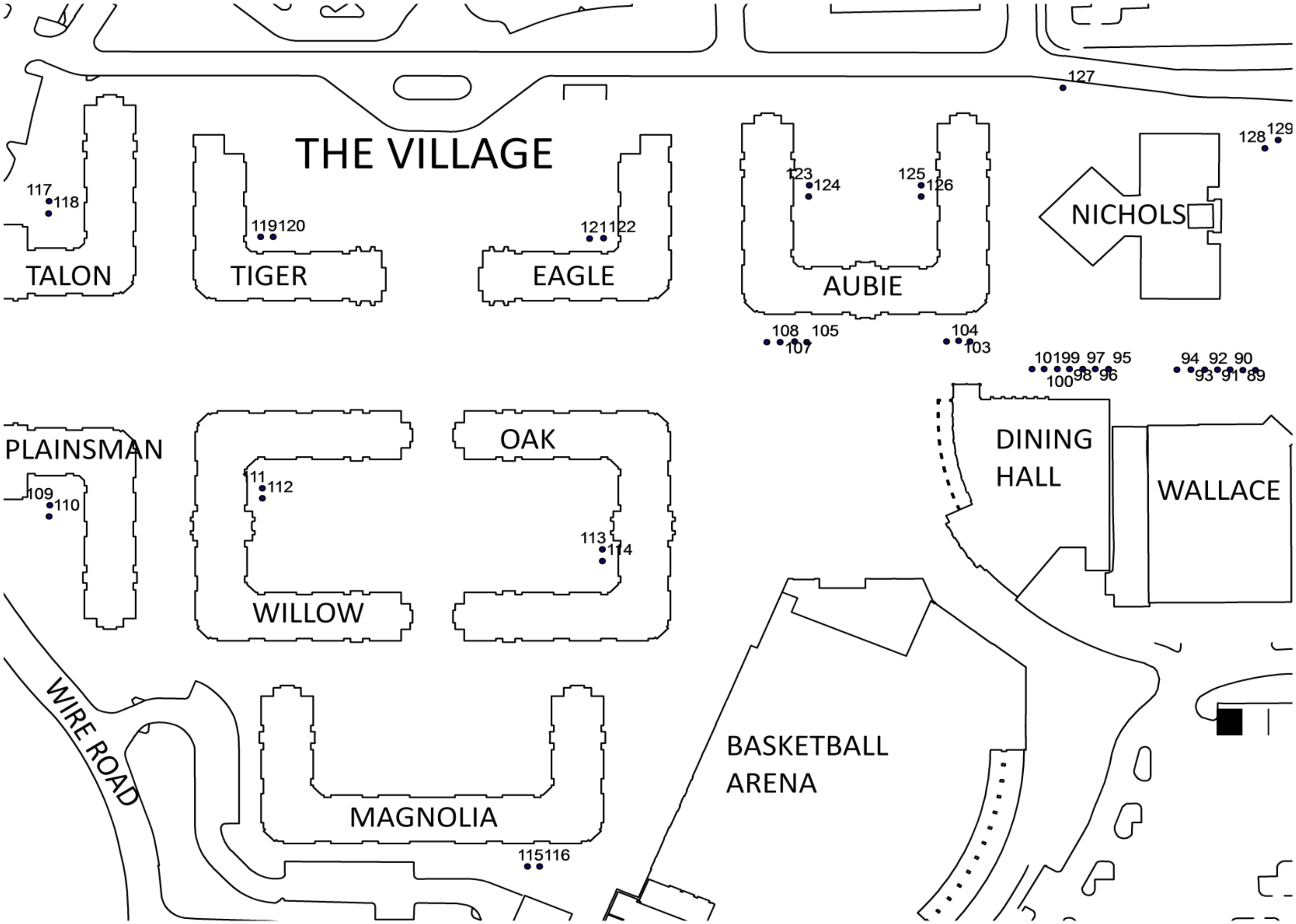

Figure B-3: Zone Map for Data Collection at The Village

THE VILLAGE **THURSDAY**

DATE: ____________ COLLECTOR: ____________

WEATHER: ____________

		6 - 7 am	
RaCK ID #	Building	Time	Usage
88	Wallace		
89	Wallace		
90	Wallace		
91	Wallace		
92	Wallace		
93	Wallace		
94	Wallace		
95	Dining		
96	Dining		
97	Dining		
98	Dining		
99	Dining		
100	Dining		
101	Dining		
102	Aubie		
103	Aubie		
104	Aubie		
105	Aubie		
106	Aubie		
107	Aubie		

		6 - 7 am	
RaCK ID #	Building	Time	Usage
108	Aubie		
109	Plainsman		
110	Plainsman		
111	Willow		
112	Willow		
113	Oak		
114	Oak		
115	Magnolia		
116	Magnolia		
117	Talon		
118	Talon		
119	Tiger		
120	Tiger		
121	Eagle		
122	Eagle		
123	Aubie		
124	Aubie		
125	Aubie		
126	Aubie		
127	Nichols		

Comments: ____________

Instructions:

1. Fill in the top of the form with the date, your name, and the approximate weather conditions
2. During the indicated time range, count the number of bicycles on each rack. Record the number under 'usage'
3. Attached to this page are two maps, one showing the entire campus and one showing the racks to be collected
4. The first map is intended to show you where your zone is located in relation to other buildings on campus. The second map is intended to show you the location of each rack in your zone.
5. Count all the bicycles on and around the racks. If there are bicycles chained up near the racks, record them separate from the actual count. (Example: 5 bikes on rack and 2 chained up nearby... Record as 5 (2)

