

ASSESSING THE WEEKEND ACCESSIBILITY OF
RUTGERS UNIVERSITY LIBRARIES

by

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A THESIS

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ABSTRACT

Rutgers University- New Brunswick is a public four-year institution located within the limits of New Brunswick and Piscataway, New Jersey. Separated into four sub-campuses, Rutgers University – New Brunswick has developed an intricate campus transit system. Rutgers is one of many institutions who have sought to become more sustainable entities, in order to continue to provide exceptional services to students for the foreseeable future. In order to do so, universities are beginning to look towards alternative methods of transportation for their students to limit the use of private vehicles. This thesis research highlights the weekend accessibility of the four major campus libraries on the New Brunswick campus of Rutgers, comparing the usage of the campus transit system and one's private vehicle. Using the potential interaction model of accessibility, this research measures the accessibility of each sub-campus to the library on the other 3 sub-campuses and each library to students coming from the other sub-campuses. The results of this research show which campus library is the most accessible to students from the other sub-campuses and which sub-campus is the most accessible to the 3 other libraries. This research also highlights the accessibility gap between students who take the campus transit system and those who make use of their private vehicle.

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1. INTRODUCTION

Transportation plays a major part in one's daily activities, as it can control the way in which we get from place to place. Different transportation methods can change the length of time we spend travelling, thereby affecting how we plan our days. Currently, the automobile is the preferred method as it provides an ease of access for many people. As more and more research is done concerning the unsustainability of increased vehicle use, there has been an increased interest in alternative transportation methods, including public transit. This study seeks to find if different transportation methods have an effect on an individual's accessibility to destinations.

Accessibility is a vital detail associated with transportation. Defined as the "ease of interaction", accessibility changes have the ability to affect travel decisions. Understanding accessibility differences between transit systems and car usage may help to influence decisions made by the transportation officials in order to improve service and serve the ever-growing population of students. With limited parking options offered to students on campuses, use of the public transit system is increasingly important, and there is a lack of study on how students there make their travel choices.

University campuses have been attempting to become more "sustainable" entities, teaching students to make use of alternative transportations methods, such as public transit (Delmelle & Delmelle, 2012; Bond & Steiner, 2006; Miller, 2001). A sustainable university is defined as "[a] higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or a global level, the minimization of negative environmental, economic,

societal, and health effects generated in the use of their resources in order to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles.’’ (Velazquez, Munguia, Platt, & Taddei, 2006). These universities, by definition, work to educate their students to be stewards for the upcoming generations. In order to accomplish this, many universities are transitioning to the use of sustainable transportation planning, where the designs are created so that the system can meet current needs without compromising those in the future (Hashim, Haron, & Hassan, 2013; Balsas, 2003). This can often be met with opposition, because as a nation we have become entirely dependent on the automobile, often choosing mobility over accessibility. Serious transportation planning must shift this focus and begin to shape transportation network and land use patterns to better fit the accessibility model (Bertolini, le Clercq, & Kapoen, 2005).

Universities offer a unique environment, in that habits are often formed during time there, meaning that students may take the advice of making use of transit systems into their later commuting decisions (Delmelle & Delmelle 2012). It is believed to be the responsibility of the university to teach students about the benefits of sustainability and how it can be accomplished (Alshuwaikhat & Abubakar, 2008; Tolley, 1996). This is a pivotal time to influence the decisions of students, as they are often more willing to learn and change, as compared to older people (Tolley, 1996). Students are also typically more environmentally conscious, as universities have begun to include more environmental issues in their curriculum (Balsas, 2003; Tolley, 1996). This is not without the possibility for improvement, though. While it is important to maintain the environmental side of sustainability, many sustainability initiatives neglect the other parts of the concept, that of economy and equity (Norton, Brix, Brydon, Davidian, Dinse, & Vidyarthi, 2007).

Universities are seeking to create these sustainable environments as they continue to grow larger and larger, spending more money than ever on capital investments on campus. Rutgers University – New Brunswick in New Jersey is no different. This university's situation is made more challenging as it has multiple campuses. Since 2006, the university has spent upwards of 1.5 billion dollars on new projects on the New Brunswick campus, including new residence halls, an improved business school, and the expansion of the pharmacy school (OIRAP, 2013). These improvements have garnered an ever increasing number of students enrolled, growing by nearly 6000 between 2003 and 2012 (OIRAP, 2013). This issue now becomes how you transport all of these students between campuses. The university has a public transport system allowing for mobility between and within campuses, but it is becoming overloaded by recent growth. There are ideas of expanding the bus service, to better serve the student population, but there are concerns about costs (Shah, 2010). This improved bus service could prove critical when evaluating accessibility for students on campus.

This research will seek to determine the existing level accessibility offered by the Rutgers bus system using the four libraries on the Rutgers campus as a set of destinations. The ease of reaching these locations by campus transit and a private vehicle will be compared. This will be done in a number of steps. The first is creating an accessibility index for each bus stop and parking lot, for four different scenarios. These accessibility measures will then be compared by campus and library. Finally, an accessibility gap will be computed in order to see the difference in accessibility between transit and car usage. This accessibility gap will allow researchers to more easily assess the separation between the use of private vehicles and campus transportation. As campuses seek to transition to more sustainable practices, it is important that they have data

that shows why they must look to move away from their current practices. The accessibility gap created in this study can be one such data point to be used as evidence for more sustainable options.

2. LITERATURE REVIEW

2.1 Mode choice

Since its introduction, the automobile has been taking over as the preferred method of travel by Americans. One of the first appearances of the gasoline powered automobile can be documented as early as 1893. While many had become accustomed to the use of the horse and carriage or their own two feet, this new invention introduced new freedoms afforded by the speed with which it traveled (Sachs, 1992). As with any new technology, automobile use was often limited to the social elite, with many poorer Americans referring to the vehicle as the “devil wagon” (Kline and Pinch, 1996). Kline and Pinch (1996) note that as time went on, automobiles became increasingly less expensive, including Henry Ford’s Model T, allowing for many more people to indulge themselves with a private vehicle. Over time, transportation planning initiatives focused on providing increased automobile access, at the expense of alternative methods (Litman, 1999). As of 2009, public transit made up only 2% of trips in urban neighborhoods (NHTS, 2009). Auto dependency is largely a North American issue, with Americans driving at least 4,000 more kilometers annually than drivers throughout the world (Litman, 1999). Europeans make much more use of the public transportation systems provided (Lavery, Páez, Kanaroglou, 2013). For years the way that the success of a transportation system was evaluated on the basis of increased travel speed (Levine, Grengs, Shen, & Shen, 2012). It has been noted that we often associate this automobility with accessibility, as we take our mobility for granted (Weber, 2006).

One must consider a number of different factors when determining travel mode. Most of the time one does not just travel for the fun of it. Instead travel is a derived demand; trips are made because a person has somewhere to be (Levine et al., 2012; Benenson, Martens, Rofe, Kwartler, 2011; Bertolini et al., 2005). One's desire to travel is a direct function of the opportunity they are looking to reach (Levine et al., 2012).

It has been shown that convenience and time are the most important influencers of mode choice (Zhou, 2012, Delmelle & Delmelle, 2012; Hough, Hegland, Miller & Ulmer, 2005; Papinski, Scott, & Doherty, 2009). Commuters might also take into account other variables, such as personal comfort, weather, and safety when making their determination (Joireman, Van Lange, Kuhlman, Van Vugt, & Shelley, 1997). It can be said that mode choice is many times not just an individual decision, rather one's method of travel may depend on what methods other commuters make use of. One must determine if they will receive greater benefits by working with other commuters to reduce travel time, or if they should make an individual decision, that is not concerned with the method that other commuters choose to use (Joireman et al., 1997). It is also safe to say that previous commuting habits have a large influence on what method of travel one chooses to use (Bond, 2005).

SOV, or single occupancy vehicle, usage is found to be the most popular method of commuting (Aoun, Abou-Zeid, Kaysi & Myntti, 2013), for a great number of reasons. The socioeconomic status of the commuter might have an effect on their decision. For many, owning a car is seen as a status symbol, so if they can afford a car, they will buy one (Zhou, 2012). The use of a SOV also provides the driver considerably more freedom than using public transit (Hough et al., 2005). SOV users have the ability to get almost anywhere that they could desire to go, unlike those who ride transit, who are limited to the routes that are available. Commuting

distance and time also have an effect on how one chooses their mode. As distances and time spent get larger, so too does the likelihood that one will choose to make use of a SOV (Delmelle & Delmelle, 2012).

Commuters also take into account the disadvantages of alternative transportation methods when deciding to use a SOV for their commute. Most commuters have a very poor perception of their local public transportation system. Complaints about public transit, including long wait times, high costs, and lack of convenient routes, were major factors that led commuters to choose their own vehicle (Daggett & Gutkowski, 2003, Hough et al., 2005). In a study of a college campus, the number one reason that students chose to make use of their own vehicle was because of the higher degree of convenience that it afforded them (Polacek & Graham, 2011). In many cases, people vastly overestimate the time in which it will take to make a trip using public transit (Zhou, 2012). It has been shown that most commuters believe that time spent waiting for the bus is more than double what is empirically observed (Hess, Brown & Shoup, 2004). They also have misinterpreted the actual cost of transit versus the cost of a vehicle. Because one must pay a fare each time they ride a transit system, riders feel as though the cost of transit is much higher than that of owning a vehicle. The costs of things such as insurance, car payments, etc. are not being paid on a day-to-day basis, so they often are not fully acknowledged when determining the cost of the car versus transit usage (Hough et al., 2005, Miller, 2001).

The price that one pays for transportation directly affects how one chooses to make their trips. The concept of transit elasticity helps to explain how cost both in price and time, can affect transportation decisions. It has been noted that, especially for public transportation, as price goes up, ridership goes down. The idea can easily be translated to cost as measured in travel time. One can say that as travel times on public transit increase, that more riders will find alternative

methods of transportation (Litman, 2013). But not all trips are created equal. Islam, Rahaman, and Ahmed (2008) found that travelers were willing to go further for out of work trips than trips for work. That being said, work trips are often inelastic, with accessibility having little to no influence on work trips, as people need to get to their job, whether the trip is easier or not (Hanson and Schwab, 1987). Outside of the work environment, trips taken on the weekend are often more elastic than weekday trips, as people have a wider variety of destinations and transportation methods (Kemp, 1973).

2.2 Accessibility

Accessibility has become a major factor when developing and evaluating transportation and land-use plans. In order to understand the concept, one must first know the two basic components of accessibility, that of travel and opportunities (Páez, Scott, & Morency, 2012). Conceptualized in a variety of different ways, the broadest understanding of accessibility is the ease with which one can reach different types of opportunities (Rubulotta, Ignaccolo, Inturri, & Rofè, 2012). Hansen (1959) and Bertolini et al. (2005) go further into detail in their definitions of the concept, explaining accessibility as "the potential of opportunities for interaction" and "the amount and the diversity of places of activity that can be reached within a given travel time and/or cost"(pg 209)), respectively. Accessibility has long been used in the planning profession, but many times with the wrong intentions, as there is often a lack of understanding of the what accessibility actually entails (Páez et al., 2012).

Just as there a variety of ways to define accessibility, there are also a number of ways in which it can be calculated. In their review of different accessibility measures, Guers and van Wee (2004) touch upon four different measures, most notably location based measures. These

measures are used to "describe the level of accessibility for spatially distributed activities" (Guers and van Wee, 2004; Rubulotta et al., 2012). Examples of location based accessibility measures are the cumulative opportunities measure, the gravity model, and the potential interactions model.

The cumulative opportunities model measure the number of places one can reach in a predetermined time frame (Bertolini et al., 2005; Levine et al., 2012). This model does not account for differing sizes of opportunities or if the destination is preferred, but rather just the location relative to the origin. It is known that accessibility is largely associated with the concept of centrality, that is that often the most central location becomes the most accessible (Rubulotta et al., 2012; Levine et al., 2012). This concept is operationalized through the use of the gravity model. While the idea of the gravity model has been longstanding, it was not fully developed until recently (Carrothers, 1956). Closely aligned with the gravity model is that of the potential interaction. The most common interpretation of the accessibility models, the potential interaction model gives weight to the amount or quality of the opportunities while also accounting for spatial separation (Bruinsma & Rietveld, 1998).

Accessibility provides a vital piece of information for planners and geographers as it more carefully examines the correlation between location and how it affects one's availability of opportunities (Farrington, 2007). Guers and van Wee (2004) note that accessibility can be used when discussing social equity. The "accessibility gap" between car owners and non-car owners can be seen when comparing accessibility measures between automobiles and any other transport method (Benenson et al., 2011).

Accessibility can be important when it comes to discussing the ideas and plans that are associated with sustainability. Transport planning and policy in the United States has been largely focused on increasing automobility, with the idea that increased mobility will lead to higher accessibility (Levine et al., 2012). Unfortunately, the two concepts are not mutually exclusive, as mobility does not always ensure accessibility (Hodge, 1997). It has been the conventional practice though, when trying to increase accessibility in the United States, to just increase roadway mileage and, therefore, travel speeds (Weber, 2006).

2.3 On campus transit systems

There are an assortment of issues that must be discussed when examining campus transit systems.

The first is that of ownership. Many campuses began their system with small, university owned campus/parking shuttle systems. Now, though, the majority of universities contract their transit systems out to more regional transit systems (Miller, 2001, Hough et al., 2005). Once there is an understanding of just who owns the system, we must then try to identify who runs the system. That is, who makes decisions regarding how the system operates. These decisions include who can ride the system, how the system is funded, etc. Options for control range from one individual making all the decisions to the inclusion of a transit advisory board (Miller, 2001). The issue of student involvement is important when discussing campuses that make use of an advisory board, in that student input is required if the system is funded with student fees (Miller, 2001, Hough et al., 2005). Funding for the transit system can come from a mixture of sources, including student fees, parking fees and fines, and federal/state funding (Miller, 2001, Hough et al., 2005, Bond & Steiner, 2006). An important question that must be asked is if

students are willing to pay to fund transit, especially those who are unlikely to make use of the system (Hough et al., 2005).

