Mineta Transportation Institute Publications

7-2017

Feasibility Study of a Campus-Based Bikesharing Program at UNLV

Hualiang Teng
University of Nevada, Las Vegas

Boniphace Kutela
University of Nevada, Las Vegas

Eneliko Mulokozi
University of Nevada, Las Vegas

Bingyi Hu
Beijing Jiaotong University

Yang Jiao
University of Nevada, Las Vegas

See next page for additional authors

Authors

Hualiang Teng, Boniphace Kutela, Eneliko Mulokozi, Bingyi Hu, Yang Jiao, and Haiqing Li

MINETA NATIONAL TRANSIT RESEARCH CONSORTIUM

Feasibility Study of a Campus-Based Bikesharing Program at UNLV

MNTRC Report 12-64

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REPORT 12-64

FEASIBILITY STUDY OF A CAMPUS-BASED BIKESHARING PROGRAM AT UNLV

Hualiang (Harry) Teng, PhD
Boniphace Kutela
Eneliko Mulokozi
Bingyi Hu, PhD
Yang Jiao
Haiqing Li

July 2017

A publication of

Mineta National Transit Reseaerch Consortium

College of Business
San José State University
San José, CA 95192-0219

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. CA-MNTRC-16-1248	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Feasibility Study of a Campus-Based Bikesharing Program at UNLV		**5. Report Date** July 2017 **6. Performing Organization Code**
7. Authors Hualiang (Harry) Teng, PhD, Boniphace Kutela, Eneliko Mulokozi, Bingyi Hu, PhD, Yang Jiao, and Haiqing Li		**8. Performing Organization Report** MTI Report 12-64
9. Performing Organization Name and Address Mineta National Transit Research Consortium College of Business San José State University San José, CA 95192-0219		**10. Work Unit No.** **11. Contract or Grant No.** DTRT12-G-UTC21
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology University Transportation Centers Program 1200 New Jersey Avenue, SE Washington, DC 20590	Transportation Research Center Sciences and Engineering Building, Room 3253 University of Nevada, Las Vegas 4505 S. Maryland Parkway Las Vegas, NV 89154-4007	**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code**
15. Supplemental Notes		

16. Abstract

Bikesharing systems have been deployed worldwide as a transportation demand management strategy to encourage active modes and reduce single-occupant vehicle travel. These systems have been deployed at universities, both as part of a city program or as a stand-alone system, to serve for trips to work, as well as trips on campus. The Regional Transportation Commission of Southern Nevada (RTCSNV) has built a public bikesharing system in downtown Las Vegas, approximately five miles from the University of Nevada, Las Vegas (UNLV). This study analyzes the feasibility of a campus-based bikesharing program at UNLV. Through a review of the literature, survey of UNLV students and staff, and field observations and analysis of potential bikeshare station locations, the authors determined that a bikesharing program is feasible at UNLV.

17. Key Words Bicycle sharing; bike sharing; nonmotorized transportation; active transportation; bicycle travel	**18. Distribution Statement** No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 145	**22. Price** $15.00

Form DOT F 1700.7 (8-72)

Library of Congress Catalog Card Number:
2017949396

To order this publication, please contact:

Mineta National Transit Research Consortium
College of Business
San José State University
San José, CA 95192-0219

Tel: (408) 924-7560
Fax: (408) 924-7565
Email: mineta-institute@sjsu.edu

transweb.sjsu.edu/mntrc

072717

ACKNOWLEDGMENTS

The authors would like to thank Dr. Bruce Turner at UNLV for his contribution to this project. Dr. Turner helped develop the scope, reviewed the survey, and provided a peer review of the report. The authors would also like to thank Mr. David Swallow at the Regional Transportation Commission of Southern Nevada (RTCSNV), who provided the data for this research project.

The authors thank MTI staff, including Executive Director Karen Philbrick, Ph.D.; Publication Support Coordinator Joseph Mercado; and Executive Administrative Assistant Jill Carter.

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BACKGROUND

Bikesharing systems have been deployed worldwide as a transportation demand management strategy to encourage active modes and reduce single-occupant vehicle travel. Bikesharing may be one strategy to mitigate roadway congestion. Additionally, bikesharing systems have been deployed at universities — as part of a city program or as a stand-alone system — that serve both for trips to work as well as trips on campus. The Regional Transportation Commission of Southern Nevada (RTCSNV) has built a public bikesharing system in downtown Las Vegas, approximately five miles from the University of Nevada, Las Vegas (UNLV). This study analyzes the feasibility of a campus-based bikesharing program at UNLV.

METHODOLOGY

To achieve the objectives of this study, the authors conducted a literature review on university bikesharing systems in the U.S. and abroad. The goals of the proposed program at UNLV were developed as well as metrics to use when monitoring the program's performance. A questionnaire was distributed to UNLV faculty, staff, and students to obtain the users' preferences regarding the locations of proposed bikesharing stations as well as the likelihood and frequency that respondents would use the program. Survey responses were used to estimate the demand for a bikesharing system on and around the UNLV campus.

In addition, various cases of bikesharing programs were analyzed, and each case consisted of a different number and location of stations. The demand corresponding to these stations was used as input for a simulation model developed in this study in order to determine the number of docks in stations and bicycles in the system. These sizing parameters were then used in a cost-benefit analysis to determine which cases could achieve the maximum benefit, given a limitation in initial costs. The revenue generated in each case was calculated by estimating the demand. Comparing the revenue with the costs, the cases that could generate sufficient funds for the proposed bikesharing system to be sustainable were determined. After determining the system's scale, connections with transit were evaluated based on the location of the bikesharing stations and the presence of bus stops in close proximity to the stations.

Researchers performed field observations to identify existing bike racks and their usage. University officials were interviewed about future developments on and off campus to determine the influence of these developments on the bikesharing program. The bike paths between proposed stations were examined to identify which locations might have greater conflicts between bicycles and pedestrians, and identify possible measures to reduce conflicts. Researchers also identified recommendations for infrastructure improvements to enhance safety, reduce potential collisions, and improve cyclist wayfinding.

STUDY FINDINGS

The primary goal of the bikesharing program at UNLV is to reduce congestion on nearby roads by increasing the use of public transportation. This could be achieved by providing enhanced bicycle infrastructure to facilitate first- and last-mile connectivity. In addition, the proposed bikesharing program could improve productivity on campus. The performance metrics included the number of customers using the system for commuting and on-campus travel as well as metrics on fleet usage and customer service.

In total, 241 faculty (n=37), staff (n=94), and students (n=110) responded to a survey that was distributed to the entire university community of 31,500 faculty, staff, and students. Even with a small response rate of 0.76, the sample size was sufficient to conduct a demand analysis. About 50% of those participating in the survey expressed a willingness to use the bikesharing system for commuting, and 60% said they were willing to use the system for on-campus travel. Commuting and on-campus travel are two different types of travel, and the factors determining whether an individual would use a bikesharing system are quite different for each.

For commuting to school, factors that were important to the respondents included:

- distance from where they returned the bikes to their destination;
- proximity to a bus line connecting from where they live;
- income;
- whether they currently drive to school;
- whether they come to school for work or classes before 8 a.m.; and
- education level.

The factors that influenced the frequency of the respondents using a bikesharing system for commuting were quite different. These factors included:

- gender;
- whether they have an office on campus;
- whether they are a faculty member; and
- education level.

For on-campus travel, the distance from the bikesharing station where the users returned the bikes to their destination, as well as income, were critical factors in choosing to use the bikesharing program.

The factors that determined frequency of use for on-campus travel included:

- gender;
- whether they have an office on campus;
- whether the customer is a faculty member;
- education level; and
- whether they would use the bikes to attend classes.

Based on a travel demand analysis for a bikesharing system with 16 stations (six on the periphery and 10 on campus), it was estimated that there would be 3,450 members for a program at UNLV, with each making trips of varying frequencies and producing 1,966 trips per day. Some of the stations would only serve a small proportion of total demand, so they may not be worth installing. If one of the six stations on the periphery and three of the 10 stations on campus were installed, the system would serve 216 trips per day. This estimate was based on the average of trips served by bikesharing programs at other universities in the U.S., and thus can be viewed as reasonable.

This study evaluated 14 bikesharing systems, each with a different size in terms of the number of docks, bikes, and locations of stations. Among these cases, two that were considered to be cost-effective included one station on the periphery and three stations on campus. The initial equipment, installation, and operations costs were calculated to be less than $300,000, based on cost data from other universities. The revenue generated from this system was estimated to be greater than the operating cost. The researches recommend these two cases be considered when planning for implementation of a bikesharing system at UNLV.

This study considered six stations along the campus periphery; each located within 400 meters (1/4 mile) from a bus stop to facilitate connections to the transit system. The locations of the proposed stations were identified, taking into consideration the existing bike racks on campus. Spaces are available for every proposed station. In addition, the UNLV master plan and other off-campus development projects were reviewed, which provided strategic direction for possible future expansion of the bikesharing program.

The bike paths connecting all of the stations were identified. Potential conflicts between cyclists and pedestrians were identified, along with recommendations for safety improvements to mitigate these risks. In addition, researchers evaluated overall bicycle network connectivity. The evaluation noted potential improvements that can be made to the bicycle network; however, no critical gaps were identified.

CONCLUSIONS

This study concludes that a bikesharing program is feasible at UNLV. However, several improvements should be implemented before program deployment.

1. The spatial distribution of the demand for a bikesharing program should be confirmed to determine the precise locations of stations on and off campus.

2. Bike paths connecting the stations on and off campus should be developed to ensure a seamless connection with public transportation and safe operations.

3. A cost-effective system (e.g., a dock-smart or bike-smart system) should be chosen that takes into consideration the trends in technology development.

4. The proposed bikesharing system should be integrated with existing bicycle and transportation demand management programs at UNLV to maximize complementarity.

For the success of the system, a fee structure better suited to UNLV should be developed to attract people to participate in the program. Resources to operate the system in terms of personnel and equipment, such as bicycle-redistributing vehicles, should be dedicated. Sufficient resources should be made available to maintain the system in a timely manner. In terms of the number and location of stations and the number of bikes and docks, the system should be adjusted with changing dynamics over time. For example, class schedules, which determine travel temporal patterns and spatial patterns, change each semester.

I. INTRODUCTION

Bicycles are an important transportation mode for many travelers and, in recent years, bikesharing systems have been implemented worldwide facilitating first- and last-mile connections to public transportation. Public bikesharing — the shared use of a fleet of bicycles owned and operated by a public or private entity — have been installed in a number of cities and closed-campus communities (e.g., Washington D.C. and Purdue University).

Bikesharing programs in the United States and Canada have shown great growth in the years since the first program was introduced in 1994. The introduction of programs that take advantage of information technology (IT) coincided with significant system growth. By 2009, seven systems existed in the U.S. and Canada, including four conventional reservation systems and three IT-based systems. By 2012, 39 systems were in operation in North America — 17 IT-based programs in the U.S. and four IT-based programs in Canada — as well as 18 conventional first- and second-generation bikesharing programs in the U.S. and Canada, representing a 229% increase in three years. According to a study by the Toole Design Group and the Pedestrian and Bicycle Information Center, Tulsa, Oklahoma and Washington, D.C. were early adopters of IT-based bikesharing in the United States. Many studies on bikesharing focus on such aspects as demand forecasting, location design of bike parking, bike equipment, marketing, and business models.

In Las Vegas, a total of three bikesharing program exist. Two are hosted by private companies and are closed systems available only to their employees or renters, respectively: Zappos.com and the Molasky Corporate Center. Zappos.com provides 10 Electra Townie cruisers for employees to ride around downtown Las Vegas. During office hours, employees can check out bikes from the front desk and return them after they use them. A large-scale program with 100 bikes was planned where dockless technology was proposed. This system was not implemented. The Molasky Corporate Center, located in downtown Las Vegas, unveiled the city's first bikesharing program, making 10 Electra Townie model bikes available at no charge to the building's 1,000 tenants (Warren and Sebelius, 2012). The bikes are available at the building's property services desk, and helmets and bike locks are provided as well.

In contrast to the two private systems, the Regional Transportation Commission of Southern Nevada (RTCSNV) implemented a public bikesharing system in downtown Las Vegas. Through a partnership with Bicycle Transit Systems (Bike Transit) and BCycle, 180 bicycles were distributed among 21 stations and are available 24 hours a day. Users can check out bikes for the first 30 minutes for free, and daily passes and monthly memberships are available. Initially, the authors had planned to conduct a before-and-after analysis of the RTCSNV bikesharing program. During to project scheduling, however, this part of the study was not conducted. However, copies of the surveys developed are available in Appendix A and Appendix B and can be used as a reference for other studies. In addition, a detailed description of the downtown Las Vegas bikesharing program is available in Appendix C.

UNLV is the largest public agency in Las Vegas, and trips to and from the university contribute significantly to road congestion. According to Southern Nevada Strong, Maryland Parkway, which connects downtown Las Vegas, McCarran International Airport, and UNLV's campus, has a bus line that carries the second highest bus ridership outside the Las Vegas Strip. To mitigate the congestion on a regional scale, the researchers propose to develop a bikesharing system at UNLV that has stations close to bus stops on one end and campus buildings on the other end. The researchers realize that bicycles available for work trips to UNLV could also be available for trips between buildings on campus, since these two types of trips are generated during different time periods. Additional stations could be added to fully serve the trips on campus.

The primary purpose of this study was to evaluate the feasibility of such a bikesharing program at UNLV. Specifically, the study addressed the following questions:

- Is there sufficient demand for the bikesharing program?
- How big should the system be to serve the demand?
- Can the system run in a sustainable manner?
- Would the bikesharing stations be well connected to bus stops or terminals?
- Does the university have future development plans that might influence the system?
- Is there a bicycle and pedestrian infrastructure on and off campus sufficient to allow travelers to travel from their origin to their destination?

It should be noted that the proposed bikesharing system at UNLV is isolated from the system in downtown Las Vegas, as shown in Figure 1. This setting, in which UNLV is located far from the downtown system, makes it different from bikesharing systems in other cities such as New York City, where New York University is part of the downtown system. Due to this difference, there would be no bikesharing trips generated between downtown and UNLV.

Figure 1. Location of the University of Nevada, Las Vegas (UNLV) with Respect to Downtown Las Vegas, Located Several Miles North of the Campus

To achieve the objectives of this study, the authors conducted a literature review on university bikesharing systems in the U.S. and abroad. The goals of the proposed bikesharing program at UNLV were developed, as well as metrics to monitor the program's performance. A questionnaire was distributed to UNLV faculty, staff, and students to obtain their preferences as to the locations of the proposed bikesharing stations, and the likelihood that and frequency with which they might use bikesharing. The authors used the survey responses to estimate the demand for the bikesharing system on and around the UNLV campus.

Researchers analyzed bikesharing cases with different numbers of bicycles and station locations. The demand corresponding to these stations was used as an input to a simulation model developed in this study to determine the number of docks needed at UNLV for each station and the number of bicycles in the system. These sizing parameters were used in a cost-benefit analysis to determine which scenario could achieve the maximum benefit given the limitation of the initial costs. In addition, the revenue to be generated for each case was calculated based on the estimated demand. The revenue was compared to the costs to determine which scenarios could generate sufficient funds to make the bikesharing system financially sustainable.

After determining the scale of the bikesharing system, potential multimodal nodes were evaluated, based on the location of the stations and proximity to bus transit. Researchers performed field observations to identify existing bike racks and their usage. Researchers interviewed university officials and reviewed the UNLV master plan regarding future development on and off campus in order to determine the influence these developments might have on the bikesharing program. The bike paths between the proposed bikesharing stations were audited to identify which locations might have higher conflicts between bicycles and pedestrians as well as to identify possible measures to reduce conflicts. In addition, researchers developed recommendations regarding roadway infrastructure to facilitate safer bicycling to and from campus and regarding on-campus infrastructure to facilitate bicycle navigation.

This report is organized as follows:

- Section II presents the research framework and briefly discusses the research methods.
- Section III presents a literature review that focused on university bikesharing programs in order to gather information regarding what type of system might be needed at UNLV.
- Section IV presents the goals for the proposed bikesharing system at UNLV as well as the performance metrics that could be used in monitoring the proposed system.
- Section V presents the methods and findings from a survey conducted of the university's faculty, staff, and students. In addition, a demand analysis for the bike-sharing program is estimated.
- Section VI presents a cost-benefit and financial analysis of the bikesharing program.
- Section VII analyses the transit and bikesharing connectivity at UNLV.
- Section VIII examines the existing transportation program on campus as well as future development both on and off campus.
- Section IX presents recommendations to minimize conflicts between bicycles and pedestrians.
- Section X presents overall conclusions and recommendations from the study.

II. RESEARCH FRAMEWORK AND METHODS

RESEARCH FRAMEWORK

The primary purpose of this study was to evaluate the feasibility of such a bikesharing program at UNLV. Specifically, the study addressed the following questions:

- Is there sufficient demand for the bikesharing program?
- How big should the system be to serve the demand?
- Can the system run in a sustainable manner?
- Would the bikesharing stations be well connected to bus stops or terminals?
- Does the university have future development plans that might influence the system?
- Is there a bicycle and pedestrian infrastructure on and off campus sufficient to allow travelers to travel from their origin to their destination?

The proposed system cannot go into operation without these issues being addressed. In this study, these issues are investigated, one by one, by following the framework shown in Figure 2.

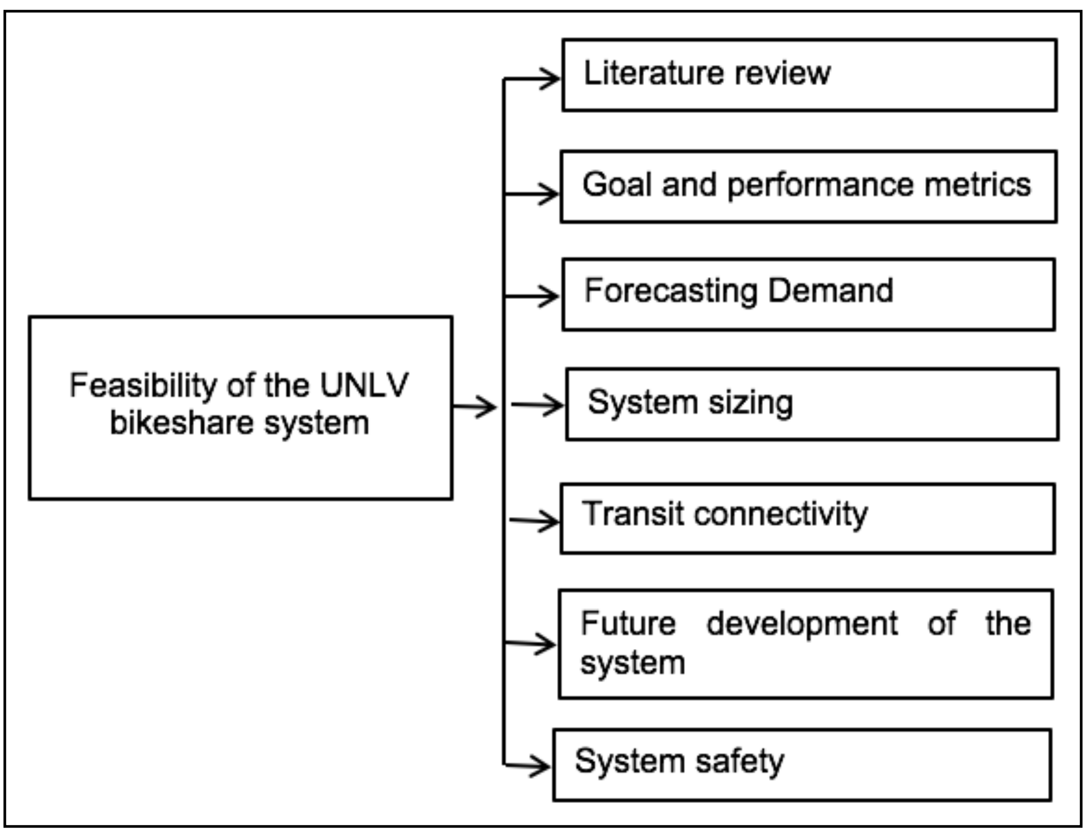


Figure 2. Research Framework

METHODS

First, the goal of the bikesharing system was developed by examining the trips that would be served by the system. With this type of investigation, it is ensured that the bikesharing system to be installed has customers to serve. These customers are the basis of the system's market for which demand can be estimated.

Second, demand for the bikesharing system was estimated based on a survey of members of the university community and ridership data from existing university bikesharing systems. The demand was analyzed to make sure that customers would use the system for real and reasonable purposes.

Third, the system's size was determined with an optimization-based, cost-benefit analysis. The benefits of having a bikesharing system include a savings in travel time by using bicycles for travel rather than walking. The costs include capital, installation, and operating costs for the lifetime of the system. The optimization process involved looking at a set of stations and the corresponding docking and fleet size to determine what could attract a sufficient number of customers to make the system sustainable. This process recognizes the relationship between the potential market and the market to be served by considering the size of the bikesharing program. To fully address the interrelationship among the number of bikesharing stations, docks, and bicycles, a simulation model was developed, making sure that these critical parameters were not estimated based on data from other systems. In addition to the cost-benefit analysis, the authors conducted a cost-revenue analysis to take into consideration the membership pricing and make sure that sufficient funds could be generated from the system's operation.

Fourth, the connectivity of the proposed bikesharing stations with transit was evaluated to ensure that buses pass close to the stations.

Fifth, the future development at UNLV was evaluated to make sure that the proposed bikesharing system could accommodate it.

Sixth, the potential for the bikesharing system to cause safety hazards was evaluated to make sure that there was sufficient roadway capacity for using bicycles. The major routes connecting the bikesharing stations were reviewed, and safety concerns were examined. This report suggests some ways to improve the roadways to support bikesharing and increased bicycle ridership on the UNLV campus.

III. LITERATURE REVIEW

Campus-based bikesharing has recently gained prominence due to the rapid expansion of bikesharing more broadly and new information technologies (IT) being deployed that support closed-campus bikesharing operations. Various studies have identified universities as the main sources and attractors for bikesharing trips. This section provides an overview of bikesharing technologies, demand for campus-based programs, operations of campus-based systems, and financial aspects of these programs. The authors also conducted a review of selected city bikesharing programs which is available in Appendix D.

A study by El-Assi et al. analyzed a station-level commercial program in Toronto and evaluated the effects of the built environment and the weather on bikesharing demand.[1] It was found that university campuses outpaced transit zones, employment density zones, and populated zones in the use of bikesharing. In a study of Minneapolis and St. Paul, Minnesota, Wang et al. revealed that the average trips taken when using city bikesharing stations located within university campuses were at least 42.6% higher than the ones located outside this zone.[2] However, in studying Bike Share Toronto, El-Assi et al. noted that the higher positive correlation between bikesharing trips and the zones on university campuses was seasonal, with fall and winter seasons exhibiting higher coefficients and reflecting student use during the academic year.[3] Their finding that university campuses are attractive to bikesharing users was consistent with findings by Hampshire and Marla from a study based in the cities of Barcelona and Seville, Spain.[4]

BIKESHARING TECHNOLOGIES

Existing literature categorizes public bikesharing into four key phases or generations:[5]

1. First Generation—Free Bikes: Bicycles were placed throughout an area that could be freely accessed by the public.

2. Second Generation—Coin-deposit Systems: Users were required to deposit a coin into a dock, check out a bicycle, and return the bicycle to a dock where their deposit was returned.

3. Third Generation—IT-based Systems: Bicycles are made available at digital bike-sharing kiosks that are capable of accepting RFID, credit, and/or debit cards for membership payment or usage.

4. Fourth Generation—Advanced IT-based Bikesharing Systems: Bikesharing networks that include advanced IT features such as demand-responsive rebalancing (e.g., real-time information that informs the system where there are imbalances in supply and demand) and may include dockless station strategies; electric bikes; transit linkages; and mobile, solar docking stations.[6]

Third and fourth generation IT-based bikesharing (the focus of this feasibility study) utilize electronic and wireless communications for bicycle pick up, drop off, and tracking. North America's first IT-based bikesharing system, Tulsa Townies, started operating in 2007 in Tulsa, Oklahoma. In 2008, this was followed by the launch of SmartBike in Washington, D.C.

The typical design of third and fourth generation IT-based systems include docking stations; kiosks or user interface technology for check in and check out; and advanced technology (e.g., magnetic stripe cards, smartcards, smart keys). Typically, these systems enable program operators to track bicycles and access user information that can improve system management and deter bicycle theft. More recent innovations include multimodal billing integration, real-time transit information integration, GPS tracking of bicycles, dynamic pricing (to reduce the need to “rebalance” or relocate bicycles), and flexible and dockless bikesharing systems.

A number of bikesharing vendors, such as Social Bicycles (known as SoBi), offer flexible and dockless equipment using smart bikes. Typically, these bicycles host the locking system on the bicycle itself, enabling users to pick up and drop off bicycles anywhere within a geographic area by either “docking” the bicycle to a station or “locking” the bicycle to an existing bicycle rack or street furniture.[7] With flexible and dockless systems, users identify bicycle availability and locations in real time through mobile or Internet applications or bikesharing kiosk screens. Finally, the geographic proximity of a bikesharing bicycle (docked and dockless systems) may be limited through a technique known as “geofencing.” A geofence is a virtual perimeter that limits the range of mobility of an enabled bicycle by comparing the GPS satellite coordinates of the bicycle, preventing usage outside of the allowable geographic area.[8]

Bikesharing can be deployed as either “open systems” available to the public or “closed community systems” with access limited to predefined groups, such as members of a university community, residents of an apartment complex, or employees of a particular employer or office park (Shaheen, et al., 2016).[9] These closed-campus systems are available only to the particular campus community they serve. Closed systems typically exclude ineligible users through a combination of mechanisms such as limiting user access as well as employing techniques like geofencing to limit equipment functionality outside a designated campus area.

As of 2013, at least 33 universities in the United States had a bikesharing program (Maynard, 2013).[10] In the fall of 2016, Zipcar announced a partnership with Zagster to launch Zipbike, a campus-based bikesharing program, on 10 college campuses across the United States in January 2017 (McFarland, 2016).[11]

DEMAND FOR CAMPUS BIKESHARING PROGRAMS

Various studies have utilized a questionnaire to quantify the demand for a bikesharing program.[12] Brougham et al. at Dalhousie University in Halifax, Nova Scotia analyzed 800 responses and showed “… that 63% of Dalhousie students were interested in a bike-sharing program; 43% of students would use a bike-sharing program for free or for a small fee and 20% would only use the program if it were free.”[13] Bowmick and Varble conducted the feasibility study for having a bikesharing program at Indiana State University. These authors distributed more than 12,000 online questionnaires to faculty and students through the Student Government Association, and 398 valid surveys were used for the data analysis. The analysis revealed that around 65% of the respondents were willing to use a bikesharing program if it was made available on campus.[14]

The same trend was observed by Zonobi and Melara at San José State University in California, where results showed that 69% of the students and 57% of employees would use the program. The survey response rate was 6.2% and 10.3% for students and employees, respectively.[15] At Bridgewater State University in Massachusetts, Ashley collected 252 responses (32 electronically and 220 by paper) from students, faculty, administrators, and staff. It was discovered that 84% of the respondents would like to participate in a bikesharing program.[16] Among these studies on university bikesharing programs, most (40%) wanted to use the system for travel between classes, with a typical use of four times or more every week during the semester.[17]

Actual demand may differ significantly from survey results. Kyung summarized the results of a survey across 41 universities located in the United States that had bikesharing or bike rental programs. Kyung revealed that 83% of these universities had 1,000 members or fewer, and more than 50% had 250 members or fewer.[18] This situation calls for more advanced methodologies to quantify the demand prior to establishing the program.

OPERATION OF CAMPUS BIKESHARING PROGRAMS

Campus bikesharing programs can be owned either by the university, a private company, or jointly; bikes can be rented by means of traditional renting, a bike library, or the use of smart docks/bikes. Kyung found a significant portion (37%) of bikesharing programs were owned by universities, and 73% were operated by universities. Traditional renting and a bike library were the rental modes used by most university programs (45%). Smart bikes accounted for only 5%, and kiosks accounted for 15%. Further, 44% of the universities operated their bikesharing programs year-round, and 77% of the programs operated during semester breaks. A significant number of universities stopped operating the program between January and February.[19]

At Purdue University in Indiana, McNamara and Mathew found that 15,259 rentals occurred during the first 14 weeks of their bikesharing program. This program had 77 bikes and 13 locations. The most-used bike was rented 450 times within that period, even though some bikes remained idle for as long as 100 days. The peak day had 52 bikes out of 77 that were checked out. Weekends had a very low frequency of bike usage.[20]

On the Danforth Campus of Washington University in Saint Louis, Heda determined that 13 bike stations equipped with 350-400 bikes best served student travel.[21] This number of bikes was higher than the average number reported by Kyung, who had found that among the respondent universities, 37% (15 universities) had 50 or more bikes, 8% had more than 200 bikes in their systems, and 18% had 50-100 bikes. Regarding the number of stations, two extremes were observed: 53% of the universities had fewer than or equal to five bike stations, while the rest had seven or more. Most universities (33%) had 10-20 bikes at one station.[22]

FINANCIAL ASPECTS OF CAMPUS BIKESHARING PROGRAMS

Using survey methods, Ashley found that faculty, staff, and administrators were willing to pay a higher membership fee than students. Most respondents would prefer a monthly or yearly subscription-based service with the option to pay using cash or credit cards.[23] Respondents in a study by Bhowmick and Varble mostly indicated they preferred a daily charge of $3 and the yearly charge of $20-$50.[24] Roughly the same amount for a membership fee was reported by Zonobi and Melara, who found that most of the students and employees were willing to pay up to $3 a day and $29 a month for usage.[25] Kyung reported that for most universities (40%), there were no membership fees charged, and the university helped subsidize the cost of the program.[26] Only 3% of the universities collected membership fees from the student fees in order to fund the program. Other funding sources included private companies and student congresses, among others.

The initial capital to establish a bikesharing program ranged from less than $4,000 (for bike renting only) to greater than $200,000 (bikes rented out for a short period of time like 30 minutes with GPS tracking), and most of the universities (53%) were in the range of $0-$100,000. The annual operating cost for most of existing bikesharing programs (57%) was found to be $65,000 or less.[27] Ashley indicated that an IT-based bikesharing system using cell phones would cost $1,100 per bike for purchase; approximately $100/bike for shipping and onsite assembly; $8/bike/month for wireless connectivity and hosting; and 10% of revenues booked on the platform.[28] With three levels of varying technology options for 32 bikes proposed by Bhowmick and Varble, the startup costs and operating costs were estimated to be from $21,896-$163,668 for high-tech bikes and from $2,480-$5,240 for low-tech bikes. The study pointed out that the program revenue would come from a user subscription, with additional sources from sponsors.[29] Work, et al., estimated the total cost for 24 bikes to be $118,345, while the expected annual revenue was forecasted at $702,000.[30] Heda estimated the capital cost ranging between $425,000-$475,000 and the yearly operating cost to be $140,000. The largest portion of the capital cost was estimated to be for equipment purchase and installation.[31]

IV. GOALS OF A BIKESHARING PROGRAM AT UNLV AND PERFORMANCE METRICS TO ASSESS PROGRAM IMPLEMENTATION

A bikesharing program at a university may serve a variety of trip purposes:

1. Part of a commute to campus (for work or school);
2. Travel between offices for employees;
3. Travel between classes on campus for students; and
4. Travel between the university and nearby community.

The primary goal of the bikesharing program at UNLV is to reduce road congestion by increasing usage of public transportation by providing the infrastructure for the last mile traveled. A secondary goal is to improve productivity on campus. By reducing travel time on campus, people can save time for other activities. The availability of a bikesharing program may also mitigate demand for parking by providing an alternative mobility option to single-occupant vehicle travel.

To measure the performance of the bikesharing system in reducing road congestion, the following metrics could be used:

- Commute trips using the bikesharing program made during peak and non-peak periods.
- Bus stops from which commute trips are made using the bikesharing program.
- Areas in the Las Vegas Valley from which commute trips are made using the bike-sharing program.
- Monthly and yearly trends of bikesharing commute trips.

In addition to these performance measures, other macroscopic measures of the bikesharing system for commuting are:

- Number of bikesharing stations accessible from a bus stop.
- Number of bus stops from which a traveler to UNLV could access a bikesharing station.
- Number of faculty and students who take buses to campus.
- Number of trips made by UNLV faculty and students to campus.

The data for these performance measures can be obtained from such sources as the bus management system maintained by the bus operating agency in the Las Vegas area.

To measure the performance of the bikesharing system for on-campus travel, the following metrics could be used:

- Total number of daily, monthly, and annual trips made on campus.
- Trip patterns from origin to destination, by time periods during the day, of faculty, students, or others.
- Travel time by bikes.

In addition to performance measures related to congestion and productivity, there are performance measures related to the system facilities.[32]

Fleet Performance and Safety

- Number of bicycles that are in service.
- Number of bicycles that are inspected/repaired each month.
- Number of bicycles that are damaged each month.

Fleet Utilization

- How often stations are full or empty.
- How long stations are full or empty.
- Frequency of rebalancings (e.g. during a specific time period).
- Number of trips each bike made.
- Duration of idle time for a bike during a trip.

Customer Service

- Number of incoming calls.
- Number of lost calls.

Membership

- Total number of users.
- Total number of regular users.
- Total number of occasional users.
- Number of new members.

V. FORECASTING DEMAND FOR A BIKESHARING PROGRAM AT UNLV

In this section, a survey is described, including how it was developed and distributed. Descriptive statistics are presented about the responses to the survey. The factors causing people to choose to use the bikesharing program are analyzed based on the survey data using a probit discrete choice model. Actual demand was estimated based on UNLV's population of faculty, staff, and students, as well as the percentage of the population likely to use the bikesharing program.