Figure B-4: Data Collection Sheet for The Village

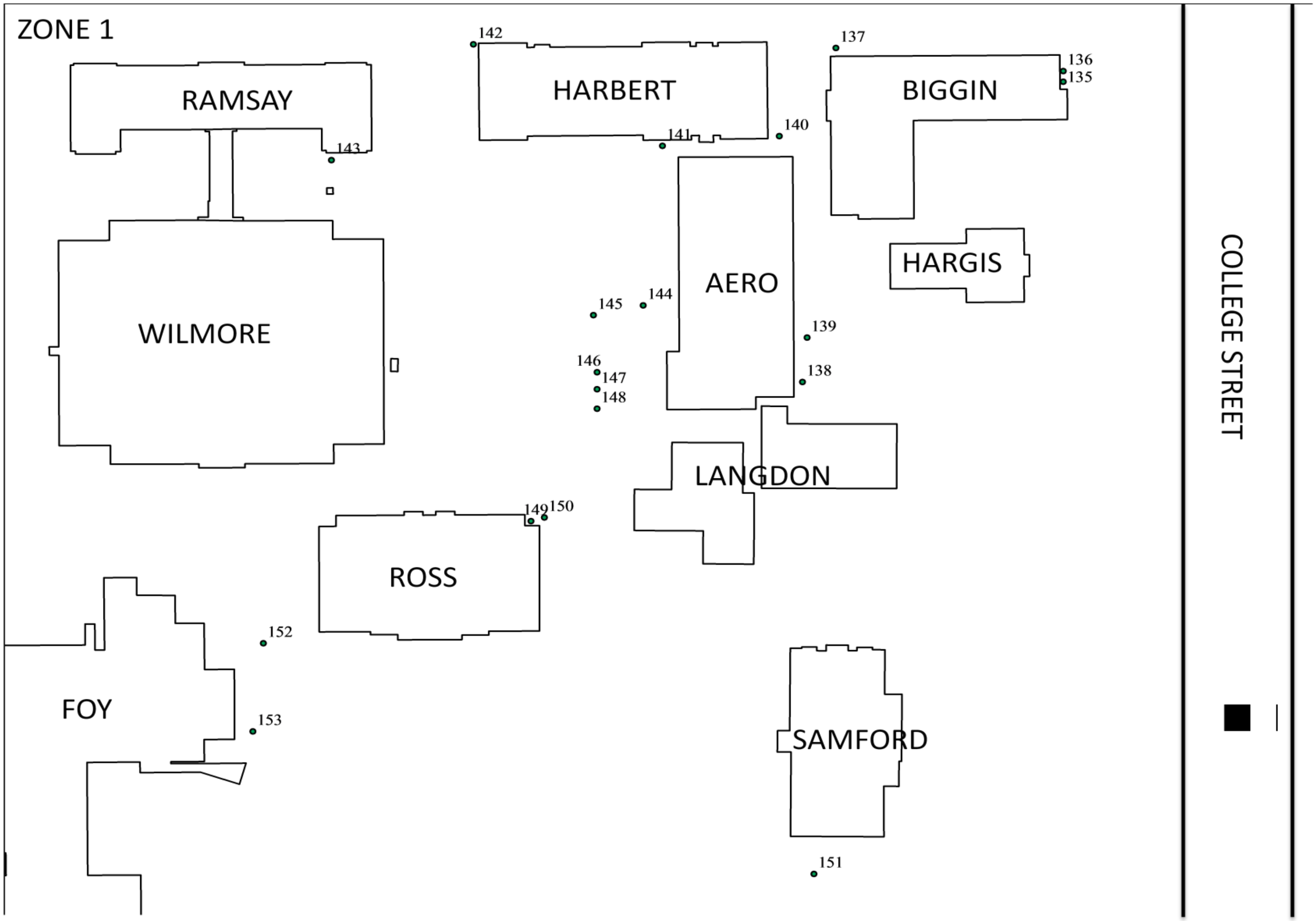

Figure B-5: Zone Map for Data Collection of the Academic Buildings

DATE: ____________ COLLECTOR: R. Turochy WEATHER: ____________

		9:10-9:40		10:10-10:40		11:10-11:40		12:10-12:40		1:10-1:40	
Rack ID #	**Bldg**	Time	Usage	Time	Usage	Time	Usage	Time	Usage	Time	Usage
135	Biggin										
136	Biggin										
137	Biggin										
138	Aero										
139	Aero										
140	Aero										
141	Harbert										
142	Harbert										
143	Ramsay										
144	Aero										
145	Aero										
146	Aero										
147	Aero										
148	Aero										
149	Ross										
150	Ross										
151	Samford										
152	Foy										
153	Foy										

Comments: ____________

Instructions: 1. Fill in the top of the form with the date, your name, and the approximate weather conditions
2. During the
3. Attached to this page are two maps, one showing the entire campus and one showing the racks to be collected
4. The first map is intended to show you where your zone is located in relation to other buildings on campus.
The second map is intended to show you the location of each rack in your zone.
5. Count all the bicycles on and around the racks. If there are bicycles chained up near the racks, record them separate from the actual count. (Example: 5 bikes on rack and 2 chained up nearby... Record as 5 (2)

Figure B-6: Data Collection Sheet for The Village

Table B-1: Comparison of 2010 Collected Rack Usage for Monday and Tuesday for The Hill

The Hill	**Collection Time 6 - 7 am**			**Building Total**	
Building Id	Rack FID #	Monday	Tuesday	Monday	Tuesday
Hollifield	221	6	4	27	24
Hollifield	222	4	5		
Hollifield	231	8	7		
Hollifield	232	9	8		
Dobbs	223	11	1	21	2
Dobbs	224	10	1		
Dunn	225	19	14	19	14
Graves	226	9	9	24	26
Graves	227	9	10		
Graves	228	6	7		
Toomer	229	7	7	16	17
Toomer	230	9	10		
Duncan	233	7	7	14	14
Duncan	234	7	7		
M	235	2	1	35	35
M	236	7	9		
M	237	7	6		
M	238	19	19		
Knapp	239	3	4	3	4
Boyd	240	9	8	48	50
Boyd	241	6	9		
Boyd	242	14	12		
Boyd	243	11	13		
Boyd	244	8	8		
Dowell	247	12	12	21	18
Dowell	248	9	6		
Sasnett	249	12	10	58	57
Sasnett	250	13	12		
Sasnett	251	18	17		
Sasnett	252	15	18		
Leischuck	253	6	6	20	19
Leischuck	254	3	2		
Leischuck	255	3	3		
Leischuck	256	8	8		

Table B-2: Comparison of 2010 Collected Rack Usage for Monday and Tuesday for The Quad

The Quad	Collection Time 6 - 7 am			Building Total	
Building Id	Rack FID #	Monday	Tuesday	Monday	Tuesday
Broun	0	8	8	42	40
Broun	1	10	10		
Broun	2	9	8		
Broun	3	15	14		
Teague	4	25	25	25	25
Little	5	10	10	26	26
Little	-	16	16		
Keller	42	8	6	12	13
Keller	43	4	7		
Lane	44	14	9	14	9
Glenn	45	10	8	36.1	35.1
Glenn	46	4.1	6.1		
Glenn	47	5	5		
Glenn	48	5	5		
Glenn	49	4	3		
Glenn	50	4	4		
Glenn	51	4	4		
Owen	52	6	5	16	16
Owen	53	3	2		
Owen	54	0	1		
Owen	55	2	3		
Owen	56	3	2		
Owen	40	0	0		
Owen	41	2	3		
Harper	-	22	22	22	22
Dowdell	-	4	5	4	5
Lupton	-	26.9	23.9	26.9	23.9

Table B-3: Comparison of 2010 Collected Rack Usage for Monday and Tuesday for The Village

The Village	Collection Time 6 - 7 am			Building Total	
Building Id	Rack FID #	Monday	Tuesday	Monday	Tuesday
Aubie	102	14	15	128	123
Aubie	103	15	15		
Aubie	104	15	15		
Aubie	105	11	10		
Aubie	106	6	7		
Aubie	107	5	5		
Aubie	108	8	7		
Aubie	123	15	13		
Aubie	124	12	11		
Aubie	125	15	10		
Aubie	126	12	15		
Plainsman	109	29	20	47	41
Plainsman	110	18	21		
Willow	111	13	16	30	30
Willow	112	17	14		
Oak	113	8	8	17	18
Oak	114	9	10		
Magnolia	115	19	18	38	37
Magnolia	116	19	19		
Talon	117	23	21	52	50
Talon	118	29	29		
Tiger	119	30	28	47	47
Tiger	120	17	19		
Eagle	121	15	15	30	33
Eagle	122	15	18		

Table B-4: 2010 Individual Building Model Data for Monday

Building Name	Gross Area	Room Area	Monday	
			Peak Rack Usage	Enrollment
Biggin Hall	53395	3951	9.83	164
Broun Hall	101459	4820	22.27	293
Cary Hall	-	-	5.00	90
Charles E. Davis Aerospace Hall	72899	9981	80.95	501
Chemistry Bldg	72179	7148	37.00	360
Comer Hall	45625	2790	15.86	30
Corley Hall	23679	2201	3.00	10
Dudley Hall	56286	3952	22.00	146
Forestry and Wildlife Science Bldg	112067	8027	27.00	124
Funchess Hall	151454	4402	12.20	182
Goodwin Hall	49766	4580	12.00	118
Gorrie Center	37278	3181	9.00	141
Haley Center	414651	62278	191.00	2163
Harbert Center	46446	1432	6.14	33
Lowder Hall	161848	38635	64.00	1357
Miller Hall	25347	2692	4.00	76
Nichols Center	33709	4332	13.86	22
Parker Hall	90660	18558	94.00	859
Pharmacy Bldg -Walker Building	130100	20371	7.05	132
Poultry Science Bldg	-	-	4.00	28
Ramsay Hall	47963	3365	8.00	100
Ross Hall	57320	1646	7.00	22
Rouse Life Sciences Bldg	71384	1847	18.00	123
Sciences Center Auditorium	10809	5373	33.00	269
Science Center Laboratory	-	-	32.00	0
Shelby Center	198169	10315	26.00	223
Spidle Hall	50843	5469	16.00	362
Swingle Hall	30243	754	1.00	0
Telfair Peet Univ Theatre	54444	676	3.00	10
Textile Engineering Bldg	51446	2539	3.00	0
Thach Hall	42871	3460	26.26	241
Tichenor Hall	-	-	21.03	96
Upchurch Hall	70695	3147	6.00	61
Wallace Center	42134	2919	30.14	34