Once the details of the system, such as decision making and funding are hammered out, the final step is to determine what types of routes will be run. Most activity is located at the core of the campus, so it is important that the system includes a route that runs solely on campus that allows students to get from one class to another, as well as to get to parking lots throughout campus. Approximately one quarter of transit trips are a method to get around campus (Daggett and Gutkowski, 2003). Daggett and Gutkowski (2003) found that the majority of on campus transit systems service a hub in a central region of campus. For many systems, the buses run on a variety of different loops, with their route originating and terminating at said hub. While a much of the activity occurs on campus, there are a large number of students that reside in off campus housing. Nearly half of campus transit trips are for the trip from home to school (Daggett and Gutkowski, 2003). Transit systems must take this into account and plan routes that will provide the students with access to campus and the surrounding area. Finally, more and more campuses are implementing late night service in order to create more safe options for students to travel after normal campus hours. Many campuses see the value of reduced drinking and driving with the operation of a late night service (Miller, 2001, Bond & Steiner, 2006).

Unlimited access is an important incentive that is often used as a part of TDM strategies in order to incite higher transit usage. Unlimited access provides transit to all students of a university without the payment of a fare (Brown, Hess & Shoup, 2001; Miller, 2001; Hough et al., 2005; Bond & Steiner, 2006). Unlimited access provides a number of incentives to both the university as well as the transit system, which produce a variety of benefits for the both the system and the user (Brown et al., 2001). Brown, Hess, and Shoup (2003) make an important

point that the money that the student saves, by not paying a fare, can be used for more effective uses, such as buying books. The transit system also benefits from an unlimited access program, as the university provides a guaranteed payment, regardless of ridership, so revenue is likely more consistent (Meyer and Beimborn, 1998). As mentioned earlier, automobile usage has a negative effect on air quality. Meyer and Beimborn (1998) show that the introduction on a transit pass program at the University of Wisconsin-Milwaukee led to a reduction in auto emission by roughly 20 percent. It has been shown that transit usage increases up to 300 percent with the implementation of unlimited access to transit (Miller, 2001, Hough et al., 2005, Bond & Steiner, 2006, Brown et al., 2001). It also provides more people the opportunity to access a greater number of locations (Brown et al., 2001). Providing unlimited access also provides a number of services for the university. By increasing the number of students using the transit system, there is a reduction the demand for new parking space, which often cost exorbitant amounts to build (Brown et al., 2003).

2.4 On campus driving environment

Universities suffer from a number of parking issues. The most common concern with parking on campus is that parking demand overwhelmingly outnumbers parking supply (Aoun et al., 2013, Bond & Steiner, 2006, Hough et al., 2005, Miller, 2001, Daggett & Gutkowski, 2003). Students often complain that they spend a large amount of time searching for a parking spot on campus (Aoun et al., 2013, Brown et al., 2001). It has been found that inexpensive or free parking with cause more people to commute using a SOV, and there is a negative correlation between the cost of parking and SOV usage (Delmelle & Delmelle, 2012, Hough et al., 2005, Aoun et al., 2013).

As campuses continue to grow and expand, they must find ways to accommodate the incoming demand. Unfortunately, this expansion comes with a variety of issues. First, parking fees charged by the university do not cover the cost of building new parking facilities (Bond & Steiner, 2006, Miller, 2001). Second, many campuses, especially those in urban areas, lack the available space to construct new facilities (Miller, 2001). Even if there were the available space, campus administrations would like to preserve the aesthetics of the campus, with greater pedestrian access and maintain the “livability” of the campus environment (Miller, 2001). As campuses look to transition away from automobile dependence, they must look to solve parking issues, with transit becoming a more dominant commuting method. The campus environment is helpful with this transition, as both the parking and transit systems are run by the same department (Miller, 2001).

Universities have unique congestion issues that affect commuting patterns. Unlike traditional congestion patterns, campus congestion is not limited to the normal peak hours of 7-9 AM and 5-7 PM. Instead there are a number of peaks throughout the day that correspond with the daily class schedule. There is also a greater seasonal variation in congestion found on university campuses, as the number of students found on campus is drastically different between the summer months and the school year. Congestion issues on campus can be a cause for many students to begin to use campus transit systems rather than a SOV (Kaplan & Clapper, 2007, Hough et al., 2005).

2.5 Mode change

Overall, university campuses are looking to transition away from the use of SOVs (Bond & Steiner, 2006, Miller, 2001, Hough et al., 2005, Delmelle & Delmelle, 2012, Daggett & Gutkowski, 2003). As environmental concerns regarding the use of vehicles becomes more

apparent, campuses are trying to become more sustainable entities (Bond & Steiner, 2006, Delmelle & Delmelle, 2012). Previous experience can help to shape travel and commuting behaviors, and a university campus can be the laboratory in which both students and faculty can experiment with new forms of commuting (Zhou, 2012, Bond & Steiner, 2006, Delmelle & Delmelle, 2012, Miller, 2001).

Current issues found on campus can be seen as motivation for users to switch to alternative travel modes. Both parking concerns and congestion are reasons that one would want to avoid the use of a SOV (Zhou, 2012, Delmelle & Delmelle, 2012). In addition, high automobile usage leads to a great deal of emission, which is bound to affect the air quality around campus (Polacek & Graham, 2011). In order for the campus population to switch to alternate methods, such as public transit, there would have to be service improvement to incite ridership (Hough et al., 2005, Miller, 2001).

Transportation demand management (TDM) is an important topic to discussing when evaluating how campuses switch from SOV usage to the use of transit. TDM is a set of policies and strategies that make use of a number of incentives and disincentives in order to stimulate the transition away from the SOV (Bond & Steiner, 2006, Miller, 2001, Hough et al., 2005). These strategies fall into three different groups: positive, negative, and mixed. Positive policies increase access to transportation for everyone. Mixed policies improve the transportation opportunities for one group without negatively affecting another. Finally, negative policies seek to reduce opportunities for SOV users (Bond & Steiner, 2006). TDM makes use of both incentives and disincentives in order to cause commuters to make the switch to transit. Incentives could include transit improvements and fare reductions. Disincentives would include increased parking costs and vehicle restricted areas, such as pedestrian streets. In order for the TDM strategies, the

system must implement a combination of incentives and disincentives (Bond & Steiner, 2006, Miller, 2001, Hough et al., 2005).

Change won't occur if just one strategy is employed. The system must give benefits in order to take away from others. In addition to applying multiple policies, the system must be flexible to the needs of the users (Miller, 2001, Hough et al., 2005). Often, people are multimodal (Zhou, 2012). One day they might take transit, but the next use their own vehicle, depending on their needs for the day. If the user feels as if they do not have the opportunity to use multiple methods for their commute then they are likely to choose the SOV, as it provides them with the most freedom (Hough et al., 2005).

3. RESEARCH QUESTIONS AND METHODOLOGY

3.1 Research problem

There is a great deal of research on how one might choose their preferred method of travel. Mode choice can be based on a number of different variables, ranging from travel time to the weather. There is a lack of understanding, though, as to how accessibility affects the mode choice decision. Campuses throughout the country are beginning to seek out more sustainable alternatives to automobiles on campus, so understanding how accessibility might alter the commuting decision is of increasing importance to campus planning departments. Evaluating how accessibility differs between the use of the campus transit system and one's private vehicle, planners can work to improve the transit system, in order to incite higher transit ridership.

3.2 Research objectives

This study is designed to measure the weekend accessibility to libraries for students on the campuses of Rutgers University – New Brunswick. The goal of this study is to analyze how accessibility to the campus libraries varies between those who utilize the on-campus bus system, as opposed to those who make use of their private automobile. There is a lack of research on how the use of campus transit systems affects student accessibility. As universities look to transition away from auto-dependency, it is important to recognize how accessibility is altered when making use of campus transportation. This will hopefully lead to more informed decisions being made regarding transit routes and schedules. As many cite unreliability and deviation from

schedules as a major reasoning for their aversion to public transit, this study also seeks to find if observed accessibility is different from that which is associated with the provided bus schedule.

This research will seek to answer the following questions:

- 1) What campus provides its residents with the highest degree of accessibility to the campus libraries?
- 2) What campus library has the highest degree of accessibility to residents of other campuses?
- 3) Does observed accessibility deviate from calculated accessibility?
- 4) Do public transit users have a higher or lower degree of accessibility than private vehicle users?
- 5) Where is the accessibility gap between transit use and automobile use the highest?

3.3 Study area

Rutgers University-New Brunswick is a public, four-year research university located within the cities of New Brunswick and Piscataway, New Jersey. Rutgers is the state university of New Jersey and has two other campuses in Camden and Newark. Rutgers- New Brunswick is the main campus of the university, where the university was originally founded in 1766. New Brunswick has a population of over 56,000 within just over 5 square miles of land. Piscataway also has just over 56,000 residents on just over 19 square miles of land (US Census). The university currently enrolls over 41,000 students in over 100 majors. 86 percent of students were undergraduates and 14 percent were graduates or professional. Rutgers is a major employer within the region, employing over 6,600 faculty members and over 12,500 other staff members.

The main campus is divided into five sub-campuses with both academic and residential buildings found on each campus (OIRAP, R).

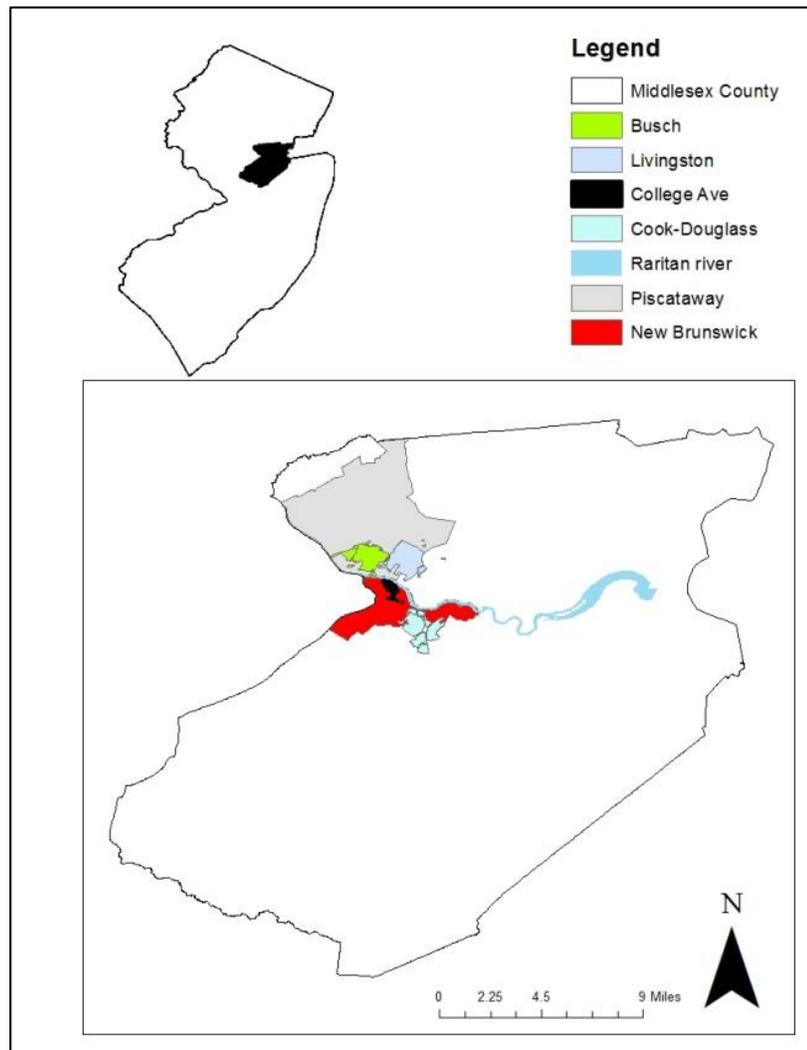


Figure 1. Map of Rutgers University

3.3.1 Campuses

The College Avenue campus is the original campus of Rutgers. Approximately 3,500 students reside within residence halls on College Ave, not including the many students that reside in the large area of homes located throughout the neighborhood surrounding the campus.

Busch campus is the home to many of the science fields, including health sciences and engineering. Busch houses the largest number of students, with close to 4,100 students calling it home. The youngest of the five campuses, Livingston was first opened in 1969. Located in Piscataway, over 3,400 students reside on the Livingston campus. Cook campus, is known as the agricultural center of the Rutgers community. Currently, close to 1,900 students reside on the Cook campus. Originally designed as the women's college, Douglass campus is now the home to the arts programs on campus. The smallest of the campuses, Douglass houses just over 1,600 residents.

3.3.2 Libraries

Alexander library, the oldest library on the New Brunswick campus, is located on College Ave, at the intersection of College Avenue and Richardson Street. Alexander supplies materials for a large variety of different disciplines, from anthropology to medieval studies. Especially extensive is Alexander's collection of governmental documents, ranging from local New Jersey papers to international publications. Though it is the largest building of the four major libraries, Alexander can seat just 644 students. For the purpose of this study, data regarding the number of seats was collected from the Rutgers library system and refers to all public seating within the library building (G.Springs, personal communication, December, 3, 2013).

Founded in 1918, the Douglass library was originally founded to support the New Jersey College for Women. Located on the Douglass campus, the library is the main library for both the Cook and Douglass campuses. Currently the main library for the Mason Gross School of the Arts, its front lobby is used as a gallery space to showcase such work. At one time the library

could hold over 1000 students, but the capacity to date is 697 seats (G.Springs, personal communication, December, 3, 2013).

The Library of Science and Medicine, or LSM for short, is the main library on the Busch campus. Originally designed to house a collection to be used by physicians throughout the state, the library now serves the science community as a whole, with the medical community being just one of the many user of its collections. The largest library, in terms of seating capacity, LSM can hold up to 698 students (G.Springs, personal communication, December, 3, 2013).