The demand for a bikesharing program at UNLV was estimated based on a stated-preference method. According to Kroes and Sheldon, the stated-preference method enables the researcher to extract individual preferences for alternatives with which he or she may not have any experience or for which the alternatives do not exist yet.[33] Numerous methods fall under the stated-preference method, including contingent valuation, group valuation, and discrete choice experiments.

One of the advantages of this method is that it allows researchers to have relatively good-quality information at a relatively low cost. In travel-demand studies, the stated-preference method has been used to determine commuter behavior with respect to introduced or improved transportation systems.[34] However, use of stated-preference data in forecasting does have some limitations because it is hypothetical and is less likely to account for all types of practical constraints.[35]

Using the stated-preference method for this study, a survey was conducted and a choice model was developed for data analysis. Given this methodology, the following steps were used to estimate the demand for a bikesharing program at UNLV.

1. A survey was conducted; this involved designing, distributing, and collecting the surveys. After the surveys were collected, they were processed for analysis.

2. Demand analysis was conducted that pertained to the factors that might influence respondents as to their likeliness and frequency of using the bikesharing program at UNLV. Ordered probit models were developed to measure these factors.

3. Demand was estimated based on UNLV's population of faculty, staff, and students, as well as the percentage of the population likely to use the bikesharing program. The percentage was determined based on the respondents' statements as to their willingness to use the bikesharing system and the uncertainty of those statements. The uncertainties were determined based on the range of trips made by the bike-sharing programs at other universities.

SURVEY DESIGN, DISTRIBUTION, AND COLLECTION

In designing the survey, questionnaires were developed to solicit the likeliness that an individual might choose the bikesharing program for either commuting or on-campus activities. They included questions about demographics, socioeconomic conditions, education level, income level, and home location by zip code. Questions regarding background information of the people being surveyed included their current mode of transportation to the university. The survey had a description of the bikesharing program, and respondents were asked whether they would use the program for commuting and on-campus travel. In addition, they were asked about the purposes for choosing to use the bikesharing system.

Figure 3 shows the locations of the potential bikesharing stations for both commuting and the on-campus travel that was presented in the survey. Based on the map, if respondents expressed a willingness to use the bikesharing system, they were asked at which locations they might pick up and drop off the bikes as well as the number of trips they would make. For on-campus travel, questions were asked about the trip purposes, such as going to class or attending meetings.

Bikesharing stations on the periphery of the campus were chosen because of their connection to transit services as well as the number of autos in and out of campus in each direction. The number of bus stops within a 400-meter radius of the station was used to measure bus connectivity. The traffic flow of automobiles in and out of campus represented the potential that people would shift their travel mode from auto to public transportation. Traffic flows in and out of the campus (shown in Figure 4) were obtained from the travel-demand model of the Regional Transportation Commission of Southern Nevada.

The potential stations on campus were identified based on data about student enrollment and building occupancy of faculty and staff (see Appendix F). These data were used to determine the percentage of building utilization falling within the service area of each bike station. Distribution of stations inside the campus was based on the following factors:

- Walking Distance. A walking distance of 400 meters was assumed for a user to have access to a given bike station.

- Accessibility. A selected station should be accessed easily by users from any direction.

- Building Service Type. The service area of any selected bike station should consist of buildings that provide several different functions such as libraries, classroom complexes, offices for faculty, staff and students, and residential buildings. This would ensure that all bike stations could service the intended users of the university: faculty, staff, and students.

Survey responses regarding the likelihood of using the bikesharing program can be used to analyze the characteristics of the people who would use the system. When combined with the frequency of the trips respondents indicated they would make, the demand can be estimated. Information on where they checked a bike out and in can be used to determine the origin and destination of their trip, and then to determine the location of the bikesharing stations.

A complete survey is provided in Appendix E for reference.

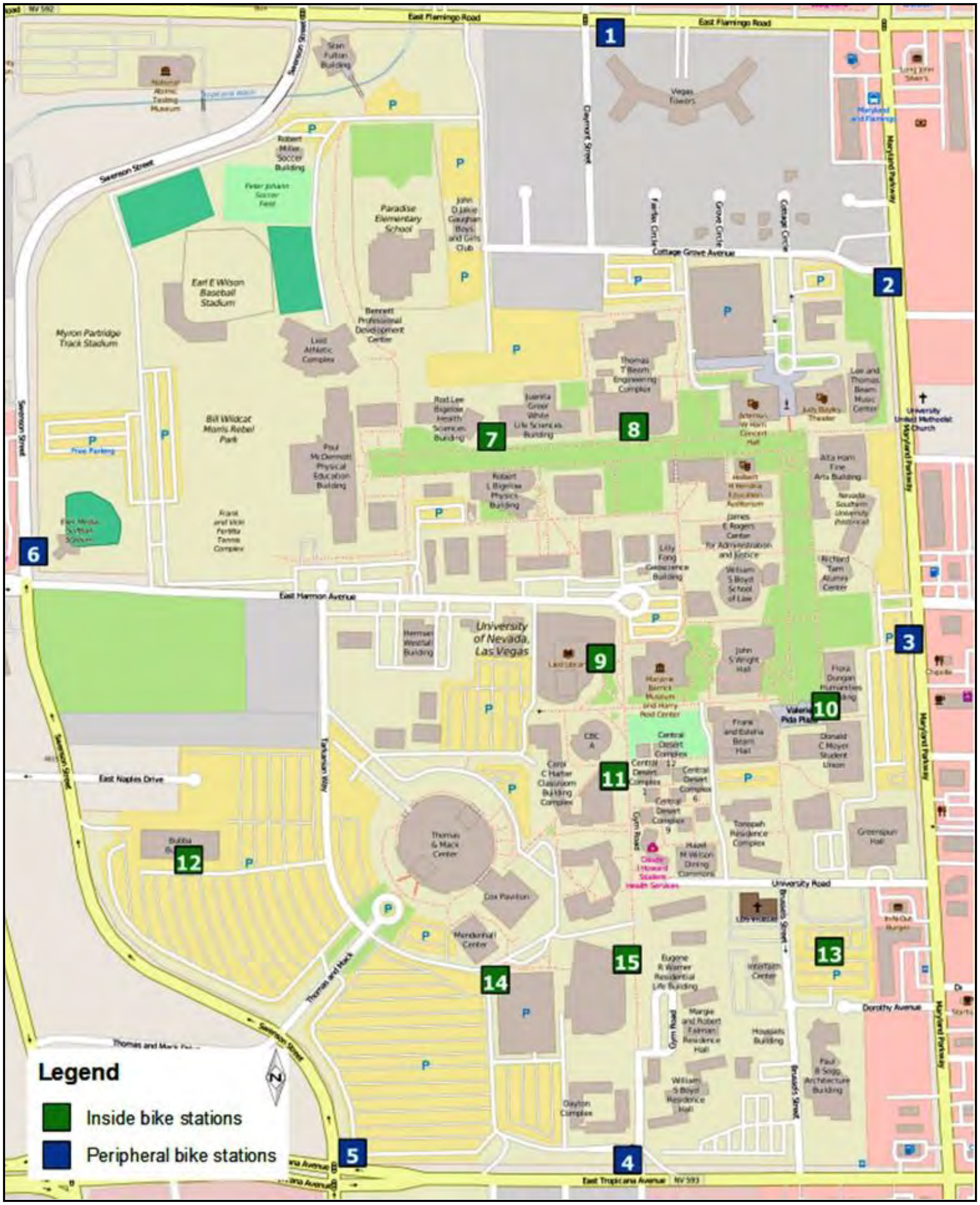


Figure 3. Proposed Locations for Bikesharing Stations on the Main Campus of UNLV

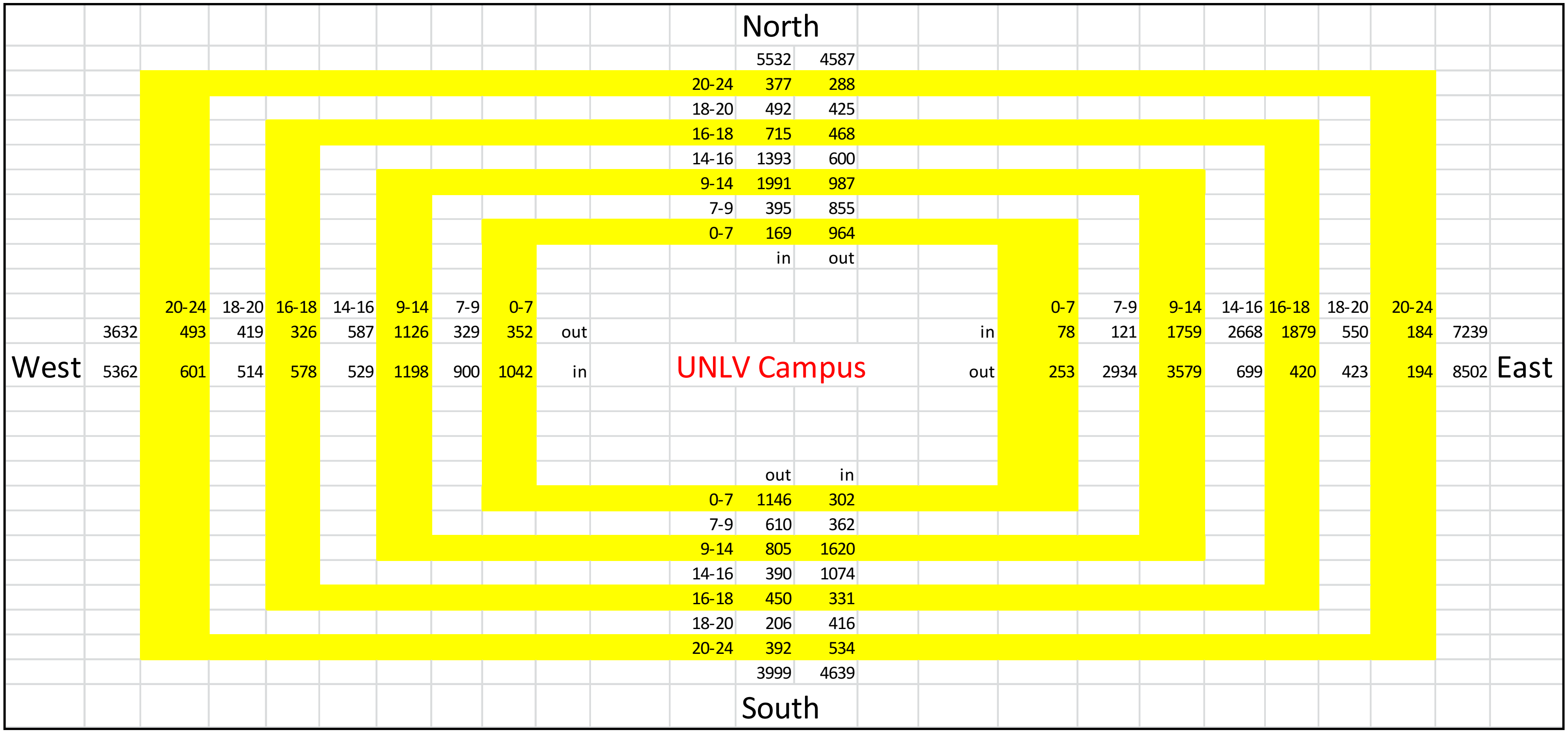


Figure 4. Traffic Flow In and Out of the UNLV Campus

The research team first developed the questionnaire, which was reviewed by a professional who had extensive experience in conducting surveys. After it was revised several times, it was approved by UNLV's Institutional Review Board before it was distributed to the faculty, staff, and students.

The survey was distributed by using Qualtrics software.[36] The survey designed in this study was coded in Qualtrics such that a uniquely identifiable web link was provided to those being surveyed. The people who received an announcement requesting their participation in the survey were able to log onto the link and fill out and submit the survey electronically.

Announcements about the survey were sent to the university population in various ways.

- First, the announcement was made on UNLV Today (http://www.unlv.edu/news/unlvtoday), an electronic newsletter sent out to faculty and staff. Viewers could choose to participate in the survey right away or sometime later.

- Second, the announcement was sent to the entire university population by email to make sure that each member of the UNLV community had the opportunity to participate. Email announcements were sent out three times: first by the communications director at UNLV's College of Engineering, followed by counterparts in other colleges and schools of the university. Unfortunately, during the time of sending out these notices, there was a transition from one person to another in the position of communications director at the College of Engineering; however, both distributed the announcement the same way.

- Third, the students associated with transportation studies were highly encouraged by their faculty to participate in the survey.

FINDINGS

Descriptive Statistics of Survey Responses

After four months of sending out the survey (August to December 2015), researchers collected 241 responses and analyzed them in this study. The survey was distributed to the entire university of 31,500 faculty, staff and students. Even with a small response rate of 0.76, the sample size was sufficient to conduct demand analysis. These 241 respondents included 38 faculty members, 74 staff, 110 full-time students, six part-time students, and five other people not in these categories. Among the responses, 113 were males and 122 were females; six respondents did not reveal their gender. Regarding age, about 80% of the respondents were 50 or younger, and most respondents (80) were between 21 and 30 years old, as shown in Table 1. This observation is consistent with the age distribution among the university community.

Table 1. Age Distribution of the Respondents

Age Category	Count	%
<20	32	13
21-30	80	33
31-40	52	22
41-50	35	15
51-60	26	11
61-70	9	4
>71	3	1
No response	4	2
	241	

Table 2 presents the education profile of the respondents**.** Of the 231 respondents who answered this question, 16 had a high-school education, 41 had a bachelor's degree, and 51 had other college degrees; 35% of the respondents (82) did not reveal their education levels. The implicit observation is that most of them were undergraduate students since they either had a high-school education, college credits, or some other degree.

Table 2. Education Profile of the Respondents

Education Level	Count	%
Grade 12 or less	0	0
High-school graduate	16	7
Some college credit	2	1
Assoc./tech school degree	3	1
Bachelor's degree	41	18
Graduate degree	3	1
Some other degree	51	22
Prefer not to answer	82	35
No response	33	14
	231	

The survey responses revealed the annual incomes of the respondents clustered around two ranges, a lower level of around $10,000-$19,000 and a higher level of around $75,000-$99,999 (see Table 3). The lower level may represent students and the higher level faculty and staff.

Table 3. Income Profile of the Respondents

Income	Count	%
Less than $10,000	28	12
$10,000 to $19,999	33	14
$20,000 to $29,999	17	7
$30,000 to $39,999	10	4
$40,000 to $49,999	19	8
$50,000 to $59,999	13	6
$60,000 to $74,999	21	9
$75,000 to $99,999	25	11
$100,000 to $124,999	4	2
$125,000 to $149,999	1	0
$150,000 to $199,999	3	1
$200,000 or more	3	1
Prefer not to answer	14	6
Do not know	5	2
No response	35	15
	231	

Among the respondents who answered this question, 184 (74%) drove to the university, 19 (8%) biked, and 11 (5%) walked. Only eight (3%) used the bus and two were in the "Other" category, one of them using a motorcycle (see Table 4). On average, these respondents took 24.16 minutes to get to the campus, regardless of the modes they took. The standard deviation of the travel time was found to be 14.48 minutes.

Table 4. Respondents' Distribution by Current Mode of Transportation

Mode	Count	%
Car	184	76
Bus	8	3
Bike	19	8
Walking	11	5
Other	2	1
No response	7	3
	231	

Among 241 respondents, 231 respondents lived off campus and 10 lived on campus. Among the respondents who lived off campus, 105 were full-time students. The presence of a high percentage of student respondents who live off campus and whose current mode of transportation to UNLV is by car implies that UNLV is a commuter school.

Figure 5 shows the distribution of respondents according to the zip codes of their residences. It can be observed that their locations covered almost every part of the Las Vegas metropolitan area. However, most respondents (74) came from the zip codes that border the university's zip code.

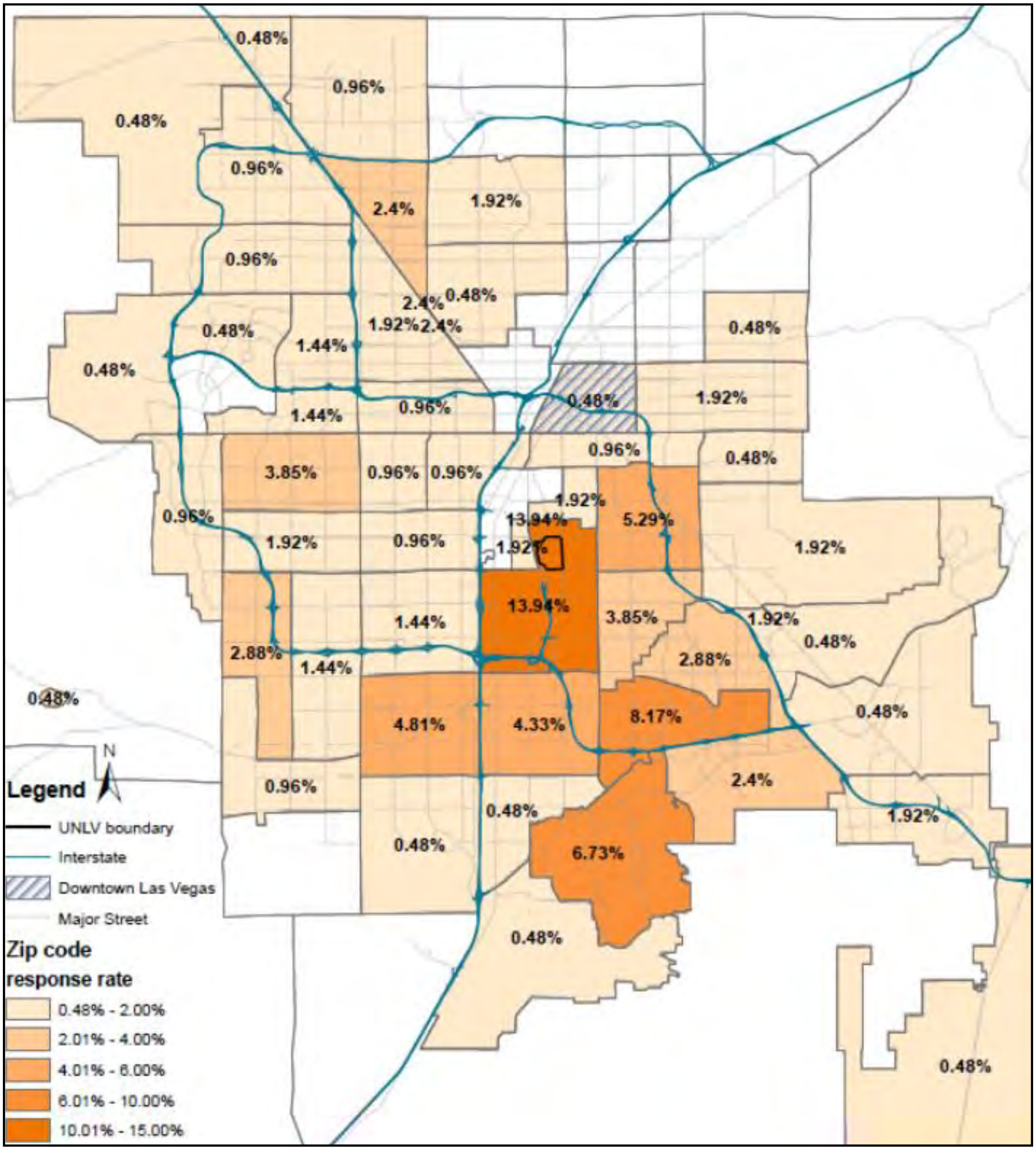


Figure 5. Distribution of the Respondents by Zip Code

Whether users have an office on campus is important in understanding the possible origins and destinations of the users of a bikesharing program. The survey revealed that among the 241 respondents, 154 (64%) had offices on campus and 70 (30%) did not. Among those 154 respondents who had an office on campus, 37 (24%) were faculty, 69 (45%) were staff, 40 (26%) were full-time students, and 1% were part-time students.

Whether it was likely that the respondents would use the bikesharing program was the most important part of the questionnaire. The responses indicated that of the 231 respondents, 50 chose "Very Likely" and 66 chose "Somewhat Likely" to use a bikesharing program for commuting. The total of these two groups of respondents are about 50% of all those who participated in the survey; this percentage is much higher than those choosing "Somewhat Unlikely" and "Very Unlikely" (10% + 27% = 37%). The same trend was observed for on-campus activities. About 66% of the respondents either were very likely or somewhat likely to use the bikesharing system for their day-to-day movements within the campus (Table 5).

Table 5. Likeliness to Use a Bikesharing Program

	Commuting		On Campus Activities	
Likelihood	**Count**	**%**	**Count**	**%**
Very likely	50	22	88	37
Somewhat likely	66	29	69	29
Neutral	21	9	22	9
Somewhat unlikely	23	10	14	6
Very unlikely	62	27	25	10
No Answer	9	4	13	5
	231		231	

The on-campus trips could occur in varying frequencies. Table 6 indicates that about 30% of the respondents would make such an on-campus trip once a day, making the bikesharing program significant at UNLV.

Table 6. Frequency of Use of the Bikesharing Program

	Count	%
Once a month	29	13
Once a week	67	29
Once a day	61	26
More than once a day	25	11
No response	49	21
	231	

The respondents indicated that on-campus trips would be for various purposes, the most popular being attending meetings and going to classes. Going to the library also was noticeably popular. The other trip purposes, as shown in Table 7, include going to work out, going to have lunch, trips for work, and other miscellaneous activities. These trips are popular off campus as well and would benefit from the bikesharing program.

Table 7. Purpose for Using the Bikes

	Count	%
Going to library	23	10
Attending meetings	61	26
Going to classes	58	25
Miscellaneous	40	17
No response	49	21
	231	

The motives for using the bikesharing program were identified as well. Table 8 indicates that more than half of the respondents expressed that they were likely to use the program due to either the convenience or the health benefits. Cost and security benefits also were significant motives, as revealed by around 30% of the respondents. Respondents were asked to explain if any other benefits/motives might influence them to use the program. They stated several reasons, including being able to get around campus without needing a golf cart (commonly used by university employees), the ability to get around campus faster, exercise, and other bike security reasons.

Table 8. Motives for Using the Bikesharing Program

	Count	%
More convenient	82	71
Benefit to health	74	64
Not expensive	41	35
Bike security	33	28
Other	7	6

As shown in Table 9, when asked which stations were most likely to be used to check out a bike, the majority of respondents chose Station 4, followed by Stations 1, 2, 3, 5, 6, 7, and 9 (see Figure 3 for locations of these stations). The reason for choosing these stations might be that the respondents could drive to school and park at a location close to a bikesharing station, and from there bike to their destination on campus. That may be the reason that some stations inside campus also were chosen for commuting.

Table 9. Stations for Commuting and for On-Campus Activities

	Commuting		On-Campus Activities	
Station ID	**Count for Check Out**	**Count for Return**	**Count for Checking Out**	**Count for Checking In**
1	46	0	1	1
2	22	0	13	5
3	13	0	3	3
4	66	0	0	0
5	10	0	3	1
6	5	0	3	0
7	1	10	16	13
8	0	58	62	29
9	1	19	28	17
10	0	25	26	65
11	0	15	6	27
12	0	7	5	13
13	0	2	3	0
14	0	2	4	4
15	0	9	13	14
16	0	0	0	3
No response	67 (29%)	84 (36%)	45 (19%)	36 (15%)
	231	231	231	231

The station chosen most for returning bikes was Station 8, perhaps because a significant number of respondents have their destinations located close to Station 8, such as TBE, the engineering building. Other stations chosen for returning bicycles were Stations 10, 9, 11, 15, 12, 13, and 14. No one specified other locations.

In addition, Table 9 indicates the preferred stations for on-campus activities. The stations most popular for checking out a bike were Stations 8, 9, 10, 7, 15, and 2, which correspond to the major origins of the trips on campus, such as the College of Engineering. The stations mostly chosen to return a bike were Stations 10, 8, 11, 9, 15, 12, and 7. These stations are close to the major destinations of the trips on campus.

It should also be noted that many responses to the survey did not specify the stations where respondents would check out and return their bikes, particularly for the commuting trips. It can be perceived that the origin and destination information for on-campus trips is more reliable.

DEMAND ANALYSIS METHODOLOGY

Demand for the bikesharing program at UNLV was analyzed based on developing ordered probit models for how likely and frequently people would use the system for commuting and on-campus travel. By analyzing the models, factors that influence the likelihood of the bikesharing program being used can be identified. In addition, measures to improve demand for the program can be derived from the analysis.

Based on Greene, an ordered probit model was built around a latent regression model:

$$y^* = \sum \beta_i X_i + \varepsilon, \quad (1)$$

where X_i represents explanatory variables that influence the extent of the likelihood of use and frequency of use; y^* is the dependent variable that is *unobservable*, and represents the extent of likeliness and frequency; β_i represents the coefficient for X_i; and å denotes the error term.[37] Let y represent the *observed* likeliness and frequency. Based on the ordered probit model, y can be determined by the unobserved variable y^* as follows:

1. $Y = 1$ if $y^* \leq 0$,
2. $= 2$ if $0 < y^* \leq \mu_1$,
3. $= 3$ if $\mu_1 < y^* \leq \mu_2$, (2)
4. $= 4$ if $\mu_2 < y^* \leq \mu_3$,
5. $= 5$ if $y^* \geq \mu_3$,

The μ represents unknown parameters that need to be estimated with β. Under the assumption that the error term ε is normally distributed across observations, and its mean and variance are normalized to 0 and 1, respectively, the probabilities for y can be derived and used to estimate the parameters of b and m using the maximum likelihood method.

Table 10 lists all the variables used in modeling the likelihood and frequency of using the bikesharing program. The variables used in the models for the likelihood are different from those in the models for the frequency, and they are listed in the tables below when the corresponding models are introduced.

Table 10. Description of Variables

Variable name	Variable type	Description
Dependent variables		
Likely for commuting	Categorical	1. Very likely; 2. Somewhat likely; 3. Neutral; 4. Somewhat unlikely; 5. Very unlikely
Likely for on campus travel	Categorical	1. Very likely; 2. Somewhat likely; 3. Neutral; 4. Somewhat unlikely; 5. Very unlikely
Frequency of use	Categorical	The frequency of use of the bikes; 1. Once per month, 2. Once per week, 3. Once per day, 4. More than once per day.
Independent variables		
faculty	Binary	1 for faculty and staff, 0 for others
student	Binary	1 for part-time and full-time students, 0 for others
gender_male	Binary	1 for male, 0 for females
use_own_car	Binary	1 if a person uses his/her own car to come to UNLV, 0 for other modes
use_bus	Binary	1 if a person uses a bus to come to UNLV, 0 for other modes
use_own_bicycle	Binary	1 if a person uses his/her own bicycle to come to UNLV, 0 for other modes
walk	Binary	1 if a person walks to come to UNLV, 0 for other modes
bus_lineyes_no	Binary	1 if there is a bus line in the respondent's zip code, 0 for no bus line
go to library	Binary	1 if intended to use bike to go to library, 0 for no
go to meeting	Binary	1 if intended to use bike to go to meeting, 0 for no
go_classes	Binary	1 if Intended to use bike to go to classes
convenience reason	Binary	1 if stated using the program for convenience
health reason	Binary	1 if stated using the program for health
inexpensive reason	Binary	1 if stated using the program because it is inexpensive
bike security reason	Binary	1 if stated using the program because of bike security
o_d_distance	Continuous	distance from origin building to destination building in miles
orgn_station_dist_100ft	Continuous	distance from origin building to origin station in 100 feet
station_dest_dist_100ft	Continuous	distance from destination station to destination building to origin station in 100 feet
income_rec	Categorical	Income; 0. Less than $20 k; 1. From $20 k to 59,999; 2. From $59,999 to 200 k or more
trans_mode	Categorical	Current transportation mode; 0. Walking and others modes; 1. Car; 2. Bus; 3. Bicycle

Likelihood of Using the Bikesharing Program for Commuting

The results of the ordered probit model for the likelihood of using the bikesharing program for commuting are presented in Table 11. The variable for likelihood of use was coded as 1 for Very Likely, 2 for Somewhat Likely, 3 for Neutral, 4 for Somewhat Unlikely, and 5 for Very Unlikely. The independent variables include:

- Distance from residences by zip code to their destinations on campus;
- Distance from the check-in stations to the destinations of the users;
- Whether any bus line connects from the zip code areas to UNLV;

- Income level (between $20,000-$60,000; more than $60,000; prefer not to say);
- Transportation mode currently used to come to UNLV (car, bus, their own bicycle);
- Arrival time to UNLV (before 8 a.m., between 8 a.m. to 12 p.m.); and
- Education level (high school, college and associate degree, bachelor degree, graduate degree, and others).

Table 11 shows that the coefficient for the distance between where the users would return the bikes to where their buildings are located was positive, implying that they are less likely to use shared bikes in their last or first mile for commuting. This observation makes sense, and is consistent with studies by Fuller, et al. and Bachand-Marleau, et al.[38] This observation suggests locating bikesharing stations close to buildings where offices are located.

The coefficient for respondents having a bus line connecting where they live to UNLV is negative, implying that they would tend to use the bikesharing program. It suggests that bus lines should be well connected to the communities to attract more people to use the program.

The coefficient for high-income users is positive, implying that they would tend not to use the bikesharing program for commuting, which is understandable. The variable for users driving to school has a positive coefficient, which implies that they are less likely to use the program for commuting. This is reasonable as well.

The coefficient for users who come to UNLV before 8 a.m. is positive, meaning that they are less likely to use the shared bikes to come to school. The reason for this may not be straightforward. Coming to school before 8 a.m. may mean that time is limited for them, which may cause them to use other modes having fewer travel transfers.

Table 11. Ordered Probit Model for the Likelihood of Using the Bikesharing Program for Commuting

Ordered probit regression			**Number of observations**		=	**161**
			LR chi²(14)		=	**95.79**
			Prob > chi²		=	**0**
Log likelihood = -190.52611			**Pseudo R^2**		=	**0.2009**

Likelihood to use shared bikes for commuting	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95% Confidence Interval]**	
Origin destination distance (mi)	0.512	0.525	0.970	0.330	-0.517	1.542
Check-in station to destination distance (100 ft.)	0.063	0.036	1.780	0.075	-0.006	0.133
Bus line (yes/no)	-1.549	0.215	-7.200	0.000	-1.971	-1.127
Income level						
Between $20,000-$60,000	0.232	0.259	0.900	0.370	-0.276	0.741
More than $60,000	0.791	0.280	2.820	0.005	0.241	1.340
Prefer not to say	0.451	0.355	1.270	0.203	-0.244	1.147
Transportation model to UNLV						
Car	0.733	0.414	1.770	0.077	-0.078	1.544
Bus	-0.181	0.649	-0.280	0.781	-1.454	1.092
Their own bicycle	0.615	0.501	1.230	0.220	-0.367	1.598
Arrival time to UNLV						
Before 8 a.m.	0.383	0.216	1.770	0.076	-0.041	0.807
Between 8 a.m. to 12 p.m.	-0.424	0.336	-1.260	0.207	-1.083	0.234
Education level						
High school, college, or associate's degree	0.701	0.330	2.120	0.034	0.053	1.348
Bachelor's degree	0.651	0.278	2.340	0.019	0.105	1.196
Graduate degree and others	0.041	0.258	0.160	0.873	-0.464	0.546
/cut1	-0.347	0.483			-1.293	0.600
/cut2	0.929	0.492			-0.035	1.893
/cut3	1.260	0.496			0.288	2.231
/cut4	1.745	0.500			0.764	2.725

The coefficients for the variables of having lower education degrees are positive, which indicates that these people would tend not to use the bikesharing program for commuting compared to users having higher education.

The ordered probit models were developed for how frequently the respondents would use the bikesharing program for commuting, and results are presented in Table 12. In general, the coefficient for being male was negative for frequency of commuting travel; this implies that male users would use the program more frequently than females. The coefficient for prospective users who have offices within the campus was positive, which implies that they would tend to use the bikesharing program for commuting less frequently. This observation may indicate that people who do not have an office on campus, such as students, would tend to use the program more frequently than those who have an office on campus, such as faculty and staff.

The coefficient for faculty members was positive as well, suggesting that faculty would tend to use the bikesharing program less frequently. They might have a fixed travel choice already that they may not want to change. The coefficient for people who take a longer time to get on campus, by taking a bus and walking, is positive; this implies that these people would tend to use the bikesharing program for commuting less frequently. This observation is contradictory to common sense and needs more investigation. The coefficient for users with graduate degrees or higher is positive, which implies that they would tend not to use the system as frequently as those with other degrees. This finding is understandable because they may have high incomes and thus not pay attention to the bikesharing program.

How Frequently the Bikesharing Program Would Be Used for Commuting

Comparing the results from the ordered probit model for the likelihood of using the bikesharing program with the model for how frequently the program would be used for commuting (Table 12), it can be seen that the factors influencing people to use a bikesharing program are different from those that determine who would use the program more frequently. First, the distance between the stations where the bikes are returned and the buildings that are destinations is not an influential factor in the decision to use the bikesharing program more frequently for commuting. Whether there is a bus line in the respondents' neighborhood also is not a factor in whether they would use the program more frequently. The factors that are important are gender and whether they have an office on campus. People with lower education do not show a significantly high tendency to use the bikesharing program; however, they do show that they are likely to use the program more frequently than people having higher education.