Table B-5: 2010 Individual Building Model Data for Tuesday

Building Name	Gross Area	Room Area	Tuesday	
			Peak Rack Usage	Enrollment
Biggin Hall	53395	3951	8.70	119
Broun Hall	101459	4820	34.63	320
Cary Hall	-	-	2.00	51
Charles E. Davis Aerospace Hall	72899	9981	42.51	303
Chemistry Bldg	72179	7148	20.00	395
Comer Hall	45625	2790	16.03	104
Corley Hall	23679	2201	3.00	9
Dudley Hall	56286	3952	17.00	37
Forestry and Wildlife Science Bldg	112067	8027	15.00	167
Funchess Hall	151454	4402	13.22	92
Goodwin Hall	49766	4580	12.00	134
Gorrie Center	37278	3181	6.00	52
Haley Center	414651	62278	175.00	2194
Harbert Center	46446	1432	5.43	27
Lowder Hall	161848	38635	76.00	1332
Miller Hall	25347	2692	6.00	28
Nichols Center	33709	4332	19.83	64
Parker Hall	90660	18558	73.00	818
Pharmacy Bldg -Walker Building	130100	20371	11.09	0
Poultry Science Bldg	-	-	1.00	8
Ramsay Hall	47963	3365	4.00	19
Ross Hall	57320	1646	9.00	29
Rouse Life Sciences Bldg	71384	1847	15.00	61
Sciences Center Auditorium	10809	5373	27.00	259
Science Center Laboratory	-	-	32.00	426
Shelby Center	198169	10315	18.00	210
Spidle Hall	50843	5469	18.00	357
Swingle Hall	30243	754	0.00	0
Telfair Peet Univ Theatre	54444	676	6.00	30
Textile Engineering Bldg	51446	2539	1.00	15
Thach Hall	42871	3460	23.27	164
Tichenor Hall	-	-	15.71	76
Upchurch Hall	70695	3147	5.00	104
Wallace Center	42134	2919	26.17	82

Table B-6: 2010 Individual Building Model Data for Thursday

Building Name	Gross Area	Room Area	Wednesday	
			Peak Rack Usage	Enrollment
Biggin Hall	53395	3951	11.28	214
Broun Hall	101459	4820	22.42	293
Cary Hall	-	-	4.00	90
Charles E. Davis Aerospace Hall	72899	9981	82.14	501
Chemistry Bldg	72179	7148	34.00	34
Comer Hall	45625	2790	17.16	30
Corley Hall	23679	2201	3.00	27
Dudley Hall	56286	3952	24.00	166
Forestry and Wildlife Science Bldg	112067	8027	21.00	112
Funchess Hall	151454	4402	19.43	182
Goodwin Hall	49766	4580	11.00	203
Gorrie Center	37278	3181	5.00	60
Haley Center	414651	62278	187.00	2195
Harbert Center	46446	1432	5.59	55
Lowder Hall	161848	38635	55.00	1453
Miller Hall	25347	2692	4.00	14
Nichols Center	33709	4332	12.59	3
Parker Hall	90660	18558	82.00	767
Pharmacy Bldg -Walker Building	130100	20371	7.88	0
Poultry Science Bldg	-	-	1.00	0
Ramsay Hall	47963	3365	8.00	100
Ross Hall	57320	1646	11.00	0
Rouse Life Sciences Bldg	71384	1847	12.00	43
Sciences Center Auditorium	10809	5373	29.00	245
Science Center Laboratory	-	-	33.00	146
Shelby Center	198169	10315	38.00	308
Spidle Hall	50843	5469	17.00	444
Swingle Hall	30243	754	2.00	5
Telfair Peet Univ Theatre	54444	676	4.00	63
Textile Engineering Bldg	51446	2539	2.00	0
Thach Hall	42871	3460	25.43	253
Tichenor Hall	-	-	16.03	70
Upchurch Hall	70695	3147	6.00	64
Wallace Center	42134	2919	29.41	203

Table B-7: 2010 Individual Building Model Data for Thursday

Building Name	Gross Area	Room Area	Thursday	
			Peak Rack Usage	Enrollment
Biggin Hall	53395	3951	14.96	214
Broun Hall	101459	4820	30.48	319
Cary Hall	-	-	1.00	51
Charles E. Davis Aerospace Hall	72899	9981	56.55	370
Chemistry Bldg	72179	7148	33.00	292
Comer Hall	45625	2790	16.03	61
Corley Hall	23679	2201	2.00	2
Dudley Hall	56286	3952	15.00	29
Forestry and Wildlife Science Bldg	112067	8027	20.00	145
Funchess Hall	151454	4402	14.48	111
Goodwin Hall	49766	4580	10.00	134
Gorrie Center	37278	3181	5.00	50
Haley Center	414651	62278	139.00	2209
Harbert Center	46446	1432	8.13	88
Lowder Hall	161848	38635	43.00	1332
Miller Hall	25347	2692	2.00	0
Nichols Center	33709	4332	10.97	45
Parker Hall	90660	18558	68.00	817
Pharmacy Bldg -Walker Building	130100	20371	6.56	0
Poultry Science Bldg	-	-	1.00	8
Ramsay Hall	47963	3365	9.00	50
Ross Hall	57320	1646	13.00	29
Rouse Life Sciences Bldg	71384	1847	15.00	61
Sciences Center Auditorium	10809	5373	26.00	264
Science Center Laboratory	-	-	32.00	298
Shelby Center	198169	10315	27.00	254
Spidle Hall	50843	5469	10.00	254
Swingle Hall	30243	754	1.00	0
Telfair Peet Univ Theatre	54444	676	6.00	53
Textile Engineering Bldg	51446	2539	4.00	30
Thach Hall	42871	3460	19.07	164
Tichenor Hall	-	-	8.46	56
Upchurch Hall	70695	3147	4.00	104
Wallace Center	42134	2919	26.03	110

Table B-8: 2010 Individual Building Model Data for the Peak Day of Each Building

Building Name	Gross Area	Room Area	PEAK DAY	
			Peak Rack Usage	Enrollment
Biggin Hall	53395	3951	14.96	214
Broun Hall	101459	4820	30.48	319
Cary Hall	-	-	5.00	90
Charles E. Davis Aerospace Hall	72899	9981	82.14	501
Chemistry Bldg	72179	7148	37.00	360
Comer Hall	45625	2790	17.16	30
Corley Hall	23679	2201	3.00	9
Dudley Hall	56286	3952	24.00	166
Forestry and Wildlife Science Bldg	112067	8027	27.00	124
Funchess Hall	151454	4402	19.43	182
Goodwin Hall	49766	4580	12.00	118
Gorrie Center	37278	3181	9.00	141
Haley Center	414651	62278	191.00	2163
Harbert Center	46446	1432	8.13	88
Lowder Hall	161848	38635	76.00	1332
Miller Hall	25347	2692	6.00	28
Nichols Center	33709	4332	19.83	64
Parker Hall	90660	18558	94.00	859
Pharmacy Bldg -Walker Building	130100	20371	11.09	0
Poultry Science Bldg	-	-	4.00	28
Ramsay Hall	47963	3365	9.00	50
Ross Hall	57320	1646	11.00	0
Rouse Life Sciences Bldg	71384	1847	18.00	123
Sciences Center Auditorium	10809	5373	33.00	269
Science Center Laboratory	-	-	33.00	146
Shelby Center	198169	10315	38.00	308
Spidle Hall	50843	5469	18.00	357
Swingle Hall	30243	754	2.00	5
Telfair Peet Univ Theatre	54444	676	6.00	30
Textile Engineering Bldg	51446	2539	4.00	30
Thach Hall	42871	3460	26.26	241
Tichenor Hall	-	-	21.03	96
Upchurch Hall	70695	3147	6.00	61
Wallace Center	42134	2919	30.14	34