Kilmer library is the main library on the Livingston campus. It is the home for the collections of various liberal art concentrations. Kilmer's name is one of the last memories of the

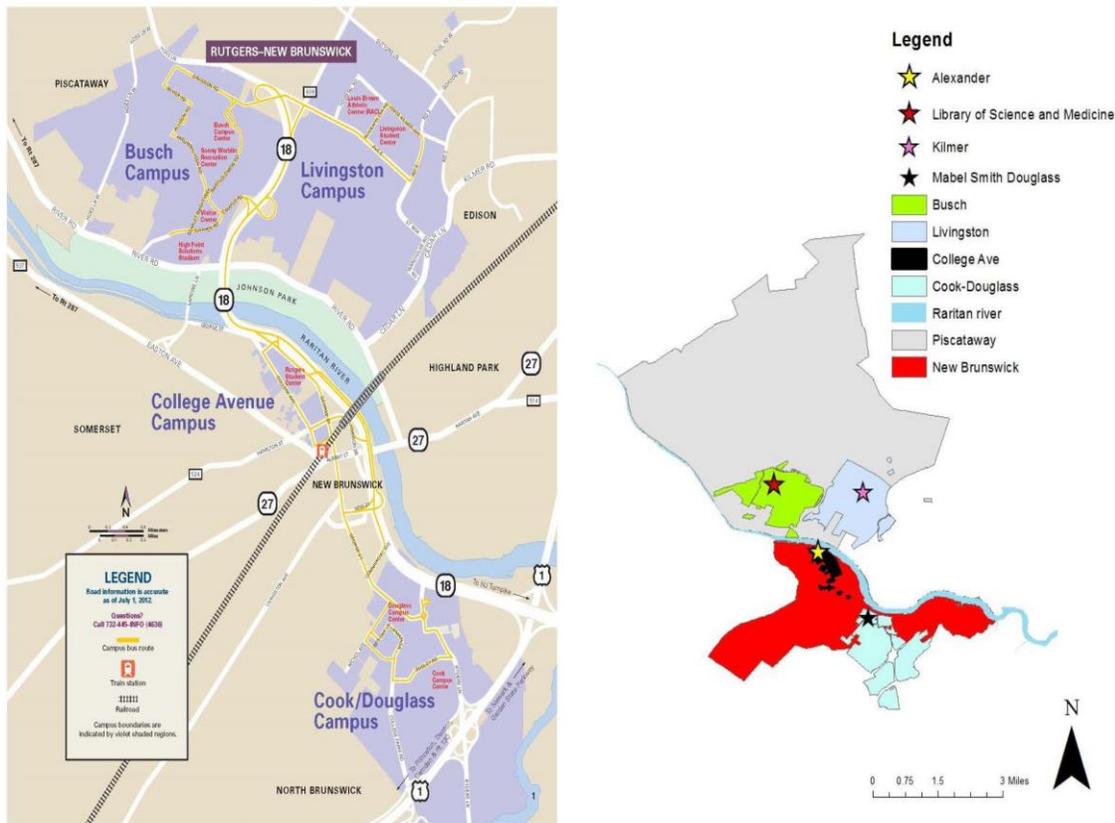


Figure 2. Map of Rutgers campus with libraries

campus's original name. The smallest campus library, Kilmer has 495 public seats (G.Springs, personal communication, December, 3, 2013).

3.3.3 Campuses buses

The university runs nine on-campus routes that run between 7 AM and 3 AM, Monday through Friday. As the campus is extraordinarily spread out, these routes are imperative, as they transport students from one campus to another, in order to take classes or return to their residences. Weekday buses run on a schedule with headways varying from four minutes to thirty minutes, based on time of travel. There are also two weekend routes that have stops on all campuses, running between Saturday morning and Monday morning. These routes run with headways between twenty-three and sixty minutes. There are two shuttles that take students to off campus locations throughout the city of New Brunswick, Monday through Friday. These buses run with headways between twenty-five and thirty minutes. Finally, the university provides a shuttle between 3 AM and 7 AM, Sunday through Wednesday night, when the normal routes are non-operational. This shuttle will respond to student calls and transport students door to door to their desired location. All campus transit is provided with unlimited access to students, faculty and members of the New Brunswick community (“Campus Buses”, 2013).

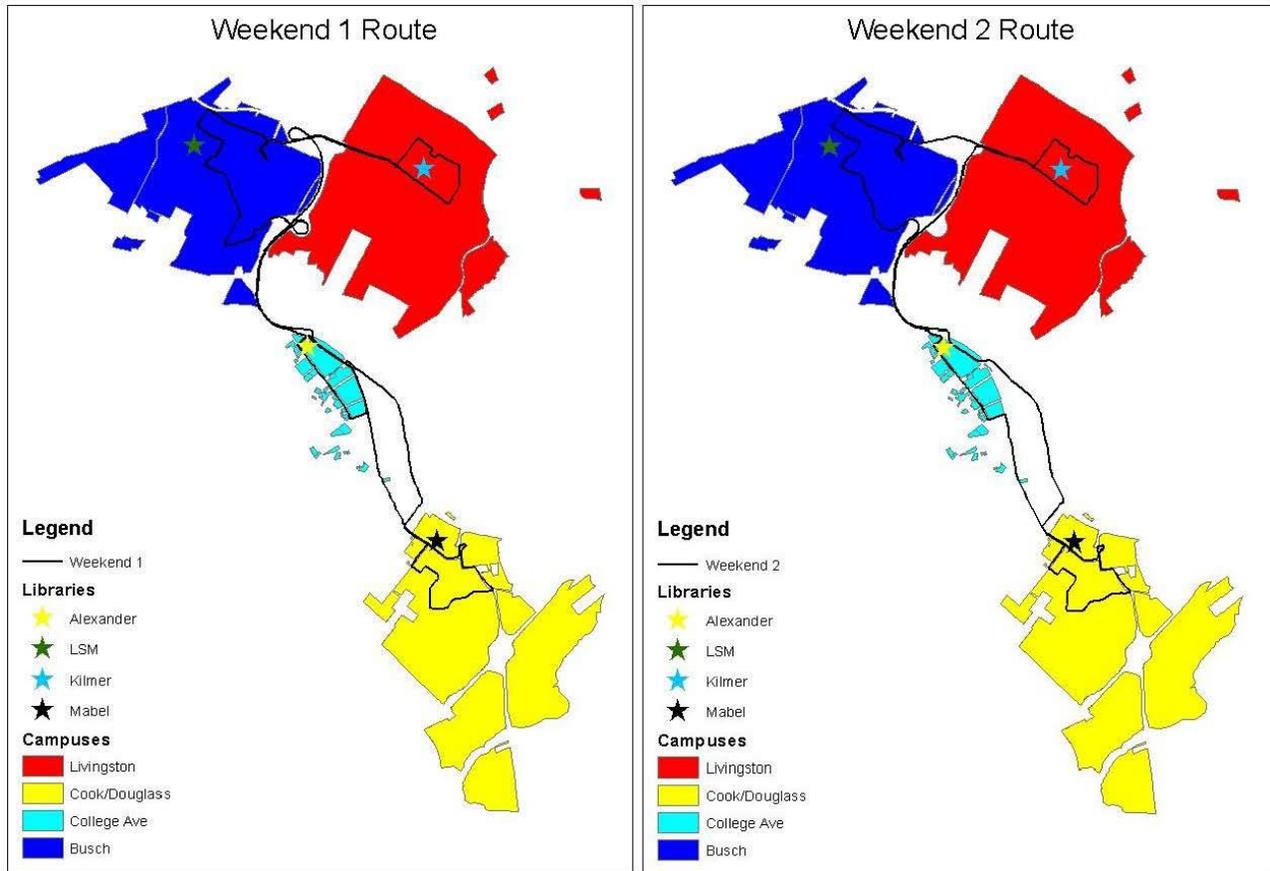


Figure 3. Maps of weekend bus routes

For the purposes of this study, we will focus on the weekend bus routes. Analysis is limited to these routes, as this is the only time where students can choose to use the bus or their private vehicle. During the week students are limited in their parking options because they are assigned a parking permit for only one of the campuses. Beginning in 2011, Rutgers eliminated the old weekend bus routes and introduced two new routes, the Weekend 1 and Weekend 2. Both routes make stops on all five campuses, in opposite directions. Starting at the Rutgers Student Center on College Ave, the Weekend 1 heads northwest towards the Busch campus. After circling Busch, the Weekend 1 bus returns southeast circling Livingston then Cook/Douglass, before it returns to College Ave. The Weekend 2 route runs in the complete opposite direction, first making stops around Cook/Douglass, then Livingston and, finally,

Busch, before it returns to the Rutgers Student Center. Both weekend routes make a stop at the Student Activities Center on College Ave on the way to the second leg of their trip, which for the Weekend 1 would be following the last stop on the Livingston campus and for the Weekend 2 after the last stop on Cook/Douglass.

In addition, analysis was only completed on bus stops associated with the dorms on campus. As there are just a small amount of classes taking place on the weekends, it is likely that the majority of those making their trip to the library would be starting their journey from one of the dorms. In addition, many campus academic building are locked for security on the weekends, meaning that few trips would be originating from those locations.

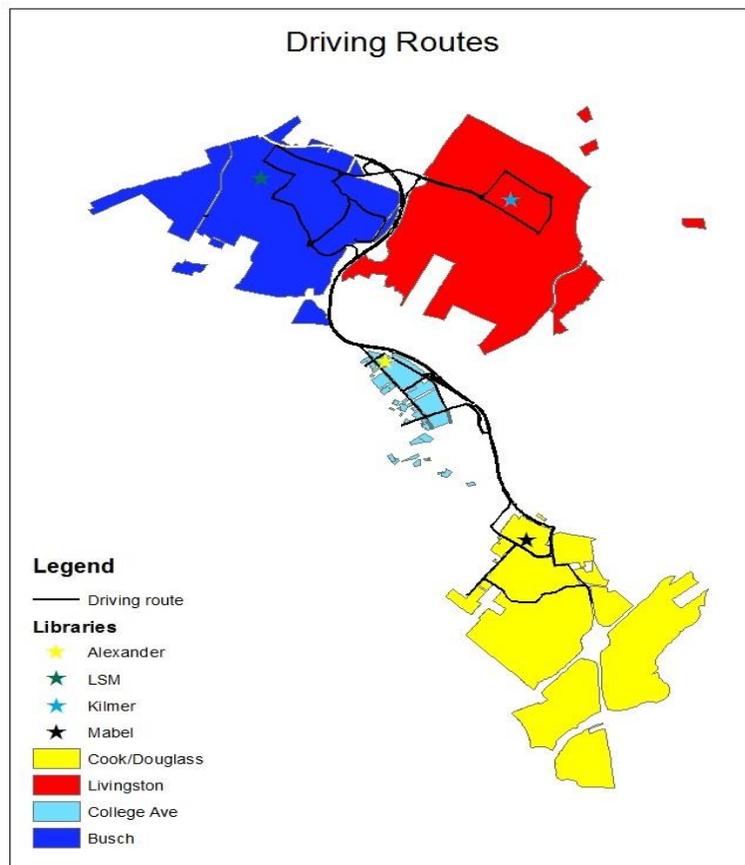


Figure 4. Map of driving routes

3.4 Data

Data for this research was acquired from a variety of sources, including Rutgers University and user created data sets.

3.4.1 Bus travel times

Two distinct datasets were created in order to analyze student travel times when using the on campus bus system. First, the Rutgers University Department of Transportation provided sample manifests of the weekend 1 and weekend 2 bus routes. From those, a dataset of travel times was compiled. A second dataset was created, composed of bus travel times that were observed and recorded by the researcher. Riding each weekend bus route four times in each direction, the researcher used GPS technology in order to record bus travel times over the course of a two day period in January 2014. It has been shown that GPS units provide more accurate and complete data collection (Papinski et al., 2009). The data from the GPS units were compared to a travel diary recorded by the researcher, in order to ensure accurateness. In addition to time spent on the bus, both waiting and walking times were added travel times, in order to get a more complete understanding of total travel time.

It has been shown that when bus headways are large enough that passengers' arrivals follow differing patterns (Fries, Dunning & Chowdhury, 2001). For the purpose of this study, it was assumed, because the weekend bus routes have regular headways, that wait time would be half of that (Marguier & Ceder, 1984). The weekend buses at Rutgers run with consistent headways of 30 minutes, so the average wait time would be 15 minutes.

Walking times were calculated using the following equation:

$$W_{i \rightarrow j} = SD_{i \rightarrow j}$$

where $W_{i \rightarrow j}$ is the walking time from origin i to destination j , $D_{i \rightarrow j}$ is the mileage distance between i and j , and S is the average pedestrian walking speed, which for the purposes of this study was a constant of 3.3 miles per hour (Carey, 2005). For bus stops that served a number of different residences, walking times were calculated for all residences and then averaged to determine the final time.

3.4.2 Driving travel times

In order to analyze driving travel times, two different datasets were created by the researcher. Routes for driving trips were determined with the intent of minimizing travel time, which was achieved by choosing the shortest driving distance, avoiding traffic lights, and driving on major roadways (Papinski et al., 2009; Hall, 1986). The first dataset was created by calculating the ideal travel times between the origin and the destination. The following equation was used to calculate ideal travel time:

$$T_{i \rightarrow j} = \sum_{i=1}^n S D_{i \rightarrow n}$$

where $T_{i \rightarrow j}$ is travel time between the origin i and the destination j , S is the speed limit on the road, and $D_{i \rightarrow n}$ is the distance between i and point n . The second dataset was compiled using observed driving travel times. In addition to time spent in the vehicle, walking time from the residence to the parking lot and the destination parking lot to the library was calculated in the same fashion as earlier discussed.

For the purpose of continuity in comparisons, driving travel times were compared to bus stops. Parking lots were assigned to the closest bus stop for analysis. In the case where there

were multiple parking lots associated with one bus stop, the driving times were calculated for each lot and then averaged to get a final value.

3.5 Accessibility measures

Once the datasets of travel times were compiled, analysis was begun to find accessibility values. As previously discussed, there are a variety of ways for accessibility to be calculated. For the purposes of this study, the potential interaction equation, developed by Hansen (1959) will be used to create an accessibility index for each bus stop and parking lot. The following equation will be used to create said index:

$$A_{i \rightarrow j} = \frac{O_j}{D_{i \rightarrow j}^x}$$

where $A_{i \rightarrow j}$ is the accessibility of stop i to location O_j is the number of opportunities at location j , for this study being the number of seats at each library; $D_{i \rightarrow j}^x$ is the distance, measured in minutes, between node i and node j , and x is the effect of travel time.