Table 12. Ordered Probit Model for the Frequency for Commuting

Ordered probit regression			**Number of observations**		**=**	**178**
			LR $chi^2(6)$		**=**	**40.15**
			Prob > chi^2		**=**	**0.000**
Log likelihood = -212.136			**Pseudo R^2**		**=**	**0.0865**
Frequency of using bikes for commuting	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95% Confidence Interval]**	
Gender (male)	-0.437	0.169	-2.590	0.010	-0.767	-0.106
Have office in campus	0.523	0.254	2.060	0.039	0.026	1.020
Faculty member	-0.826	0.214	-3.860	0.000	-1.245	-0.407
Education level						
High school, college and associate degree	0.390	0.320	1.220	0.223	-0.237	1.017
Bachelor degree	0.224	0.215	1.040	0.297	-0.198	0.647
Graduate and others	0.765	0.250	3.060	0.002	0.275	1.254
/cut1	-1.531	0.335			-2.188	-0.873
/cut2	-0.334	0.321			0.964	0.296
/cut3	0.826	0.327			0.184	1.468

Likelihood of Using the Bikesharing Program for On-Campus Travel

Results of the ordered probit model for on-campus travel are presented in Table 13. The same set of variables used for commuting was used for on-campus travel. It can be seen that the distance from the station where users return the bikes on campus to where their buildings are located is significant statistically, at a level of 5%. This positive coefficient implies that the longer the distance, the less likely it is that a person would use the shared bikes; this is consistent intuitively. The implication is that the bikesharing stations need to be located close to buildings where offices are located. This observation is consistent with independent survey-based studies by Fuller et al. and Bachand-Marleau, et al.[39] Fuller, et al. found that people living within 250 meters of a docking station were over twice as likely to become users of the bikesharing system than those living farther away.[40]

The coefficient for the income variable is significant and negative. This implies that low-income users would tend to be more likely to use the shared bike, which is consistent with common sense.

Table 13. Ordered Probit Model for the Likeliness of Using the Bikesharing Program for On-Campus Travel

Ordered probit regression			**Number of observations**		**=**	**160**
			LR $chi^2(9)$		**=**	**23.15**
			Prob > chi^2		**=**	**0.0059**
Log likelihood = -183.97765			**Pseudo R^2**		**=**	**0.0592**
Likeliness to use bikesharing on campus	**Coef.**	**Std. Err.**	**Z**	**P>z**	**[95% Confidence**	**Interval]**
Check-in station to destination distance (100 ft.)	0.137	0.037	3.730	0.000	0.065	0.208
Use bike to go to classes	-0.359	0.220	-1.630	0.103	-0.790	0.072
Income level						
Between $20,000-$60,000	-0.674	0.251	-2.680	0.007	-1.166	-0.182
More than $60,000	-0.058	0.249	-0.230	0.815	-0.547	0.430
Prefer not to say	-0.234	0.339	-0.690	0.491	-0.898	0.431
Transportation model to UNLV						
Car	0.730	0.400	1.820	0.068	-0.054	1.514
Bus	0.384	0.661	0.580	0.561	-0.911	1.679
Own bicycle	0.727	0.502	1.450	0.148	-0.257	1.710
/cut1	0.163	0.397			-0.616	0.942
/cut2	1.273	0.408			0.473	2.072
/cut3	1.686	0.417			0.870	2.502
/cut4	2.346	0.441			1.481	3.211

How Frequently the Bikesharing Program Would Be Used for On-Campus Travel

Table 14 lists the results for the frequency of on-campus travel. It can be seen that the coefficient for male users is negative, which implies that this group would use the bikesharing program more frequently than others. This is consistent with the findings in other studies.

The coefficient for having an office on campus is positive, implying that users who have an office on campus, such as graduate students, would use the bikesharing program less frequently than undergraduate students, who usually do not have an office on campus. The undergraduate students would use the bikesharing program frequently for such activities as going to the library.

The coefficient for faculty is negative, which implies that they would use the bikesharing program more frequently for such purposes as attending meetings, which is understandable. The coefficient for users who have a graduate degree is positive, implying that they would use the bikesharing program less frequently. This is consistent with the previous observation. The coefficient for users who would use the program to attend class is positive, which implies that they would use the program to do other things more frequently, such as going to the library and gym. This might be due to the fact that attending class is a more time-sensitive activity, and using a bikesharing program might have some uncertainty in checking out and returning bikes and then walking to classrooms.

Table 14. Ordered Probit Model for the Frequency of On-Campus Travel

Ordered probit regression		**Number of observations**		**=**	**176**	
		LR $chi^2(7)$		**=**	**49.50**	
		Prob > chi^2		**=**	**0.000**	
Log likelihood = -204.51254		**Pseudo R^2**		**=**	**0.1079**	
Frequency of using bikes within UNLV campus	**Coef.**	**Std. Err.**	**z**	**P>z**	**[95% Confidence**	**Interval]**
Gender (male)	-0.492	0.172	-2.860	0.004	-0.829	-0.155
Have office on campus	0.600	0.257	2.330	0.020	0.096	1.105
Faculty member	-0.635	0.223	-2.850	0.004	-1.072	-0.198
Education level						
High school, college and associate degree	0.202	0.327	0.620	0.537	-0.438	0.842
Bachelor degree	0.288	0.219	1.320	0.188	-0.141	0.718
Graduate and others	0.601	0.256	2.340	0.019	0.099	1.103
Intended use						
Go to classes	0.732	0.220	3.330	0.001	0.301	1.163
/cut1	-1.347	0.343			-2.020	-0.674
/cut2	-0.078	0.331			-0.727	0.571
/cut3	1.102	0.340			0.435	1.769

Comparing the model for the likelihood of on-campus travel and that for travel frequency, similar differences in the influencing factors can be observed.

- First, the distance between the stations where users return their bikes and their destination building is not an influencing factor with regard to frequency of use, but it is important to the likelihood of using bikesharing.
- Second, people's gender, whether they have an office on campus, and whether they are faculty are important in determining the frequency that people would use the bikesharing program.
- Third, education level is important in determining the number of trips that would be made on campus with the bikesharing program; however, it is not a factor when deciding whether to use the program.
- Fourth, attending class was not a reason given when deciding whether to use the bikesharing program or how frequently.

Demand Calculation

In order to establish the expected demand from the survey responses, the levels of likelihood of using the bikesharing program were tabulated, including the expected frequencies of usage. It was assumed that those who would choose bikesharing either once or more than once a day were going to be the regular members, while those who stated that they would use the program once a month or once a week were going to be casual members.

With regard to commuting, Figure 6 indicates that:

- Around 17% of the respondents were very likely to use the bikesharing program on a regular basis for commuting, and 12.6% were somewhat likely to use the program for commuting on a regular basis. This indicates these people might be regular users of the bikesharing program for commuting.
- Of the respondents, 4.3% were very likely to use the bikesharing program occasionally for commuting and 12.6% were somewhat likely to use this program occasionally for commuting. This indicates that these people might be casual users for commuting.
- More of the commuting would be done by students than faculty and staff.
- The number of faculty and staff who would choose not to use the bikesharing program for commuting is comparable to those who would choose to do so.

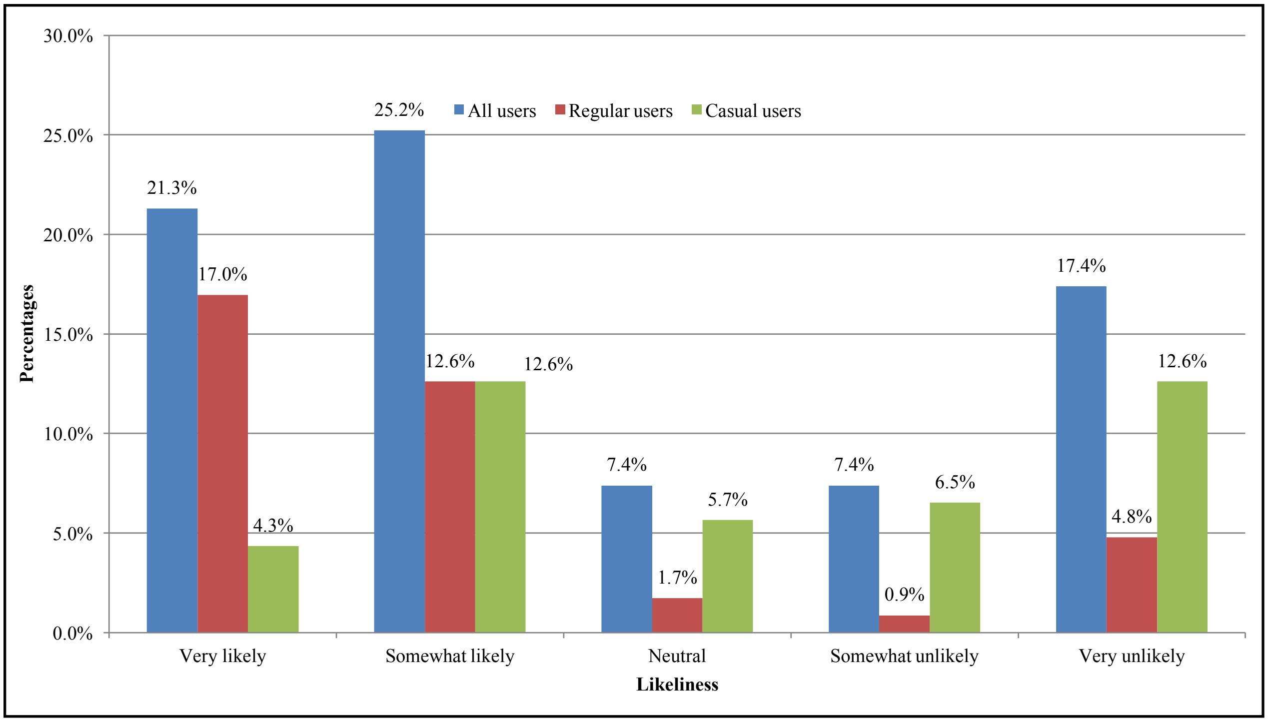


Figure 6. Forecast of Casual and Regular Members for Commuting Using the Bikesharing Program

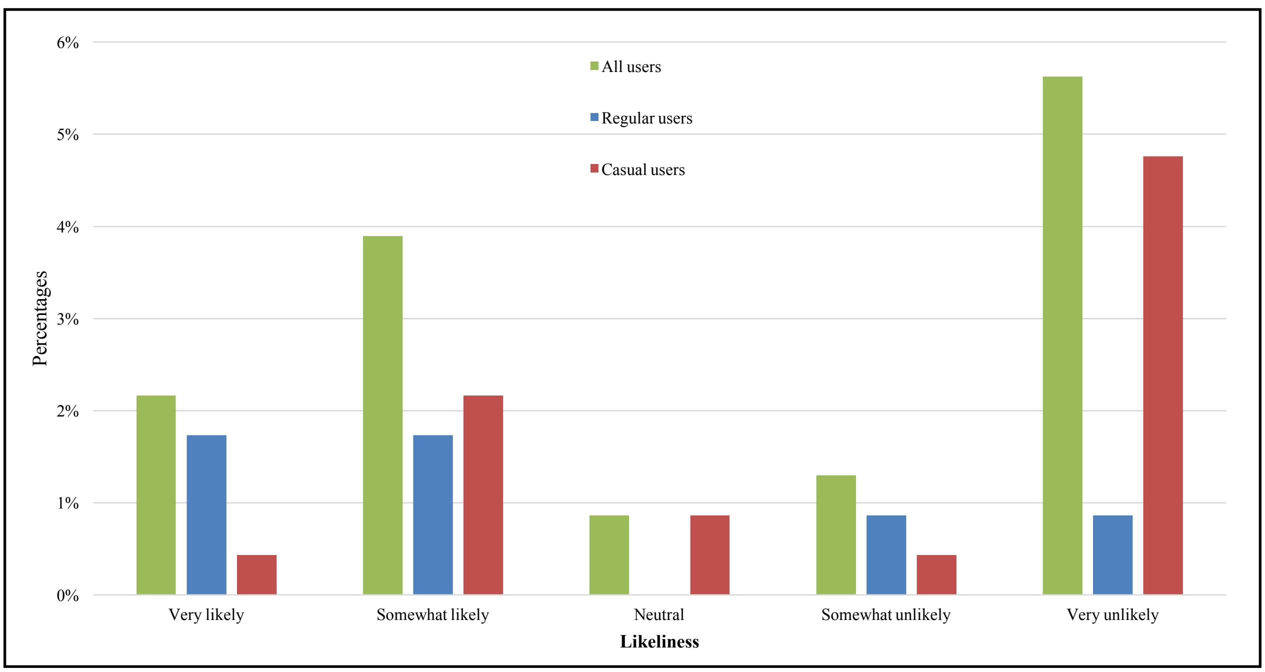


Figure 7. Forecast of Casual and Regular Faculty Members for Commuting

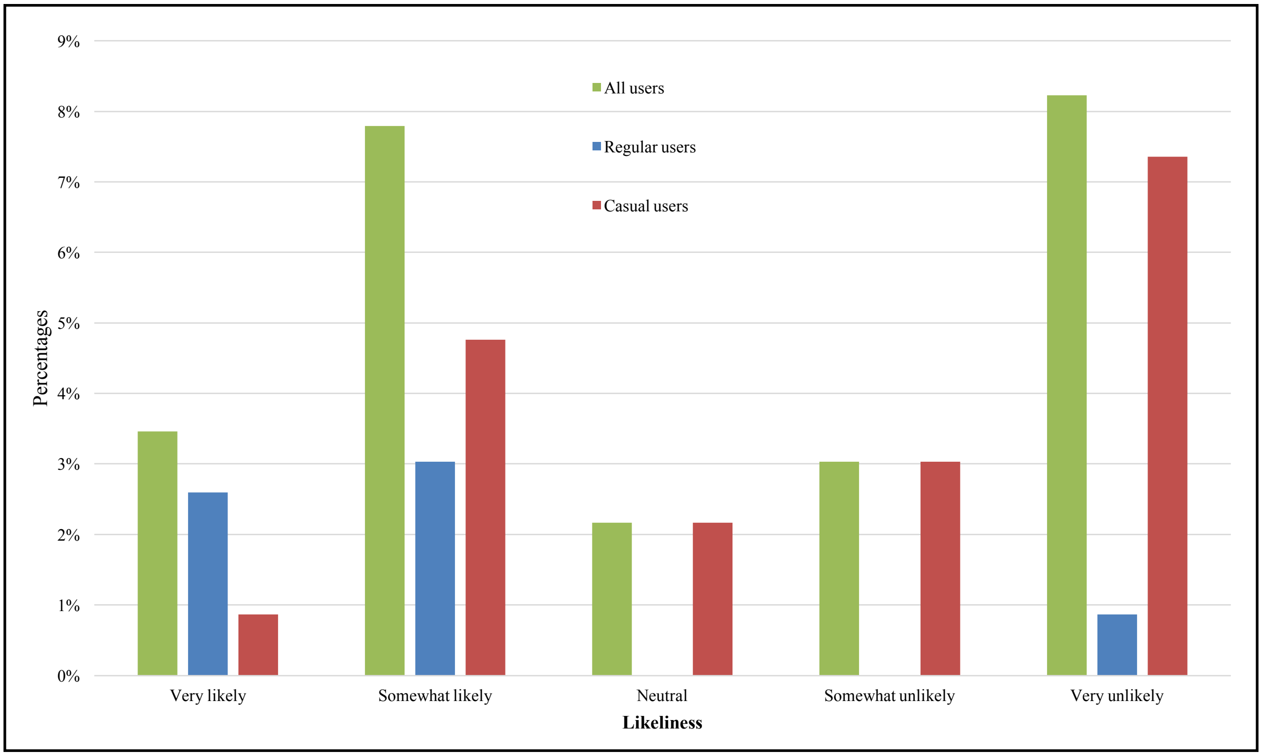


Figure 8. Forecast of Casual and Regular Staff Members for Commuting

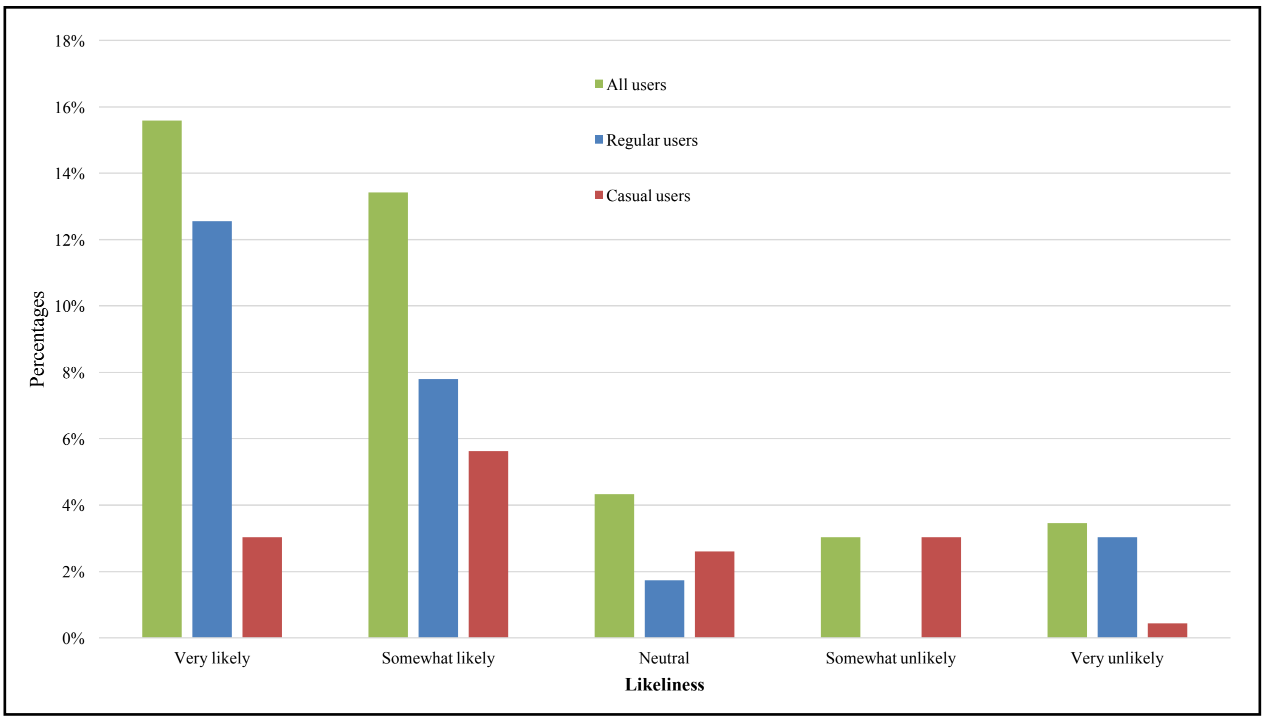


Figure 9. Forecast of Casual and Regular Student Members for Commuting

For on-campus travel, Figure 7 shows that:

- More than 25% of the respondents were very likely to use the program on a regular basis, and 12.6% would use it occasionally.
- There were higher percentages of casual users (18.6%) than regular users (10.4%) who were somewhat likely to choose bikesharing for on-campus travel.
- As with the commuting trips, students would make the most on-campus trips.

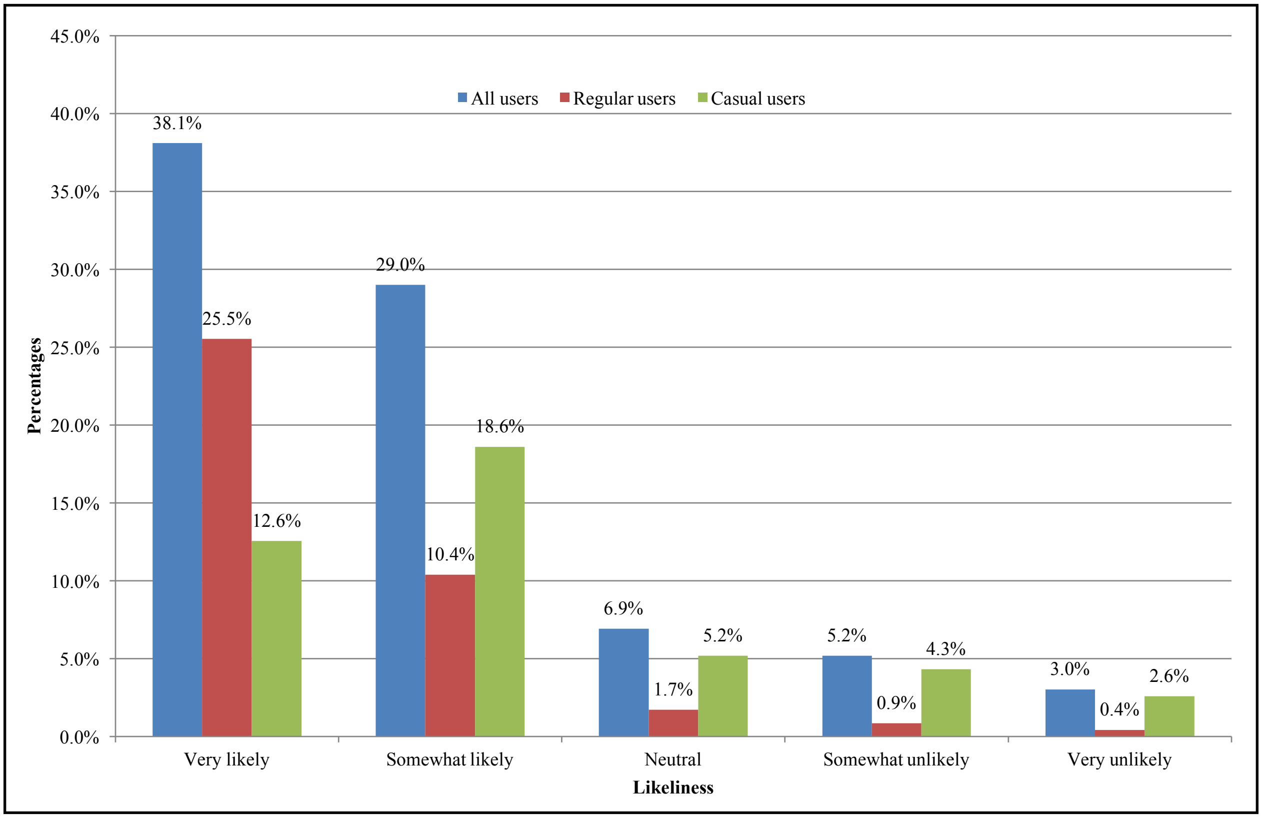


Figure 10. Forecasted Casual and Regular Members for On-Campus Travel

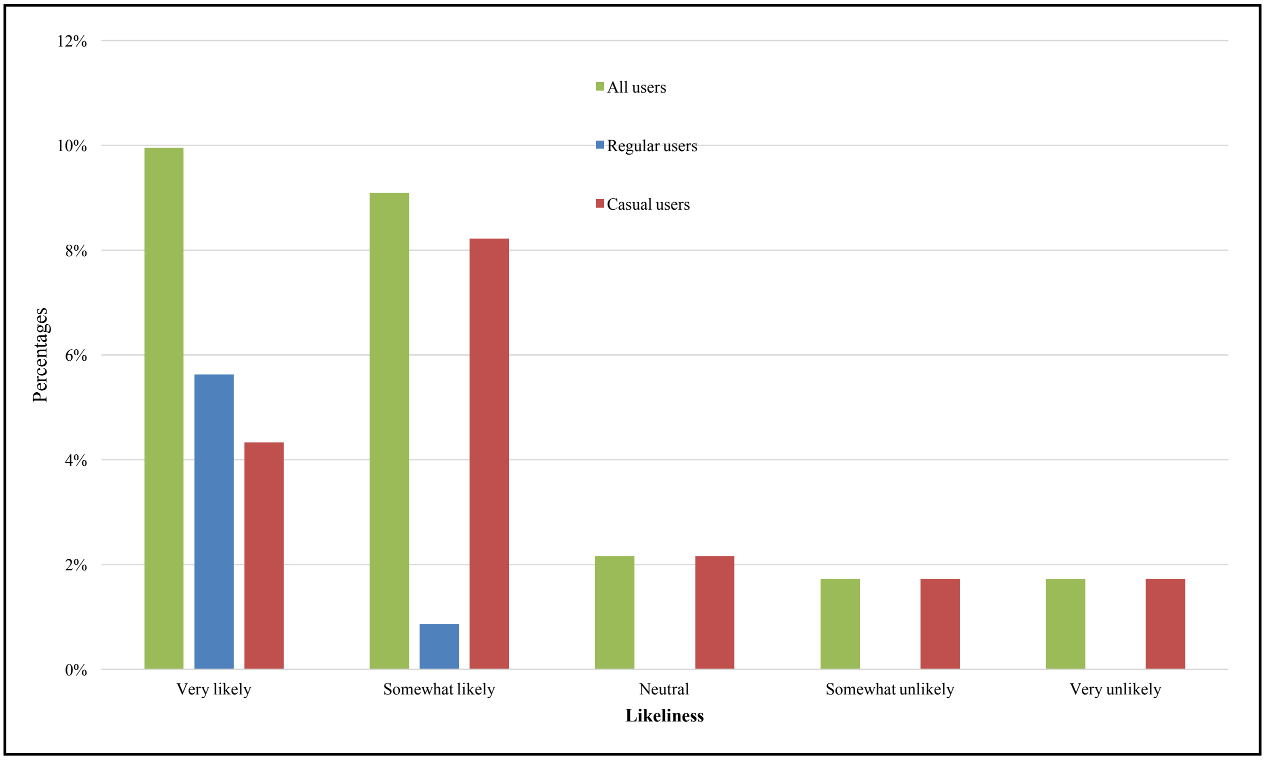


Figure 11. Forecasted Casual and Regular Faculty Members for On-Campus Travel

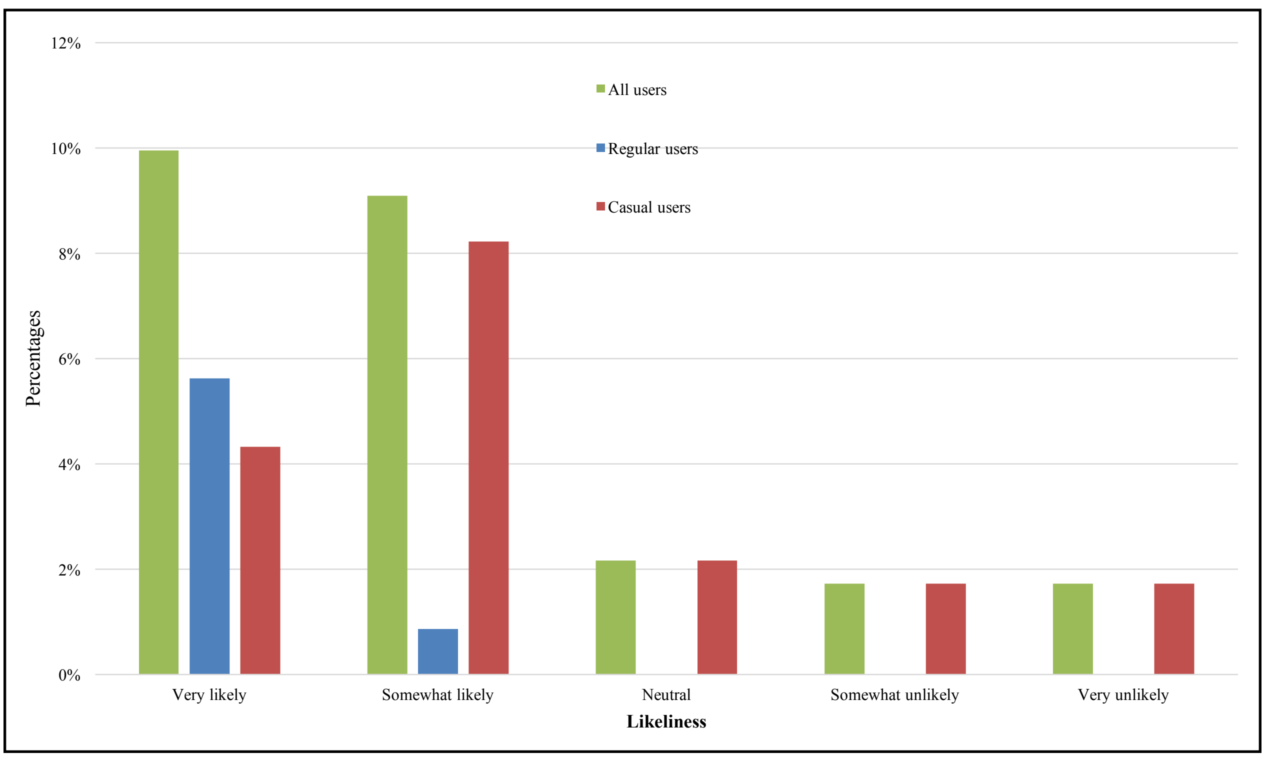


Figure 12. Forecasted Casual and Regular Staff Members for On-Campus Travel

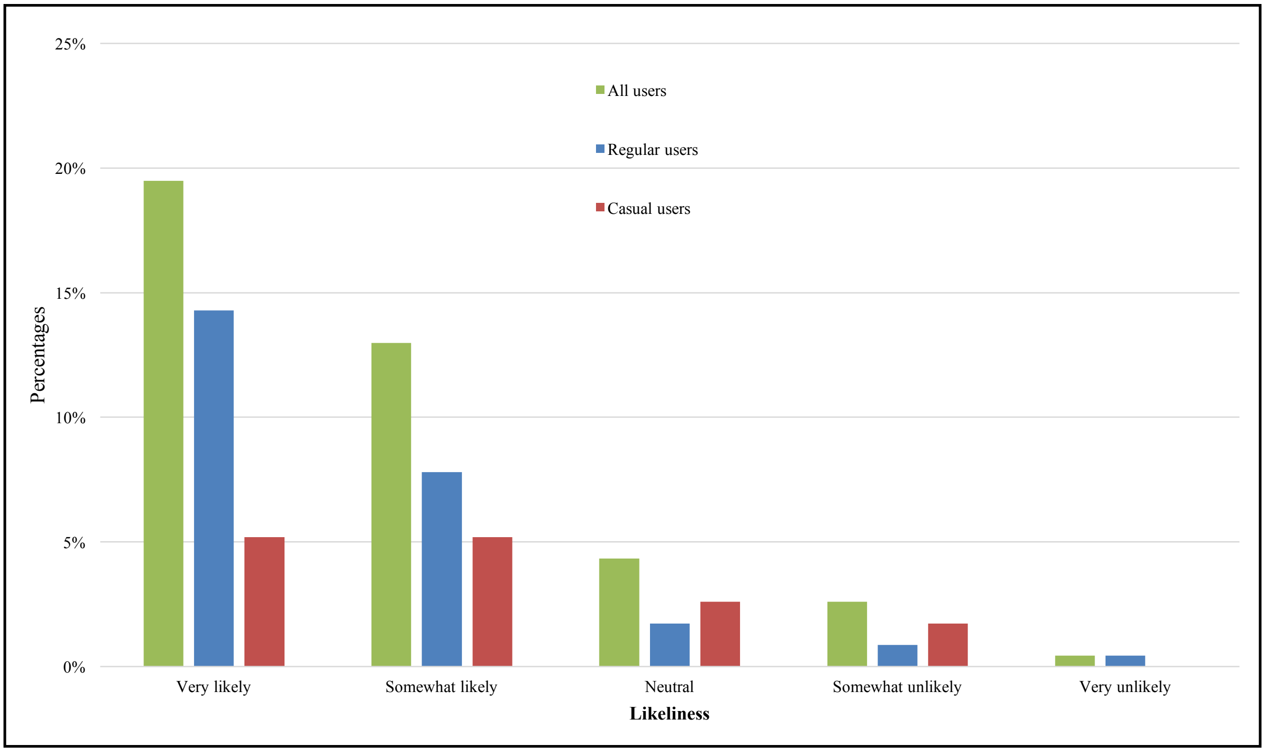


Figure 13. Forecasted Casual and Regular Student Members for On-Campus Travel

In this study, the respondents to the survey who were very likely or somewhat likely to use the bikesharing program for both commuting and on-campus activities were defined as "members." Not every respondent who expressed likelihood to participate in the program was considered 100% trustworthy. It was assumed that 30% of the respondents who stated that they were very likely to use the program and use it regularly would be those who actually were going to participate in the program. Additionally, it was assumed that the 25% of the respondents who expressed that they were very likely to use the program, but less frequently—as well as respondents who stated they would be somewhat likely to use the program frequently—would actually be part of the program. Finally, it was assumed that the 15% of the respondents who expressed that they would be somewhat likely to use the program and those who said they would tend to use the program less frequently would actually participate in the program. These factors are listed in Table 15.

Table 15. Stated Preference for Data Discount Factors

	Regular users	Casual users
Very likely	30%	15%
Somewhat likely	15%	7.5%

Given these discount factors, the number of members of the bikesharing program was calculated as the product of the total population of the university, and the corrected percentages took into consideration the stated preference factors. The membership was calculated as follows:

5. # of members = [0.3*21.25% + 0.15*(11.5% + 8.4%) + 0.075*15.6%]*32,882 = 3,462 (3)

For convenience, this figure was rounded to 3,450 members, in which 73% (2,518) are students and 27% (932) are faculty and staff.

The number of trips that would be made per day was computed by considering trip frequencies. For users who stated they would use the program once a week, the number of trips a person might make a day was computed as 1/7 = 0.14. As an example, for 475 members, the trips per day were computed as 0.14 * 475 = 68. Following this step, the total trips per day were derived to be 1,966 (Table 16). The corresponding trip table is provided in Table 17.