Table B-9: 2010 Zone Model Data for Monday

ZONE	Gross Area	Room Area	Monday	
			Peak Rack Usage	Enrollment
1	278024	20375	106	813
2	51446	2539	3	19
3	198169	10315	40	223
4	161848	38635	64	1357
5	75844	7251	44	56
6	299778	31343	70	491
7	50843	5469	16	362
8	89143	-	4	28
9	112067	8027	27	124
10	160495	9208	37	449
11	67521	3935	10	160
12	95858	9348	39	373
13	101469	23931	192	1104
14	339158	12186	47	328
15	414651	62278	191	2163

Table B-10: 2010 Zone Model Data for Tuesday

ZONE	Gross Area	Room Area	Tuesday	
			Peak Rack Usage	Enrollment
1	278024	20375	67	531
2	51446	2539	1	15
3	198169	10315	26	210
4	161848	38635	76	1332
5	75844	7251	46	146
6	299778	31343	85	509
7	50843	5469	18	357
8	89143	-	1	8
9	112067	8027	15	167
10	160495	9208	31	171
11	67521	3935	6	52
12	95858	9348	23	404
13	101469	23931	176	1526
14	339158	12186	44	259
15	414651	62278	175	2194

Table B-11: 2010 Zone Model Data for Wednesday

ZONE	Gross Area	Room Area	Wednesday	
			Peak Rack Usage	Enrollment
1	278024	20375	113	813
2	51446	2539	2	7
3	198169	10315	38	234
4	161848	38635	55	1453
5	75844	7251	41	250
6	299778	31343	69	651
7	50843	5469	17	444
8	89143	-	1	8
9	112067	8027	21	112
10	160495	9208	39	432
11	67521	3935	5	69
12	95858	9348	34	400
13	101469	23931	198	1112
14	339158	12186	52	319
15	414651	62278	187	2195

Table B-12: 2010 Zone Model Data for Thursday

ZONE	Gross Area	Room Area	Thursday	
			Peak Rack Usage	Enrollment
1	278024	20375	91	683
2	51446	2539	4	30
3	198169	10315	27	254
4	161848	38635	43	1332
5	75844	7251	36	164
6	299778	31343	66	744
7	50843	5469	10	339
8	89143	-	1	8
9	112067	8027	20	145
10	160495	9208	28	163
11	67521	3935	6	52
12	95858	9348	34	292
13	101469	23931	167	1227
14	339158	12186	46	371
15	414651	62278	139	2209

Table B-13: 2010 Zone Model Data for the Peak Day of Each Building

ZONE	Gross Area	Room Area	PEAK DAY	
			Peak Rack Usage	Enrollment
1	278024	20375	113	813
2	51446	2539	4	30
3	198169	10315	40	223
4	161848	38635	76	1332
5	75844	7251	46	146
6	299778	31343	85	509
7	50843	5469	18	357
8	89143	-	4	28
9	112067	8027	27	124
10	160495	9208	39	432
11	67521	3935	10	160
12	95858	9348	39	373
13	101469	23931	198	1112
14	339158	12186	52	319
15	414651	62278	191	2163

APPENDIX C

RESULTS FOR THE COMPARISON OF ESTIMATED PEAK RACK USAGE AND THE 2010 COLLECTED PEAK RACK USAGE

Table C-1: Analysis Results for The Hill Residence Halls

The Hill					
Name	**Beds**	**Estimated Peak Usage**	**Collected Peak Usage**	**Model Error**	**% Error**
Hollifield	107	13	27	-14	-53.62%
Dobbs	107	13	21	-8	-40.37%
Dunn	107	13	19	-6	-34.09%
Graves	107	13	26	-13	-51.84%
Toomer	107	13	17	-4	-26.34%
Duncan	107	13	14	-1	-10.55%
M	101	11	35	-24	-68.26%
Knapp	107	13	4	9	213.07%
Boyd	212	37	50	-13	-25.44%
Dowell	107	13	21	-8	-40.37%
Sasnett	212	37	58	-21	-35.72%
Leischuck	101	11	20	-9	-44.46%
			Average	-10	-18.17%

Table C-2: Analysis Results for The Quad Residence Halls

The Quad					
Name	**Beds**	**Estimated Peak Usage**	**Collected Peak Usage**	**Model Error**	**% Error**
Broun	101	11	42	-31	-73.55%
Teague	90	9	25	-16	-65.94%
Little	90	9	26	-17	-67.25%
Keller	104	12	13	-1	-9.11%
Lane	104	12	14	-2	-15.61%
Glenn	104	12	36.1	-24	-67.27%
Owen	104	12	16	-4	-26.16%
Harper	78	6	22	-16	-74.16%
Dowdell	104	12	5	7	136.30%
Lupton	88	8	26.9	-19	-70.10%
			Average	-13	-33.29%

Table C-3: Individual Building Analysis Results for Equation 4 on a Tuesday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	119	8.91	8.70	0.21	2.38%
Broun Hall	101459	4820	320	21.11	34.63	-13.52	-39.04%
Charles E. Davis Aerospace Hall	72899	9981	303	15.54	42.51	-26.97	-63.44%
Chemistry Bldg	72179	7148	395	21.46	20.00	1.46	7.30%
Comer Hall	45625	2790	104	8.34	16.03	-7.70	-48.00%
Corley Hall	23679	2201	9	2.72	3.00	-0.28	-9.28%
Dudley Hall	56286	3952	37	5.20	17.00	-11.80	-69.44%
Forestry and Wildlife Science Bldg	112067	8027	167	12.73	15.00	-2.27	-15.16%
Funchess Hall	151454	4402	92	13.76	13.22	0.54	4.08%
Goodwin Hall	49766	4580	134	9.03	12.00	-2.97	-24.75%
Gorrie Center	37278	3181	52	5.10	6.00	-0.90	-14.96%
Haley Center	414651	62278	2194	98.37	175.00	-76.63	-43.79%
Harbert Center	46446	1432	27	5.49	5.43	0.06	1.14%
Lowder Hall	161848	38635	1332	54.18	76.00	-21.82	-28.71%
Miller Hall	25347	2692	28	3.46	6.00	-2.54	-42.37%
Nichols Center	33709	4332	64	4.79	19.83	-15.03	-75.82%
Parker Hall	90660	18558	818	36.37	73.00	-36.63	-50.18%
Pharmacy Bldg -Walker Building	130100	20371	8	-0.59	1.00	-1.59	-159.10%
Ramsay Hall	47963	3365	19	4.13	4.00	0.13	3.16%
Ross Hall	57320	1646	59	7.60	9.00	-1.40	-15.51%
Rouse Life Sciences Bldg	71384	1847	61	8.50	15.00	-6.50	-43.31%
Sciences Center Auditorium	10809	5373	259	11.99	27.00	-15.01	-55.60%
Shelby Center	198169	10315	210	19.10	18.00	1.10	6.11%
Spidle Hall	50843	5469	357	19.20	18.00	1.20	6.69%
Swingle Hall	30243	754	0	3.53	0.00	3.53	0.00%
Telfair Peet Univ Theatre	54444	676	30	6.58	6.00	0.58	9.71%
Textile Engineering Bldg	51446	2539	15	4.63	1.00	3.63	362.73%
Thach Hall	42871	3460	122	8.64	23.27	-14.63	-62.87%
Upchurch Hall	70695	3147	104	9.77	5.00	4.77	95.46%
Wallace Center	42134	2919	82	6.99	26.17	-19.18	-73.28%
					AVERAGE	-8.67	-14.53%