In order to find the accessibility of each campus to each campus library, the following equation was used:

$$A_{c \rightarrow j} = \frac{\sum_{i=1}^n A_i}{n}$$

where A_c is the accessibility index for campus c to destination j and n is the number of bus stops on campus c . This allows for the campuses to be compared on an equal ground, as some campuses have a greater number of bus stops than another, which would skew their accessibility index. In order to calculate the accessibility of campus c to all other campus libraries, the following equation was used

$$A_t = \sum A_c$$

where A_t is the total accessibility for campus c .

Each library was analyzed for its accessibility to students from other campuses. In order to calculate each library's accessibility value, the following equation was used:

$$A_j = \sum_{c=1}^x A_c$$

where A_j is the accessibility of library j and x is the number of other campuses.

In order to analyze the scheduled/calculated accessibility values, an equation for relative accessibility was created (Páez, et al., 2012). The equation was used to compare both the accessibility values for the campus accessibility measures, as well as those for the individual libraries. The equation for relative accessibility is as follows

$$A_r = \frac{A_o}{A_s}$$

where A_r is the relative accessibility, A_o is the accessibility that was observed, and A_s is the accessibility that was based on the schedule/calculations.

Finally, in order to evaluate the accessibility gap between transit users and SOV users, the following equation was used (Benenson et al., 2011). Like with the relative accessibility, the accessibility gap was assessed for both the campus and library accessibility measures.

$$A_{gap} = \frac{A_t}{A_a}$$

where A_{gap} is the accessibility gap, A_t is the accessibility on transit, and A_a is the accessibility using a SOV.

4. RESULTS

4.1 Campus accessibility

When assessing accessibility, one can choose to analyze the values in terms of the origin of the trip. Such is the case when we evaluate accessibility measures by campus.

4.1.1 Campus transit access

As there are two distinct bus routes that operate on the campus during the weekends, it is important that we analyze them separately, as that makes a large difference when evaluating student accessibility. As discussed earlier, the weekend 1 bus route begins its journey at College Ave, making its way through Busch, Livingston, and finally Cook/Douglass. Running the opposite route of the Weekend 1, the Weekend 2 loops from College Ave to Cook/Douglass, then Livingston, and finally Busch. Accessibility for students who ride the bus varies based on the campus from which they are coming and what library they are seeking out.

Students that are coming from the College Avenue experience the highest degree of accessibility when calculate for both the scheduled times and what is observed, with accessibility values of 54.04 and 53.75, respectively. When assessing the scheduled times, students coming from Busch have the next greatest accessibility, with a value of 44.6, followed by Livingston who's students have an accessibility index of 43.61. That order is switched when evaluating the observed travel time. Livingston students closely follow those from College Ave, with a value of 51.69, trailed by students from Busch who have an accessibility of 47.42. Cook/Douglass

experiences the lowest level of accessibility, when using the Weekend 1 route. Students traveling from that campus have an accessibility rate of 40.45 when using the scheduled times, and 40.85 when assessing the observed data (Table 1).

<u>WEEKEND 1</u>			
<u>Campus</u>	<u>Scheduled</u>	<u>Observed</u>	<u>Relative</u>
Busch	44.60	47.42	1.06
Livingston	43.61	51.69	1.19
College Ave	54.02	53.73	0.99
Cook/Douglass	40.45	40.85	1.01

Table 1. Accessibility measures for the Weekend 1 by campus

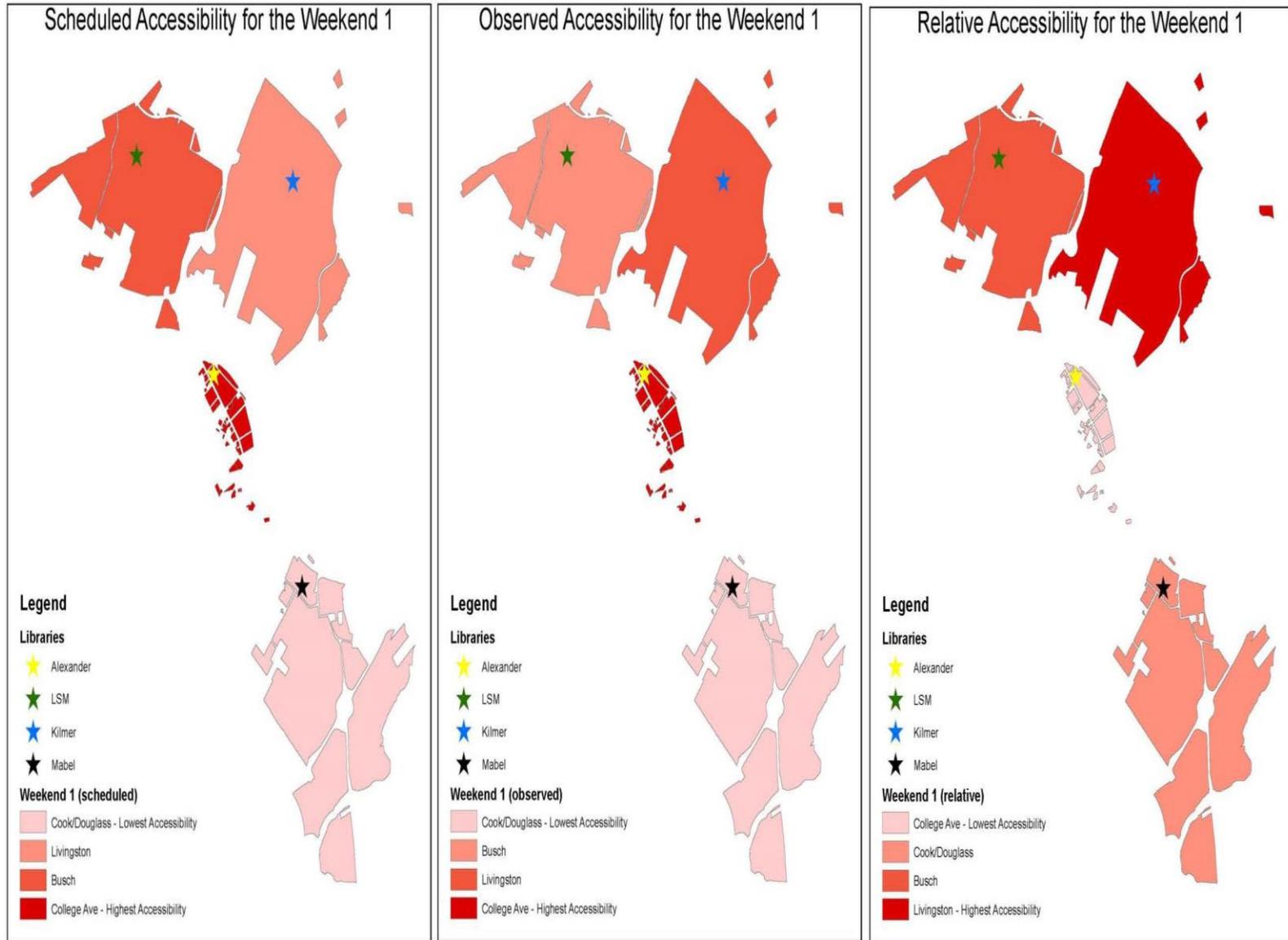


Figure 5. Accessibility measures for the Weekend 1 by campus

For the Weekend 1 route, it seems that trips originating from Livingston see the highest relative accessibility, with a value of 1.19. Following Livingston is Busch campus, with a relative accessibility of 1.06. Cook campus is next, with a value of 1.01. Finally, the only campus whose scheduled time travels are longer than what was observed is College Avenue, with an accessibility value of .99 (Table 1).

Using scheduled travel times, those students whose trips originate from Livingston see the highest accessibility to the other three libraries, with an accessibility index of 50.96. Following Livingston is Cook/Douglass, with a value of 50.93. After that are students from College Ave, who have an accessibility index of 44.08. Students coming from Busch experience the lowest level of accessibility, at just 39.47. Observed travel times have a different result. The campus with the highest observed accessibility is Cook/Douglass, with a value of 51.55. Closely following that is Livingston, just .02 behind at 51.53. Next are students who are coming from Busch, with a value of 44.34. Finally, students traveling from College Ave on the Weekend 2 experience the lowest levels of accessibility, at 43.52 (Table 2).

<u>WEEKEND 2</u>			
<u>Campus</u>	<u>Scheduled</u>	<u>Observed</u>	<u>Relative</u>
Busch	39.47	44.34	1.12
Livingston	50.96	51.53	1.01
College Ave	44.08	43.52	0.99
Cook/Douglass	50.93	51.55	1.01

Table 2. Accessibility measures for the Weekend 2 by campus

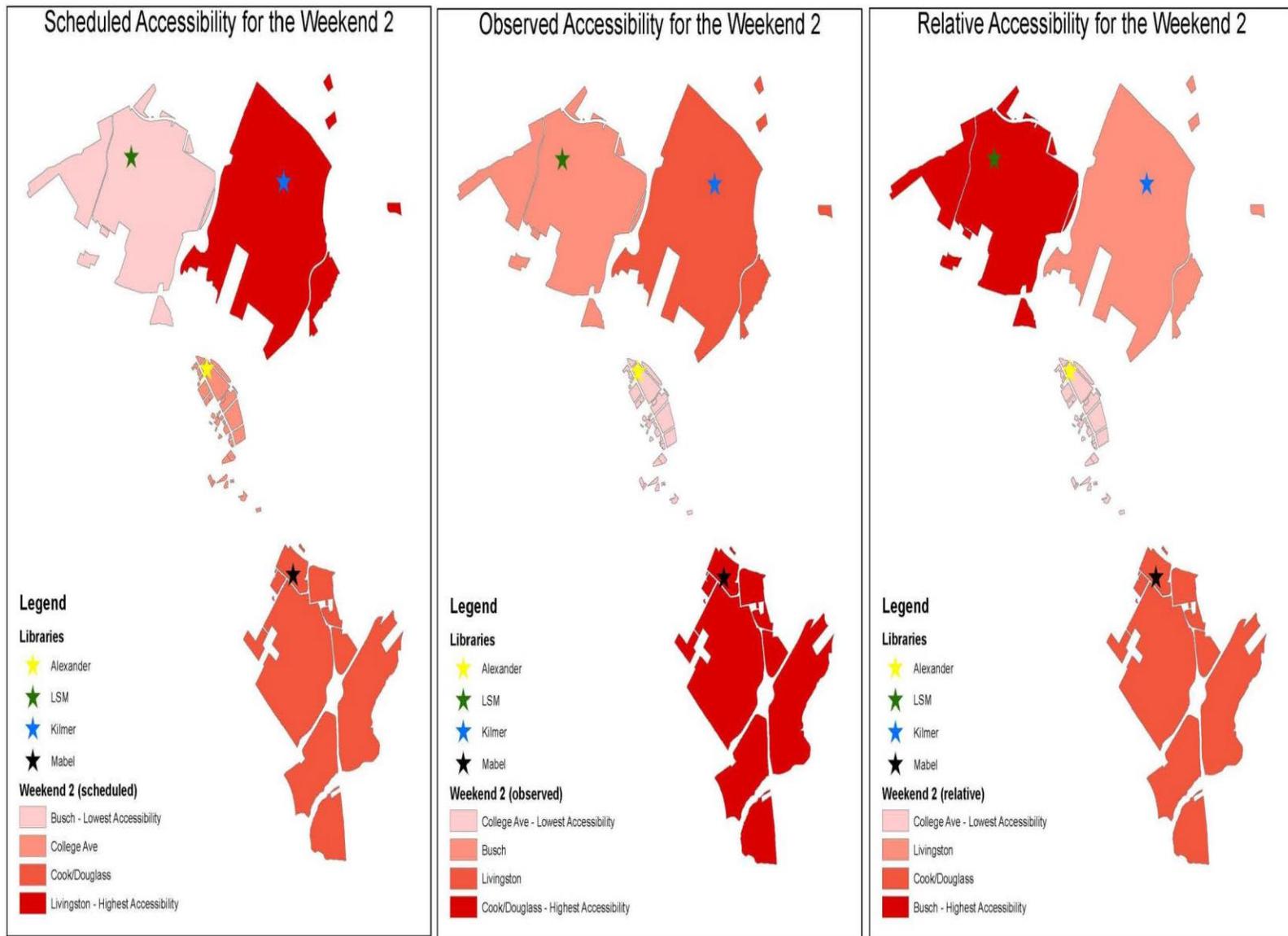


Figure 6. Accessibility measures for the Weekend 2 by campus

Evaluating relative accessibility for the Weekend 2 route, it is shown that students traveling from the Busch campus have the highest relative accessibility, at 1.12. Both Livingston and Cook/Douglass have relative accessibility values of 1.01. Like with the weekend 1, students travelling from College Ave have a relative accessibility value, of .99 (Table 2).

4.1.2 Automobile access

In terms of calculated driving time, Busch campus has the highest accessibility to the other libraries, with a value of 226.2. Next are students that drive from College Ave, with an accessibility index of 218.39. Following that are trips that originate at Cook/Douglass, at 186.43. Finally, with a value of 174.67, students travelling from Livingston have the least amount of accessibility. Contrarily, when evaluating observed values, College Ave has the highest degree of accessibility to the other libraries, at 148.79. After that is Cook/Douglass, with a value of 138.52. Third is Busch campus, having a value of 133.24. For both calculated and observed data, Livingston has the lowest accessibility value, at 186.43 and 138.52, respectively (Table 3).