Table 16. Demand and Projected Trips per Day

	Survey Data		Projected Users			Trips/Day	
	Very likely	**Somewhat likely**	**Students**	**Employees**	**Trips/day/person**	**Students**	**Employees**
Once a month	0%	3%	70	26	0.0195	1	1
Once a week	8%	19%	699	259	0.078	56	21
Once per day	29%	17%	1,154	427	0.39	450	167
More than once a day	19%	4%	595	220	1.56	927	343
Total	57%	43%	2,518	932		1,435	531
	100%				Total trips	1,966	

Table 17. Origin-Destination Matrix

		Destination															
	Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Total**
Origin	**1**	0	0	0	0	0	0	20	150	14	7	0	0	0	7	7	204
	2	0	7	3	0	0	0	20	88	0	41	7	7	0	7	7	187
	3	0	0	3	0	0	0	0	14	34	34	0	0	0	0	0	85
	4	0	0	0	0	0	0	7	27	54	82	61	7	7	0	34	279
	5	0	0	0	0	0	0	0	0	0	20	27	20	0	0	0	68
	6	0	0	0	0	0	0	7	14	7	20	0	0	0	0	0	48
	7	0	0	0	0	0	0	20	14	14	34	7	0	0	0	10	99
	8	3	0	0	0	0	0	14	34	44	92	44	10	7	17	37	303
	9	0	3	3	0	0	0	14	44	27	41	3	10	0	0	7	153
	10	0	7	0	0	0	0	34	92	41	27	17	20	0	7	20	265
	11	0	3	0	0	0	0	7	44	3	17	14	7	3	0	0	99
	12	0	0	0	0	0	0	0	10	10	20	7	0	0	0	10	58
	13	0	0	0	0	0	0	0	7	0	0	3	0	0	0	0	10
	14	0	0	0	0	0	0	0	17	0	7	0	0	0	0	0	24
	15	0	0	0	0	0	0	10	37	7	20	0	10	0	0	0	85
	Total	3	20	10	0	0	0	99	299	146	259	95	58	10	24	85	1,966

It should be understood that the trips in the trip table consist of four groups:

1. From peripheral stations to peripheral stations;
2. From peripheral stations to internal stations;
3. From internal stations to peripheral stations; and
4. From internal to internal stations.

These four groups of trips occur during different periods during the day. The first group of trips occurs between peak morning periods, and they are in one direction only. The second group occurs in the morning, and they are two-way trips. The third group occurs between peak periods, and they are in one direction only. The fourth group occurs during the peak periods between 8 a.m. and 5 p.m., and they are two-way trips.

It should be noted that maximum utilization of the system would not occur during the first years of operation. Experiences at other universities indicate that users make fewer trips per day when the system is in its initial stages. For example, the maximum number of trips per day at the University of Chicago was observed to occur three years after starting program operations.

Validation of Bikesharing Demand

Data from five universities whose city bikesharing programs have stations within campuses were extracted from the cities' publicly available data, and are presented in Tables 18 and 19. It can be seen from this table that the number of trips served by these universities' bikesharing programs varies significantly. The maximum and the minimum numbers of trips served a year was 101,686 and 6,524; these are equivalent to 521 and 25 a day, assuming that the system operates during weekdays only. Four of these universities are in the northern part of the U.S., and one is in the south. Two universities do not operate their bikesharing programs in the winter because of the weather. Note that four of these universities are clearly part of city bikesharing programs since they are located within metropolitan areas. It is verified that there are bikesharing stations located both on campuses and at the peripheries of these universities, making them comparable with the proposed bikesharing program at UNLV. Looking more closely at the data (see figures 14 and 15), it can be seen that there is a positive relationship between the density of bikes in terms of population and acres and the trips made by using the bikesharing program.

Assuming that the proposed system at UNLV has five stations only (Stations 1, 4, 8, 9, and 10 as shown in Figure 3), the number of trips served by this system would be 261. The average number of trips per day served by these five universities is 284, and the number of trips served by the proposed five stations at UNLV is very close to this average. Las Vegas has mild weather (except in summer) for bicycling, and the terrain at UNLV is flat. Putting the densities of the bikes in terms of population and area, as shown in figures 14 and 15, the number of trips to be served by the proposed bikesharing program is at the middle point of those at other universities. This implies that the estimation of the demand that the proposed bikesharing program can provide is reasonable.

Table 18. Bikesharing Ridership Data for Other Universities

University	University of Illinois at Chicago, IL	University of Minnesota, MN	University of Tennessee, Chattanooga TN	University of Washington, WA	Harvard University, MA	UNLV
Trips per Year	86,568	101,686	6,524	13,211	95,236	67,860
Fall	25,960	54,769	1,753	1,304	45,029	
Spring	17,995	11,475	1,605	5,596	13,659	
Summer	36,909	35,442	2,214	4,113	36,548	
Winter	5,704		952	2,198		
Max # of Trips per Day	666	1,307	44	154	947	261
# of Stations	11	16	5	8	12	5
Max # of Bikes	202	305	77	101	204	121
Population	39,164	50,174	12,115	67,190	23,599	32,882
Size (Acres)	240	1,204	134	703	5,076	332
Bikes per Acre	0.84	0.25	0.57	0.14	0.04	0.36
Bikes per Population	0.005	0.006	0.006	0.002	0.009	0.004

Table 19. Sources for Bikesharing Ridership Data for Other Universities

University	Ridership data extracted from
University of Illinois at Chicago, *IL*	http://www.divvybikes.com/data
University of Minnesota, *MN*	https://www.niceridemn.org/data/
The University of Tennessee, Chattanooga *TN*	https://data.chattlibrary.org/Transportation/Bike-Chattanooga-Trip-Data/8yba-nwv8
University of Washington, *WA*	https://www.prontocycleshare.com/data
Harvard University, *MA*	http://hubwaydatachallenge.org/data-api/
Undergraduate student data	
University of Illinois at Chicago, *IL*	colleges.usnews.rankingsandreviews.com/best-colleges/uic-1776
University of Minnesota, *MN*	colleges.usnews.rankingsandreviews.com/best-colleges/university-of-minnesota-3969
The University of Tennessee, Chattanooga *TN*	http://colleges.usnews.rankingsandreviews.com/best-colleges/university-of-tennessee-chattanooga-3529
University of Washington, *WA*	colleges.usnews.rankingsandreviews.com/best-colleges/university-of-washington-3798
Harvard University, *MA*	colleges.usnews.rankingsandreviews.com/best-colleges/harvard-university-2155
Graduate student and faculty data	
University of Illinois at Chicago, *IL*	https://www.uic.edu/about
University of Minnesota, *MN*	https://twin-cities.umn.edu/about-us
The University of Tennessee, Chattanooga *TN*	https://www.utc.edu/planning-evaluation-institutional-research/pdfs/factbook/fact-summary-15-16.pdf
University of Washington, *WA*	https://opb.washington.edu/sites/default/files/opb/Data/2015_Fast_Facts.pdf
Harvard University, *MA*	http://www.harvard.edu/about-harvard/harvard-glance

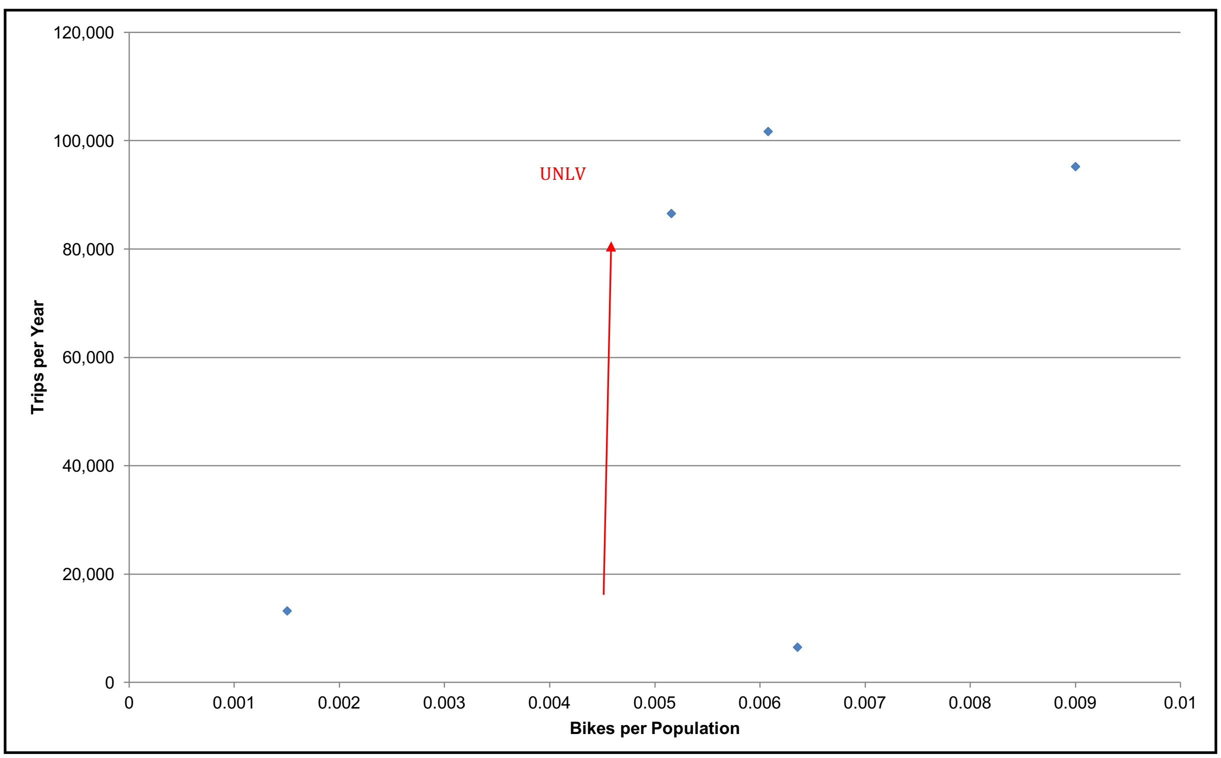


Figure 14. Relationship between Bike Trips and Bike Population Density

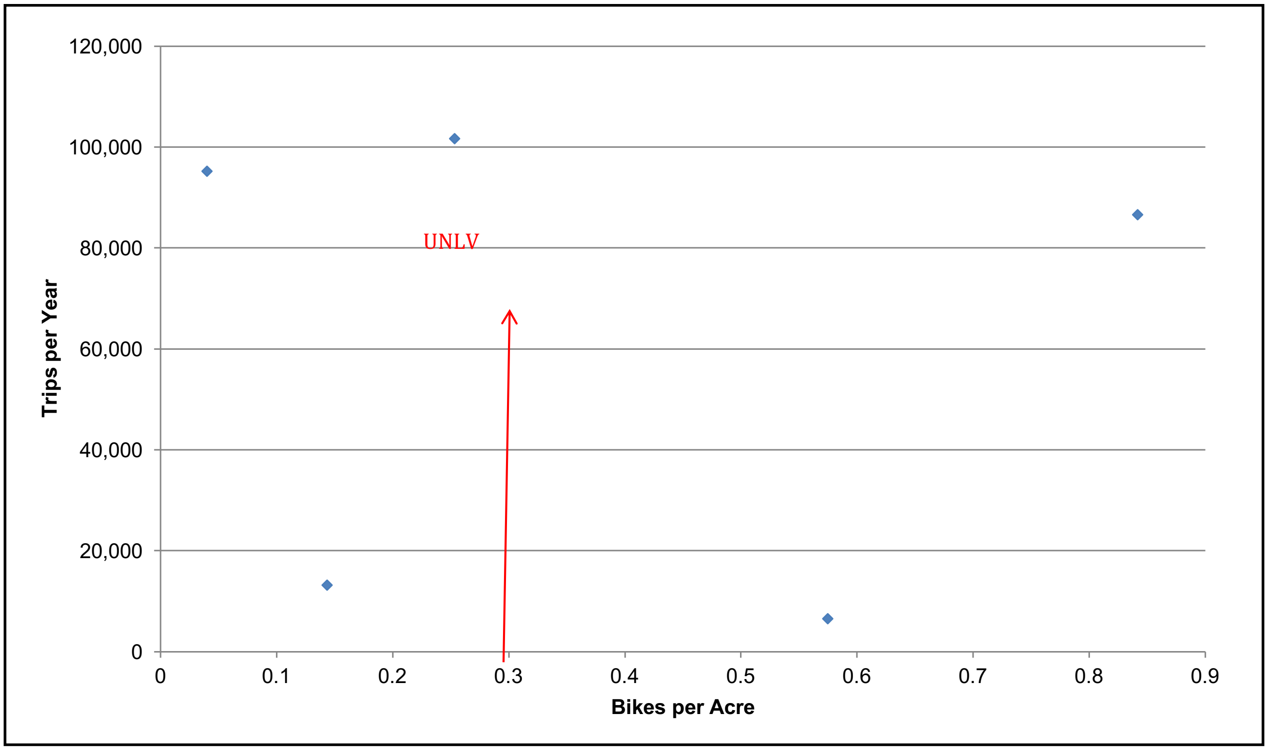


Figure 15. Relationship between Bike Trips and Bike Acre Density

VI. DETERMINATION OF LOCATIONS FOR DOCKING STATIONS ON AND AROUND CAMPUS

BENEFIT AND COST ANALYSIS

The locations of bikesharing stations on and around campus were determined based on the forecasted demand and the evaluation of the cost, benefit, and estimated usage of the system. The forecasted demand for peak periods was used to determine the station locations and facility capacity. If the forecasted daily demand averaged for 24 hours was used to estimate the capacity of the bikesharing system, the system would not be able to accommodate the demand during peak periods. In this case, delays would occur and users would have to wait for bikes to become available. This would discourage potential users, and thus reduce the demand.

The trips per day, shown in Table 17, were used to obtain the number of trips during peak hours. The peak-hours factor was computed based on the utilization of the bikesharing system in the San Francisco Bay Area, and the peak-hour flow is shown in Table 20. Note that the bikesharing system in the Bay Area is a city program; this is different from a university program, and thus the peak periods in these two types of systems differ. Peak periods for both systems would coincide for commuting trips; however, for on-campus travel in a university, the peak periods may be smaller than for that in the city bikesharing program.

Table 20. Peak-Hour Flow

		Destination															
	Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Total**
Origin	**1**	0	0	0	0	0	0	7	50	5	2	0	0	0	2	2	68
	2	0	2	1	0	0	0	7	30	0	14	2	2	0	2	2	63
	3	0	0	1	0	0	0	0	5	11	11	0	0	0	0	0	28
	4	0	0	0	0	0	0	2	9	18	27	20	2	2	0	11	93
	5	0	0	0	0	0	0	0	0	0	7	9	7	0	0	0	23
	6	0	0	0	0	0	0	2	5	2	7	0	0	0	0	0	16
	7	0	0	0	0	0	0	7	5	5	11	2	0	0	0	3	33
	8	1	0	0	0	0	0	5	11	15	31	15	3	2	6	13	101
	9	0	1	1	0	0	0	5	15	9	14	1	3	0	0	2	51
	10	0	2	0	0	0	0	11	31	14	9	6	7	0	2	7	89
	11	0	1	0	0	0	0	2	15	1	6	5	2	1	0	0	33
	12	0	0	0	0	0	0	0	3	3	7	2	0	0	0	3	19
	13	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	3
	14	0	0	0	0	0	0	0	6	0	2	0	0	0	0	0	8
	15	0	0	0	0	0	0	3	13	2	7	0	3	0	0	0	28
	Total	3	20	10	0	0	0	33	100	49	86	32	19	3	8	28	658

The bikesharing program at UNLV will strive to build stations that are cost effective. Similar to those presented in the survey, some potential locations of these stations would not attract a significant amount of users to cover the costs for installing a station. This study adopted an optimization process in selecting bikesharing stations such that only a set of stations could generate enough revenue to cover costs.

The cases of stations considered in this study are listed in Table 21. The first case includes all of the potential stations, and can be viewed as the baseline that can attract the greatest demand to the program. The second case removes Station 13, assuming that the existing RTC (Regional Transportation Commission) Transit Center at that location provides all the needed facilities already. Cases 3 to 13 include at least one location at the periphery of the campus and one location at the core.

Table 21. Set of Bikesharing Stations Considered in the Selection Process

Cases	Stations in a Case	Trips	Bikes	Trip/Bike
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1962	286	6.86
2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	1935	284	6.81
3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15	1873	279	6.71
4	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 15	1825	264	6.91
5	1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 15	1758	242	7.26
6	1, 2, 3, 4, 7, 8, 9, 10, 11, 15	1630	237	6.87
7	1, 2, 3, 4, 7, 8, 9, 10, 11	1434	221	6.48
8	1, 2, 4, 7, 8, 9, 10, 11	1343	194	6.92
9	1, 2, 4, 7, 8, 9, 10	1116	171	6.52
10	1, 2, 4, 8, 9, 10	925	155	5.96
11	1, 4, 8, 9, 10	261	112	2.33
12	1, 8, 9, 10	206	59	3.49
13	4, 8, 9, 10	202	54	3.74
14	8, 9, 10	148	14	10.57

The costs of the system include the following capital and operational expenditures:

1. Bicycles, dock, and terminals;

2. Vehicles to be used to redistribute the bikes between stations; and

3. Personnel to manage the program's operation.

The number of bikes needed for different sets of locations for the stations also varies. Factors include the number of trips generated at each station, the distance between the stations, the exchanges of trips between stations, and how the bicycles are utilized. At certain times of the day, a surplus of bicycles at certain stations could be distributed to other stations that have customers waiting or expected to arrive. The relation between the number of bicycles needed and the influencing factors are complicated, and cannot be expressed as a simple equation. Therefore, a simulation model was developed that could emulate the interactions regarding the trips between stations and bicycle-utilization strategies.

The simulation starts with trip table, distance table, and bicycle redistribution strategies. The clock in the simulation progresses second by second. At each second, the model checks whether a user is generated at a station and where the user goes. If a bicycle is available at the station, it is assigned to the user. In this model, a record is kept for each bicycle in order to store the bicycle's status, whether it is idling at a station or being used for a trip to a destination. As the clock moves forward, a bike can continue to be on the road, taking into consideration the distance between where the bicycle starts its trip and where its current destination is located. It can be on idle again if it is idle at a station and no new user arrives.

A record is created for each user as well in order to store the status of users over time, whether they are on the road or arriving at a destination. In the simulation, a user does not have to wait for a bicycle. Whenever a bicycle is not available for a user at a station, a bicycle is generated at that station right away. The number of bicycles generated at all the stations during the entire simulation period is the number of bicycles needed for the set of stations that generated the given number of users.

By the end of each 10 minutes of one hour the number of bikes at each station is evaluated, and it is decided whether some bikes at some of the stations need to be redistributed to other stations. To determine this, the distances between the stations that have bicycle surpluses and those expected to have significant users arriving in the near future are considered. The strategies specify when the operation personnel need to move bicycles from certain stations to others. Thus, the redistribution strategies differ for each case having different numbers of bikesharing stations and their locations.

A flowchart of this simulation is presented in Figure 16. The first block of the flowchart shows the inputs to the simulation at the beginning of the simulation, including matrices of the trips, distances, and redistribution strategies. The second block, which is at the bottom of the left side of the figure, presents a procedure to generate the number of trips, which are evenly distributed over the peak period. The third block, in the middle of the chart, is for the reuse of a bicycle after it takes a user from a station as well as redistribution of bicycles by operations personnel. The last block illustrates the process of serving the users arriving at the bikesharing system.

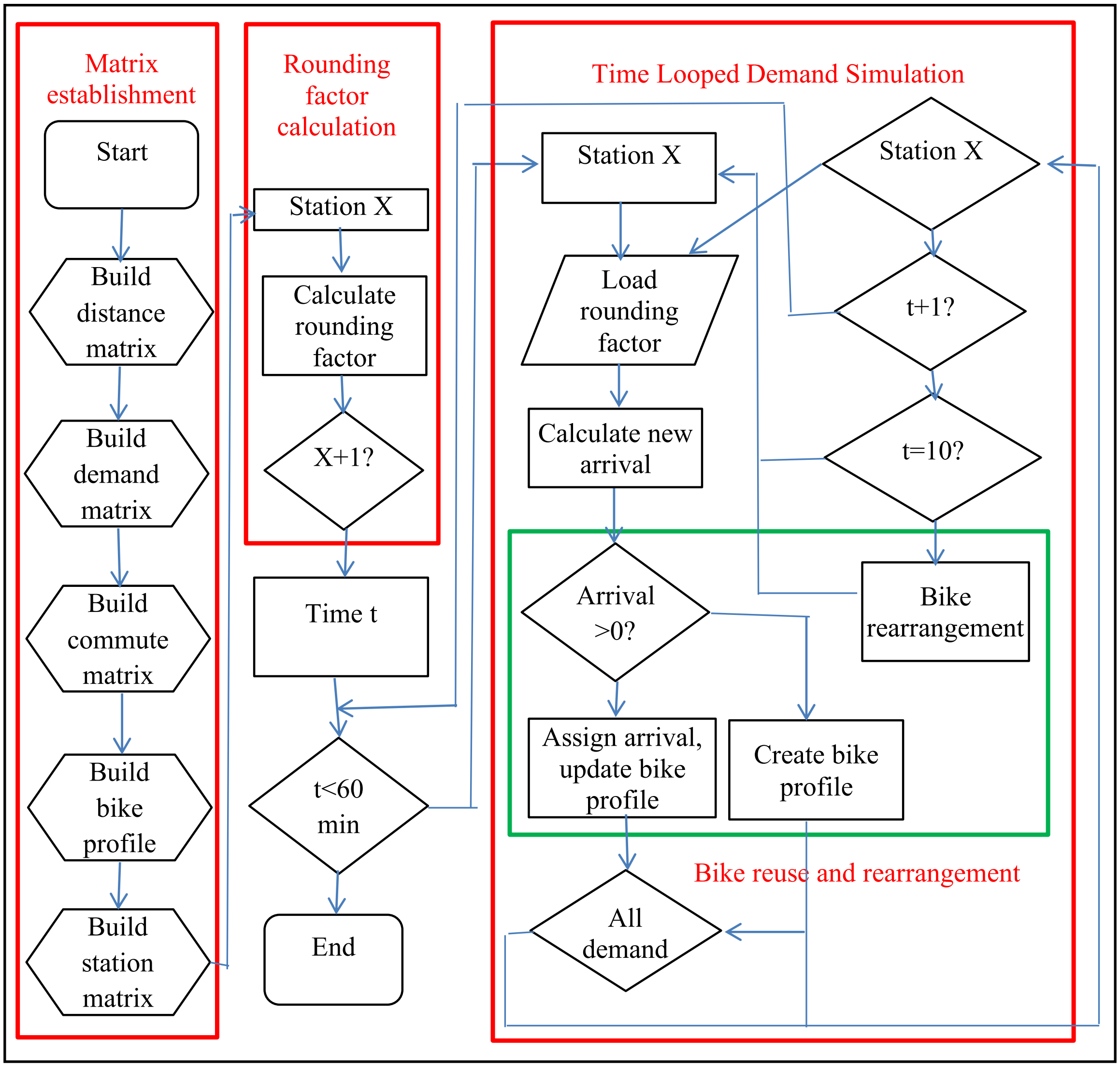


Figure 16. Flowchart of Simulation Program for the Proposed Bikesharing Program at UNLV

The bicycles that are needed, derived from the simulation, are listed in Table 21. It can be seen that the ratio between the number of trips that can be served by a bike increases with the number of stations in each case, except Case 14 where there is no station on the periphery of campus. A decision on which station to adopt will depend on the cost-benefit analysis.

Two bikesharing systems are considered: dock-smart and smart bike. In the dock-smart system, the docks are equipped with advanced devices that can determine the check-in and checkout of bicycles and their locations, while in the smart bike system, or dockless system, bicycles have devices such as GPS that can complete check-in and checkout without going through docks.

For the dock-smart system, the cost items are listed below:

Estimated capital costs[41]

Purchase cost per bike: $1,234

Purchase cost for dock base (per item): $1,540

One-time fees (software installation, connectivity tests, project management): $20,236

Shipping cost per bike: $75

Shipping cost per dock: $312

AC platform, processor per station: $5,536

Travel expenses/installers (per station): $1,500

Estimated operating costs[42]

Annual software per station: $4,000

Annual connectivity fees per station: $1,896

Bike replacement, parts and general maintenance (per bike): $831

Part-time staff: $20,000

Two part-time student workers: $16,000

Rebalancing per bike per station: $17[43]

The costs for the smart bike system are listed below:

Estimated capital costs[44]

Smart bike purchase cost per bike: $1,600

Purchase cost for docking point plus base (per item): $450

Web design: $10,000

Shipping cost per bike: $100

Shipping cost per docking point plus base: $250

Installation services per station: $5,000

Payment kiosk and base plate (optional and included in calculation): $10,000

Large map and add panel and base plate (optional and included in calculation): $2,750

Compact map and add panel and base (optional and included in calculation): $1,250

Estimated operating costs:[45]

Software license fee: $30,000

Platform connectivity fee per bike: $96

Bike replacement, parts, and general maintenance (per bike): $100

Part-time staff: $20,000

Two part-time student workers: $16,000

Rebalancing per bike per station: $17[46]

It was assumed that the life cycle of a bike is five years.

Bikesharing programs have numerous benefits, which can be grouped on the basis of economics, environmental considerations, and community and user (individual) needs. In this study, saving time during travel due to biking rather than walking was used as a measure of benefit. Travel-time unit cost (cents per minute or dollars per hour) could be applied to the travel time savings in order to derive the benefit in dollars.

For commuting, the travel-time savings from the peripheral stations to stations on campus is assumed to be the determining factor that makes customers choose using a bus rather than an automobile, even though there are other factors that may influence their mode choice in commuting. With no bikesharing program, walking from a bus stop to people's destinations on campus is long enough that it makes them to drive to school. For on-campus travel, the travel-time savings from building to building is also considered as a deciding factor in choosing a means to travel on campus. The distances in miles between origin and destination stations were extracted from Google Maps. The shortest distance was 0.07 miles, which was between Stations 7 and 8, while the longest distance (0.68 miles) was between Stations 8 and 12. Savings in travel time was computed as the difference between the travel times by bicycle and walking.

Researchers found that a user could save up to more than nine minutes if he or she opted for the bikesharing program for movements on campus. The travel-time unit cost values of $60, $30, and $15 are assumed for faculty, staff, and students, respectively, when converting the travel time to monetary values. The expected minimum value of travel-time savings was 16 cents, while the maximum was $1.68 per trip.

The value for total travel-time savings for the entire project will depend on the number of trips made per day as well as the trip origins and destinations. The aggregated value of travel-time savings per day was computed by considering the number of forecasted trips and the value of travel-time savings for that particular trip. In order to include this as a program benefit, the value of travel-time savings for the entire year was determined. Only weekdays were considered, 260 days per year.

In the cost-benefit analysis, the present worth of the cost and benefit used the following formula:

$$PV_{Ordinary\ Annuity} = C * \left[\frac{1-(1+i)^{-n}}{i}\right] \quad (4)$$

where:

C = Cash flow per period
i = Interest rate
n = Number of payments

The costs for purchasing bikes were converted to the present worth by using the following formula:

$$PV = \left[\frac{F}{(1+i)^{n}}\right] \quad (5)$$

where:

F = Cash flow per period
i = Interest rate
n = Number of years

The cost-benefit ratio was calculated by dividing the present worth (values) of benefit to the cost, presented in Table 22 and Table 23 for the dock-smart and bike-smart systems, respectively.

First, the cost-benefit ratios may not have a uniform changing pattern, either increasing or decreasing, with the changes of the number of stations included in the bikesharing program. This is due to the fact there are many factors that determine the benefits and costs. Fewer stations result in lower system costs. On the other hand, less savings would be generated from the excluded customers associated with the excluded stations. In addition, the loss in savings would be even more if the trips associated with the excluded stations were long.

Second, including one peripheral station, either Station 1 or 4, was significantly better than including both of them in the program. The cost-benefit ratios of cases that had one station increased significantly. This is because the peripheral stations such as Stations 1 and 4 involve commuting trips in the morning and afternoon only, for which the bikes would be used two times only. The trips between the on-campus stations can be trip chained, allowing one bike to be used multiple times.

Third, having bikesharing stations that were internal only, with no peripheral stations, showed the highest cost-benefit ratios. This case, in particular, shows that a bike can be used multiple times for trips on campus.

Fourth, it can be observed that cases 12 and 13 have lower equipment installation and annual operations costs compared with other cases, considering $300,000 as the acceptable total initial investment. In addition, these two cases have stations to support both commuting and on-campus travel. Thus, these two cases are recommended for consideration in implementation.

It has been observed that the costs for bicycles and docks have been reducing over the past years. This trend makes feasible cases of bikesharing programs more attractive.

FINANCIAL ANALYSIS

The financial condition of the bikesharing program was analyzed by comparing the revenue and cost of the system. This analysis could help determine the fees for using the system. The revenue was computed as the predicted fees collected from the users. There are two categories of users, casual and regular users. The casual users are those who prefer to use the bikesharing program once a month or once a week, while the regular users choose to use the program once a day or more than once a day. The 24-hour fee was set at $8 (for casual users), and an annual pass was set at $80 (for regular users). The total revenue is calculated as $7,651,257 when all the stations are considered in Case 1 for the smart-dock system. The revenue-cost ratio is 0.98. These total revenues and ratios are derived for all the cases considered in this study, and they are listed in Tables 22 and 23 for smart-dock and smart-bike systems, respectively. It can be seen that most cases for the smart-dock system have revenue and cost ratios greater than 1, making the systems feasible financially. For the smart bike systems, all of the cases have a revenue and cost ratio greater than one. With lower fees (i.e., $5 for 24 hours and $60 for an annual pass), all of the cases for the smart-bike systems have revenue and cost ratios greater than one as well.

It is critical to set up fee levels that are both acceptable to the users and feasible financially to the agencies that will install and maintain the system. Based on both the cost-benefit analysis and the revenue-cost analysis, it is concluded that cases 12 and 13 are recommended for implementation.

Table 22. Costs and Benefits Smart-Dock System

Cases	# of Bikes	# of Stations	Total Initial Capital Cost	Approximate Annual Operating Costs	Total 15-Year Cost	Value of Travel-Time Saving (VTTS)	Benefit-Cost Ratio	Total Membership Revenue	Revenue-Cost Ratio
Case 1	286	15	1,159,443	436,343	7,812,096	15,262,893	1.95	7,651,257	0.98
Case 2	284	14	1,138,674	354,548	6,685,707	15,032,961	2.25	7,545,964	1.13
Case 3	279	13	1,108,420	344,497	6,506,564	14,271,251	2.19	7,304,181	1.12
Case 4	264	12	1,053,962	326,136	6,164,039	13,616,464	2.21	7,116,995	1.15
Case 5	242	11	977,373	301,958	5,701,960	12,853,429	2.25	6,855,713	1.20
Case 6	237	10	936,004	291,907	5,511,702	11,305,028	2.05	6,356,549	1.15
Case 7	221	9	863,564	272,715	5,137,279	9,622,264	1.87	5,592,203	1.09
Case 8	194	8	771,168	244,382	4,589,804	9,213,117	2.01	5,237,328	1.14
Case 9	171	7	674,745	219,373	4,093,973	7,858,692	1.92	4,352,091	1.06
Case 10	155	6	604,157	200,181	3,721,402	6,658,691	1.79	3,607,244	0.97
Case 11	112	5	461,177	158,552	2,900,661	5,664,209	1.95	3,037,884	1.05
Case 12	59	4	282,876	108,613	1,905,423	3,869,223	2.03	2,402,229	1.26
Case 13	54	4	270,774	104,458	1,823,732	4,119,972	2.26	2,359,332	1.29
Case 14	14	3	129,868	65,322	1,046,818	2,324,986	2.22	1,723,678	1.65

Table 23. Costs and Revenues Smart-Bike System

Cases	# of Bikes	# of Stations	Total Initial Capital Cost	Annual Operating Costs	Total 15-Year Cost	Value of Travel-Time Saving (VTTS)	Benefit-Cost Ratio	Total Membership Revenue	Revenue-Cost Ratio (with High Fees)	Revenue-Cost Ratio (with Low Fees)
Case 1	286	15	856,100	196,293	4,512,567	15,262,893	3.38	7,651,257	1.70	1.13
Case 2	284	14	843,500	190,467	4,414,505	15,032,961	3.41	7,545,964	1.71	1.14
Case 3	279	13	823,700	183,448	4,282,527	14,271,251	3.33	7,304,181	1.71	1.14
Case 4	264	12	782,700	172,565	4,041,849	13,616,464	3.37	7,116,995	1.76	1.17
Case 5	242	11	724,900	159,497	3,730,104	12,853,429	3.45	6,855,713	1.84	1.23
Case 6	237	10	700,900	153,464	3,607,193	11,305,028	3.13	6,356,549	1.76	1.18
Case 7	221	9	651,900	143,735	3,370,479	9,622,264	2.85	5,592,203	1.66	1.11
Case 8	194	8	582,100	130,881	3,031,844	9,213,117	3.04	5,237,328	1.73	1.15
Case 9	171	7	515,600	120,230	2,740,354	7,858,692	2.87	4,352,091	1.59	1.06
Case 10	155	6	467,300	112,473	2,530,874	6,658,691	2.63	3,607,244	1.43	0.95
Case 11	112	5	359,100	97,643	2,070,396	5,664,209	2.74	3,037,884	1.47	0.98
Case 12	59	4	225,500	81,648	1,533,326	3,869,223	2.52	2,402,229	1.57	1.05
Case 13	54	4	214,900	80,322	1,487,123	4,119,972	2.77	2,359,332	1.59	1.06
Case 14	14	3	111,100	69,471	1,095,233	2,324,986	2.12	1,723,678	1.57	1.05

VII. ANALYSIS OF TRANSIT/BIKESHARING CONNECTIVITY AT UNLV

In quantifying the connectivity between the bikesharing stations and the transit system, six peripheral stations were considered for the system at UNLV. These stations are considered to be used as part of the first-mile or last-mile trips for the program's users. The measures of the connectivity between the stations included the presence of crosswalks, the distance between bus stops and bikesharing stations, and the frequency of buses.

PRESENCE OF BUS STOPS, PEDESTRIAN CROSSING FACILITIES, AND BIKE LANES

Along the university boundaries, six bikesharing stations and 14 bus stops are proposed. Each station would be close to at least two bus stops.

Station 1: Flamingo Road

There are four possible locations for positioning Station 1. As shown in Figure 17, these are along Flamingo Road—either behind the current bus stop or at the corner of Flamingo Road and Claymont Street on both sides—or along Claymont Street. While all of these possible locations attract bikesharing users from the bus stops, the distance from the bus stops and the existence of crosswalks and bike paths to the campus may affect one's selection of the station.