Table C-4: Individual Building Analysis Results for Equation 4 on a Wednesday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	214	13.42	11.28	2.15	19.04%
Broun Hall	101459	4820	293	19.83	22.42	-2.59	-11.55%
Charles E. Davis Aerospace Hall	72899	9981	501	24.96	82.14	-57.18	-69.62%
Chemistry Bldg	72179	7148	34	4.29	34.00	-29.71	-87.37%
Comer Hall	45625	2790	95	7.91	17.16	-9.25	-53.90%
Corley Hall	23679	2201	27	3.58	3.00	0.58	19.25%
Dudley Hall	56286	3952	166	11.33	24.00	-12.67	-52.79%
Forestry and Wildlife Science Bldg	112067	8027	112	10.11	21.00	-10.89	-51.85%
Funchess Hall	151454	4402	182	18.04	19.43	-1.39	-7.14%
Goodwin Hall	49766	4580	203	12.31	11.00	1.31	11.92%
Gorrie Center	37278	3181	60	5.48	5.00	0.48	9.65%
Haley Center	414651	62278	2195	98.42	187.00	-88.58	-47.37%
Harbert Center	46446	1432	55	6.82	5.59	1.24	22.20%
Lowder Hall	161848	38635	1453	59.93	55.00	4.93	8.97%
Miller Hall	25347	2692	14	2.79	4.00	-1.21	-30.20%
Nichols Center	33709	4332	31	3.22	12.59	-9.37	-74.39%
Parker Hall	90660	18558	767	33.95	82.00	-48.05	-58.60%
Pharmacy Bldg -Walker Building	130100	20371	8	-0.59	1.00	-1.59	-159.10%
Ramsay Hall	47963	3365	100	7.98	8.00	-0.02	-0.27%
Ross Hall	57320	1646	22	5.85	7.00	-1.15	-16.50%
Rouse Life Sciences Bldg	71384	1847	43	7.65	12.00	-4.35	-36.27%
Sciences Center Auditorium	10809	5373	245	11.32	29.00	-17.68	-60.96%
Shelby Center	198169	10315	308	23.76	38.00	-14.24	-37.47%
Spidle Hall	50843	5469	444	23.34	17.00	6.34	37.30%
Swingle Hall	30243	754	5	3.77	2.00	1.77	88.60%
Telfair Peet Univ Theatre	54444	676	63	8.15	4.00	4.15	103.79%
Textile Engineering Bldg	51446	2539	7	4.25	2.00	2.25	112.35%
Thach Hall	42871	3460	253	14.87	25.43	-10.56	-41.53%
Upchurch Hall	70695	3147	64	7.87	6.00	1.87	31.19%
Wallace Center	42134	2919	203	12.75	29.41	-16.66	-56.66%
					AVERAGE	-10.34	-16.31%

Table C-5: Individual Building Analysis Results for Equation 4 on a Thursday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	214	13.42	14.96	-1.53	-10.24%
Broun Hall	101459	4820	319	21.06	30.48	-9.42	-30.90%
Charles E. Davis Aerospace Hall	72899	9981	370	18.73	56.55	-37.82	-66.88%
Chemistry Bldg	72179	7148	292	16.56	33.00	-16.44	-49.81%
Comer Hall	45625	2790	104	8.34	16.03	-7.70	-48.00%
Corley Hall	23679	2201	2	2.39	2.00	0.39	19.43%
Dudley Hall	56286	3952	29	4.82	15.00	-10.18	-67.90%
Forestry and Wildlife Science Bldg	112067	8027	145	11.68	20.00	-8.32	-41.60%
Funchess Hall	151454	4402	111	14.67	14.48	0.18	1.27%
Goodwin Hall	49766	4580	134	9.03	10.00	-0.97	-9.70%
Gorrie Center	37278	3181	50	5.01	5.00	0.01	0.14%
Haley Center	414651	62278	2209	99.09	139.00	-39.91	-28.71%
Harbert Center	46446	1432	88	8.39	8.13	0.26	3.23%
Lowder Hall	161848	38635	1332	54.18	43.00	11.18	26.00%
Miller Hall	25347	2692	0	2.13	2.00	0.13	6.31%
Nichols Center	33709	4332	45	3.89	10.97	-7.08	-64.54%
Parker Hall	90660	18558	817	36.32	68.00	-31.68	-46.58%
Pharmacy Bldg -Walker Building	130100	20371	8	-0.59	1.00	-1.59	-159.10%
Ramsay Hall	47963	3365	50	5.60	9.00	-3.40	-37.77%
Ross Hall	57320	1646	29	6.18	13.00	-6.82	-52.48%
Rouse Life Sciences Bldg	71384	1847	61	8.50	15.00	-6.50	-43.31%
Sciences Center Auditorium	10809	5373	264	12.23	26.00	-13.77	-52.98%
Shelby Center	198169	10315	254	21.19	27.00	-5.81	-21.51%
Spidle Hall	50843	5469	254	14.31	10.00	4.31	43.07%
Swingle Hall	30243	754	14	4.20	1.00	3.20	319.99%
Telfair Peet Univ Theatre	54444	676	53	7.68	6.00	1.68	27.93%
Textile Engineering Bldg	51446	2539	30	5.34	4.00	1.34	33.51%
Thach Hall	42871	3460	164	10.64	19.07	-8.44	-44.23%
Upchurch Hall	70695	3147	104	9.77	4.00	5.77	144.33%
Wallace Center	42134	2919	110	8.32	26.03	-17.70	-68.02%
					AVERAGE:	-6.89	-10.63%

Table C-6: Individual Building Analysis Results for Equation 6 on a Monday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	164	11.00	9.83	1.16	11.83%
Broun Hall	101459	4820	293	17.48	22.27	-4.78	-21.48%
Charles E. Davis Aerospace Hall	72899	9981	501	23.97	80.95	-56.99	-70.40%
Chemistry Bldg	72179	7148	360	18.82	37.00	-18.18	-49.14%
Comer Hall	45625	2790	95	8.20	15.86	-7.66	-48.29%
Corley Hall	23679	2201	10	4.29	3.00	1.29	43.03%
Dudley Hall	56286	3952	146	10.45	22.00	-11.55	-52.49%
Forestry and Wildlife Science Bldg	112067	8027	124	11.75	27.00	-15.25	-56.50%
Funchess Hall	151454	4402	182	15.33	12.20	3.12	25.61%
Goodwin Hall	49766	4580	118	9.19	12.00	-2.81	-23.41%
Gorrie Center	37278	3181	141	9.56	9.00	0.56	6.19%
Haley Center	414651	62278	2163	97.13	191.00	-93.87	-49.15%
Harbert Center	46446	1432	33	5.98	6.14	-0.16	-2.65%
Lowder Hall	161848	38635	1357	58.38	64.00	-5.62	-8.78%
Miller Hall	25347	2692	76	6.75	4.00	2.75	68.75%
Nichols Center	33709	4332	22	5.10	13.86	-8.76	-63.18%
Parker Hall	90660	18558	859	37.63	94.00	-56.37	-59.97%
Pharmacy Bldg -Walker Building	130100	20371	28	8.94	4.00	4.94	123.41%
Ramsay Hall	47963	3365	100	8.47	8.00	0.47	5.87%
Ross Hall	57320	1646	22	5.99	7.00	-1.01	-14.45%
Rouse Life Sciences Bldg	71384	1847	123	10.18	18.00	-7.82	-43.43%
Sciences Center Auditorium	10809	5373	269	13.21	33.00	-19.79	-59.96%
Shelby Center	198169	10315	223	18.57	26.00	-7.43	-28.58%
Spidle Hall	50843	5469	362	18.09	16.00	2.09	13.07%
Swingle Hall	30243	754	5	4.36	1.00	3.36	335.55%
Telfair Peet Univ Theatre	54444	676	10	5.44	3.00	2.44	81.49%
Textile Engineering Bldg	51446	2539	19	5.66	3.00	2.66	88.64%
Thach Hall	42871	3460	241	13.40	26.26	-12.86	-48.97%
Upchurch Hall	70695	3147	61	7.91	6.00	1.91	31.77%
Wallace Center	42134	2919	34	5.85	30.14	-24.29	-80.58%
					AVERAGE:	-10.95	1.79%