<u>DRIVING</u>			
<u>Campus</u>	<u>Calculated</u>	<u>Observed</u>	<u>Relative</u>
Busch	226.20	133.24	0.59
Livingston	174.67	126.72	0.73
College Ave	218.39	148.79	0.68
Cook/Douglass	186.43	138.52	0.74

Table 3. Accessibility measures for driving by campus

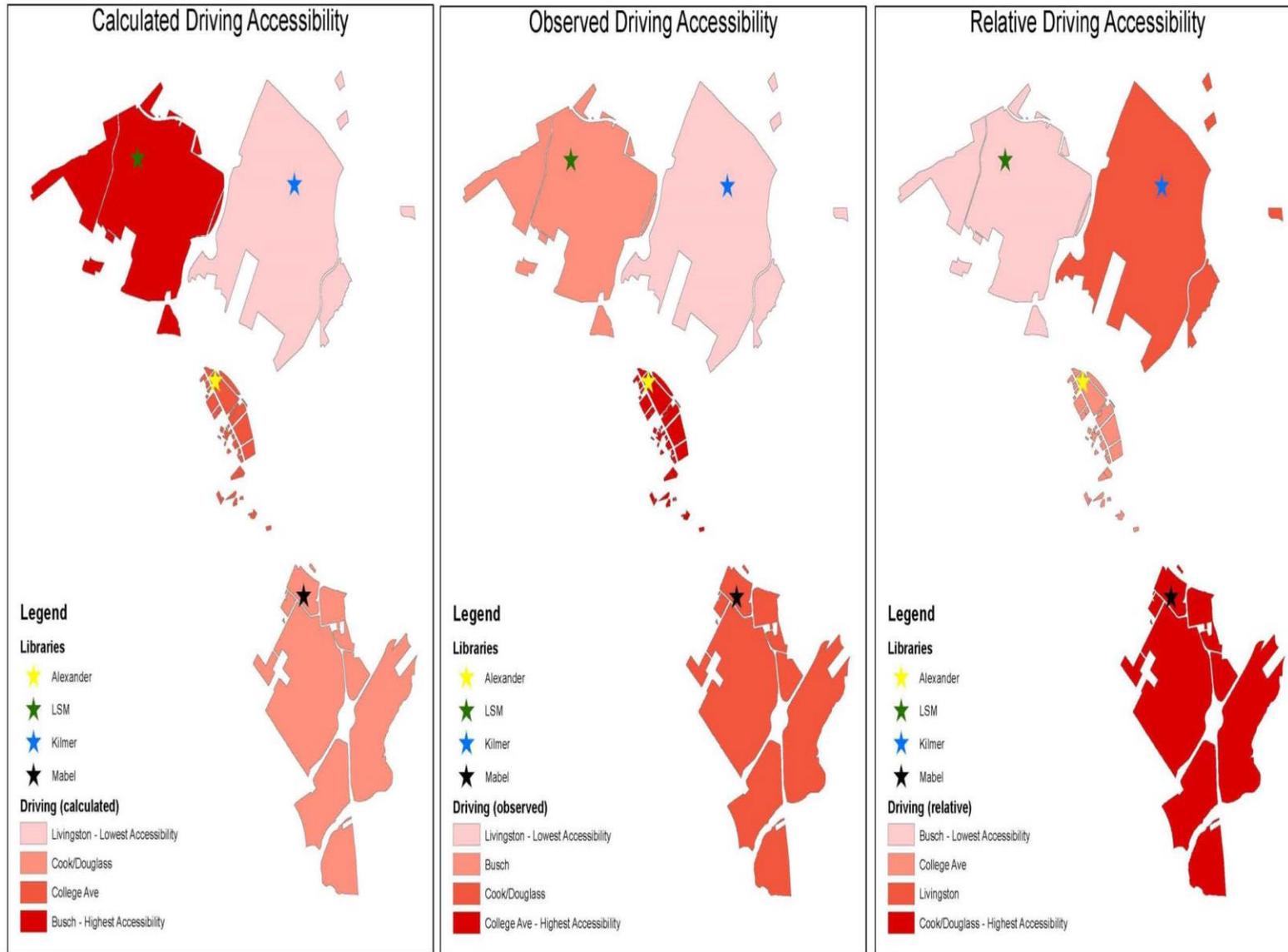


Figure 7. Accessibility measures for driving by campus

For relative accessibility, Cook/Douglass has the highest value, at .74. Closely following that are trips from Livingston, with a value of .73. Drivers from College Ave are next, with a value of .68. Busch has the lowest relative accessibility, with a value of .59 (Table 3).

4.1.3 Accessibility gap

When comparing the scheduled bus travel times and the calculated driving times for the Weekend 1 route, travelers from Cook/Douglass see the largest accessibility gap as the bus accessibility is just 19% of that when using a car. Following that are trips from Busch, where the accessibility of transit users is only 20% of that for car users. Next are students from Livingston, whose transit users experience a quarter of the accessibility that drivers’ enjoy. Finally, students from College Avenue experience the smallest accessibility gap, with transit riders facing a 29% difference in accessibility as compared to those making use of their car (Table 4).

<u>WEEKEND 1</u>		
<u>Campus</u>	<u>Gap (S)</u>	<u>Gap (O)</u>
Busch	20%	36%
Livingston	25%	41%
College Ave	29%	39%
Cook/Douglass	19%	27%

Table 4. Accessibility gaps for the Weekend 1 by campus

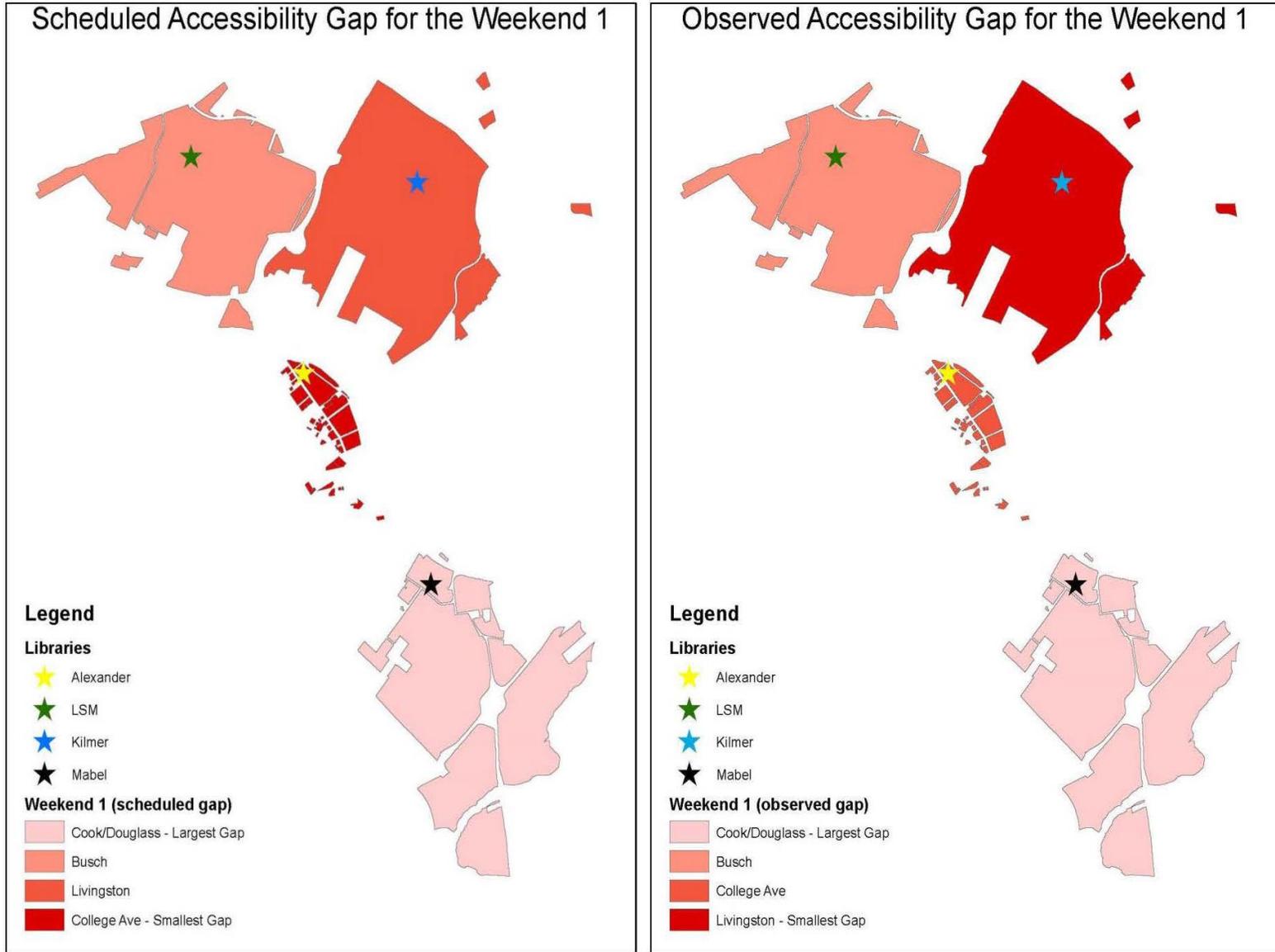


Figure 8. Accessibility gap measures for the Weekend 1 by campus

The observed accessibility gap for the Weekend 1 has much larger values. Trips originating at Cook/Douglas again have the largest accessibility gap as bus users see just 27% of the accessibility experienced by car users. Next are students traveling from Busch on the bus, who experience only 36% of the accessibility that drivers do. Third are College Ave students, whose accessibility is 39% of that for those who use their car. Finally, Livingston trips see the lowest accessibility gap, where transit trips have an accessibility value that is 41% of the value for those that drive (Table 4).

The accessibility gap for the Weekend 2 shows a different distribution than that for the Weekend 1. Using the scheduled accessibility index, Busch campus has the highest accessibility gap, with transit users experiencing just 17% of the accessibility that car users see. After that is Cook/Douglass, with bus riders seeing 23% accessibility of drivers. Third is College Ave, as bus travelers have an accessibility index that is 24% of that for car users. Livingston has the smallest accessibility gap, with transit users seeing accessibility that is 29% of drivers (Table 5).

<u>WEEKEND 2</u>		
<u>Campus</u>	<u>Gap (S)</u>	<u>Gap (O)</u>
Busch	17%	33%
Livingston	29%	41%
College Ave	24%	31%
Cook/Douglass	23%	35%

Table 5. Accessibility gaps for the Weekend 2 by campus

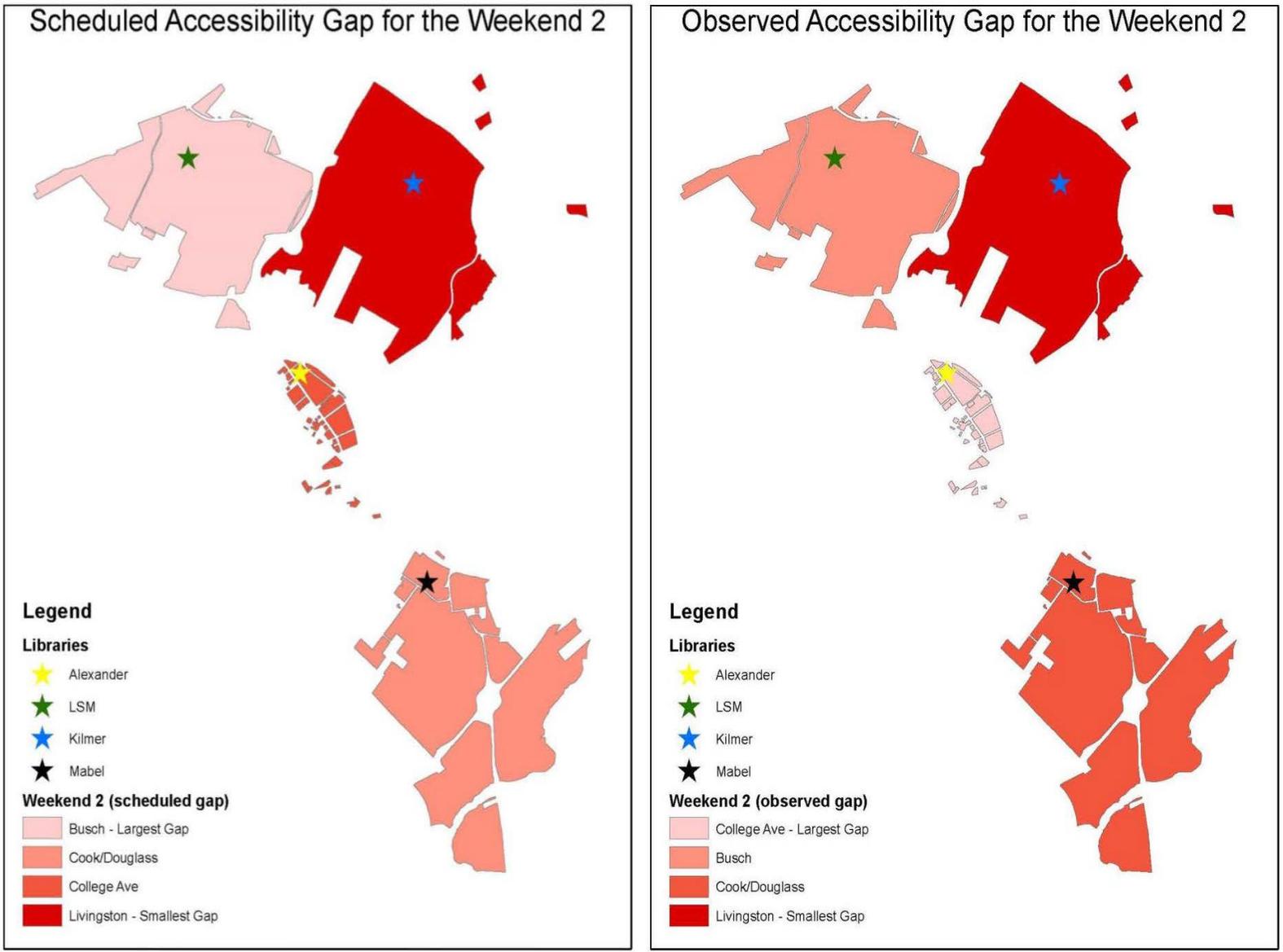


Figure 9. Accessibility gap measures for the Weekend 2 by campus

The observed accessibility gap, like for the Weekend 1 route, is much smaller than for the bus schedule. Here, College Ave experiences the largest accessibility gap, at 31%. Next is Busch, with transit users experiencing just 33% of the accessibility that car user do. Third is Cook/Douglass, with bus riders experiencing accessibility at 35% of the level of drivers. Finally, Livingston again has the smallest accessibility gap, at 41% (Table 5).