Figure 17. Possible Locations for a Bikesharing Station at Flamingo Road and Claymont Street

The two locations on Flamingo Road east of Claymont (Figure 17) are very close to the bus stop in the eastbound direction, but they are far from the bus stop in the westbound direction. The presence of the crosswalks at the intersection makes it possible for both bikesharing locations to be accessed from the westbound bus stop. There are, however, no dedicated bike routes/lanes from any of these locations to the campus. Nevertheless, the sidewalks are wide and can be used as bike routes (Figure 18). A crosswalk should be provided at the intersection of Claymont Street and Cottage Grove Avenue to enable easy flow of bicyclists onto and off campus.

Behind the Bus Stop on the South of Flamingo Road

On the East Side of Claymont Street Close to Flamingo Road

Figure 18. Possible Locations for Bikesharing Station 1 on (left) Flamingo Road or (right) Claymont Street

In addition to the provision of the crosswalk, the first two parking spots at the north of Lot P (Figure 19) should be removed so as to provide space for the bike route. In addition, a connection between parking lot P and the road network within the campus should be established.

Claymont Street and Cottage Grove Avenue

Parking Lot P

Figure 19. Bike Route from Station 1 to Campus

Station 2: Maryland Parkway

Bike Station 2 could be located either at the corner of Cottage Grove Avenue and Maryland Parkway or just behind the bus stop for Maryland Parkway and Cottage Grove Avenue on Maryland (Figure 20). The location at the corner of Cottage Grove and Maryland Parkway might best suit travelers from the Maryland Parkway and Rochelle Avenue bus stop (northbound); for bus riders traveling south, the location could be placed behind the Maryland Parkway and Cottage Grove bus stop.

This section of road has no crosswalks; therefore, bike users from the northbound bus stop would need to walk a long distance to access these two possible bikesharing station locations. A traveler from both of the locations could ride the bike to the campus either along Cottage Grove Avenue or Maryland Parkway. It is noted, however, that there are no bike routes on either of the roadways.

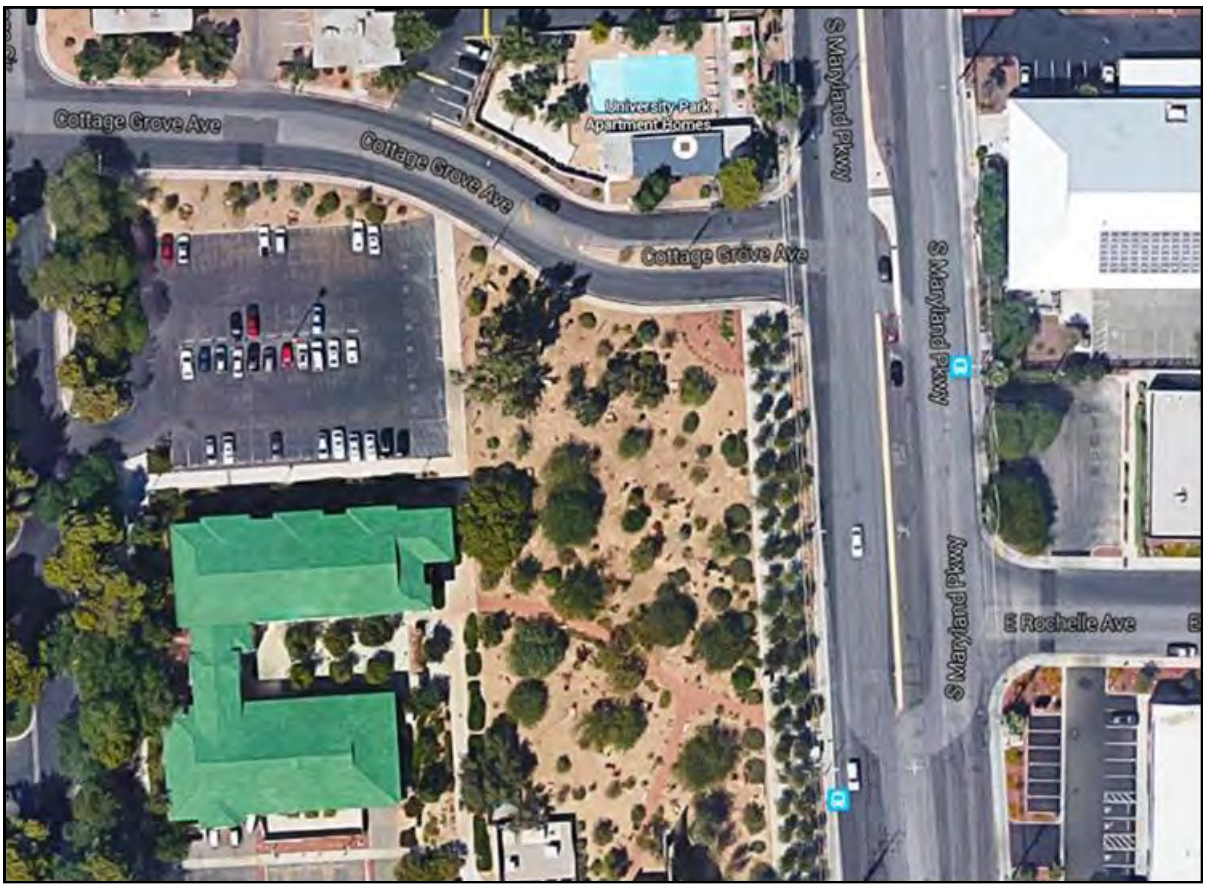


Figure 20. Possible Locations for a Bikesharing Station on Maryland Parkway

Station 3: Maryland Parkway

A candidate for the bikesharing station could be either 1) at the corner of Maryland Parkway and Harmon Avenue (Figure 21) or 2) behind the Maryland Parkway and Harmon Avenue bus stop on southbound Maryland (Figure 22). Both locations could attract users to and from the southbound bus stop due to the presence of a crosswalk.

On the Corner of Cottage Grove Avenue and Maryland Parkway

Behind the Southbound Bus Stop on Maryland

Figure 21. Possible Locations for Bikesharing Station 2 on Maryland Parkway

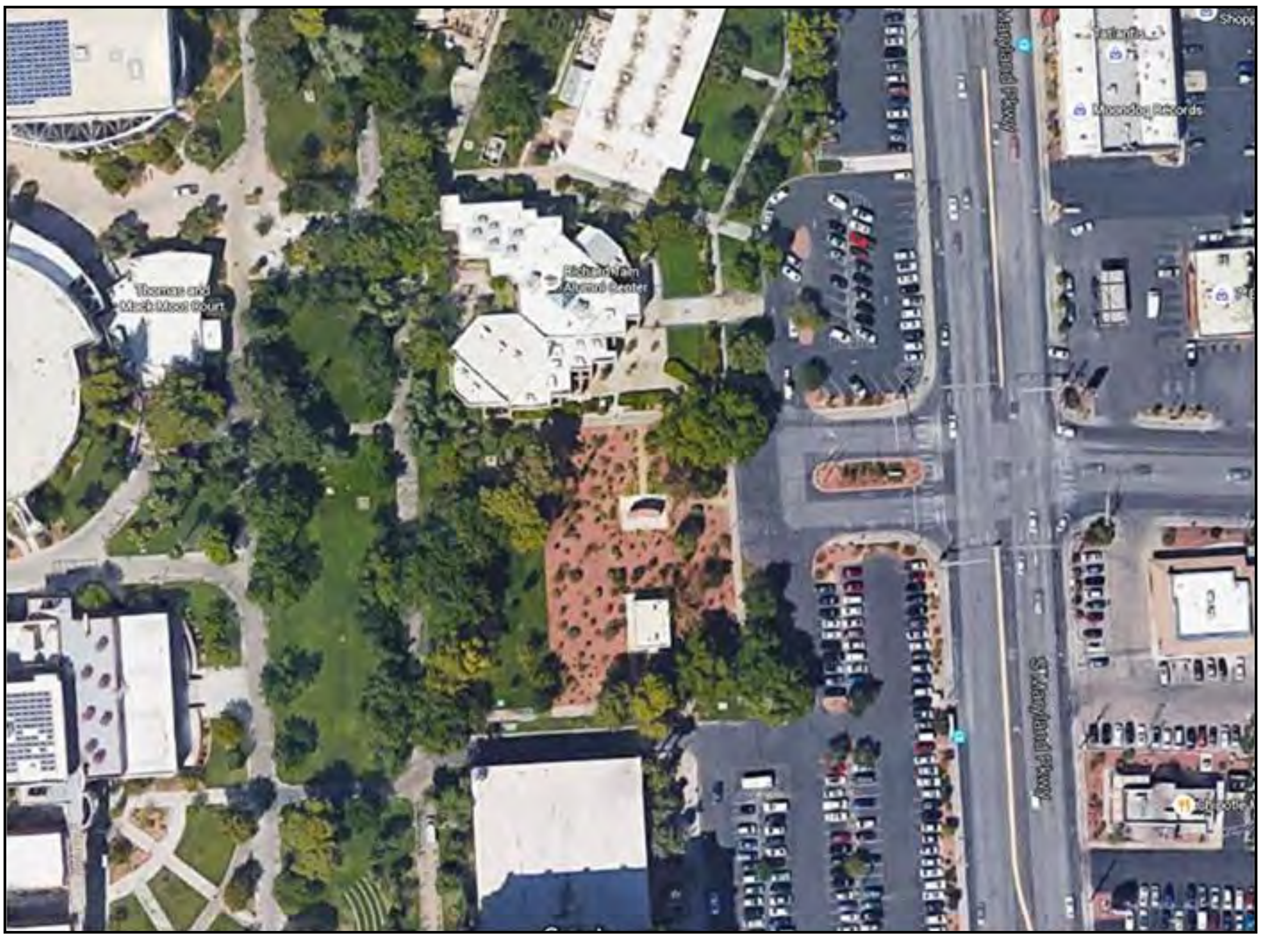


Figure 22. Possible Locations for Bikesharing Station 3 on Maryland Parkway

There are no dedicated bike routes from any of these bikesharing stations (Figure 23). Users from the location at the corner of Maryland Parkway and Harmon Avenue could access the campus at the crosswalk at Harmon Avenue. Those using the station behind the southbound bus stop could walk through the parking lot in front of the Flora Dungan Humanities (FDH) building.

On Maryland Parkway and E. Harmon Avenue

On Maryland Parkway behind the Southbound Bus Stop

Figure 23. Possible Locations for Bikesharing Station 3

Station 4: Tropicana Avenue

Station 4 could be located behind the bus stop at Tropicana Avenue and Wilbur Street along Tropicana Avenue (Figure 24). This location is accessible by travelers from westbound and eastbound bus stops (Figure 25). Eastbound travelers could access the station by using the crosswalks located at the intersection of Tropicana Avenue and Wilbur Street.

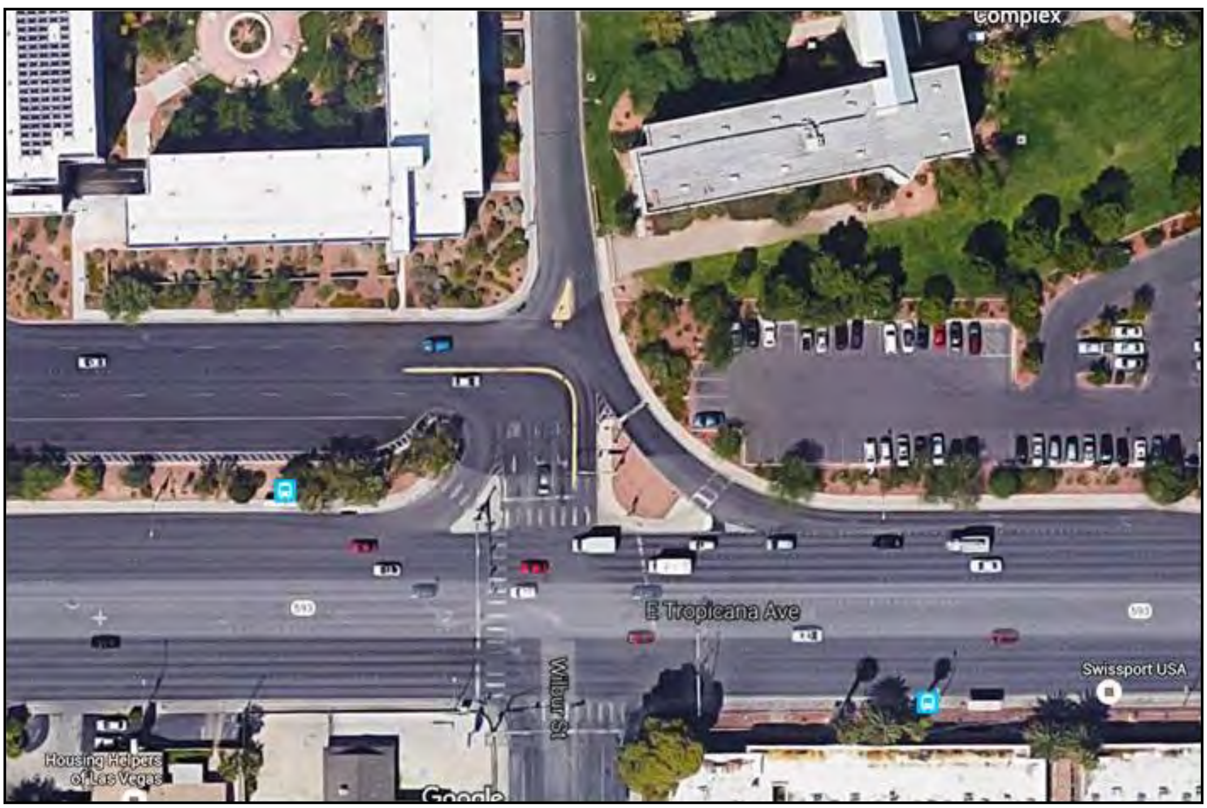


Figure 24. Possible Location for the Bikesharing Station on Tropicana Avenue

On Tropicana Avenue behind the Westbound Bus Stop

On Tropicana Avenue close to a Student Residence Hall

Figure 25. Possible Locations for Bikesharing Station 4

Regardless of where the bikesharing stations are located, there are no dedicated bike routes to the campus, as shown in Figure 26. Access can be made possible by using the sidewalk; however, there is no marked crosswalk that connects the station and the sidewalks. As seen in Figure 26, no direct crosswalk connects the two possible locations for the bikesharing station. Therefore, whichever station is chosen, there will be a need to provide a marked crosswalk at this location.

The Sidewalk to the Campus

Unmarked Crossing at Tropicana and Wilbur Street

Figure 26. The Sidewalk and Unmarked Crossings at Tropicana Avenue and Wilbur Street

Station 5: Tropicana Avenue and Swenson Street

Station 5 can be located close to the bus stop along Swenson Street (Figure 27). At this location, there are open spaces behind the bus stop and to the south of the bus stop towards Tropicana Avenue (Figure 28). The bikesharing users from bus stops along Tropicana Avenue can access this location through the crosswalk located at the intersection (Figure 27).

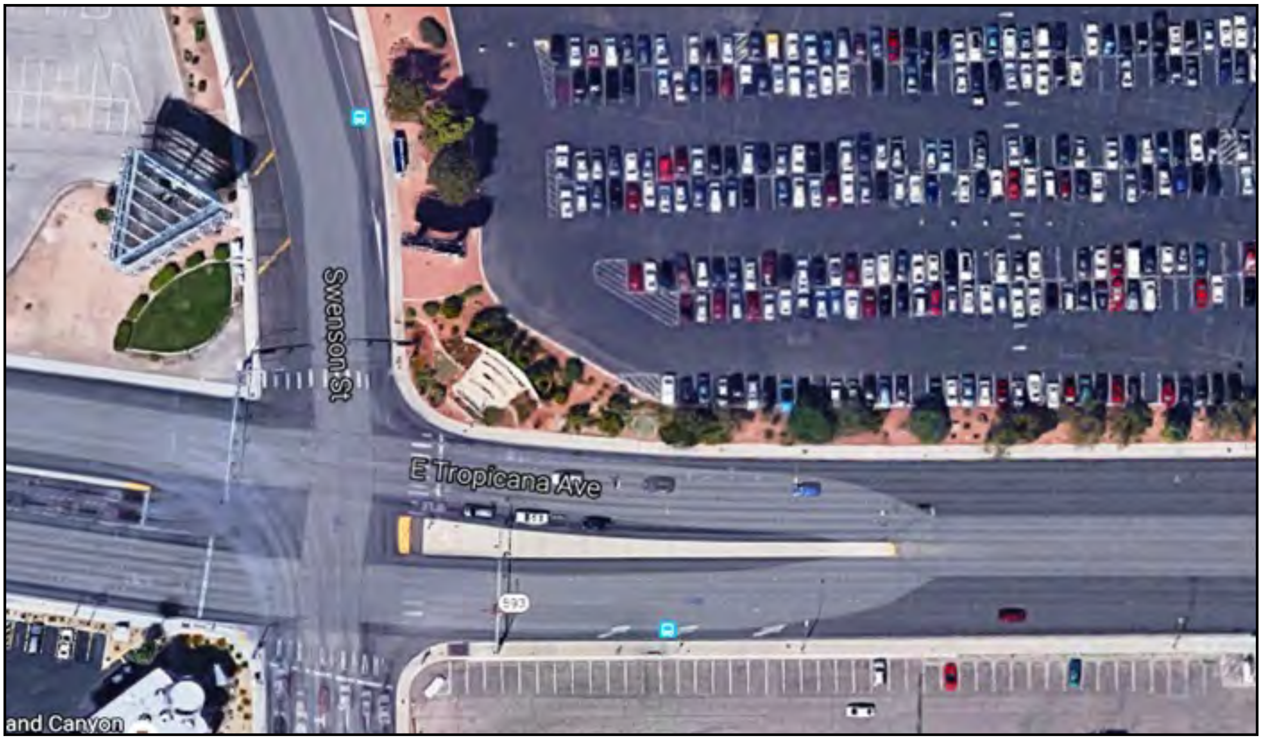


Figure 27. Possible Bikesharing Station Locations at Tropicana Avenue and Swenson Street

Open Space behind Bus Stop | Open Space south of Bus Stop

Figure 28. Photos at Bikesharing Station 5

Station 6: Swenson Street

Two locations shown in Figure 29 are the best candidates for Station 6 due to space availability. This station can be located either behind the bus stop or at the space just off the Swenson Street and Harmon Avenue intersection.

Harmon Avenue has no bus route, while Swenson Street is a one-way street. It is therefore expected that bikesharing users connecting to transit will access bikes through a station located close to the bus stop. Locating bikesharing stations at any of the locations shown in figures 29 and 30 will provide easy accessibility of bikes for riders connecting to transit as well as for ones intending to use bikesharing for off-campus movements from the playgrounds (softball, soccer, and tennis).

Figure 29. Possible Bikesharing Station Locations on Swenson Street

Open Space behind Bus Stop

Open Space off Swenson Street and Harmon Avenue Intersection

Figure 30. Photos at Bikesharing Station 6

BUS FREQUENCIES AND RIDERSHIP

Bus stops on Maryland Parkway and Flamingo Road each are connected to two bus routes. Those on Flamingo Road are connected to routes 202 and CX, while those on Maryland Parkway are connected to routes 109 and CX. Bus 201 serves Tropicana Avenue, and frequency varies on weekdays and weekends. The headway between the buses is 15 minutes for day trips and one hour for late-night trips. There is a significant number of riders at all these stations.

During weekdays, the bus stops at Flamingo Road and Claymont Street (east) and Flamingo Road and Cambridge Street (west) experience 74 trips per day, while Saturdays and Sundays yield 65 and 61 trips, respectively. According to the data from RTCSNV, 2,053 and 5,257 bus riders per day boarded and exited the buses at the Flamingo Road and Claymont Street bus stops, respectively. At the Flamingo Road and Cambridge Street (west) stop, 1,907 riders per day boarded and 2,011 exited the buses. This ridership implies that on average for every trip, there is one person who boards the bus at each of the two stops.

In relation to Station 2, both bus stops experience 75 trips per day during weekdays, 71 on Saturdays, and 62 on Sundays. On average, about 1,007 riders boarded these buses, and 1,903 exited from them, at the Maryland and Cottage Grove Street (south) stop. The Maryland Parkway and Rochelle Avenue (north) bus stop had 1,185 and 1,434 riders who boarded and exited the buses, respectively, during September 2015.

The two bus stops close to bikesharing Station 3 experience 75 trips per day during weekdays, 71 on Saturdays, and 62 trips on Sundays. At the Maryland Parkway and Harmon Avenue (north) stop, 6,458 riders got on the buses and 1,685 got off; the stop at Maryland Parkway and Harmon Avenue (south) had 2,196 riders get on and 5,809 get off the buses per day.

At the Tropicana Avenue and Wilbur Street (east) stop, 2,731 and 1,032 riders got on and off the bus, respectively; 1,784 and 1,030 got on and off, respectively, at the Tropicana Avenue and Wilbur Street (west) bus stop. These two stops experience 67 trips per day during weekdays, 62 on Saturdays, and 59 on Sundays.

DISTANCE FROM BUS STOPS TO BIKE STATIONS

The distance from a bus stop to a bikesharing station affects one's selection of a bikesharing program. Studies have shown that public transit users can walk up to 400 meters (1,310 feet) to catch a bus (.[47] The same trend might be valid for a bikesharing station. The closer the bus stop is to the bike station, however, the more likely the travelers from the buses would use the bikesharing station.

The distances from bus stops to bikesharing stations were measured using the Google Maps distance measurement tool. Figure 31 shows the distance measurement procedure for the distance from the Flamingo Road and Cambridge Street bus stop to bikesharing Station 1 on Claymont Street. All of the distances from the bus stops to the proposed bikesharing stations were measured and are presented in Table 24.

Figure 31. Procedure to Measure the Distance from a Bus Stop to a Bikesharing Station

Table 24. Distance (in Feet) from Bike Stations to Bus Stops

Routes	Bikesharing Stations	Bus Stops			
Flamingo Road	1	Flamingo @ Maryland (W) 1,100 ft.	Flamingo @ Cambridge (W) 380 ft.	Flamingo @ Claymont (E) 50 ft.	Flamingo @ Swenson (E) 1,050 ft.
Maryland Pkwy	2	Maryland @ Harmon (S) 1,340 ft.	Maryland @ Cottage Grove (S) 10 ft.	Maryland @ Rochelle (N) 1,550 ft.	Maryland @ Harmon (N) 920 ft.
Maryland Pkwy	3	Maryland @ Cottage Grove (S) 1,340 ft.	Maryland @ Harmon (S) 10 ft.	Maryland @ Harmon (N) 610 ft.	Maryland @ University (S) 1,380 ft.
Tropicana Avenue	4	Tropicana @ Maryland (W) 1,140 ft.	Tropicana @ Wilbur (W) 10 ft.	Tropicana @ Wilbur (E) 470 ft.	Tropicana @ Swenson (E) 1,360 ft.

Routes	Bikesharing Stations	Bus Stops		
Tropicana Avenue	5	Swenson @ Tropicana (N) 10 ft.	Tropicana @ Swenson (E) 390 ft.	Tropicana @ Swenson (W) 640 ft.
Swenson Street	6	Swenson @ Harmon (N) 10 ft.		

Considering the distance factor, it is expected that most of the travelers near Station 1 will be from two bus stops, Flamingo Road at Cambridge Street (west) and Flamingo Road at Claymont Street (east) (Figure 9). Station 2 would attract users only from the Maryland Parkway at Cottage Grove (south) bus stop (Figure 12).

Due to the lack of a pedestrian crosswalk, the distance from Station 2 to Maryland Parkway at Rochelle Avenue (north) would be too long for travelers. If a crosswalk is provided at this location, however, users from that bus stop would be attracted to use Station 2.

Station 3 would attract users from Maryland Parkway at Harmon Avenue (south) and Maryland Parkway at Harmon Avenue (north) (Figure 14) due to its proximity to these two bus stops, compared to the other two bus stops shown in Table 23.

Station 4 would attract users from bus stops at Tropicana Avenue and Wilbur Street (west) and Tropicana Avenue and Wilbur Street (east) (Figure 16).

The bus riders from stations at Swenson and Tropicana (north) and Tropicana and Swenson (east) would be attracted to use Station 5, while Station 6 would attract bus riders from the Swenson and Harmon (north) bus stop (Table 23).

VIII. DEVELOPING A COHERENT PROGRAM OF IMPROVEMENTS

Currently, there are 46 bike-rack locations around the campus. The priority locations are the buildings with classrooms, libraries, and dorms. The locations having a higher number of people, such as libraries, also have more bike racks compared to locations having fewer people (Figure 32).

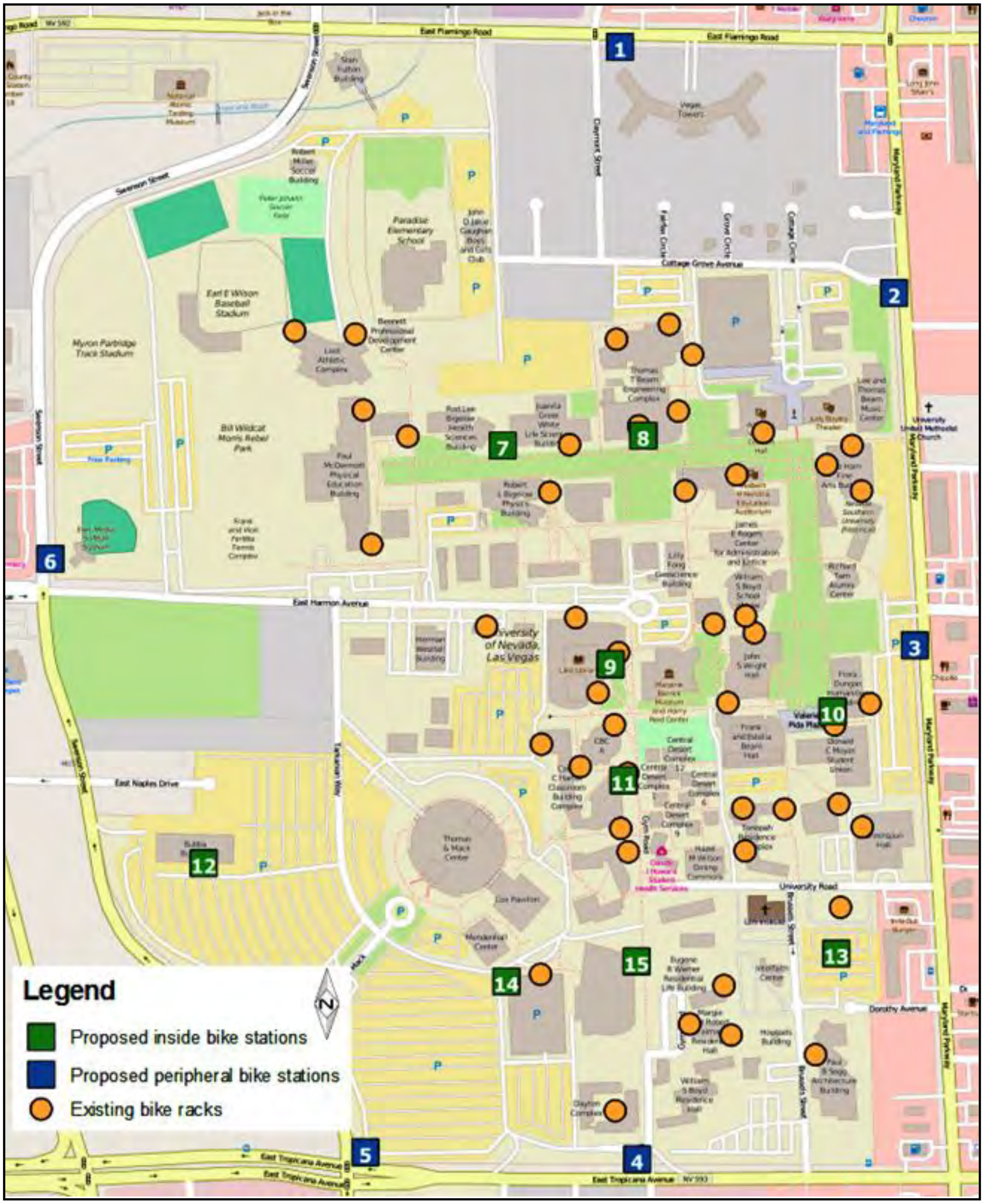


Figure 32. Existing Bike Racks and Proposed Bike Stations

In locating the proposed bikesharing stations, these bike racks should be considered.

Health Science Building

Station 7 is to be located at the Health Science Building. It is expected that users of this station will be from this department's building as well as those who use the parking lot on the north side of the building. There is no golf-cart station at this location; however, there are spaces and wide paths that could accommodate a bikesharing station and the needed path. The station is proposed to be at the empty space located southeast of the building, as shown in figures 33 and 34.

Figure 33. Station 7 at the Health Science Building

Figure 34. Proposed Site for Bikesharing Station 7

College of Engineering

The College of Engineering has four locations (Figure 35) with bike racks that can accommodate up to 31 bikes. Among the four locations, two (south of Thomas Beam Engineering (TBE) and east of Science and Engineering Building (SEB)) have been used more frequently. In addition to the bike racks, the College of Engineering has two parking locations for golf carts that are used by staff in their day-to-day activities. At this location, a bikesharing station can be placed either on the south or southeast side of TBE (Figure 36). Apart from being utilized by the students, faculty, and staff located in TBE and SEB, the bike station could provide service to users who park their cars in the Cottage Grove Parking Garage. Golf-cart users also might utilize the bikesharing program.

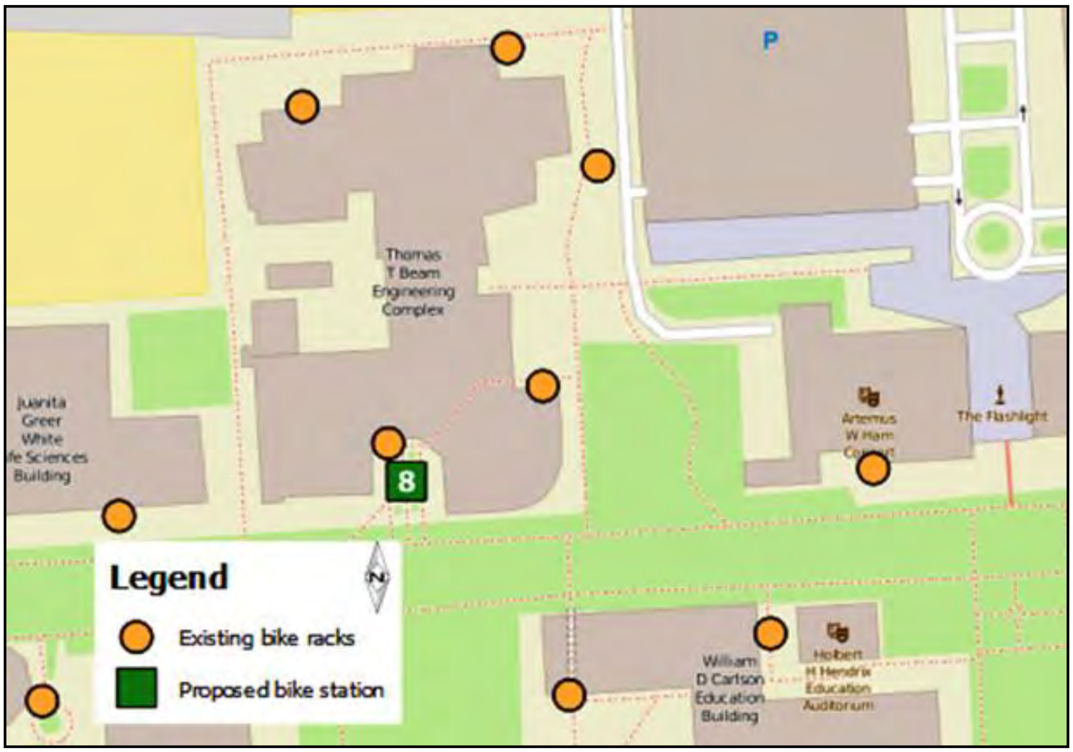


Figure 35. Station 8 at the Engineering Buildings (TBE and SEB)

South of TBE　　　Southeast side of the TBE

Figure 36. Proposed Sites for Bikesharing Station 8

Lied Library

Currently, there are three locations with bike racks at the south, southeast, and east entrances of Lied Library, with a total of nine bike racks that could accommodate a total of 27 bikes. According to the data from Parking Facilities at UNLV, the station located at the east entrance (figures 37 and 38) is the most-used station. The proposed bike station is expected to replace all of the existing stations, and would attract all of the users visiting the library. There is no golf-cart station at this location.

Figure 37. Station 9 at Lied Library

On the South East of the Library | On the East Side of the Library

Figure 38. Proposed Sites for Bikesharing Station 9

Flora Dungan Humanities (FDH) and the Student Union

This is one of the most vibrant locations as it is near the food courts, activity centers (e.g. pool tables), and meeting locations for most of the undergraduate students (figures 39 and 40). There are two bike-rack locations and one golf-cart station; the two bike-rack locations have the capacity to accommodate 20 bikes. The proposed bikesharing station (Station 10 in Figure 39) is expected to accommodate users arriving at and leaving this location as well as those from other neighboring buildings, such as the Lee Business School and John S. Wright Hall.