Table C-7: Individual Building Analysis Results for Equation 6 on a Tuesday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	119	9.36	8.70	0.66	7.63%
Broun Hall	101459	4820	320	18.46	34.63	-16.16	-46.68%
Charles E. Davis Aerospace Hall	72899	9981	303	16.78	42.51	-25.73	-60.53%
Chemistry Bldg	72179	7148	395	20.09	20.00	0.09	0.45%
Comer Hall	45625	2790	104	8.53	16.03	-7.51	-46.82%
Corley Hall	23679	2201	9	4.25	3.00	1.25	41.82%
Dudley Hall	56286	3952	37	6.49	17.00	-10.51	-61.80%
Forestry and Wildlife Science Bldg	112067	8027	167	13.31	15.00	-1.69	-11.29%
Funchess Hall	151454	4402	92	12.06	13.22	-1.16	-8.80%
Goodwin Hall	49766	4580	134	9.77	12.00	-2.23	-18.57%
Gorrie Center	37278	3181	52	6.33	6.00	0.33	5.43%
Haley Center	414651	62278	2194	98.26	175.00	-76.74	-43.85%
Harbert Center	46446	1432	27	5.76	5.43	0.33	6.09%
Lowder Hall	161848	38635	1332	57.48	76.00	-18.52	-24.37%
Miller Hall	25347	2692	28	5.01	6.00	-0.99	-16.55%
Nichols Center	33709	4332	64	6.63	19.83	-13.20	-66.57%
Parker Hall	90660	18558	818	36.14	73.00	-36.86	-50.49%
Pharmacy Bldg -Walker Building	130100	20371	8	8.21	1.00	7.21	721.00%
Ramsay Hall	47963	3365	19	5.53	4.00	1.53	38.21%
Ross Hall	57320	1646	59	7.33	9.00	-1.67	-18.53%
Rouse Life Sciences Bldg	71384	1847	61	7.93	15.00	-7.07	-47.12%
Sciences Center Auditorium	10809	5373	259	12.85	27.00	-14.15	-52.41%
Shelby Center	198169	10315	210	18.10	18.00	0.10	0.54%
Spidle Hall	50843	5469	357	17.91	18.00	-0.09	-0.50%
Swingle Hall	30243	754	0	4.17	0.00	4.17	0.00%
Telfair Peet Univ Theatre	54444	676	30	6.17	6.00	0.17	2.85%
Textile Engineering Bldg	51446	2539	15	5.51	1.00	4.51	451.39%
Thach Hall	42871	3460	122	9.08	23.27	-14.19	-60.99%
Upchurch Hall	70695	3147	104	9.47	5.00	4.47	89.35%
Wallace Center	42134	2919	82	7.60	26.17	-18.58	-70.97%
					AVERAGE:	-8.07	21.93%

Table C-8: Individual Building Analysis Results for Equation 6 on a Wednesday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	214	12.81	11.28	1.54	13.62%
Broun Hall	101459	4820	293	17.48	22.42	-4.93	-22.00%
Charles E. Davis Aerospace Hall	72899	9981	501	23.97	82.14	-58.17	-70.82%
Chemistry Bldg	72179	7148	34	6.98	34.00	-27.02	-79.47%
Comer Hall	45625	2790	95	8.20	17.16	-8.96	-52.21%
Corley Hall	23679	2201	27	4.91	3.00	1.91	63.60%
Dudley Hall	56286	3952	166	11.18	24.00	-12.82	-53.42%
Forestry and Wildlife Science Bldg	112067	8027	112	11.31	21.00	-9.69	-46.14%
Funchess Hall	151454	4402	182	15.33	19.43	-4.10	-21.11%
Goodwin Hall	49766	4580	203	12.28	11.00	1.28	11.61%
Gorrie Center	37278	3181	60	6.62	5.00	1.62	32.33%
Haley Center	414651	62278	2195	98.29	187.00	-88.71	-47.44%
Harbert Center	46446	1432	55	6.78	5.59	1.19	21.37%
Lowder Hall	161848	38635	1453	61.87	55.00	6.87	12.49%
Miller Hall	25347	2692	14	4.50	4.00	0.50	12.47%
Nichols Center	33709	4332	31	5.43	12.59	-7.16	-56.87%
Parker Hall	90660	18558	767	34.29	82.00	-47.71	-58.18%
Pharmacy Bldg -Walker Building	130100	20371	8	8.21	1.00	7.21	721.00%
Ramsay Hall	47963	3365	100	8.47	8.00	0.47	5.87%
Ross Hall	57320	1646	22	5.99	7.00	-1.01	-14.45%
Rouse Life Sciences Bldg	71384	1847	43	7.28	12.00	-4.72	-39.35%
Sciences Center Auditorium	10809	5373	245	12.34	29.00	-16.66	-57.45%
Shelby Center	198169	10315	308	21.66	38.00	-16.34	-43.01%
Spidle Hall	50843	5469	444	21.07	17.00	4.07	23.93%
Swingle Hall	30243	754	5	4.36	2.00	2.36	117.77%
Telfair Peet Univ Theatre	54444	676	63	7.37	4.00	3.37	84.23%
Textile Engineering Bldg	51446	2539	7	5.22	2.00	3.22	161.17%
Thach Hall	42871	3460	253	13.83	25.43	-11.59	-45.60%
Upchurch Hall	70695	3147	64	8.02	6.00	2.02	33.59%
Wallace Center	42134	2919	203	11.99	29.41	-17.42	-59.23%
					AVERAGE:	-9.98	18.28%

Table C-9: Individual Building Analysis Results for Equation 6 on a Thursday

Building Name	GrossSqFt	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	53395	3951	214	12.81	14.96	-2.14	-14.33%
Broun Hall	101459	4820	319	18.43	30.48	-12.05	-39.54%
Charles E. Davis Aerospace Hall	72899	9981	370	19.21	56.55	-37.34	-66.03%
Chemistry Bldg	72179	7148	292	16.35	33.00	-16.65	-50.46%
Comer Hall	45625	2790	104	8.53	16.03	-7.51	-46.82%
Corley Hall	23679	2201	2	4.00	2.00	2.00	100.02%
Dudley Hall	56286	3952	29	6.20	15.00	-8.80	-58.64%
Forestry and Wildlife Science Bldg	112067	8027	145	12.51	20.00	-7.49	-37.46%
Funchess Hall	151454	4402	111	12.75	14.48	-1.73	-11.97%
Goodwin Hall	49766	4580	134	9.77	10.00	-0.23	-2.28%
Gorrie Center	37278	3181	50	6.25	5.00	1.25	25.07%
Haley Center	414651	62278	2209	98.80	139.00	-40.20	-28.92%
Harbert Center	46446	1432	88	7.98	8.13	-0.15	-1.89%
Lowder Hall	161848	38635	1332	57.48	43.00	14.48	33.66%
Miller Hall	25347	2692	0	3.99	2.00	1.99	99.51%
Nichols Center	33709	4332	45	5.94	10.97	-5.03	-45.88%
Parker Hall	90660	18558	817	36.11	68.00	-31.89	-46.90%
Pharmacy Bldg -Walker Building	130100	20371	8	8.21	1.00	7.21	721.00%
Ramsay Hall	47963	3365	50	6.65	9.00	-2.35	-26.07%
Ross Hall	57320	1646	29	6.24	13.00	-6.76	-51.98%
Rouse Life Sciences Bldg	71384	1847	61	7.93	15.00	-7.07	-47.12%
Sciences Center Auditorium	10809	5373	264	13.03	26.00	-12.97	-49.88%
Shelby Center	198169	10315	254	19.70	27.00	-7.30	-27.05%
Spidle Hall	50843	5469	254	14.17	10.00	4.17	41.69%
Swingle Hall	30243	754	14	4.68	1.00	3.68	368.23%
Telfair Peet Univ Theatre	54444	676	53	7.01	6.00	1.01	16.77%
Textile Engineering Bldg	51446	2539	30	6.06	4.00	2.06	51.46%
Thach Hall	42871	3460	164	10.60	19.07	-8.47	-44.41%
Upchurch Hall	70695	3147	104	9.47	4.00	5.47	136.69%
Wallace Center	42134	2919	110	8.61	26.03	-17.41	-66.91%
					AVERAGE:	-6.34	27.65%