4.2 Library accessibility

Unlike the campus accessibility values, in which we were looking from the origin of the trip, when assessing the accessibility values by library, we are choosing to evaluate the accessibility based on the destination.

4.2.1 Campus transit accessibility

For the Weekend 1 route, it is the Alexander library that has the highest accessibility, with accessibility values of 56.87 and 55.26, respectively for the schedule and the observed. The order of the next three libraries is the same for both evaluations. The Mabel Smith Douglass library, on the Douglass campus, has the next highest accessibility values, 46.8 for the schedule data and 54.75 using the observed data. Third, is the Library of Science and Medicine, on Busch. Trips ending there have accessibility values of 44.51 based on the schedule and 46.71 for that which was observed. Kilmer, on Livingston, is the least accessible library using both the schedule and observed travel times. The accessibility values for Kilmer are 34.5 and 36.97, correspondingly (Table 6).

<u>WEEKEND 1</u>			
<u>Library</u>	<u>Scheduled</u>	<u>Observed</u>	<u>Relative</u>
Alexander	56.87	55.26	0.97
Kilmer	34.50	36.97	1.07
LSM	44.51	46.71	1.05
Mabel	46.80	54.75	1.17

Table 6. Accessibility measures for the Weekend 1 by library

Relative accessibility for the Mabel Smith Douglass library is the highest, at 1.17. Second, are trips to Kilmer, with a relative accessibility value of 1.07. Next, are students travelling to LSM, with a relative accessibility of 1.05. Finally, students travelling to Alexander library have the lowest relative accessibility, at .97 (Table 6).

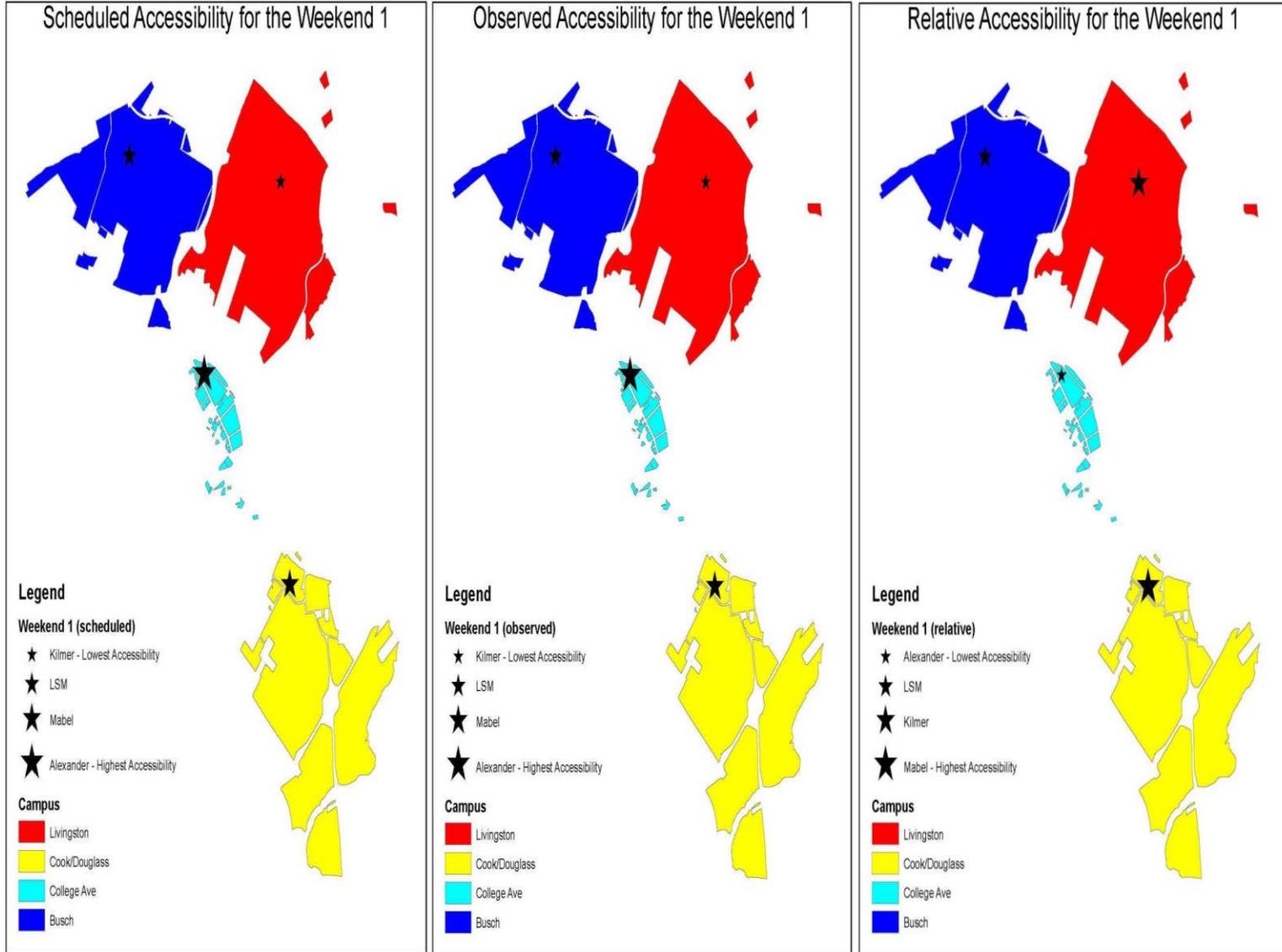


Figure 10. Accessibility measures for the Weekend 1 by library

When looking at the Weekend 2, Alexander library again has the highest degree of accessibility with a value of 53.63 when evaluating the bus schedule, and 61.09 when using observed travel times. Following Alexander are trips heading to LSM, with accessibility values of 53.23 and 50.3, respectively. After that, students travelling to Mabel Smith Douglass, see accessibility values of 43.66 when using the bus schedule and 43.71 when evaluating observed trips. Last are those making their way to Kilmer, who experience accessibility values of 34.93 based on the schedule and 35.82 which using observed travel times (Table 7).

<u>WEEKEND 2</u>			
<u>Library</u>	<u>Scheduled</u>	<u>Observed</u>	<u>Relative</u>
Alexander	53.63	61.09	1.14
Kilmer	34.93	35.82	1.03
LSM	53.23	50.30	0.95
Mabel	43.66	43.71	1.00

Table 7. Accessibility measures for the Weekend 2 by library

Relative accessibility for the Weekend 2 route is decidedly different from that of the Weekend 1. For this route, trips that terminate at Alexander have the highest degree of relative accessibility at 1.14. Next, are those travelling to Kilmer, with a value of 1.03. Students making their way to Mabel Smith Douglass have scheduled and observed values that are almost identical, giving it a relative accessibility measure of 1.00. Finally, those going to LSM see observed values that are lower than the scheduled values, giving them a relative accessibility value of .95 (Table 7).

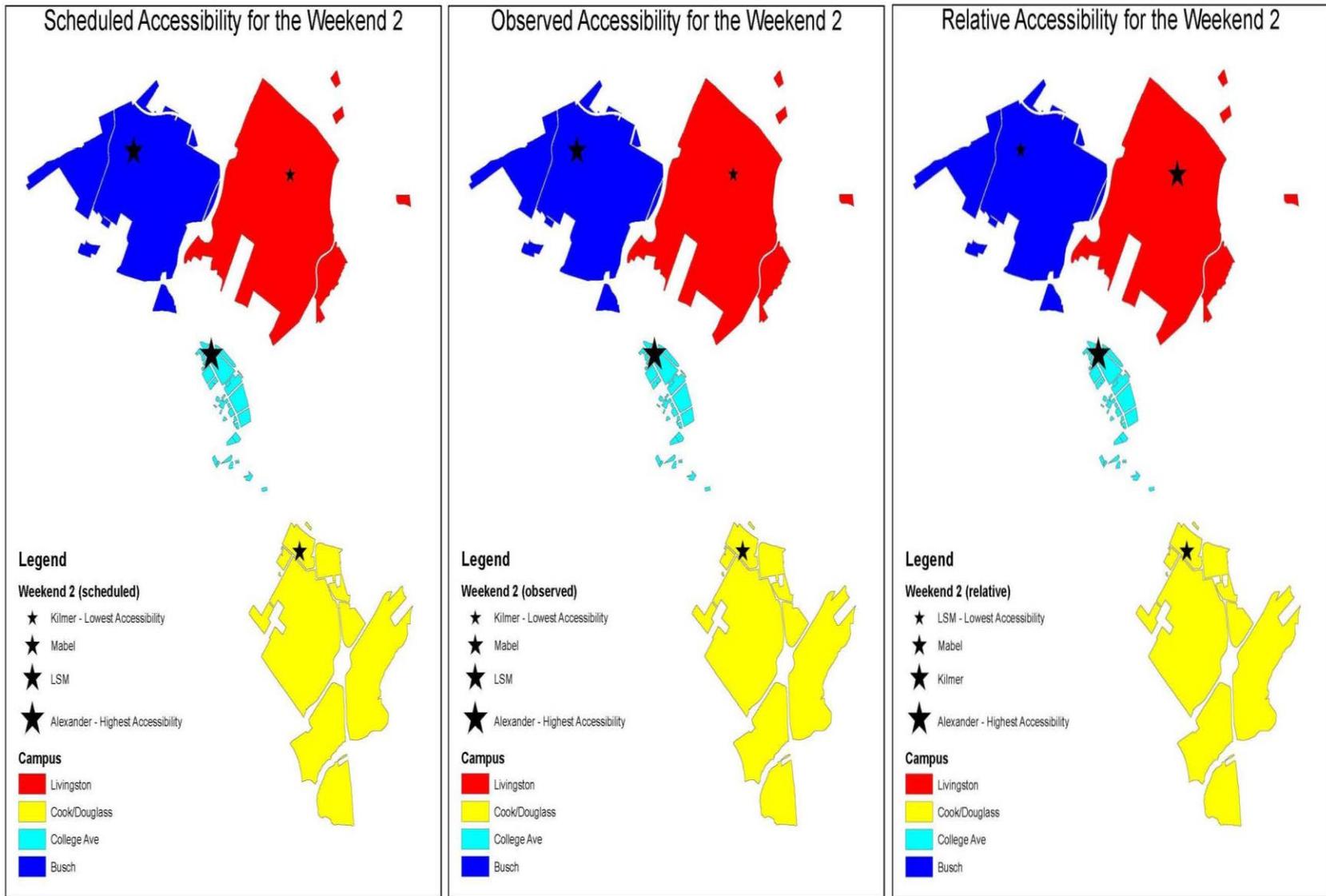


Figure 11. Accessibility measures for the Weekend 2 by library

4.2.2 Driving accessibility

Alexander library is the most accessible library to the other three campuses, when comparing calculated travel times, with a value of 221. Following that is Mabel Smith Douglass, with an accessibility index of 207.45. In third is LSM, which has an accessibility value of 204.03. Kilmer is the least accessible library to other students, with a value of 173.2. Observed accessibility values give a much different image. When using those values, LSM is the most accessible library, having a measure of 154.31. Closely behind that is Mabel Smith Douglass, with a measure of 146.67. Third is Alexander, which sees accessibility of 137.07. Finally, Kilmer is again the least accessible library, with an accessibility index of just 109.21 (Table 8).

<u>DRIVING</u>			
<u>Library</u>	<u>Calculated</u>	<u>Observed</u>	<u>Relative</u>
Alexander	221.00	137.07	0.62
Kilmer	173.20	109.21	0.63
LSM	204.03	154.31	0.76
Mabel	207.45	146.67	0.71

Table 8. Accessibility measures for driving by library

The relative accessibility values for driving to the libraries are much less variable than those for driving from the different campuses. LSM has the highest relative accessibility, at .76. Next are trips to Mabel Smith Douglass, with a value of .71. Following that is Kilmer, with a relative accessibility of .63. Just barely having the lowest relative accessibility is Alexander, at .62 (Table 8).