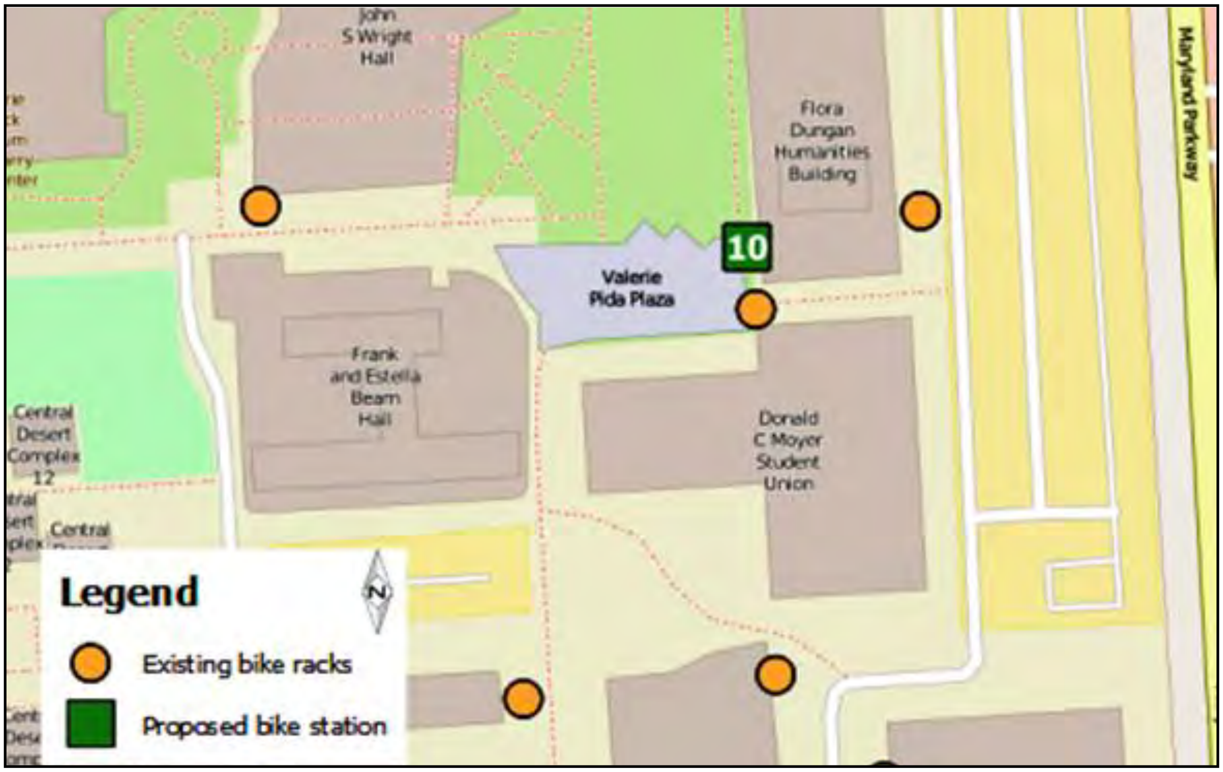


Figure 39. Station 10 at the Florence Dungan Humanities Building and the Student Union

Figure 40. Proposed Site for Bikesharing Station 10

Classroom Building Complex (CBC)

As shown in figures 41 and 42, there are five bike-rack locations, which can accommodate 55 bikes. The bike rack on the west side of CBC is the largest, with a capacity to contain 21 bikes at a time. The bike rack on the east side of CBC is the one that is most utilized. There is no golf-cart station at this location. A proposed bikesharing station would be located close to the bike rack on the east side (Figure 41).

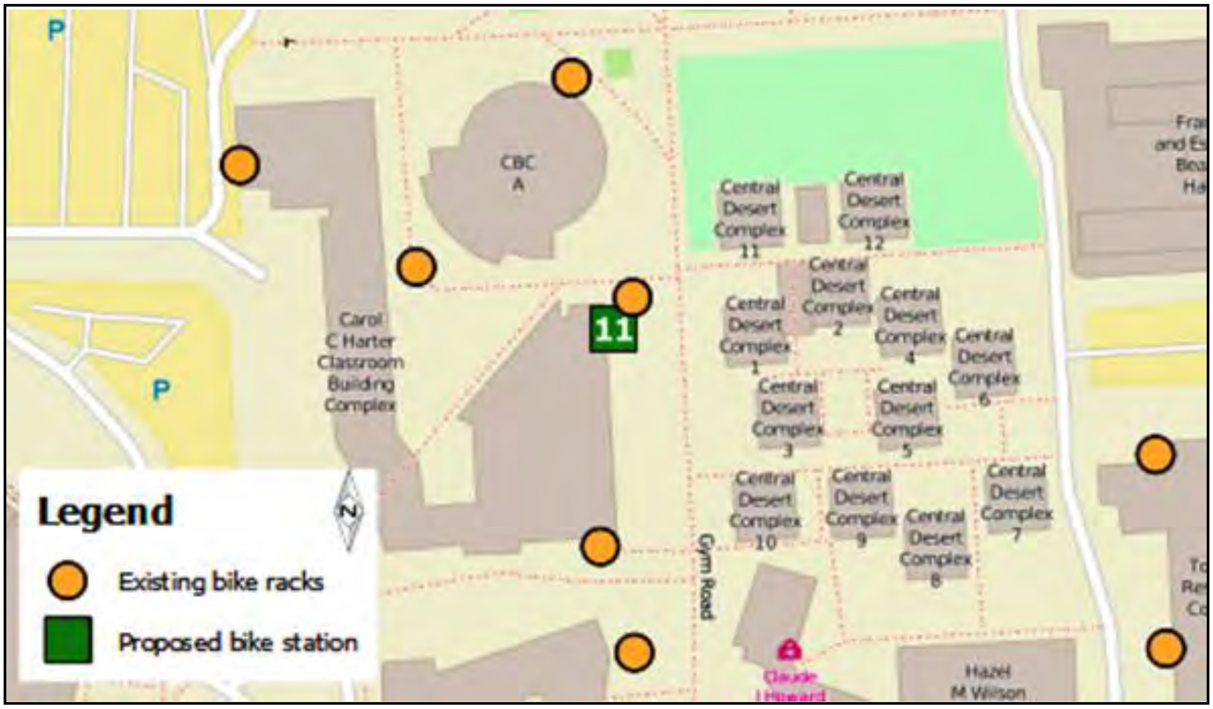


Figure 41. Station 11 at the Classroom Building Complex (CBC)

Figure 42. Proposed Site of Bikesharing Station 11

Campus Service Complex

The Campus Service Complex (CSC) (Figure 43) has no existing bike racks in its vicinity. It is located at the center of a parking lot near Swenson Avenue; all movements to other buildings are made by using golf carts (Figure 44). There is a wide area for locating the bikesharing station, which will provide service to users from the CSC building and the parking lot.

Figure 43. Station 12 at the Campus Service Complex

Figure 44. Proposed Site of Bikesharing Station 12

RTC Transit Center

The bus terminal at the RTC Transit Center (Figure 45) has 53 bike racks that can hold up to 110 bikes at a time. The racks have not been effectively used, as parking data has revealed that most of the time the racks are empty. The proposed bikesharing station at this location would provide service to users at the transit center.

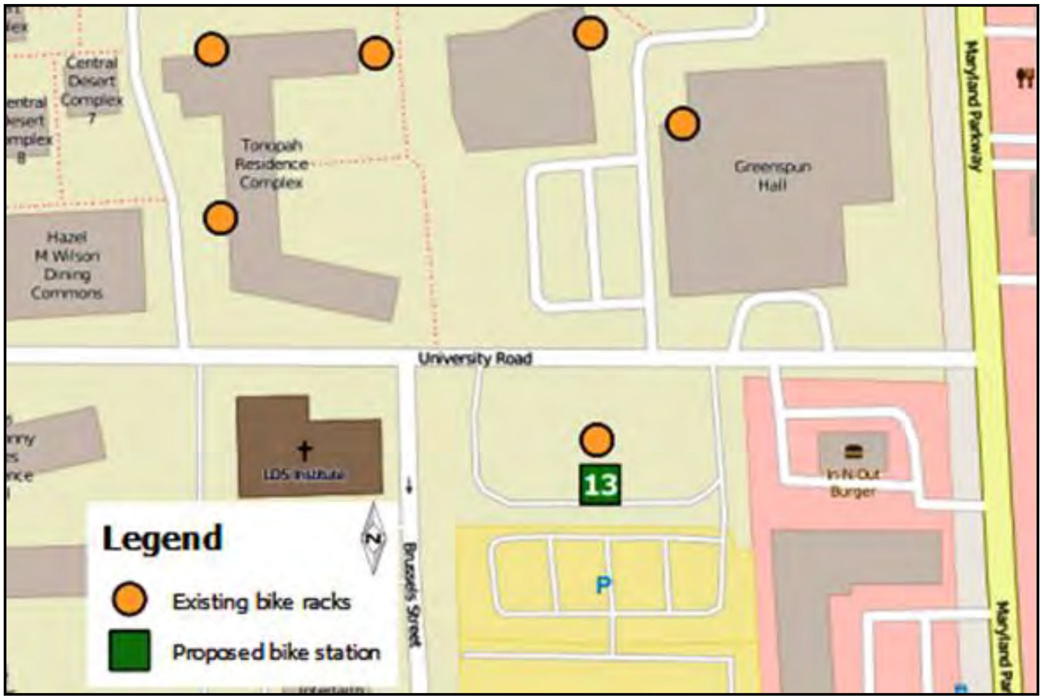


Figure 45. Station 13 at UNLV's RTC Transit Center

The users at this location will be either entering or leaving UNLV. Therefore, bikes would help them for their first mile or last mile of travel. The presence of crosswalks makes bike riding safer than at other locations. The existing bike racks are ring-shaped, as shown in Figure 46.

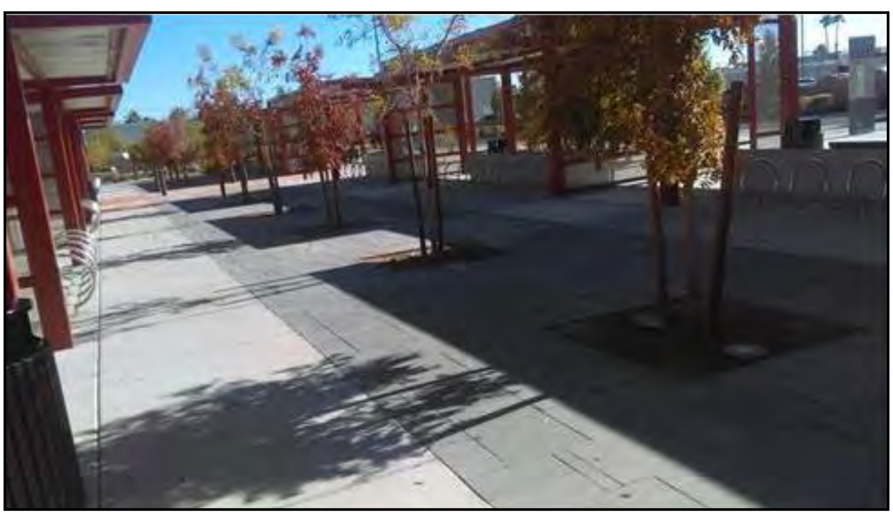


Figure 46. Bike Racks Located at the Proposed Site for Station 13

Tropicana Garage

Two bike racks are located at the Tropicana Parking Garage (Figure 47). Bike users from this parking garage and Parking Lot B could use the proposed bikesharing station (Figure 48) located at the Tropicana Parking Garage. Apart from the garage and parking lot, the bus that drops and picks up students living in the Rebel Place student apartments has a stop located in this area.

Figure 47. Station 14 at the Tropicana Parking Garage

Tropicana Garage | Parking Lot B

Figure 48. Proposed Location for Station 14 at the Tropicana Parking Garage

Student Recreation and Wellness Center (RWC)

The Student Recreation and Wellness Center (RWC) is the location used for gym workouts for most of UNLV's students. It has one existing bike rack, but has no station for golf carts. The bikesharing station at the RWC (Figure 49) will attract users from many different locations who use the facility. It is expected to be one of the major stations, considering the number of the facility's users. There is enough space on the northeast side of the facility for a bikesharing station (Figure 50).

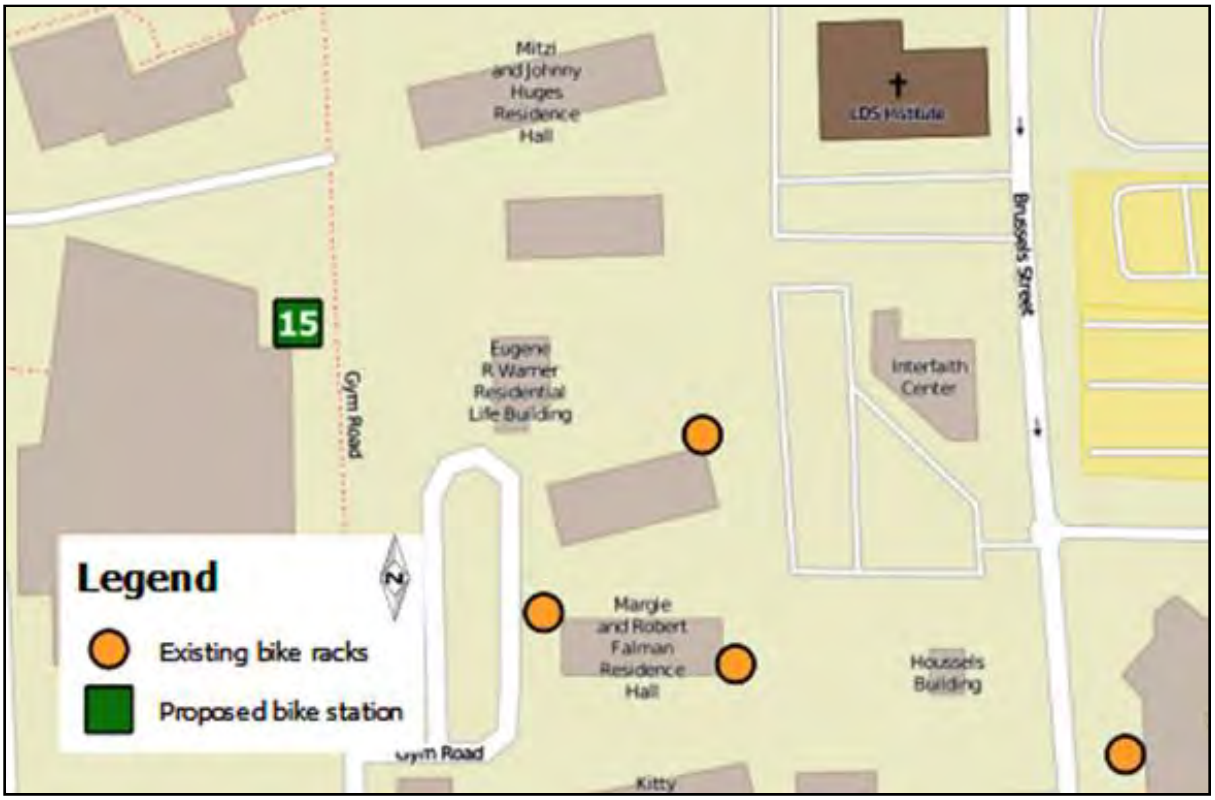


Figure 49. Station 15 at the Student Recreation and Wellness Center

Figure 50. Proposed Site for Bikesharing Station 15

UNIVERSITY MASTER DEVELOPMENT PLAN

Recently, UNLV's Board of Regents approved updates to its 2012 Campus Master Plan.[48] In the next 10 years, the major changes will occur on both the west and east sides of the campus (see Figure 51). A Mega Events Center will be built in the northwest area of the campus, and some sports fields will be moved to the southwest area on land that will be purchased from the county. A student village will be built next to the Thomas & Mack Center. These developments can be visualized from Figure 52. It is anticipated that the Mega Events Center and the student village will generate significant trips to and from different parts of the campus, for which bikesharing stations could be built in the future in response to the growing campus.

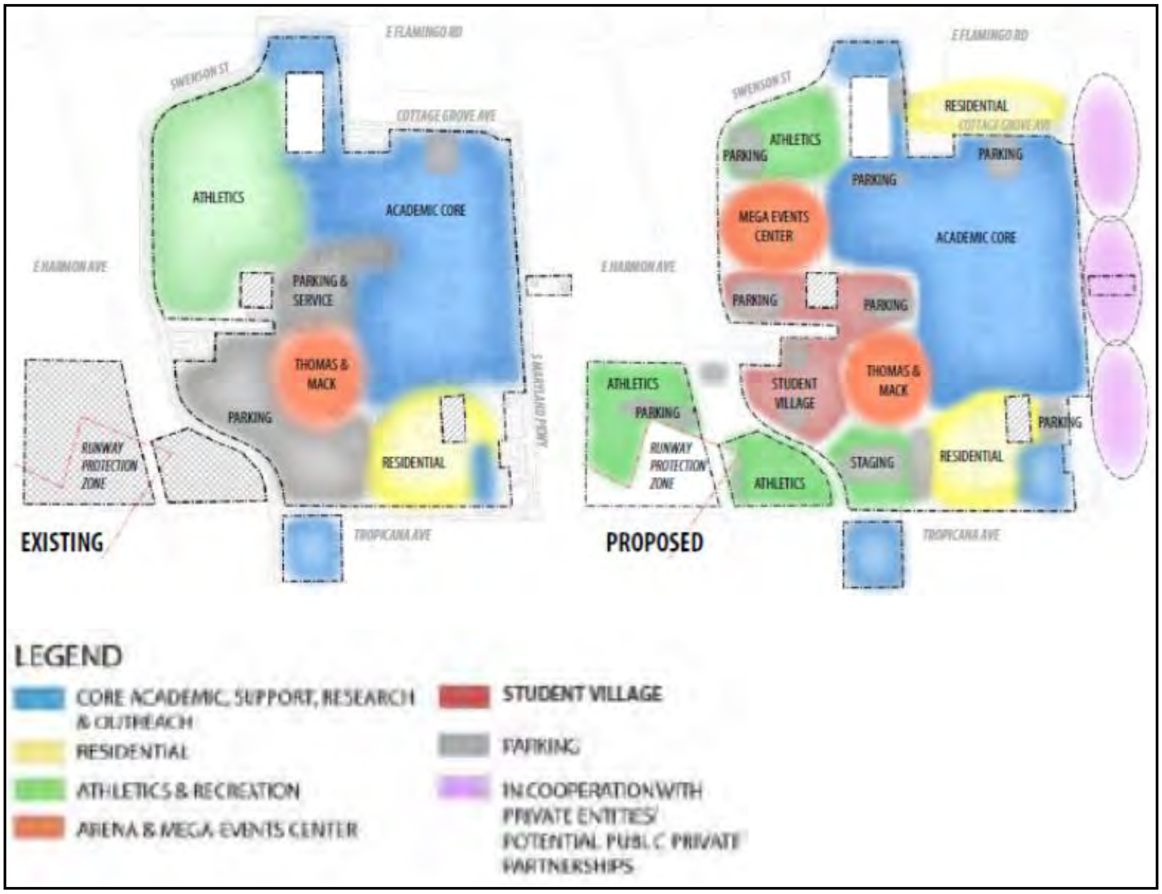


Figure 51. Existing Conditions and the Proposed 10-year Plan for Expansion at UNLV

Figure 52. Visualization of Future Expansion at UNLV

To accommodate the growth, the transportation system on campus has been planned and is included in the updates of the 2012 master plan. Figures 53, 54, 55, and 56 present the proposed expansion for pedestrian and bicycle systems, the transit system, and the parking system at UNLV. It can be observed that none of these plans consider the effects of a bikesharing system on campus.

The bikesharing system could be expanded so that more people could use it to reach newly developed areas; thus, transit expansion could be reduced. The width of pedestrian and bicycle circulation may need to be widened if the bikesharing system is installed on campus. The system would bring more bikes onto campus, so the circulation capacity would need to be enhanced. For the parking facilities, in particular, the addition of parking garages on campus would encourage the use of autos to the university, which is contradictory to the purpose of a bikesharing program. The types of trips to be served by the proposed garages should be identified, and planning on the size and location of the garages should take the bikesharing program into consideration.

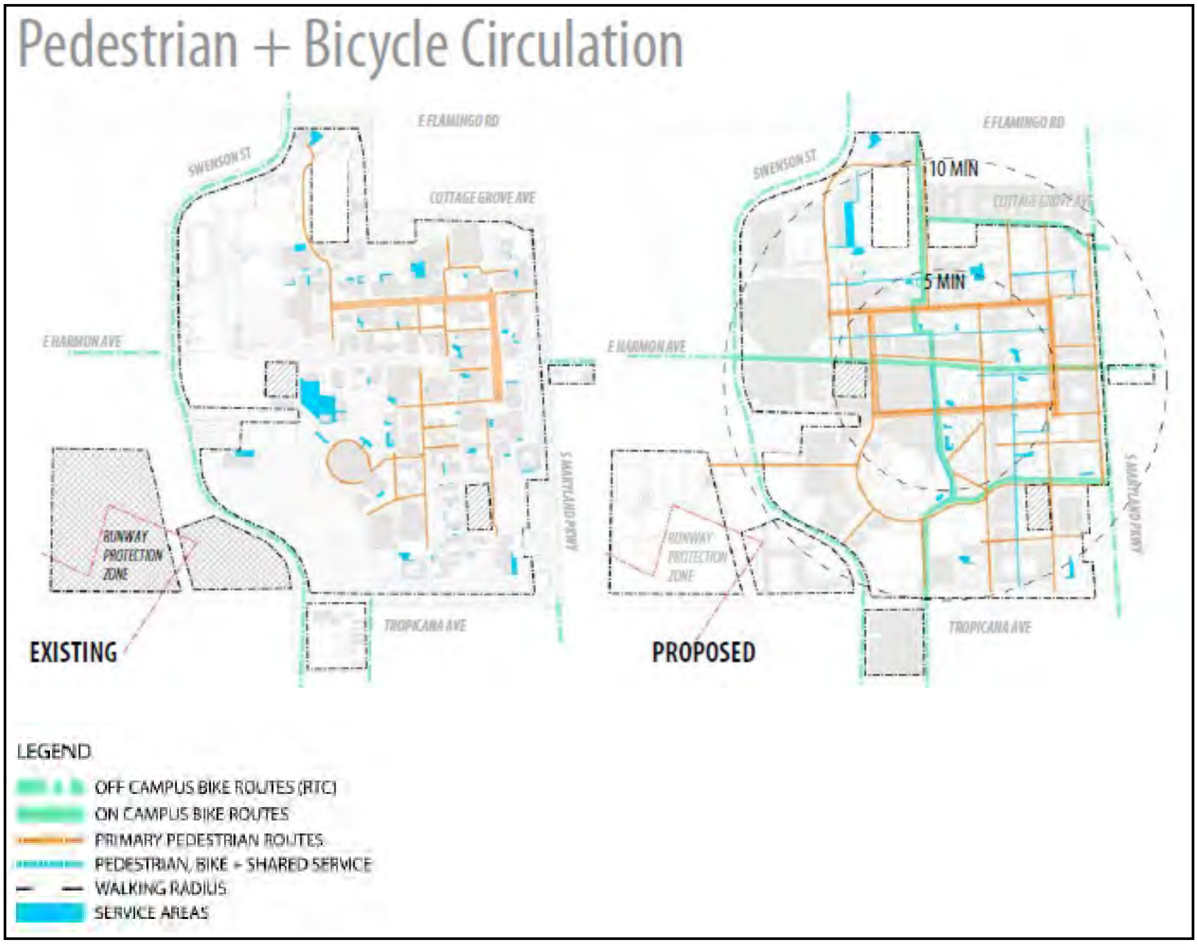


Figure 53. Existing and Proposed Pedestrian and Bicycle Circulation on Campus

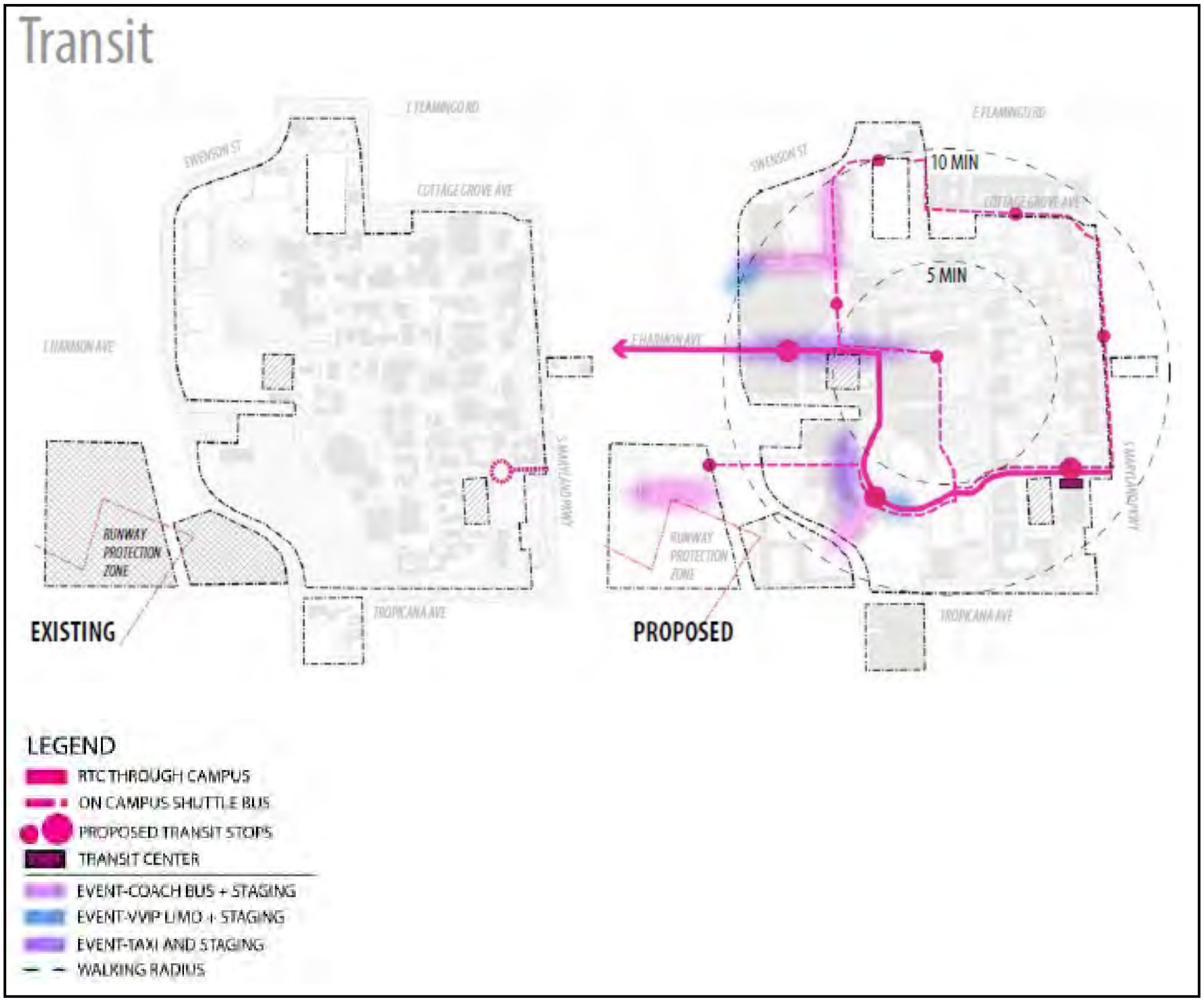


Figure 54. Existing and Proposed Transit on Campus

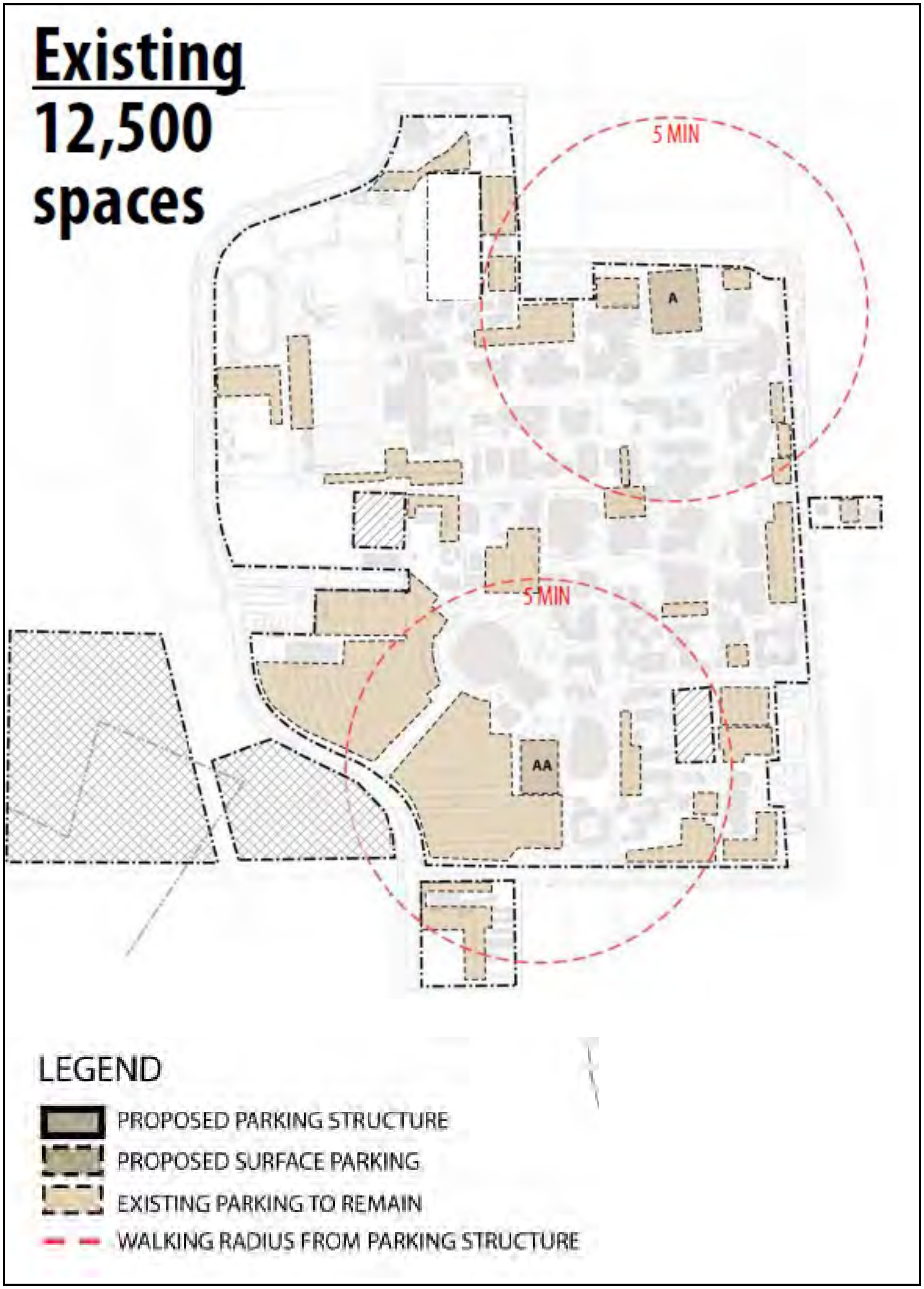


Figure 55. Existing Parking Spaces on Campus at UNLV

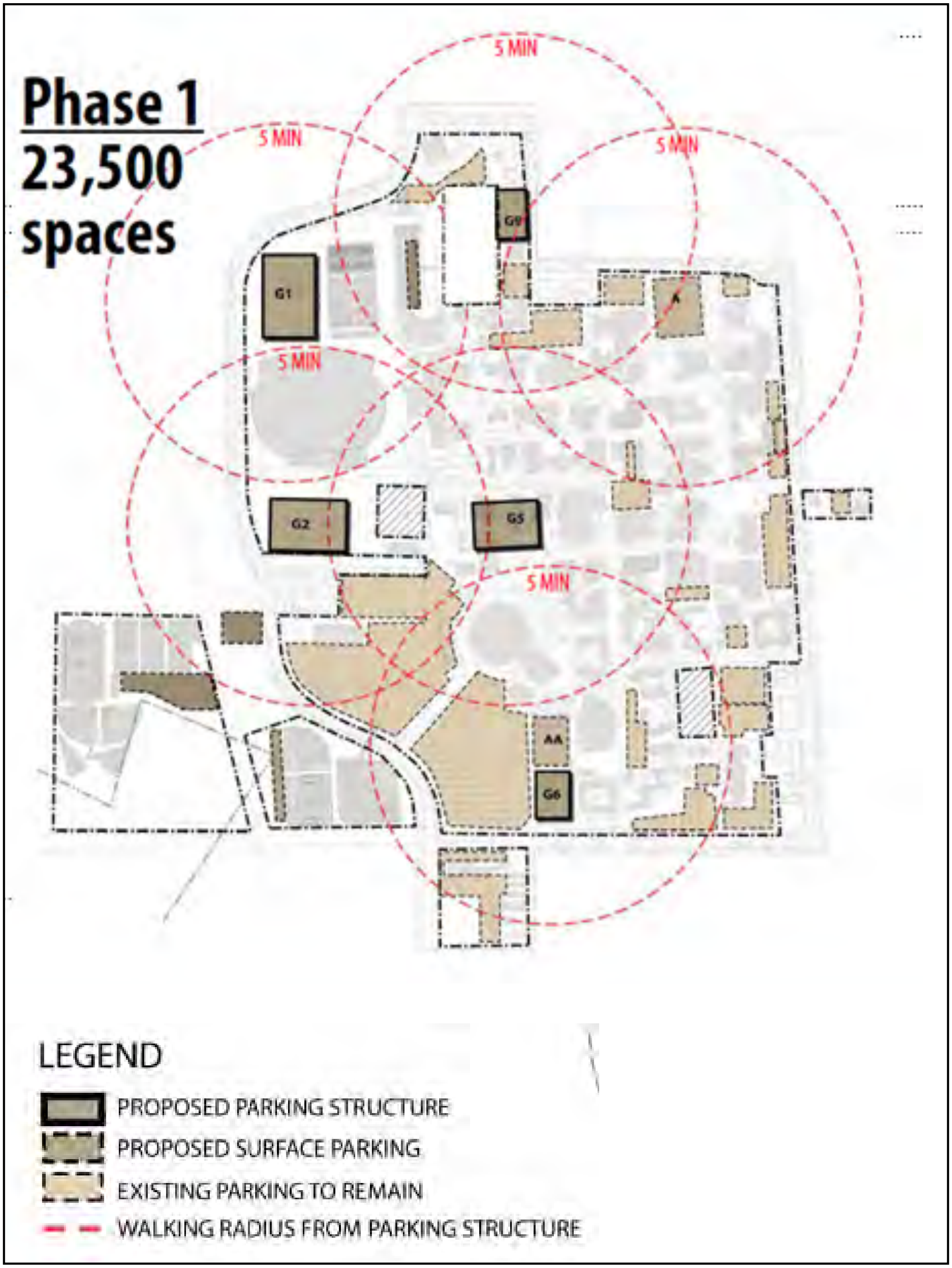


Figure 56. Proposed Parking Spaces at UNLV

SPENCER GREENWAY TRANSPORTATION TRAIL AND UNLV CAMPUS BIKE PLAN

In parallel to this bikesharing program study, a research project was being conducted for the Spencer Greenway Transportation Trail and the UNLV campus bike plan.[49] One objective of this project was to identify existing bike routes that surround UNLV. The other objective was to identify various locations within the campus where temporary bicycle storage and/or lockers, as well as other bicycle storage amenities, could be located in order to protect bicycles from theft while visiting the campus.