Table C-10: Individual Building Analysis Results for Equation 7 on a Monday

Building Name	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	3951.08	164	11.39	9.83	1.56	15.87%
Broun Hall	4819.53	293	16.74	22.27	-5.53	-24.84%
Cary Hall	-	90	8.33	5.00	3.33	66.62%
Charles E. Davis Aerospace Hall	9980.76	501	25.35	80.95	-55.61	-68.69%
Chemistry Bldg	7147.75	360	19.51	37.00	-17.49	-47.27%
Comer Hall	2790.27	95	8.54	15.86	-7.32	-46.16%
Corley Hall	2200.58	10	5.02	3.00	2.02	67.30%
Dudley Hall	3951.73	146	10.65	22.00	-11.35	-51.59%
Forestry and Wildlife Science Bldg	8026.8	124	9.74	27.00	-17.26	-63.93%
Funchess Hall	4402.2	182	12.14	12.20	-0.06	-0.53%
Goodwin Hall	4580.15	118	9.49	12.00	-2.51	-20.91%
Gorrie Center	3181.14	141	10.44	9.00	1.44	16.03%
Haley Center	62278.37	2163	94.15	191.00	-96.85	-50.71%
Harbert Center	1432.47	33	5.97	6.14	-0.17	-2.79%
Lowder Hall	38635.05	1357	60.78	64.00	-3.22	-5.02%
Miller Hall	2692.45	76	7.75	4.00	3.75	93.79%
Nichols Center	4332.2	22	5.52	13.86	-8.34	-60.20%
Parker Hall	18558.41	859	40.17	94.00	-53.83	-57.27%
Pharmacy Bldg -Walker Building	20371.44	132	10.07	7.05	3.02	42.79%
Poultry Science Bldg	-	28	5.76	4.00	1.76	44.11%
Ramsay Hall	3365.27	100	8.75	8.00	0.75	9.31%
Ross Hall	1645.62	22	5.52	7.00	-1.48	-21.20%
Rouse Life Sciences Bldg	1846.67	123	9.70	18.00	-8.30	-46.13%
Sciences Center Auditorium	5372.57	269	15.74	33.00	-17.26	-52.30%
Science Center Laboratory	-	340	18.68	31.00	-12.32	-39.74%
Shelby Center	10314.62	223	13.84	26.00	-12.16	-46.78%
Spidle Hall	5469.38	362	19.59	16.00	3.59	22.45%
Swingle Hall	753.56	5	4.81	1.00	3.81	381.21%
Telfair Peet Univ Theatre	676.15	10	5.02	3.00	2.02	67.30%
Textile Engineering Bldg	2539.21	19	5.39	3.00	2.39	79.72%
Thach Hall	3459.57	241	14.58	26.26	-11.67	-44.46%
Tichenor Hall	-	96	8.58	21.03	-12.45	-59.20%
Upchurch Hall	3146.92	61	7.13	6.00	1.13	18.84%
Wallace Center	2919.08	34	6.01	30.14	-24.13	-80.05%
				AVERAGE:	-10.26	1.05%

Table C-11: Individual Building Analysis Results for Equation 7 on a Tuesday

Building Name	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	3951.08	119	9.53	8.70	0.83	9.57%
Broun Hall	4819.53	320	17.85	34.63	-16.78	-48.44%
Cary Hall	-	51	6.72	2.00	4.72	235.83%
Charles E. Davis Aerospace Hall	9980.76	303	17.15	42.51	-25.36	-59.65%
Chemistry Bldg	7147.75	395	20.96	20.00	0.96	4.79%
Comer Hall	2790.27	104	8.91	16.03	-7.12	-44.43%
Corley Hall	2200.58	9	4.98	3.00	1.98	65.92%
Dudley Hall	3951.73	37	6.14	17.00	-10.86	-63.90%
Forestry and Wildlife Science Bldg	8026.8	167	11.52	15.00	-3.48	-23.21%
Funchess Hall	4402.2	92	8.41	13.22	-4.81	-36.38%
Goodwin Hall	4580.15	134	10.15	12.00	-1.85	-15.39%
Gorrie Center	3181.14	52	6.76	6.00	0.76	12.63%
Haley Center	62278.37	2194	95.44	175.00	-79.56	-45.46%
Harbert Center	1432.47	27	5.72	5.43	0.29	5.37%
Lowder Hall	38635.05	1332	59.75	76.00	-16.25	-21.38%
Miller Hall	2692.45	28	5.76	6.00	-0.24	-3.93%
Nichols Center	4332.2	64	7.25	19.83	-12.57	-63.41%
Parker Hall	18558.41	818	38.47	73.00	-34.53	-47.30%
Pharmacy Bldg -Walker Building	20371.44	0	4.61	11.09	-6.49	-58.49%
Poultry Science Bldg	-	8	4.94	1.00	3.94	393.63%
Ramsay Hall	3365.27	19	5.39	4.00	1.39	34.79%
Ross Hall	1645.62	59	7.05	9.00	-1.95	-21.69%
Rouse Life Sciences Bldg	1846.67	61	7.13	15.00	-7.87	-52.46%
Sciences Center Auditorium	5372.57	259	15.33	27.00	-11.67	-43.23%
Science Center Laboratory	-	426	22.24	32.00	-9.76	-30.50%
Shelby Center	10314.62	210	13.30	18.00	-4.70	-26.12%
Spidle Hall	5469.38	357	19.38	18.00	1.38	7.69%
Swingle Hall	753.56	0	4.61	0.00	4.61	0.00%
Telfair Peet Univ Theatre	676.15	30	5.85	6.00	-0.15	-2.55%
Textile Engineering Bldg	2539.21	15	5.23	1.00	4.23	422.61%
Thach Hall	3459.57	122	9.66	23.27	-13.61	-58.51%
Tichenor Hall	-	76	7.75	15.71	-7.96	-50.66%
Upchurch Hall	3146.92	104	8.91	5.00	3.91	78.21%
Wallace Center	2919.08	82	8.00	26.17	-18.17	-69.44%
				AVERAGE:	-7.85	11.31%