S

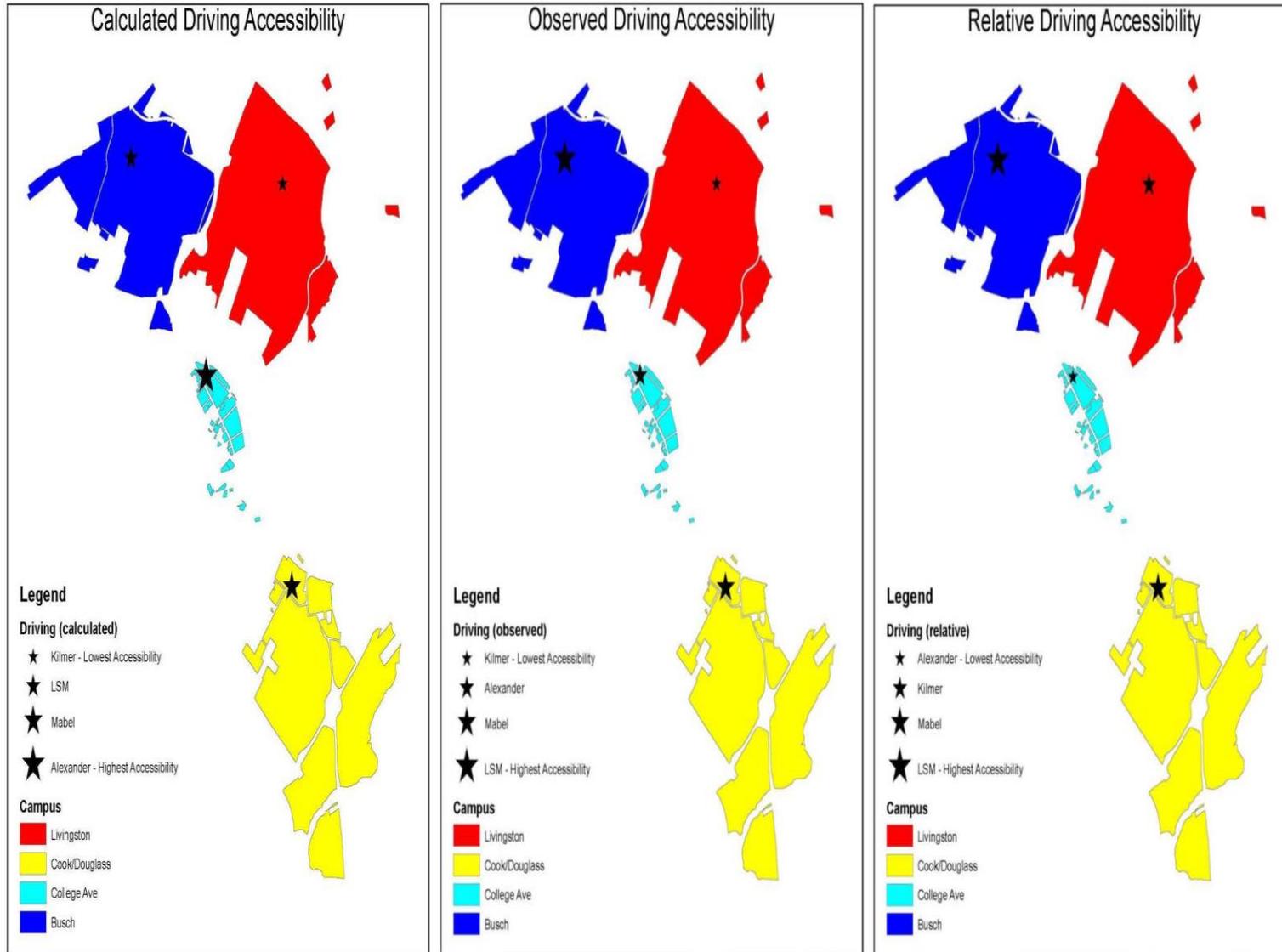


Figure 12. Accessibility measures for driving by library

4.2.3 Accessibility gap

Travelers going to Kilmer see the largest accessibility gap, when comparing scheduled bus accessibility and calculated driving times. Bus riders going there see just 20% of the accessibility that car drivers should. Following that is LSM, with 22% accessibility for transit users as compared to car users. Next is Mabel Smith Douglass, with transit riders experiencing only 23% of the accessibility that car users do. Finally, Alexander has the smallest accessibility gap, with transit having 26% accessibility of car drivers (Table 9).

<u>WEEKEND 1</u>		
<u>Library</u>	<u>Gap (S)</u>	<u>Gap (O)</u>
Alexander	26%	40%
Kilmer	20%	34%
LSM	22%	30%
Mabel	23%	37%

Table 9. Accessibility gaps for the Weekend 1 by library

The observed accessibility gap is smaller than that of the scheduled travel times. Using these values, LSM has the highest gap, at 30%. Second is Kilmer, with a value of 34%. Next is Mabel Smith Douglass, with transit riders experiencing 37% of the accessibility of drivers. Finally, Alexander has the smallest accessibility gap, with bus users getting 40% accessibility of what car users do (Table 9).

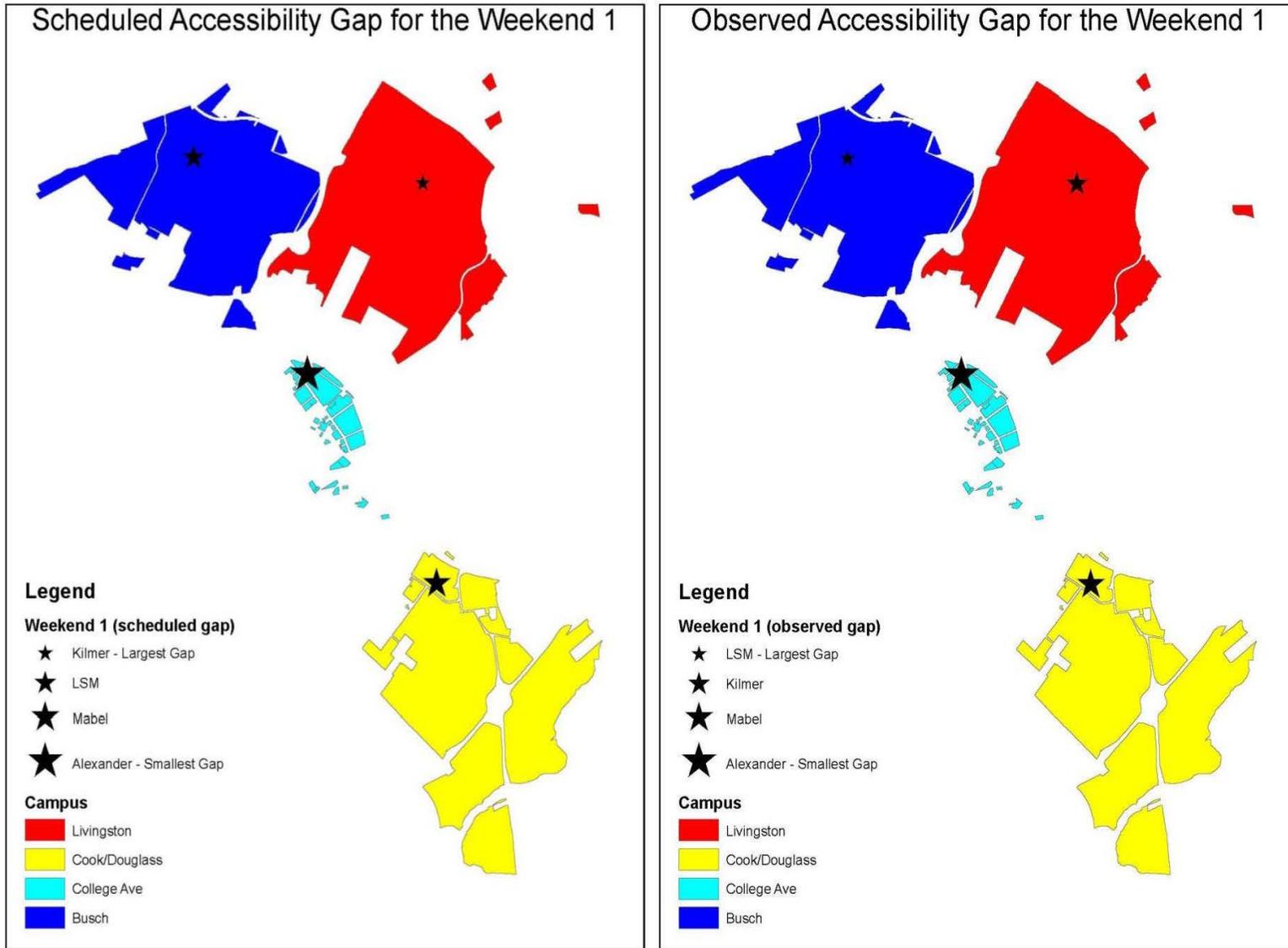


Figure 13. Accessibility gap measures for the Weekend 1 by library

When assessing the accessibility gap for the Weekend 2, we get a different ranking. Using the scheduled accessibility measures, Kilmer again has the largest accessibility gap, at 20%. Next is Mabel Smith Douglass at 21% accessibility for transit users. Third is Alexander, where bus riders experience just 24% of the accessibility that drivers do. Finally, LSM has the smallest gap, with transit users having a accessibility value that is 26% of car users (Table 10).

<u>WEEKEND 2</u>		
<u>Library</u>	<u>Gap (S)</u>	<u>Gap (O)</u>
Alexander	24%	45%
Kilmer	20%	33%
LSM	26%	33%
Mabel	21%	30%

Table 10. Accessibility gaps for the Weekend 2 by library

For the observed accessibility gap, Mabel Smith Douglass has the largest gap, with transit riders seeing 30% of the accessibility of drivers. The accessibility gap for Kilmer and LSM is the same, at 33%. Lastly, Alexander has the smallest accessibility gap, with transit users having 45% of the accessibility that car users do (Table 10).

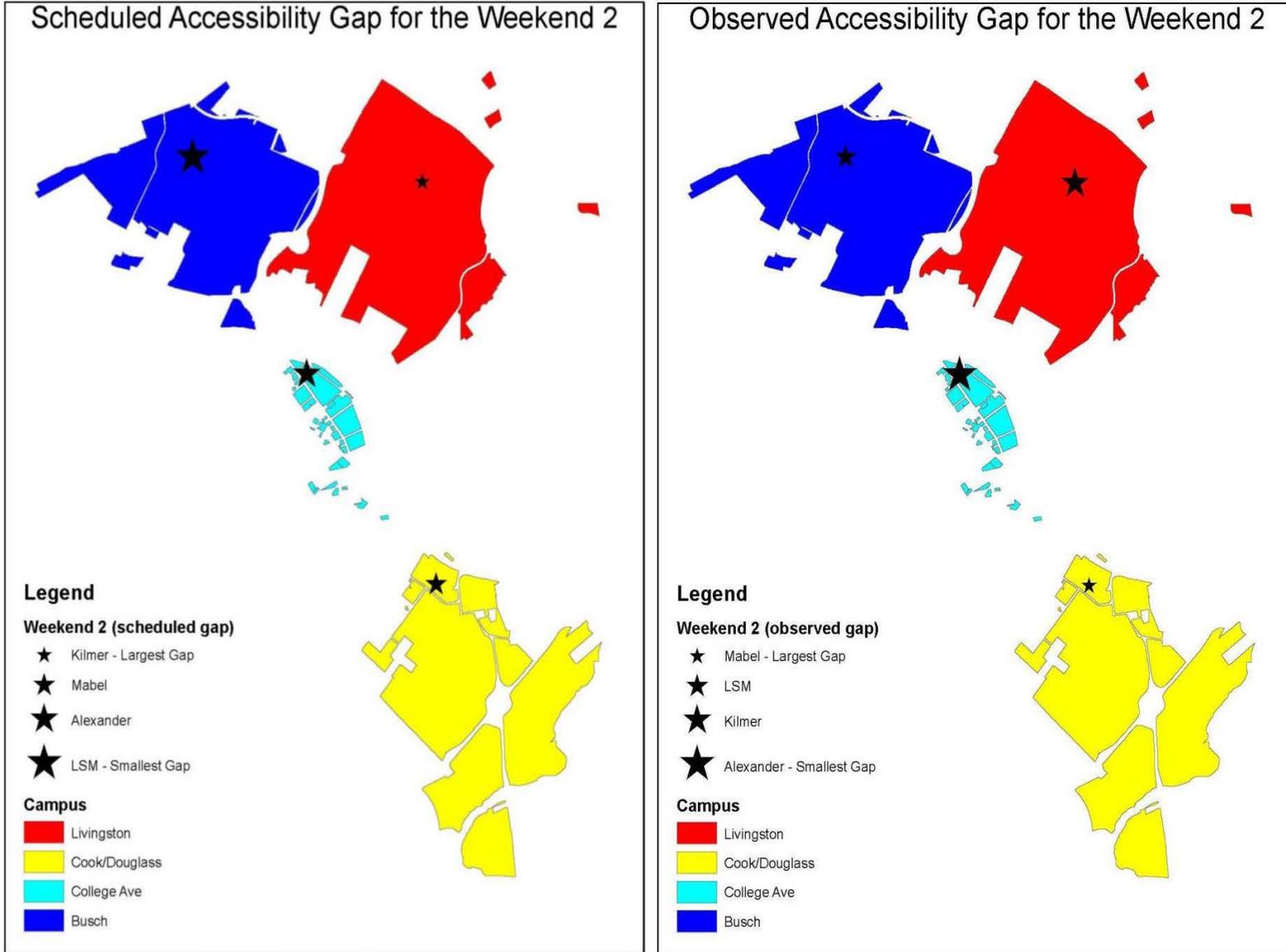


Figure 14. Accessibility gap measures for the Weekend 2 by library

5. DISCUSSION

This research created an accessibility index for each campus bus stops and its associated parking lots using “ideal” travel times, calculated by using the bus scheduled and calculated driving times and observed travels times. These accessibility measures were then aggregated to come up with an overall accessibility value for each campus and library. The higher the accessibility value, the greater the accessibility of students to the other three libraries and campuses, respectively. Using these values a relative accessibility value was calculated. Relative accessibility values less than one mean that the accessibility for the observed data was lower than that of the scheduled data and vice versa. The closer the relative accessibility value is to one then the closer the observed accessibility is to the ideal accessibility. An important part of this research is to compare the difference in accessibility for public transportation users and users of a private vehicle. An accessibility gap measure was calculated to accomplish that goal. The smaller the accessibility gap value, then the larger the difference in accessibility between transit users and automobile users.

5.1 Campus accessibility

5.1.1 Busch

Students travelling from the Busch campus experienced the highest degree of accessibility, for both the ideal and observed data, when taking the Weekend 1 route. This route stops first on the Busch campus, and students coming from there see relatively short travel times

to all the campus libraries. They see the highest degree of relative accessibility when riding the Weekend 2 route, with a value of 1.12, meaning that the observed accessibility is 12 percent greater than the ideal accessibility. This says that students travelling from Busch can on the Weekend 2 to be shorter than what the schedule predicts. Trips on the Weekend 1 will also be shorter than what the schedule predicts, but to a lesser level.

When driving, Busch experiences the highest degree of accessibility based on the ideal travel times, but is in third when it comes to observed accessibility, leaving it with a relative accessibility of .59. Students that drive from the Busch campus can expect that their trips will take longer than what can be calculated.

The accessibility gap for Busch is largest when comparing ideal values for driving and the Weekend 2 route, where transit users in this scenario have an accessibility value that is just 17 percent of what drivers have in the same situation. This means that transit users have a large disadvantage when trying to get to the other libraries as compared to drivers. It experiences the smallest accessibility gap when using the observed values for driving and the Weekend 1 route, where transit accessibility is at 36 percent of car accessibility. While it is better than any other situation for those coming from Busch, transit users still have a great handicap when trying to access other libraries.