The bikesharing project developed bike routes that connect the stations. These routes run from the periphery of the campus to inside the university, and can connect with those surrounding UNLV that have been identified in the UNLV Campus Bike Plan. At UNLV, there are racks available that have been identified in this study, and these racks can be used by visitors to UNLV for temporary storage.

MARYLAND PARKWAY ALTERNATIVE ANALYSIS

In 2014, an alternative analysis was conducted for the Maryland Parkway Corridor, in which rapid transit (buses) and guided transportation were evaluated.[50] From Figure 27, it can be seen that the alternate route would run from downtown Las Vegas along Maryland Parkway to McCarran International Airport.

If an enhanced public transportation service is provided, more people will take the service to UNLV. In this case, bikesharing stations should be built along Maryland Parkway so that people would have a chance to use bicycles to commute to work by means of the bikesharing program.

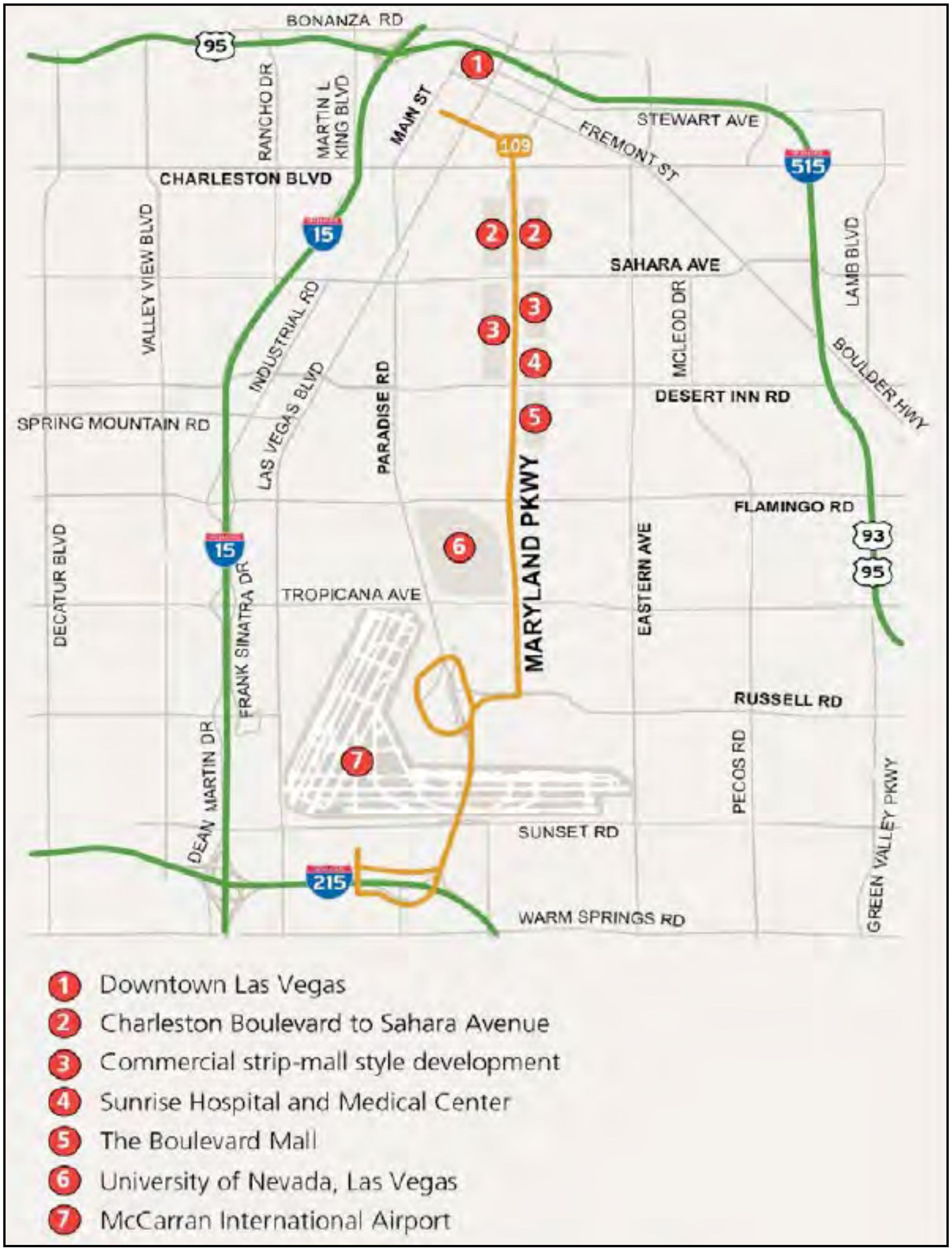


Figure 57. Alternate Route for Rail Transit[51]

IX. RECOMMENDATIONS TO MINIMIZE MODAL CONFLICTS BETWEEN BIKE RIDERS AND PEDESTRIANS

Currently, there are no dedicated bike routes within and around the UNLV campus. For the proposed bikesharing program, the bike routes that were proposed are presented in Figure 58. The routes connect all the peripheral and on-campus stations.

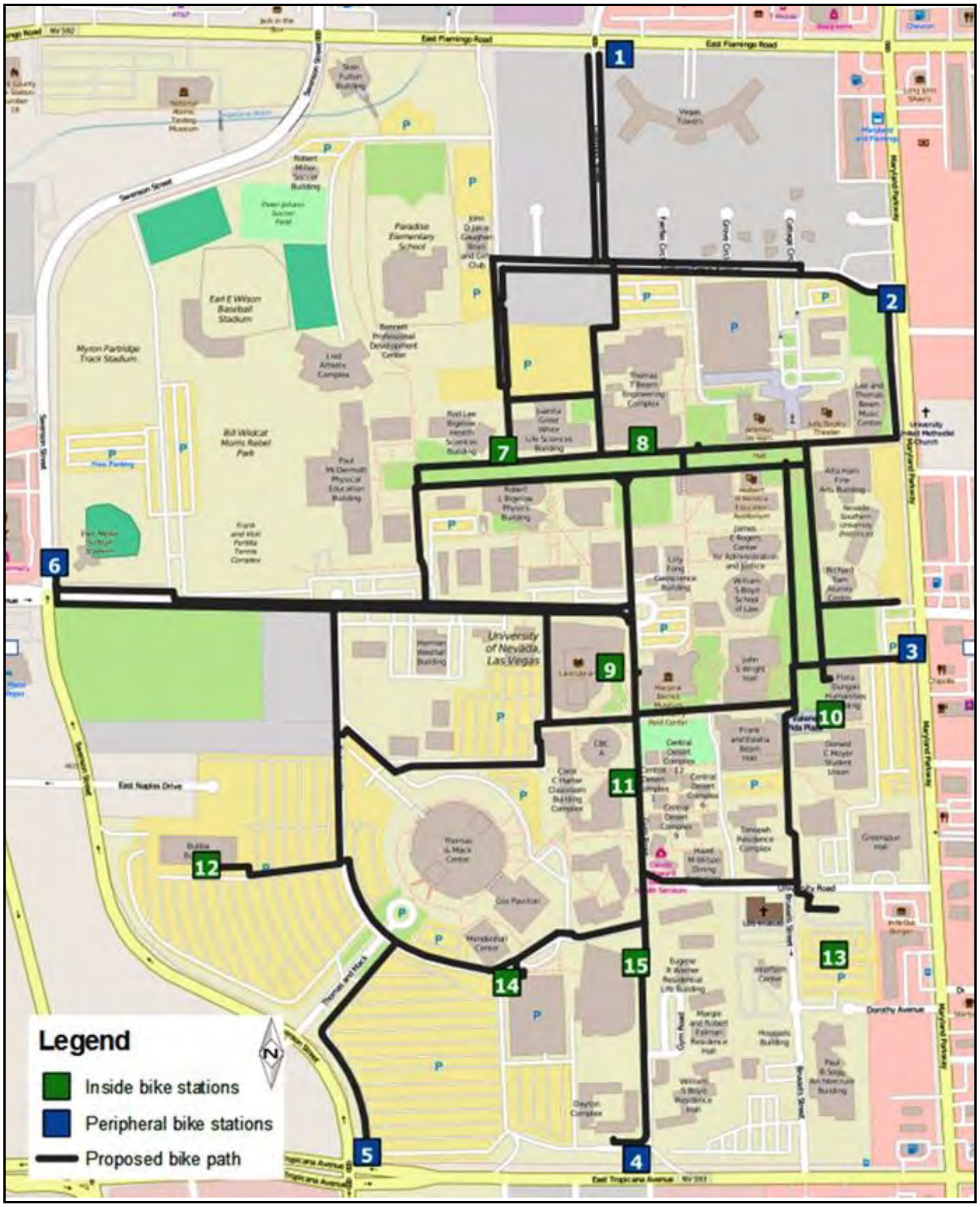


Figure 58. Proposed Bike Routes at UNLV

The conflict locations were identified by field observation, which involved walking around the entire campus and observing pedestrian movements (Figure 59).

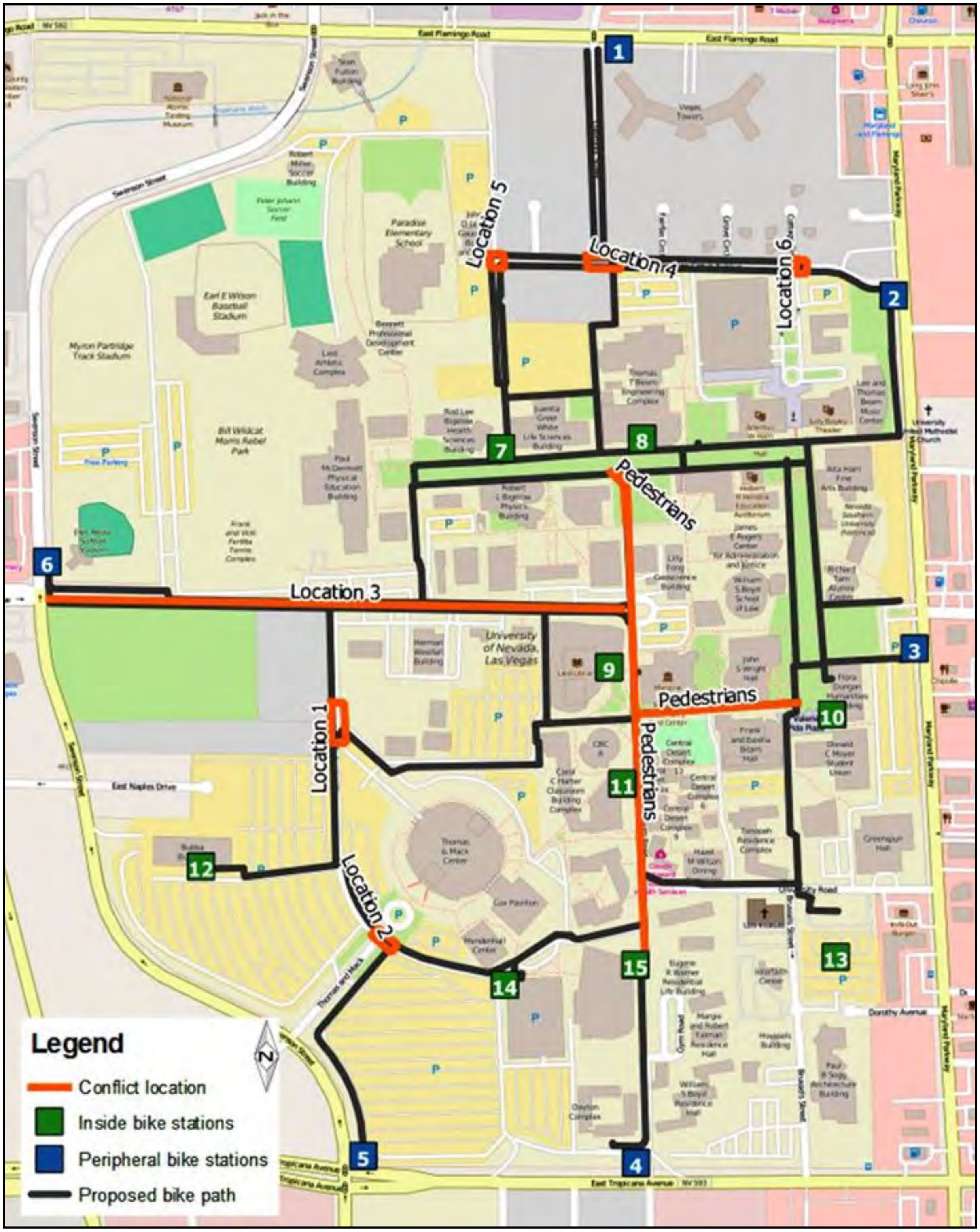


Figure 59. Identified Locations for Conflict Among Pedestrians, Bicycles, and Vehicles

Location 1 has pedestrian crossing facilities (crosswalks) that also have traffic-calming devices (Figure 60). Location 3 has a mix of pedestrians and vehicles, with a posted speed limit of 25 mph. Locations 2, 4, 5, and 6 have no crosswalks, and the vehicle speed limit is 25 mph. Thus, crosswalks should be provided at these locations.

Location 1 Location 3

Figure 60. Vehicle Conflict at Locations 1 and 3

In addition to the conflict locations identified for pedestrians, bicycles, and vehicles, regulations and rules are also recommended to facilitate establishment of a bikesharing program. These rules and regulations are developed based on existing conditions on campus, and factors observed from the review of existing city and campus programs to minimize the possibility of conflicts between pedestrians, cyclists, and vehicles on and around the campus.

First, the bike routes should be established and marked all around the campus. Traditional markings should be utilized (Figure 61). At all of the locations where conflicts with vehicles were observed, vehicle users should be alerted about the presence of pedestrians and bicyclists. All roadways within the campus should have a speed limit of 5 mph.

Bike route marking Bike lane sign

Figure 61. Traditional Bike-Lane Markings and Signs

Source: http://marilynch.com/blog/tips-for-tourists/where-to-cycle

Second, locations with high pedestrian counts should be identified as restricted pathways during a given time of day. Signs such as presented in Figure 62 should therefore be placed at appropriate locations on the campus.

Figure 62. Walk Your Bike Sign

*Source:*http://www.roadtrafficsigns.com/Bike-Sign/Walk-You-Bike-Sign/SKU-ST-0126.aspx

Third, for locations with narrow roadways that do not allow for separate bike lanes, the Share the Road marking/sign (Figure 63) should be utilized to instruct drivers, pedestrians, and cyclists.

Figure 63. Narrow Path Close to the College of Engineering and a Share the Road Sign

X. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study focused on the feasibility of a bikesharing program at UNLV. Goals of the proposed program at UNLV were developed as well as the metrics to use in monitoring its performance.

A questionnaire was distributed to obtain the preferences of potential users regarding the locations of the bikesharing stations, the likelihood they would use the bikes, and the frequency of using the bikesharing program. Responses to the survey were used to estimate the demand for the bikesharing system on and around the UNLV campus.

Various bikesharing program alternatives were analyzed, with each case consisting of a different number of stations, bicycles, and docks. The demand corresponding to the stations in these cases was used as the input to a simulation model developed in this study in order to determine the number of docks in stations and bicycles in the system on and around campus. These sizing parameters were used in a cost-benefit analysis to determine which cases could achieve the maximum benefit at UNLV, given the limitation of initial costs. In addition, the revenue to be generated for each case was calculated based on the estimated demand. Comparing the revenue with the costs, the cases that could generate sufficient funds to make the bikesharing system sustainable were determined.

After the scale of the bikesharing system was determined, connections with transit were evaluated based on the location of the bikesharing stations and the presence of bus stops in close proximity to the stations. Field observations were performed to identify existing bike racks and their usage.

The UNLV Campus Master Plan was reviewed about future development on and around campus that could influence the bikesharing program. Bike paths between the proposed stations were audited to determine which locations had a greater potential for conflicts between bicyclists and pedestrians, and possible measures to reduce conflicts were suggested. In addition, recommendations for the roadway infrastructure to facilitate safer bicycling to/from campus as well as an on-campus infrastructure to facilitate the navigation of the bicycles were proposed.

The primary goal of the bikesharing program at UNLV is to reduce congestion on the roads by increasing usage of public transportation and by providing the infrastructure for the last mile of travel using bicycles. The proposed program could improve productivity on campus as well. Performance metrics include the number of customers using the bikesharing system for commuting and on-campus travel, fleet usage, and customer service.

In total, 241 people (with significant sub-group samples of faculty, staff, and students) responded to the survey. About 50% of those participating in the survey expressed a willingness to use the bikesharing system for commuting, and 60% indicated they would use the system for on-campus travel. Commuting and on-campus travel are two different types of travel, and the factors determining whether an individual would use the bikesharing system for each are quite different. For commuting to the university's campus, factors critical for customers to decide whether they would use the bikesharing program are:

- Distance from where the users would return the bikes to their destinations;
- Access to a bus line connecting to where they live;
- Income;
- Whether they drive to school;
- Whether they come to school before 8 a.m.; and
- Education level.

The factors that influence the frequency of using the bikesharing system are quite different, and they are:

- Gender;
- Whether they have an office on campus;
- Whether they are faculty members; and
- Education level.

For on-campus travel, it was found that factors critical for customers choosing to use the bikesharing program are:

- Distance from the station where the users return the bikes on campus to their destinations, and
- Income.

The factors that determine whether the customers use the bikesharing program frequently are:

- gender;
- whether they have an office on campus;
- whether a customer is a faculty member;
- education level; and
- whether they use the bikes to attend classes.

It was estimated that there would be 3,450 members for the bikesharing program at UNLV; each user would make bicycle trips with various frequencies, which would produce an estimated 1,966 trips per day. If two stations were installed on the periphery of the campus and three stations on campus, the system would serve 261 trips per day. This is comparable to the average of trips served by bikesharing programs at five other universities in the U.S. This estimate of demand thus can be viewed as reasonable.

Among the 14 cases considered for a bikesharing system at UNLV, two cases included one station on the periphery and three stations on campus. These cases were cost-effective in terms of costs for initial equipment, installation, and operations (less than $300,000). The revenue generated from this type of system was greater than the cost. These two cases are recommended to be considered for implementation.

Along the university boundaries there would be six proposed stations and 14 bus stops. Each station would be close to at least two bus stops, with a walking distance of fewer than 400 meters. These statistics indicate that the bikesharing program would be well connected to the transit system.

The locations of the proposed stations were identified, taking into consideration the existing bike racks on campus. There are spaces available for every proposed bikesharing station.

The bike paths connecting all of the stations were identified. Problematic spots that may pose potential risks to bicyclists and pedestrians were determined, and improvements to mitigate the risks were suggested. In addition, the connectivity of the bike paths was evaluated, and the lack of bike-path capacity was presented. There were no serious issues on filling the gaps in bike-path connectivity and capacity.

The feasibility study concludes that the proposed UNLV bikesharing program could be an effective first-and-last-mile connection and an effective campus transportation demand management (TDM) strategy to mitigate congestion and reduce vehicular emissions. With that being said, there are a number of additional research needs to be met prior to deploying a bikesharing program on the UNLV campus. These include the following.

- Demand could be estimated more accurately by collecting a larger survey sample size. A total of 241 surveys were collected from members of the UNLV community.

- Demand could be characterized more accurately. The survey conducted in this study indicated that the College of Engineering would generate the most outbound trips using the bikesharing program. It is known that the engineering students need to take courses in other colleges and schools in their first two years of study. This is reflected in the study, in which more than half the bike trips were to other buildings on campus. Whether this actually is the case should be further verified by conducting a second survey.

- Interviews should be conducted in conjunction with the surveys. The bikesharing program involves using advanced technologies, such as bike tracking and multimedia communications; these may not have been fully understood by the people responding to the survey online. If questions are misunderstood, it degrades the survey quality. During an interview, the people surveyed could be given clear explanations about the bikesharing program, thus improving the quality of the survey data.

- The survey should be given more trial tests before actual collection of field data. In this study, the survey was designed and validated by experts in survey design; however, certain problems in the survey still may have been left unidentified.

- The analysis of the likelihood and frequency of the customers using the bikesharing system at UNLV could be improved by addressing multicollinearity issues during the modeling. Also, the likelihood and frequency models could be estimated simultaneously, which would improve variations in the estimation.

- A sensitivity analysis should be conducted regarding the effects of the cost of system components on the feasibility of the bikesharing system. The cost of bikes has been decreasing over the years, and the cost of the docking stations may be decreasing as well. With these major components decreasing in cost, the bikesharing program might become even more cost-effective.

- The 14 cases considered in the cost-benefit analysis are possible options for the bikesharing program at UNLV, where the number of bicycles provided by the program will satisfy all of the demand. In reality, it is also possible that fewer bicycles than the full capacity could be provided. In this case, the needed initial costs for system purchase and installation could be reduced while the demand satisfied could be reduced as well. If the cost reduction were more than the reduction in savings, there could be many possible solutions for the bikesharing program in terms of number of bicycles, docks, and stations. It would be worthwhile to have a complete investigation on this issue in the future.

- If the cost for the docks were reduced in the smart bike system, which is currently possible, there would be more ways to distribute the bicycles as long as the total number of bicycles were smaller than the demand.

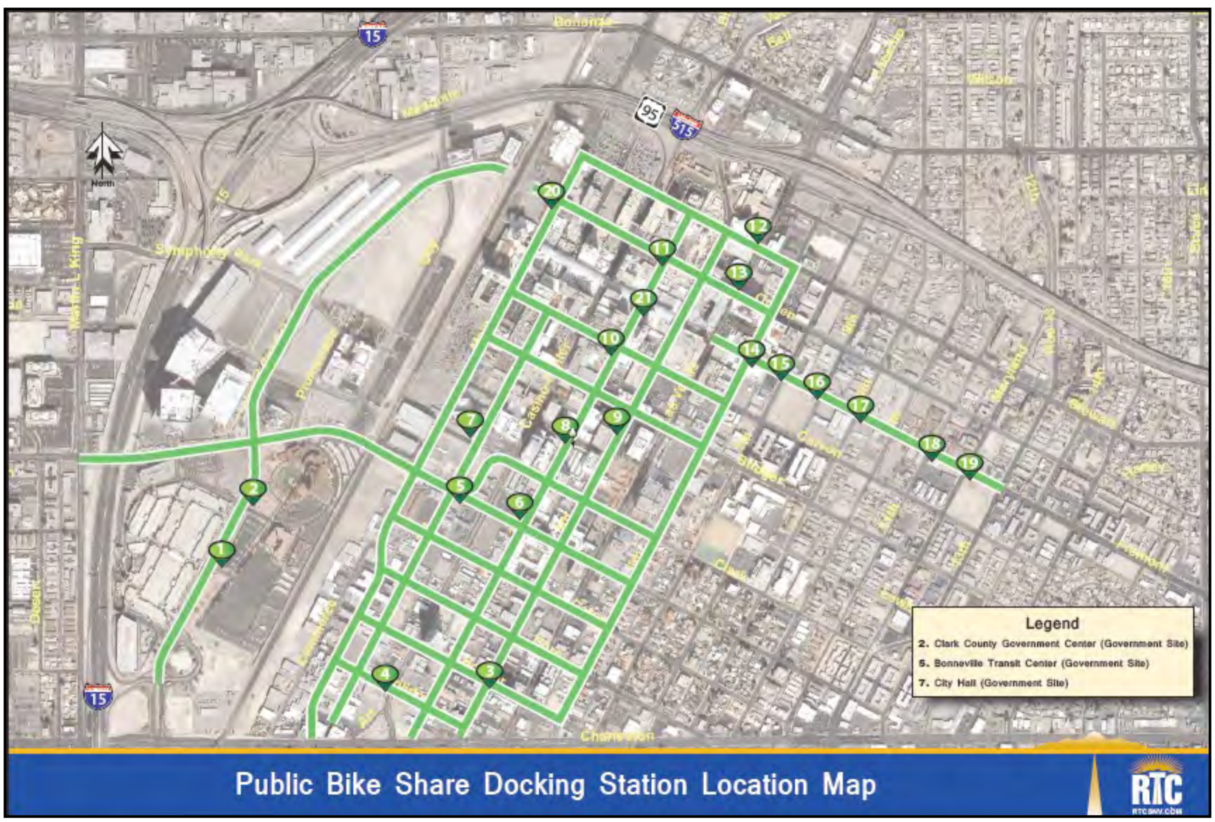
APPENDIX A: BEFORE-STUDY SURVEY OF THE RTC BIKESHARING PROGRAM

A new bikesharing program is coming to Las Vegas!

The Regional Transportation Commission of Southern Nevada will open a public bikesharing program in downtown Las Vegas in October 2015. This bikesharing program provides 200 bicycles distributed at 20 stations in the downtown area at key locations close to bus stops and major trip origins and destinations. Subscribers to the bikesharing program can take a bicycle from a station, ride to their destination, and return the bike to another station in the downtown area. Travelers are charged for riding the bicycles based on trip duration.

We are researchers from UNLV working with the Regional Transportation Commission to help them understand how well this program works and how it might be improved. As a part of that effort, we are conducting a survey of potential riders prior to opening the bikesharing system. We will conduct another survey later to assess how well the system works.

We would like your opinions and ideas. What do you expect from the bikesharing system? How will it impact your trips? Shown below is the map of the RTC's bikesharing station locations. Using the map as a reference, please answer the questions in the survey as completely as possible. Your time in completing the survey is highly appreciated.



All information gathered from this survey is kept confidential. We will not disseminate any written or oral comments or answers made by you to any outside parties. If you have any questions regarding this survey please contact the PI, Dr. Hualiang (Harry) Teng, phone 702-895-4940, email: hualiang.teng@unlv.edu.

For questions regarding the rights of research subjects, complaints or comments on the manner in which the study is being conducted, you may contact the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794, or via email at IRB@unlv.edu.

Your participation in this study is voluntary and you will not be compensated for your time. You are encouraged to ask questions about this study at the beginning or at any time during the research study. You may withdraw at any time.

Participant Consent:

I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

☐ I do not agree

☐ I agree

SURVEY QUESTIONNAIRE

1. Are you an out-of-town visitor or a local resident of Southern Nevada?

☐ Out-of-town visitor ☐ Local resident

☐ Other ______________

2. If you are an out-of-town visitor, please skip to Question 4, otherwise, please answer the following questions: What would your typical trip be?

☐ Work ☐ Shopping ☐ Business ☐ Social

☐ Other ______________

3. What method of transport do you use most often to get to downtown Las Vegas?

☐ Bus ☐ Car ☐ Other (specify) ___________________

4. Have you used a bikesharing system before?

☐ Yes ☐ No

If yes, where: _________________________

5. How likely are you to use this bikesharing program?

☐ Very likely ☐ Somewhat likely ☐ Neutral ☐ Somewhat unlikely ☐ Very unlikely

6. If likely, why would you choose to use this bikesharing program?

☐ More convenient ☐ Benefit to health ☐ Not expensive

☐ Other ___________________

7. Do you feel safe riding bicycles in traffic in downtown Las Vegas?

☐ Yes ☐ No ☐ No opinion

Pricing: Purchase a user membership in advance and the first 30 minutes are free. Additional charges will apply after the first 30 minutes.

8. Which of the three choices are you willing to pay for the membership?

☐ Annual: $65, 30 Day: $20, 7 Day: $15, 3 Day: $10, 24 Hour: $6

☐ Annual: $75, 30 Day: $25, 7 Day: $20, 3 Day: $15, 24 Hour: $7

☐ Annual: $80, 30 Day: $30, 7 Day: $25, 3 Day: $20, 24 Hour: $8

Or, what would you be willing to pay (if not any three above)?

Annual: ____, 30 Day: ___, 7 Day: ___, 3 Day: ___, 24 Hour: ___

9. Of the following choices which are you willing to pay for an additional 30 minutes after the first 30 minutes?

First additional 30 minutes	Second additional 30 minute and after
☐ $1.00	$2.50
☐ $1.25	$2.75
☐ $1.50	$3.00
☐ $1.75	$3.25
☐ $2.00	$3.50

Or, your desired payment (if not any of the above)?

____________ ___________

10. Would an app on smart phones showing the locations of stations, available bikes and available open docks for bike return be helpful to you?

☐ Very helpful ☐ Somewhat helpful ☐ Neutral ☐ Somewhat unhelpful

☐ Very unhelpful

11. Sometimes bikes may not be available at a station. How many times in a month if you find no bikes available in a station will you decide never to use the system for future trips?

☐ 2 ☐ 4 ☐ 6 ☐ More than 6

12. Sometimes there may be no place to return a bike at the station nearest your destination. How many times in a month if you find no bike docks available in a destination station when you return the bike will you decide never to use the system for future trips?

☐ 2 ☐ 4 ☐ 6 ☐ More than 6

13. Would you like the system to allow you to reserve a bike before your trip? This feature will have a bike available when you arrive at the station you specify.

☐ Like it very much ☐ Like it somewhat ☐ Neutral ☐ Do not like it very much

☐ Do not like it

14. Do you think the bikesharing program can help reduce congestion significantly?

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

15. Do you think the bikesharing program can help reduce air pollution significantly?

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

So we know where potential bikesharing users are coming from, please enter your zip code. We cannot trace your specific location from your zip code. My zip: ____________

16. What is your gender?

☐ Male ☐ Female ☐ Other

17. What is your education level?

☐ Grade 12 or less ☐ High school graduate ☐ Some college credit

☐ Assoc./tech school degree ☐ Bachelor's degree ☐ Graduate degree

☐ Some other degree ☐ Do not want to release

18. What is the general category of your annual income?

☐ Less than $10,000 ☐ $10,000 to $19,999 ☐ $20,000 to $29,999

☐ $30,000 to $39,999 ☐ $40,000 to $49,999 ☐ $50,000 to $59,999

☐ $60,000 to $74,999 ☐ $75,000 to $99,999 ☐ $100,000 to $124,999

☐ $125,000 to $149,999 ☐ $150,000 to $199,999 ☐ $200,000 or more

☐ Do not want to release

Thank you for helping us with this survey. We will conduct a follow-up survey after opening the RTC downtown Las Vegas bikesharing program. Your participation is optional. If you would like to help us with the survey, we need at least your email address.

Email address:

Phone number:

APPENDIX B: AFTER-STUDY SURVEY OF THE RTC BIKESHARING PROGRAM

A new bikesharing program has come to Las Vegas!

The Regional Transportation Commission (RTC) of Southern Nevada opened a public bikesharing program in downtown Las Vegas in Summer 2016. The area of the bikesharing program is shown in the map on the next page. You have been identified as having participated in this program. To evaluate the performance of this system, we would like your opinion and ideas. UNLV is conducting this survey for the RTC. Please answer the questions in the survey as completely as possible. Your time in completing the survey is highly appreciated.

All information gathered from this survey is kept confidential. We will not disseminate any written or oral comments or answers made by you to any outside parties. If you have any questions regarding this survey please contact the PI, Dr. Hualiang (Harry) Teng, phone 702-895-4940, email: hualiang.teng@unlv.edu.