Table C-12: Individual Building Analysis Results for Equation 7 on a Wednesday

Building Name	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	3951.08	214	13.46	11.28	2.19	19.40%
Broun Hall	4819.53	293	16.74	22.42	-5.68	-25.34%
Cary Hall	-	90	8.33	4.00	4.33	108.28%
Charles E. Davis Aerospace Hall	9980.76	501	25.35	82.14	-56.79	-69.14%
Chemistry Bldg	7147.75	34	6.01	34.00	-27.99	-82.32%
Comer Hall	2790.27	95	8.54	17.16	-8.62	-50.24%
Corley Hall	2200.58	27	5.72	3.00	2.72	90.76%
Dudley Hall	3951.73	166	11.48	24.00	-12.52	-52.18%
Forestry and Wildlife Science Bldg	8026.8	112	9.24	21.00	-11.76	-55.99%
Funchess Hall	4402.2	182	12.14	19.43	-7.29	-37.52%
Goodwin Hall	4580.15	203	13.01	11.00	2.01	18.27%
Gorrie Center	3181.14	60	7.09	5.00	2.09	41.78%
Haley Center	62278.37	2195	95.48	187.00	-91.52	-48.94%
Harbert Center	1432.47	55	6.88	5.59	1.30	23.22%
Lowder Hall	38635.05	1453	64.76	55.00	9.76	17.74%
Miller Hall	2692.45	14	5.18	4.00	1.18	29.62%
Nichols Center	4332.2	31	5.89	12.59	-6.70	-53.23%
Parker Hall	18558.41	767	36.36	82.00	-45.64	-55.66%
Pharmacy Bldg -Walker Building	20371.44	132	10.07	7.88	2.19	27.83%
Poultry Science Bldg	-	8	4.94	1.00	3.94	393.63%
Ramsay Hall	3365.27	100	8.75	8.00	0.75	9.31%
Ross Hall	1645.62	22	5.52	7.00	-1.48	-21.20%
Rouse Life Sciences Bldg	1846.67	43	6.39	12.00	-5.61	-46.79%
Sciences Center Auditorium	5372.57	245	14.75	29.00	-14.25	-49.14%
Science Center Laboratory	-	146	10.65	33.00	-22.35	-67.73%
Shelby Center	10314.62	308	17.36	38.00	-20.64	-54.33%
Spidle Hall	5469.38	444	22.99	17.00	5.99	35.22%
Swingle Hall	753.56	5	4.81	2.00	2.81	140.61%
Telfair Peet Univ Theatre	676.15	63	7.21	4.00	3.21	80.33%
Textile Engineering Bldg	2539.21	7	4.89	2.00	2.89	144.75%
Thach Hall	3459.57	253	15.08	25.43	-10.35	-40.70%
Tichenor Hall	-	70	7.50	16.03	-8.52	-53.18%
Upchurch Hall	3146.92	64	7.25	6.00	1.25	20.91%
Wallace Center	2919.08	203	13.01	29.41	-16.40	-55.77%
				AVERAGE:	-9.57	8.30%

Table C-13: Individual Building Analysis Results for Equation 7 on a Thursday

Building Name	ClassSqFt	Enrollment	Estimated	Collected	Model Error	% Error
Biggin Hall	3951.08	214	13.46	14.96	-1.49	-9.97%
Broun Hall	4819.53	319	17.81	30.48	-12.67	-41.56%
Cary Hall	-	51	6.72	1.00	5.72	571.65%
Charles E. Davis Aerospace Hall	9980.76	370	19.92	56.55	-36.63	-64.77%
Chemistry Bldg	7147.75	292	16.69	33.00	-16.31	-49.41%
Comer Hall	2790.27	104	8.91	16.03	-7.12	-44.43%
Corley Hall	2200.58	2	4.69	2.00	2.69	134.40%
Dudley Hall	3951.73	29	5.81	15.00	-9.19	-61.30%
Forestry and Wildlife Science Bldg	8026.8	145	10.61	20.00	-9.39	-46.96%
Funchess Hall	4402.2	111	9.20	14.48	-5.28	-36.48%
Goodwin Hall	4580.15	134	10.15	10.00	0.15	1.53%
Gorrie Center	3181.14	50	6.68	5.00	1.68	33.50%
Haley Center	62278.37	2209	96.06	139.00	-42.94	-30.89%
Harbert Center	1432.47	88	8.25	8.13	0.12	1.44%
Lowder Hall	38635.05	1332	59.75	43.00	16.75	38.95%
Miller Hall	2692.45	0	4.61	2.00	2.61	130.26%
Nichols Center	4332.2	45	6.47	10.97	-4.50	-41.04%
Parker Hall	18558.41	817	38.43	68.00	-29.57	-43.49%
Pharmacy Bldg -Walker Building	20371.44	0	4.61	6.56	-1.96	-29.82%
Poultry Science Bldg	-	8	4.94	1.00	3.94	393.63%
Ramsay Hall	3365.27	50	6.68	9.00	-2.32	-25.83%
Ross Hall	1645.62	29	5.81	13.00	-7.19	-55.34%
Rouse Life Sciences Bldg	1846.67	61	7.13	15.00	-7.87	-52.46%
Sciences Center Auditorium	5372.57	264	15.53	26.00	-10.47	-40.25%
Science Center Laboratory	-	298	16.94	32.00	-15.06	-47.06%
Shelby Center	10314.62	254	15.12	27.00	-11.88	-44.00%
Spidle Hall	5469.38	254	15.12	10.00	5.12	51.21%
Swingle Hall	753.56	14	5.18	1.00	4.18	418.47%
Telfair Peet Univ Theatre	676.15	53	6.80	6.00	0.80	13.32%
Textile Engineering Bldg	2539.21	30	5.85	4.00	1.85	46.18%
Thach Hall	3459.57	164	11.39	19.07	-7.68	-40.26%
Tichenor Hall	-	56	6.92	8.46	-1.53	-18.11%
Upchurch Hall	3146.92	104	8.91	4.00	4.91	122.77%
Wallace Center	2919.08	110	9.16	26.03	-16.87	-64.81%
				AVERAGE:	-6.10	31.44%

Table C-14: Results from Zone Analysis on a Monday Using Eq 11

ZONE	Monday				
	Collected Peak Rack Usage	Enrollment	Estimated Peak Rack Usage	Model Error	% Error
1	106	813	49.02	-56.98	-53.76%
3	40	223	21.62	-18.38	-45.95%
4	64	1357	74.28	10.28	16.07%
5	44	56	13.86	-30.14	-68.49%
6	70	491	34.07	-35.93	-51.34%
7	16	362	28.07	12.07	75.46%
9	27	124	17.02	-9.98	-36.96%
10	37	449	32.11	-4.89	-13.20%
11	10	160	18.69	8.69	86.93%
12	39	373	28.59	-10.41	-26.70%
13	192	1104	62.53	-129.47	-67.43%
14	47	328	26.50	-20.50	-43.63%
15	191	2163	111.71	-79.29	-41.51%
AVERAGE				**-28.07**	**-20.81%**

Table C-15: Results from Zone Analysis on a Wednesday Using Eq 11

ZONE	Wednesday				
	Collected Peak Rack Usage	Enrollment	Estimated Peak Rack Usage	Model Error	% Error
1	113	813	49.02	-63.98	-56.62%
3	38	234	22.13	-15.87	-41.76%
4	55	1453	78.74	23.74	43.16%
5	41	250	22.87	-18.13	-44.21%
6	69	651	41.50	-27.50	-39.86%
7	17	444	31.88	14.88	87.54%
9	21	112	16.46	-4.54	-21.60%
10	39	432	31.33	-7.67	-19.68%
11	5	69	14.47	9.47	189.35%
12	34	400	29.84	-4.16	-12.24%
13	198	1112	62.90	-135.10	-68.23%
14	52	319	26.08	-25.92	-49.85%
15	187	2195	113.20	-73.80	-39.47%
AVERAGE				**-25.28**	**-5.65%**

Table C-16: Results from Zone Analysis on a Thursday Using Eq 11

	Thursday				
ZONE	Collected Peak Rack Usage	Enrollment	Estimated Peak Rack Usage	Model Error	% Error
1	91	683	42.98	-48.02	-52.77%
3	27	254	23.06	-3.94	-14.60%
4	43	1332	73.12	30.12	70.05%
5	36	164	18.88	-17.12	-47.56%
6	66	744	45.81	-20.19	-30.58%
7	10	339	27.01	17.01	170.06%
9	20	145	18.00	-2.00	-10.02%
10	28	163	18.83	-9.17	-32.74%
11	6	52	13.68	7.68	127.96%
12	34	292	24.82	-9.18	-26.99%
13	167	1227	68.24	-98.76	-59.13%
14	46	371	28.49	-17.51	-38.06%
15	139	2209	113.85	-25.15	-18.09%
AVERAGE				**-15.09**	**2.89%**