5.1.2 Livingston

Being the midpoint of both routes, Livingston students have the ability to reach the other campus libraries in no more than six stops, depending on which route they choose. When coming from Livingston, students taking the Weekend 1 have the highest accessibility, using observed data. They have the lowest accessibility measure for the Weekend 1, when examining the ideal

accessibility. As the Weekend 1 has both the highest and lowest value for trips coming from there, it too has a higher relative accessibility value than the Weekend 2. With a relative accessibility value of 1.19, students traveling from Livingston can expect for their trips to the other libraries on the Weekend 1 to be shorter than was to be expected. The same can be said about the Weekend 2 route, but at a smaller degree.

Livingston has the lowest accessibility value, for both the ideal and observed data, of all four campuses. While it may have the lowest accessibility index, its relative accessibility for drivers is the second highest, meaning that those who choose to drive from there can expect their trips to more closely meet the calculated driving time.

The accessibility gap for Livingston is the smallest of all four campuses when evaluating the ideal data for the Weekend 2, even though there is still a relatively large gap. Transit users in this situation still have less than one-third of the accessibility that drivers do. The accessibility gap for observed data is the same for both the Weekend 1 and Weekend 2, with riders experiencing 41 percent of the accessibility that drivers do.

5.1.3 College Avenue

College Ave sees its highest transit accessibility for the ideal values on the Weekend 1. For those taking the Weekend 2, the accessibility values are markedly different, as students see their lowest accessibility for the observed values on the Weekend 2. Students coming from the College Ave campus are the only students who experience relative accessibility levels of below one, for both the ideal and observed values. These students can expect that their actual bus trips will take just slightly longer than the schedule predicts.

When comparing driving accessibility levels, College Ave students see the highest level of accessibility when using observed travel times, and just below the highest accessibility level when using calculated driving times. The relative accessibility for drivers from College Ave shows that they can expect their travel times will be longer than what can be estimated through calculations.

The accessibility gap for College Ave students is smallest for ideal data for those who choose to make use of the Weekend 1, with the same being true for the observed values. Transit users on this route experience a smaller difference between transit accessibility and driving accessibility than those who make use of the Weekend 2. As compared to other campuses, transit riders coming from College Ave have the largest disadvantage when using the Weekend 2, while when using the Weekend 1 are just barely behind the smallest gap.

5.1.4 Cook/Douglass

Cook/Douglass has the highest accessibility for transit users when using the Weekend 2, for both ideal and observed values. As Cook/Douglass is the first stop on this route, students travelling from there will stop at all three campus libraries with relatively short travel times. The relative accessibility for Cook/Douglass is equal for both the Weekend 1 and Weekend 2 routes, at 1.01, meaning that for both routes the observed travel time is slightly shorter than what is scheduled.

Drivers from Cook/Douglass experience accessibility values that are middle of the road when compared to the other campuses. What is important here is that students coming from here have the highest relative accessibility, meaning that their observed trips will be the closest to the travel time that can be calculated.

The accessibility gap for Cook/Douglass is the largest gap when comparing the campus for the Weekend 1, using both ideal and observed data, meaning that transit users coming from her have the greatest disadvantage to drivers. For the Weekend 2, Cook/Douglass students are in the middle in terms of ranks for accessibility gap. While it is not as large as the Weekend 1, transit users are still incredibly handicapped when trying to access the libraries from Cook/Douglass on the Weekend 2.

5.1.5 Patterns

Campus size and location could speak to changes in accessibility. One might expect students travelling from College Ave to have the highest accessibility, simply due to its central location on the Rutgers campus. But as can be seen in figures 5 and 6, students travelling from College Ave have the highest accessibility on the Weekend 1 but the lowest accessibility on the Weekend 2. The bus routes on Busch and Livingston are much smaller than those found on Cook/Douglass, which leads to lower ride times on the Weekend 1 from those students. The location of Livingston as the midpoint for both bus routes can speak to the fact that students travelling from there see the smallest accessibility gaps.

5.2 Library accessibility

5.2.1 Alexander Library

As compared to the three other libraries, Alexander library is the most accessible library for both the Weekend 1 and Weekend 2 routes. Those looking to travel to Alexander see their highest accessibility on the Weekend 2, when using the observed travel times. Students travelling there see their lowest accessibility also on the Weekend 2, but using the scheduled travel times. As the Weekend 2 has both the highest and lowest accessibility value, it also has the highest

relative accessibility, at 1.14, meaning that students choosing to use that route will see trips that are shorter than to be expected. When using the weekend 1 route, students travelling to Alexander have a relative accessibility of less than one, meaning that their trips will be longer than what the schedule predicts.

Alexander has the highest accessibility value of the four libraries when comparing the ideal accessibility values, but is closer to the bottom when it comes to the actual driving times. Its relative accessibility is at .62, meaning that drivers to Alexander can expect their trips to be much longer than was to be expected from the calculations.

Alexander has the smallest accessibility gap for the Weekend 1 route, based on both ideal and observed values. Transit users looking to get to Alexander will experience the least difference in accessibility compared to car users, when riding the Weekend 1. For the Weekend 2, Alexander has the smallest gap when it comes to observed trips, but is second when using the scheduled travel times. Transit users are at a disadvantage when looking to get to any library, but least of all Alexander.

5.2.2 Kilmer Library

Kilmer library experiences the lowest accessibility values of all the libraries. As it is the smallest library, its accessibility values are smaller because there are not as many opportunities there. Students looking to get to Kilmer will see both the highest and lowest accessibility values when riding the Weekend 1, at 36.97 and 34.5 respectively. For both the Weekend 1 and Weekend 2 routes, those seeking to go to Kilmer have a relative accessibility measure of just over one, meaning that the trips on both buses will be slightly shorter than what is scheduled.

Like with the buses, Kilmer is the least accessible library for those that use their own car. As said, because of the low number of opportunities there, accessibility values are still low, even though travel time is faster with a private vehicle. With a relative accessibility value that is almost the lowest; drivers to Kilmer see trips that vary greatly from what can be planned.

The accessibility gap for those travelling to Kilmer is the largest of all four libraries for both the Weekend 1 and 2 when using the scheduled travel times. For the observed travel time, the Weekend 1 has just a slightly smaller gap than that of the Weekend 2. Those going to Kilmer are incredibly inconvenienced as compared to those making use of their own vehicle.

5.2.3 Library of Science and Medicine

The accessibility measures for LSM are markedly different for the Weekend 1 and the Weekend 2. When travelling to LSM, one will see the highest accessibility based on the schedule of the Weekend 2, while the lowest accessibility value for the library is based on the Weekend 1 schedule. The relative accessibility for LSM on the Weekend 1 is above one, so that the observed travel times are shorter than the scheduled ones. Conversely, for the Weekend 2, the relative accessibility is at .95, meaning that the observed trips were longer than what was on the schedule.

When comparing accessibility values for drivers, those heading to LSM have the highest accessibility for observed trips, but are almost last for calculated trips, giving LSM the highest relative accessibility value. Drivers that are going to LSM can expect longer travel times than what was calculated, but will get there with fewer delays than any of the other libraries.

The accessibility gap for LSM on the Weekend 1 is just barely smaller than the largest gap when comparing scheduled accessibility. When using the observed values, LSM does, in

fact, have the largest accessibility gap. Riders on this route will see a huge disadvantage to car users. On the Weekend 2, LSM sees the smallest accessibility gap for the scheduled data, and has the same gap as Kilmer for observed trips. When analyzing the schedule data, transit riders would expect the least hindrance by using the bus, though observations show different.

5.2.4 Mabel Smith Douglass library

Mabel Smith Douglass sees its lowest accessibility values, using both the schedule and observed data, for those who are on the Weekend 2 bus. The highest accessibility was found for the observed trips on the Weekend 1. Mabel has the highest relative accessibility on the Weekend 1 of all four libraries, at 1.17, meaning that riders going there see the biggest difference between observed travel time and scheduled time, with trips being shorter than what is to be expected. When using the Weekend 2, Mabel has almost perfect accessibility, with a relative accessibility value of 1.00.

For those using their own vehicle, accessibility for trips to Mabel is relatively average, compared to the other four libraries. The observed travel times are longer than what was calculated, so its relative accessibility value is a good deal below one.

Trips to Mabel have the largest accessibility gap for observed trips on the weekend 2, and a just barely smaller than the largest gap when using the scheduled data. Transit riders on this route are likely to experience the largest disadvantage in accessibility as compared to car users. The accessibility gap for the Weekend 1 is smaller, and is near the smallest gaps of the four libraries.

5.2.5 Patterns

Location might influence the accessibility of each library. From figures 10 and 11 one can see that Alexander library is the most accessible library, which might be influenced by its central location on the larger Rutgers campus. This centralized location might also be the reasoning behind students travelling to Alexander seeing the smallest accessibility gaps. On the other hand, Kilmer library is the least accessible library. Most students travelling to Kilmer from the other campuses must travel to at least one other campus before reaching Livingston, which might speak to these results.

6. CONCLUSIONS

This research was designed to assess the accessibility of the libraries on the campus of Rutgers University – New Brunswick. The results can be important to understand, as they can lead to a better understanding of the transportation options available to Rutgers students, and how one can work to improve the quality of life. This study was the first of its kind, assessing the difference in accessibility between public transportation and private vehicles on a college campus. University planners can use the results to help improve the transportation network in order to improve the accessibility of university students.

This research set out to answer the following questions: What campus provides its residents with the highest degree of accessibility to the campus libraries? What campus library has the highest degree of accessibility to residents of other campuses? Does observed accessibility deviate from calculated accessibility? Do public transit users have a higher or lower degree of accessibility than private vehicle users? Where is the accessibility gap between transit use and automobile use the highest?

Accessibility indexes were created for both the transit system as well as car users, by bus stop and corresponding parking lot. These were then combined to create an accessibility value for each campus to the three other libraries. When comparing values for the transit system, it was found that accessibility is highly variable, based on route choice. While College Ave is the campus that provides the greatest accessibility on the Weekend 1, Cook/Douglass has the most accessible students when using the Weekend 2. Drivers from College Ave see the greatest

accessibility to the other three libraries. These aggregated accessibility values were also created for each library for trips that terminate there. Riders of both the Weekend 1 and Weekend 2 have the greatest accessibility to Alexander library, on the College Avenue campus. On the other hand, drivers from the three campuses have the greatest accessibility to the Library of Science and Medicine.

In all cases, the observed travel time deviated from that which was scheduled or calculated. Livingston saw the greatest deviance from the schedule on the Weekend 1, with Busch seeing that difference on the Weekend 2. Drivers saw a much larger difference in values, with driving times from College Ave differing from the calculated driving times by almost double. When assessing the libraries, trips to Mabel saw the greatest divergence from the schedule for riders of the Weekend 1, with Alexander on the Weekend 2. For drivers, trips to LSM saw the largest difference between calculated and observed accessibility level.

As was expected, drivers have a much higher degree of accessibility than transit users, shown through the accessibility gap measurement. For both the Weekend 1 and Weekend 2, students coming from Livingston saw the least amount of difference between accessibility on the buses and that found when driving. When evaluating the libraries, Alexander has the smallest accessibility gap between transit riders and car users, for both bus routes.

The idea of sustainable transportation has received increasing attention in past years. Car usage continues to grow and transportation planners and managers must seek ways to alter that pattern. Sustainability as a general concept does not have one, solidified working definition. Instead it is often open for interpretation and analysis. This, too, translates to the idea of sustainable transportation. While transportation planners know that they seek to design more

environmentally friendly options, they may differ in what they seek to promote and reduce. It is important that, moving forward, there is a more clear distinction as to what makes a transportation system sustainable.

While there have not been concrete definitions of sustainable transportation, there have been a variety of indicators that have gone into evaluating how sustainable a transportation system may be. Accessibility of both transit users and drivers has been used as one such indicator (Steg & Gifford, 2008). Traditional analysis of accessibility look for ease of flow for vehicles and the ability of people to get from place to place (Litman & Burwell, 2006). What must be further investigated in the equity in accessibility between transit users and car drivers. By assessing this different, transportation planners will have a better background with which to develop transit systems that work to benefit their riders in every way possible. We must seek to move away from the belief that auto-mobility is the equivalent of accessibility. Sustainable transportation and accessibility need not be opposing forces, but instead transportation officials must work to improve accessibility for sustainable transportation. Recording information, such accessibility gaps, might allow for that improved accessibility to happen.

By evaluating student accessibility when using campus transit, university planners can work to improve the system to incite higher ridership. Improving the quality of service and increasing ridership will allow universities to encourage students to transition away from their traditional auto-dependence and instead work to teach more sustainable habits moving forward. Campuses are laboratories for behavior development, so it is pivotal that students begin to develop sustainable transportation habits while there. In addition, increasing equity between transit users and car drivers on a college campus may provide transportation planners ideas on how to increase this equity to users on a larger scale. It is important that we continue to educate

students on how their actions affect the sustainability of the campus. Students must also be taught that sustainable transportation does not always mean long rides and high wait times. If students are better educated about the actual length of time that it will take to get from place to place using more sustainable transportation, they might seek to alter their travel mode.

This research can be important for the use not only on the Rutgers campus, but campuses with public transportation systems throughout the country. The concepts that are presented here are transferable to the campus at The University of Alabama. As discussed earlier, campuses are working towards creating a more sustainable environment by introducing more alternative methods of transportation. On the campus of UA, buses do not run on the weekend, invariably forcing students to take their private vehicles. Transportation planners there could look to implement service on the weekends, in order to eliminate those students driving around campus.

This study was limited in its scope in that it does not take into account the competitive value that each library has on students from its own campus. Also, in future research weight can be given based on the student population on each campus, which would greatly affect the accessibility there, as well as the libraries on the other campuses. This research was also limited in its scope, in that it focused solely on the weekend routes on campus. Future studies can delve deeper into the bus system, to include the weekday routes, as well as routes that service off-campus locations. With that, the addition of academic bus stops could also be added to the analysis.

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