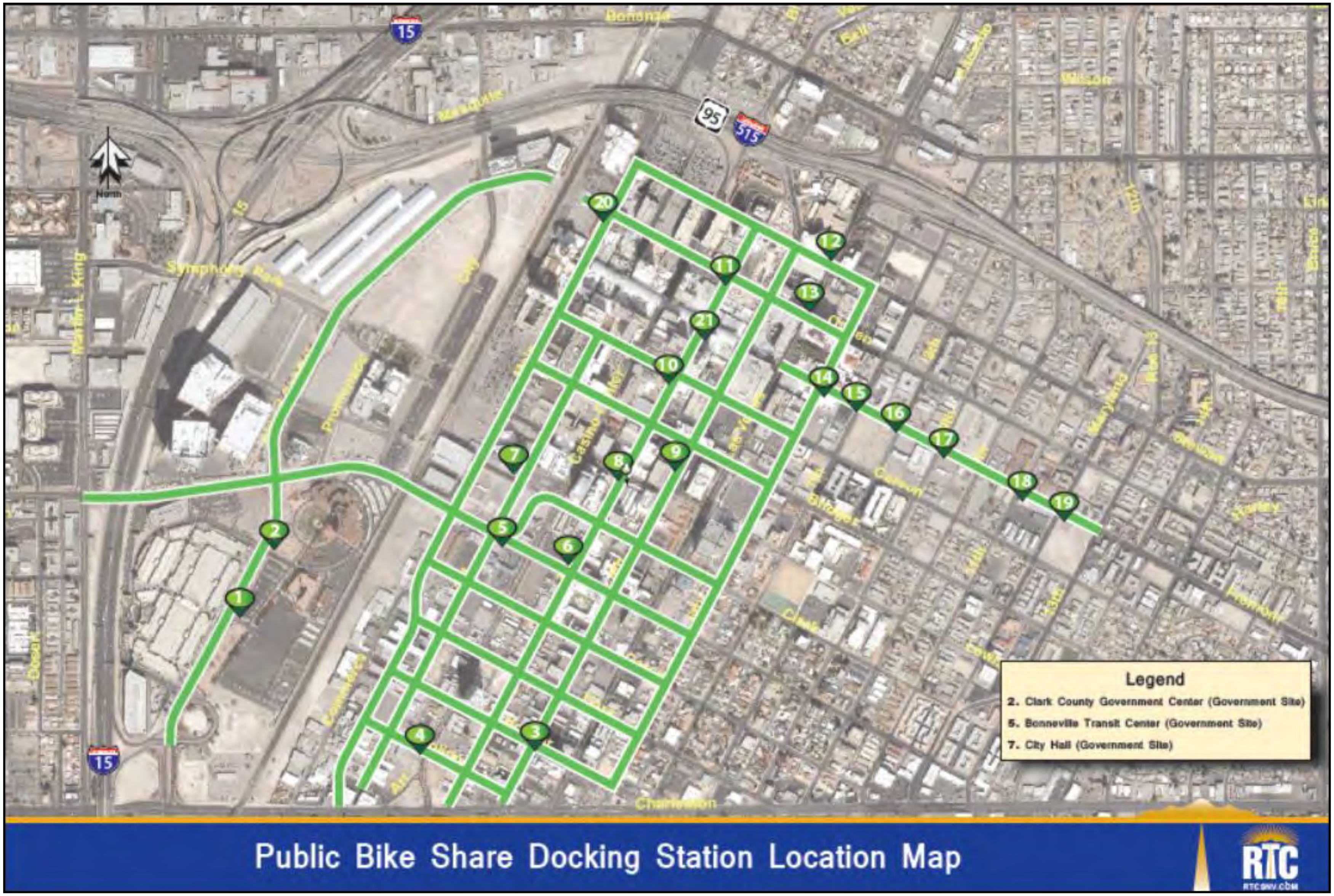
For questions regarding the rights of research subjects, complaints or comments on the manner in which the study is being conducted, you may contact the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794, or via email at IRB@unlv.edu.

Your participation in this study is voluntary and you will not be compensated for your time. You are encouraged to ask questions about this study at the beginning or at any time during the research study. You may withdraw at any time.

Participant Consent:

I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

☐ I do not agree ☐ I agree


Public Bike Share Docking Station Location Map
Legend
2. Clark County Government Center (Government Site)
5. Bonneville Transit Center (Government Site)
7. City Hall (Government Site)
Bonanza
Mesquite
Symphony Park
Charleston
RTC

SURVEY QUESTIONNAIRE

1. Are you an out-of-town visitor or a local resident of Southern Nevada?

☐ Out-of-town visitor ☐ Local resident

☐ Other _____________

2. If you are out-of-town visitor, please skip to Question4, otherwise, please answer the following questions: What would your typical trip be?

☐ Work ☐ Shopping ☐ Business ☐ Social

☐ Other _____________

3. What method of travel do you use most often to get to downtown Las Vegas?

☐ Bus ☐ Car ☐ Other (specify) __________________

4. How likely will you continue to use this bikesharing program?

☐ Very likely ☐ Somewhat likely ☐ Neutral☐ Somewhat unlikely ☐ Very unlikely

5. If likely, why do you choose to use this bikesharing program?

☐ More convenient ☐ Benefit to health ☐Not expensive

☐ Other __________________

6. Do you feel safe riding bicycles in traffic in downtown Las Vegas?

☐ Yes ☐ No ☐ No opinion

Pricing: Purchase a user membership in advance and the first 30 minutes are free. Additional charges will apply after first 30 minutes

7. Which of the nine choices are you willing to pay for the membership?

☐ Annual: $65, 30 Day: $30, 7 Day: $15, 3 Day: $20, 24 Hour: $8

☐ Annual: $75, 30 Day: $30, 7 Day: $20, 3 Day: $15, 24 Hour: $7

☐ Annual: $80, 30 Day: $30, 7 Day: $25, 3 Day: $10, 24 Hour: $6

Or, your desired payment (if not any of the above)?

Annual: ____, 30 Day: ___, 7 Day: ___, 3 Day: ___, 24 Hour: ___

8. How much are you willing to pay for the additional 30 minutes after the first 30 minutes?

First additional 30 minutes	Second additional 30 minutes and after
☐ $1.00	$3.50
☐ $1.25	$3.25
☐ $1.50	$3.00
☐ $1.75	$2.75
☐ $2.00	$2.50

Or, your desired payment (if not any of the above)?

____________ ____________

9. Would an app on smart phones showing the locations of stations, available bikes and available open docks for bike return be helpful to you?

☐ Very helpful ☐ Somewhat helpful ☐ Neutral ☐ Somewhat unhelpful

☐ Very unhelpful

10. Sometimes bikes may not be available at a station. How many times in a month if you find no bikes available in a station will you decide never to use the system for future trips?

☐ 2 ☐ 4 ☐ 6 ☐ More than 6

11. Sometimes there may be no open dock to return a bike at the station nearest your destination. How many times in a month if you find no bike docks available in a destination station when you return the bike will you decide never to use the system for future trips?

☐ 2 ☐ 4 ☐ 6 ☐ More than 6

12. Would you like the system to have a feature allowing you to reserve a bike before your trip? This feature will have a bike available when you arrive at the station you specify.

☐ Like it very much ☐ Like it somehow ☐ Neutral ☐ Do not like it very much ☐ Do not like it

13. Do you think the bike-sharing program can help reduce congestion significantly?

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

14. Do you think the bike-sharing program can help reduce air pollution significantly?

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

So we know where potential bike-sharing users are coming from, please enter your zip code. We cannot trace your specific location from your zip code. My zip: _____________

15. What is your gender?

☐ Male ☐ Female ☐ Other

16. What is your education level?

☐ Grade 12 or less ☐ High school graduate ☐ Some college credit

☐ Assoc./tech school degree ☐ Bachelor's degree 0 Graduate degree

☐ Some other degree ☐ Do not want to release

17. What is the general category of your annual income?

☐ Less than $10,000 ☐ $10,000 to $19,999 ☐ $20,000 to $29,999

☐ $30,000 to $39,999 ☐ $40,000 to $49,999 ☐ $50,000 to $59,999

☐ $60,000 to $74,999 ☐ $75,000 to $99,999 ☐ $100,000 to $124,999

☐ $125,000 to $149,999 ☐ $150,000 to $199,999 ☐ $200,000 or more

☐ Do not want to release

Thank you for taking this survey.

APPENDIX C: GOALS AND METRICS OF THE BIKESHARING PROGRAM IN DOWNTOWN LAS VEGAS

The bikesharing program in downtown Las Vegas has stations installed in the area around Fremont Street and Las Vegas Boulevard, north of the Strip. Travelers to the downtown area can have bicycles available for various trip purposes:

1. part of their commute to work;

2. part of visiting downtown Las Vegas from other states or countries; or

3. part of leisure trips or business trips in downtown Las Vegas.

With bikesharing stations available in the downtown area, the employees could use the bikes to complete the last mile of their commuting trip from a transit station or stop at their destinations in the downtown area. That option may help them choose to use transit to go to work rather than drive downtown. As a result, road congestion could be reduced, and air pollution and fuel consumption could be reduced correspondingly.

With bikesharing stations available in the downtown area, locals as well as visitors from other states or countries could arrive downtown by transit and go to their destinations by using the bicycles provided by the program. Otherwise, visitors would need to drive cars or take taxis, which would increase road congestion. With more visitors coming to the downtown area, economic conditions could improve.

With the bikesharing stations available downtown, employees in that area could access shopping locations during their lunch break or attend business gatherings. With bikes available for their trips, road congestion could be reduced and, again, economic conditions could be improved.

The primary goal of establishing the bikesharing program in the downtown area was to reduce road congestion by increasing the use of public transportation. This is done by providing the infrastructure for the last mile traveled, thus reducing the number of automobiles on the roads and improving economic conditions.

To measure the performance of the bikesharing system to reduce road congestion, the following metrics could be used:

- Commuting trips using the bikesharing program made in the peak and non-peak time periods;

- Bus stops from which commuting trips using the bikesharing program are made;

- The areas in Las Vegas from which commuting trips using the bikesharing program are made; and

- The monthly and yearly trends of bikesharing commuting trips.

In addition to these performance measures, other macroscopic measures of the bikesharing system for commuting are:

- Number of the bikesharing stations that can be accessed from a bus stop;
- Number of bus stops from which a traveler to the downtown area can access a bikesharing station;
- Number of employees who take the bus to the downtown area; and
- Number of trips made by employees to the downtown area.

The data for these performance measures could be obtained from such sources as the bus management system maintained by the bus operating agency in Las Vegas.

To measure performance of the bikesharing system for travel downtown, the following metrics could be used:

- Total number of trips made in the downtown area on a daily, monthly, and annual basis;
- Trip patterns from origin to destination by time of day by employees, visitors, or others; and
- Travel time by bike.

In addition to performance measures related to congestion and productivity, there are performance measures for the system's facilities.

Fleet Performance and Safety

Number of bicycles in service

Number of bikes inspected/repaired per month

Number of bicycles damaged per month

Fleet Utilization

Frequency stations are full or empty

Duration stations are full or empty

Number of rebalancings

Number of trips each bike made

Duration of idle time each bike takes

Customer Service

Number of incoming calls and lost calls

Membership

Total number of users, regular and casual users

Number of new members

APPENDIX D: SUMMARY OF SELECT CITY BIKESHARING PROGRAMS

There are a number of U.S. cities with active bikesharing programs. These include: Boston, Massachusetts; Indianapolis, Indiana; Columbus, Ohio; Kansas City, Kansas; Boulder and Denver, Colorado; Chattanooga, Tennessee; the San Francisco Bay Area, California; Washington, D.C.; and Seattle, Washington. All of these bikesharing programs were established in the early 2000s; however, each are operated differently. A detailed summary of the performance of existing bikesharing programs in comparable cities in the United States is provided in a study by Toole Design Group.

Boston, MA

Launched in July 2011, the bikesharing program in Boston known as the Hubway (https://www.thehubway.com/) started with 600 bikes and 60 solar-powered docking stations. This program expanded to the cities of Cambridge and Somerville and to the town of Brookline, providing in total 1,300 bicycles and 140 stations. The system is city-owned and operated by Motivate Inc. (http://www.motivateco.com/), formerly known as Alta Bicycle Share.

Indianapolis, IN

The Indiana Pacers Bikeshare program (https://www.pacersbikeshare.org/) is operated in downtown Indianapolis by a not-for-profit organization. It started with 250 stations and 25 bikes that were GPS-enabled to keep track of the members and the bikes. The program was customized to allow users from other cities to check out bikes by using their membership card at any cities that participate in a program by BCycle, LLC (https://www.bcycle.com/). This Wisconsin-based company has installed bikesharing systems in such cities as Boulder and Denver, Colorado; Kansas City, Missouri; Nashville, Tennessee; Omaha, Nebraska; Salt Lake City, Utah; and San Antonio, Texas.

Columbus, OH

In downtown Columbus, Ohio, 30 docking stations were installed with a total fleet of 300 bikes (http://www.cogobikeshare.com/). Although the marketing segmentation is downtown, users are allowed to pick up bikes and utilize them outside the downtown area. The Kansas City B-cycle program (https://kansascity.bcycle.com/) is a partnership between BikeWalkKC and Blue Cross and Blue Shield of Kansas City. In Phase 1 of the program, 12 docking stations were located mainly around the downtown core, which connects key areas including residences, employment, shopping, recreation, and tourist sites. Bike-docking stations also were placed to facilitate transit connections.

Boulder, CO

In Boulder, Colorado, the Boulder B-cycle bikesharing system (https://boulder.bcycle.com/) is community-supported. It began in 2011 with 15 stations and 100 bicycles. The program was formed by Boulder residents on a not-for-profit, financially sustainable basis. The program's bicycles have GPS radio-frequency identification (RFID) systems to help track members and bikes as well as all of the interactions between users and bikes. All ride data—such as distance, duration, calories burned, and carbon offset—are captured and uploaded to the riders' personal pages. Capital funding comes from federal, state, and local government grants as well as from private funding and foundation grants. Operational funding is generated from sponsorships, usage fees, memberships, and operating grants.

Washington, DC

The Capital Bikeshare program (https://www.capitalbikeshare.com/) consists of four jurisdictions: District of Columbia, Arlington, Alexandria, and Montgomery. All of the four jurisdictions joined the program at different points in time, with Washington, D.C. being the first to establish the program under SmartBike D.C. in 2008. Arlington, Virginia joined in 2010 and Alexandria, Virginia joined in 2012. The last community to join the program was Montgomery County in 2013. The Capital Bikeshare system is owned by the participating jurisdictions, and is operated by Motivate, Inc., formerly known as Alta Bicycle Share. Currently, the Capital Bikeshare program has over 2,500 bicycles with over 300 stations across all of the counties.

Chattanooga, TN

The Chattanooga Bicycle Transit System (http://www.bikechattanooga.com/) began operations in 2010 with 28 stations and 300 bikes. Each station has a touchscreen kiosk, system and neighborhood maps, and docking points that release the bikes by using a member key or ride code. The Pronto Cycle Share system in Seattle (https://www.prontocycleshare.com/) is a new system that currently has 500 bikes and 50 stations located throughout the city. Each station has a touchscreen kiosk, a station map, helmets, and a docking system that releases the bikes by using a member key or ride code.

Membership Fees and Additional Charges

Membership fees vary across the bikesharing programs of the cities studied. The membership fees are based on either long-term subscriptions (annually, semi-annually, and monthly) or short-term subscriptions (24 hours, 72 hours). Annual membership fees are as low as $65 in Kansas City and as high as $100 in Denver. Annual membership fees for bikesharing programs in other cities are $70 (Boulder); $75 (Columbus and Chattanooga); $80 (Indianapolis); and $85 (Boston and Seattle). The 24-hour membership fees vary from $6 in Boston, Chattanooga and Seattle; $7 in Kansas City; $8 in Seattle, Boulder, and Indianapolis; and $9 in Denver.

Members are graced with a free membership period, which varies in different cities. Most cities provide either the first 30 or 60 minutes as free membership time. After that, each bikesharing program has set the additional fee based on the duration of usage. However, most cities have limited usage to a maximum of 23:59 hours.

In cities that distinguish the additional fees based on the member type (long-term vs. short-term), long-term members are able to save up to 25% on usage fees. In some circumstances, stations are likely to be full when a user returns the bike. If this happens, various flexibilities are provided. For instance, Boston and Kansas City provided an extra 15 minutes free of charge to the user.

Rider Safety

Safety issues exist before and when cycling has been accounted for. There are free classes and workshops with certified instructors from which a user has a chance to learn about urban cycling. During severe weather in winter, stations are closed as a way of preventing users from being involved in crashes.

In many cities, including Boston, the bikes have safety features including flashing LED lights, wheel reflectors, and plastic casings around cables to prevent tampering. In Columbus, the safety rules require riders to be at least 16 year old, and riders younger than 18 years old are required to use helmets. In Chattanooga, during severe weather service is suspended temporarily.

System Sizing and Costs

The station size is the number of docking spaces at each station. Usually, it is determined by multiplying the number of bikes per station by the docking-space-per-bike ratio. For example, if the docking-spaces-per-bike ratio is 1.7, a station that needs 10 bikes will need 17 docking spaces. The average ratio in North America is one bicycle to every 1.7 docking ports. Across programs, bicycle-to-docking-port ratios range from 1:1.7 to 1:1.8, with the average being 1:1.8. Publicly owned and contractor-operated programs (e.g., Capital Bikeshare (Motivate); Capital BIXI in Ottawa, Ontario and Gatineaur, Quebec in Canada (CycleHop); and Hubway (Motivate)) tend to have higher ratios, generally 1:1.8; non-profits have an average ratio of 1:1.7.

Three major costs are associated with a bikesharing system: launch costs and capital costs (which together form start-up costs), and operating costs. The launch costs are associated with establishing the system, and mostly are onetime costs, including hiring of employees, procurement of a storage warehouse, purchase of bike and station assembly tools, website development, communications and IT set-up, and pre-launch marketing. Capital costs are associated with purchasing equipment, including stations, kiosks, bikes, and docks. Equipment costs vary depending on system parameters, such as number of bikes per station or number of docks per bike. However, they also depend on such features as additional gearing, an independent lock, or equipping bikes with GPS. Capital costs vary per station and by vendors, and depend on the features and station size. Costs typically range from $40,000 (low) to $50,000 (high) per station.

Stations consist of bicycles, docking spaces, and terminals, also known as kiosks. Station design is defined by the level of demand, the amount of space available, and the desired visual effect on the urban environment. In many systems, docking spaces represent the single largest capital cost. The higher the number of docking spaces, the lower the operating costs as the need for redistribution of the bikes is reduced. The docking station costs vary depending on the type used, namely, automatic versus manual and modular versus permanent.

Manual systems are associated with a reduction in initial capital costs compared to automated systems; however, they have higher long-term operating costs and suffer from unreliability of the system. The automated stations are more complex in design, installation, and maintenance than those of manual stations. Their capital costs are higher, but the operating costs over time are lower. Permanent stations require excavation and trenching to reach the power source. This requires a longer time frame to implement, and may entail a more onerous approval process. Modular stations can be moved easily and require solar power. Usually, they are constructed on a base that is bolted into the concrete or asphalt.

Bicycles account for a small portion of the capital cost. The large portion of the capital cost comes from the docking station. Bicycle costs vary with the accompanying technology, which includes the locking mechanism, transmission, tracking, etc. Some systems use traditional bicycles with a locking mechanism attached, while others use specialty bicycles with proprietary parts and GPS tracking. The cost of a single bike could range from as little as $100 in Asian systems to as much as $2,000 for bikes with GPS and satellite-operated unlocking systems.

Vendors usually sell complete station systems, which include bicycles, kiosks, map frames, customer keys, spare parts, supplies, and shipping. Start-up costs for fixed and portable bikesharing systems averaged from $4,200 to $5,405 per bicycle for the three large-scale systems in the U.S. According to the 10 operators who provided per-bicycle cost estimates for this study, the cost ranged from $750 to $7,000, with an average cost of about $1,800. System developers reported that start-up capital costs for the Social Bicycle System (SoBi) are approximately $1,000 per bicycle, including mobile communications, GPS, and locking systems. Start-up costs for the Grand Canyon's bike rental program totaled $60,000, an average of $706 per bike.

The magnitudes of the operating costs for bikesharing systems depended on the systems' size and sophistication. Operating costs include staffing, replacement parts, fuel for service vehicles, redistribution costs, marketing, website hosting and maintenance, electricity and Internet connectivity for stations, membership cards, warehouse and storage insurance, and administrative costs. There was variation in reporting operating costs, whereby the cost per bike or per station or per dock or per trip might be used; however, most of the time, annual operating costs as cost per trip was used.

Because city bikesharing programs currently can be considered to be a new concept in the U.S., in most cases their planning, implementation, and evaluation were based on 1) observed facts from peer programs under operation or 2) published reports for agencies that have completed their feasibility studies. Forecasting demand on bikesharing programs still is a developing concept; therefore, building and improving from past experiences increases the likelihood of success.

Service Areas

Reviews done on existing programs as well as documented research activities indicate the importance of having a method to determine the appropriate service areas, station density and/or location, and business model. This is because the sustainability of the program is a function of a number of factors, including the ability of an area to have an increasing number of system users.

The service area considered to be appropriate for a bikesharing program was observed to depend on demographic factors, trip production, attraction factors, and facility factors. Population and employment densities were characterized as generators of system users, specifically on a regular basis. Densities, which refer to the number of people and jobs, determined an increase in the number of destinations leading to business centers, education institutions, and entertainment areas as well as other areas with a mix of social services.

Retail/commercial activity density as well as proximity to tourist and recreation areas were considered to be potential attractors within the service areas designated for the bikesharing program. These factors have an effect on ridership and the distribution of bicycles, and add an option for system users in addition to the existing transportation modes.

Proximity to colleges and universities was considered a factor in selecting service areas because of the low rate of auto ownership across student populations; this increases the likelihood of generating potential users. Universities located in urban settings tend to be surrounded by mixed land-use development, leading to increased support of bikesharing. Other factors observed to determine the selection of service areas are the available bicycle infrastructure, availability and denseness of transit stations, and topography.

Areas with bicycle lanes or shared paths have the potential to facilitate smooth and safe mobility for bike users, while relatively flat areas create comfort in riding bicycles and are likely to attract subscribers to the program. Transit connections with bicycle activity create a good environment for system users to access transit stations and can provide service for the last mile of travel after leaving the transit buses. This increases the efficiency of the existing public transit services.

Weather factors, closeness to rail stations, and recreational areas were observed to contribute to determining the service area. It was noted that the highest bikesharing demand exists during the best riding weather and peak tourist season, and is lower on extremely hot days. Regression analysis techniques were conducted to determine influencing factors for the number of trips for those stations in operation. The results indicated that the number of trips was positively associated with food-related destinations near the station; alternative commuters; and accessibility to jobs, bike lanes, and trail stations.

The denseness of bikesharing docking stations and locations was considered to influence system performance and operations. Analysis conducted by the Toole Design Group on existing programs indicated that there were 3.5-5 bikesharing stations per square mile of service area. The research team suggested a distance between bikesharing stations of approximately a half mile, based on the relationship of the walking distance to a station. Although, these figures are the results of computations based on the actual stations under operation, determination of the spacing of docking stations was a function of other factors, such as capital and operation costs, safety, convenience, and visibility.

The number of factors included by different agencies in determining the service areas differed across those agencies. For instance, Cincinnati based its factors on experiences from peer programs for relatively small areas. For large areas, stations were determined based on notable activities, such as university and health institutions. Preliminary plans for station locations included public input through web-based tools, by which individuals were allowed to identify specific points of interest; these provided the basis to propose station locations.

The number of bikes per station was derived from the bike-to-station ratios from existing programs, with a restriction on maintaining the minimum number of bikes between five and seven as well as dock-to-bike ratio of 1.7. Based on the experiences of local areas, other counties and cities suggested appropriate areas to implement the program.

The above-mentioned factors were quantified in various units of measurements. To determine the concentration of these factors in a specific area, they had to be compared on the basis of the same units. For example, in its feasibility study Philadelphia used a GIS method that transforms all of the data to density surfaces, thereby facilitating comparison and selection of these areas. Density surfaces indicate locations in a density map where features are concentrated. Further, Philadelphia used GIS results obtained—together with outcomes from peer cities, including diversion rates estimated and applied as multiplication factors—for existing Philadelphia transportation models at the level of a traffic analysis zone in order to determine the demand for a bikesharing system.

APPENDIX E: A BIKESHARING PROGRAM FOR THE UNLV COMMUNITY

Please help us by completing this survey for the proposed UNLV Bikesharing Program!

Why bikesharing? Bikesharing programs promote sustainable travel and provide convenience for the UNLV community while cutting traffic and pollution. Some universities have already adopted bikesharing programs for commuting and on-campus travel (see the photo below).

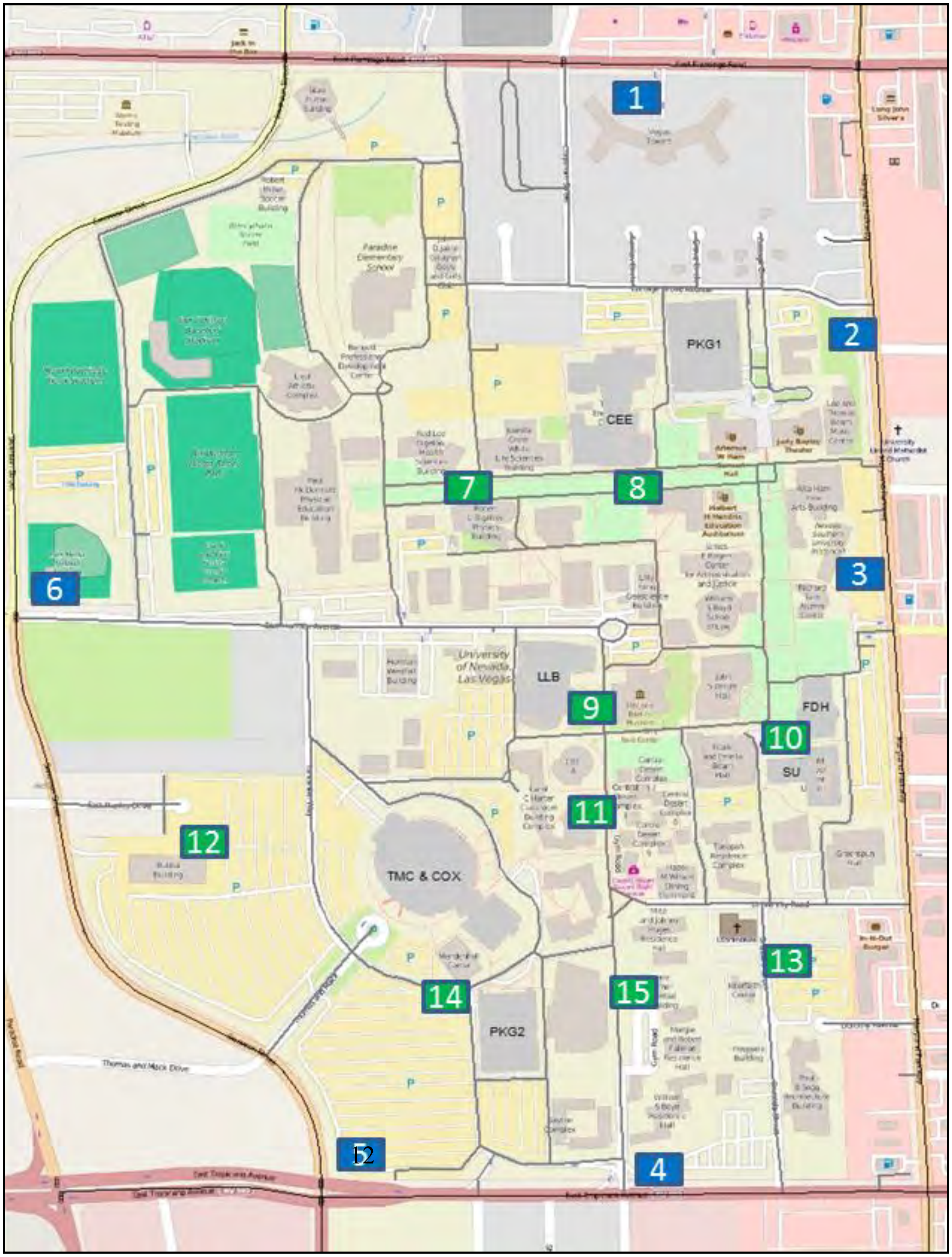
How does it work? In a typical bikesharing program, a customer commuting to the university can extract a bicycle from a docking station near a bus stop around campus, ride to a station near their destination, and return the bike there. For an on-campus rider, he/she can extract a bicycle from a docking station inside the campus, ride to a station near their destination, and return the bike there. Riders can check availability of bikes in stations online in real time. Payment is made through a subscription or hourly rate. Some universities include the cost in student fees.

Who are we? We are researchers from the Howard R. Hughes College of Engineering at UNLV, with funding support from the Regional Transportation Commission of Southern Nevada (RTC) and the Mineta National Transit Research Consortium.

Why the survey? We're conducting this survey to find out what you think of the proposed bikesharing system and where to locate the docking stations. We've included a campus map with candidate bikesharing docking stations for the proposed system. Please answer the questions in the survey as completely as possible. Your time in completing the survey is highly appreciated.

Bicycles and a Docking Station

https://www.parking.uci.edu/zotwheels/about.cfm



Proposed Bicycle Docking Station Locations

Survey Questionnaire

1. Are you a faculty, staff, full time student, or part time student?

☐ Faculty () ☐ Staff ☐ Full time student ☐ Part time student

☐ Others, specify ____________

2. What is your gender?

☐ Male ☐ Female ☐ Other

3. What is age?

☐<20 ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐>71

If you live off campus, please answer the questions below. If you live on-campus, please go to Question 19.

4. To help us know where potential bike-sharing users are coming from, please enter your zip code below. We cannot trace your specific location from your Zip Code.

____

5. Do you have an office on campus?

☐ Yes ☐ No

6. At what time do you usually come to campus? Choose one that is the most frequent.

☐before 8 am ☐8 am – 12 pm ☐12 pm – 5 pm ☐5 pm – 10 pm ☐after 10 pm

7. In which building is your office located (TBE, FDH, etc.)?

____

8. What mode of transportation do you use to come to work at UNLV?

☐ Car ☐ Bus ☐Bicycle ☐Walking ☐Other (specify) _________

9. How long does it take you to commute to UNLV (minutes)?

____

10. How likely are you to use this bikesharing program for commuting?

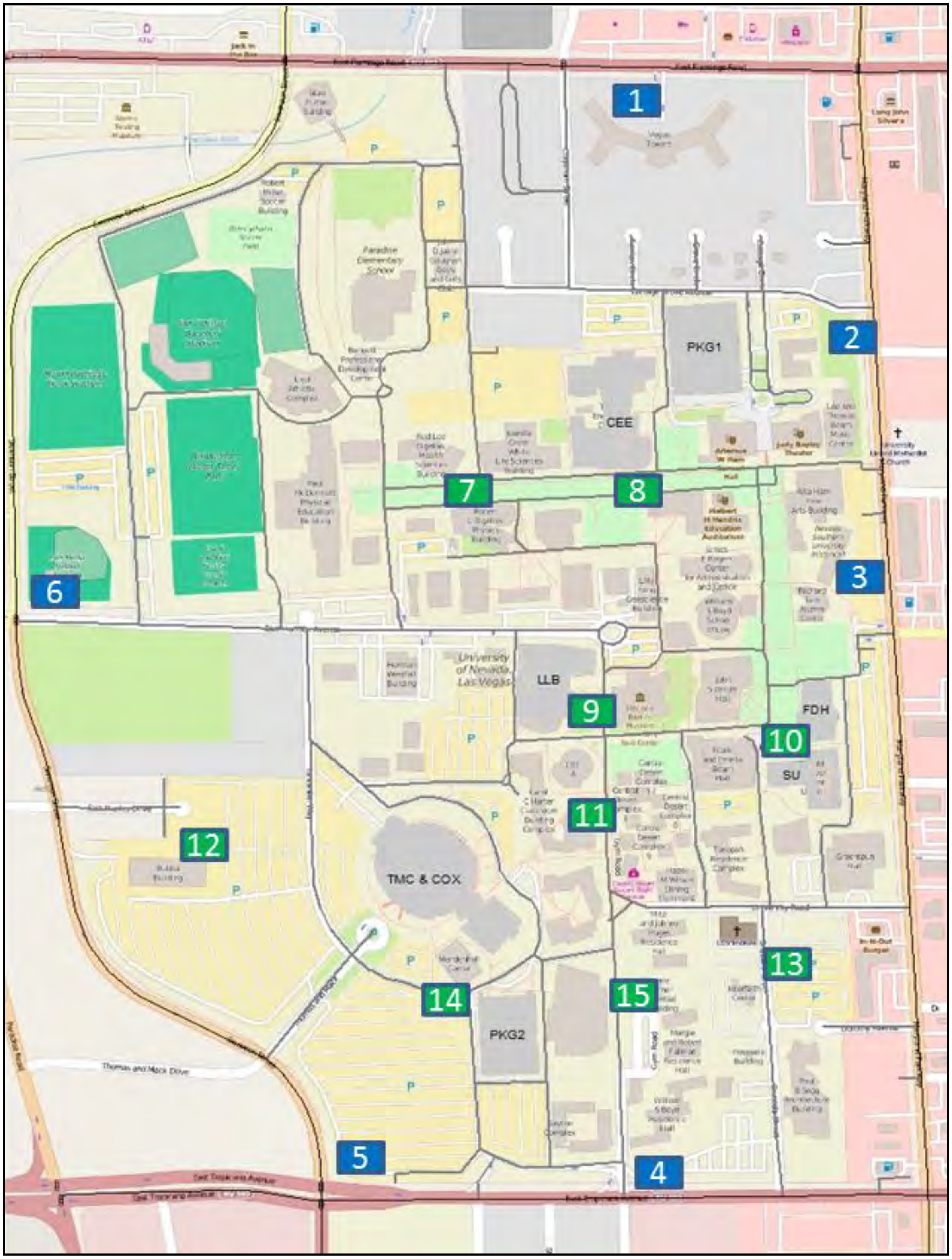
☐ Very likely ☐ Somewhat likely ☐ Neutral ☐ Somewhat unlikely ☐ Very unlikely

11. If very or somewhat likely, why would you choose to use this bikesharing program (choose any applicable to you)?

☐ More convenient ☐ Benefit to health ☐ Not expensive ☐ Bike security

☐ Other __________________

12. If very or somewhat likely to use the bikesharing program for commuting, indicate the station shown in



13. Where you would check out a bike when you come to UNLV.

 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

 Other (specify) ___________________

14. How likely are you to use this bikesharing program for your activities on campus (going to the library, attending meetings, etc.)?

 Very likely Somewhat likely Neutral Somewhat unlikely

 Very unlikely

15. If likely, indicate which station you would use for the most frequent trip:

To check out a bike:

 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

 Other locations (specify) ___________________

Where would you most likely return a bike:

 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

 Other locations (specify) ___________________

16. Which building would you go from (TBE, FDH, etc.) for the most frequent trip?

____

17. Which building would you go to (TBE, FDH, etc.) for the most frequent trip?

____

18. How often in a day would you use a docking station on campus for the most frequent trip?

 Once a month Once a week Once a day
 More than once a day

19. For what activities?

 Going to library Attending meetings Going to classes

 Miscellaneous (specify) ___________

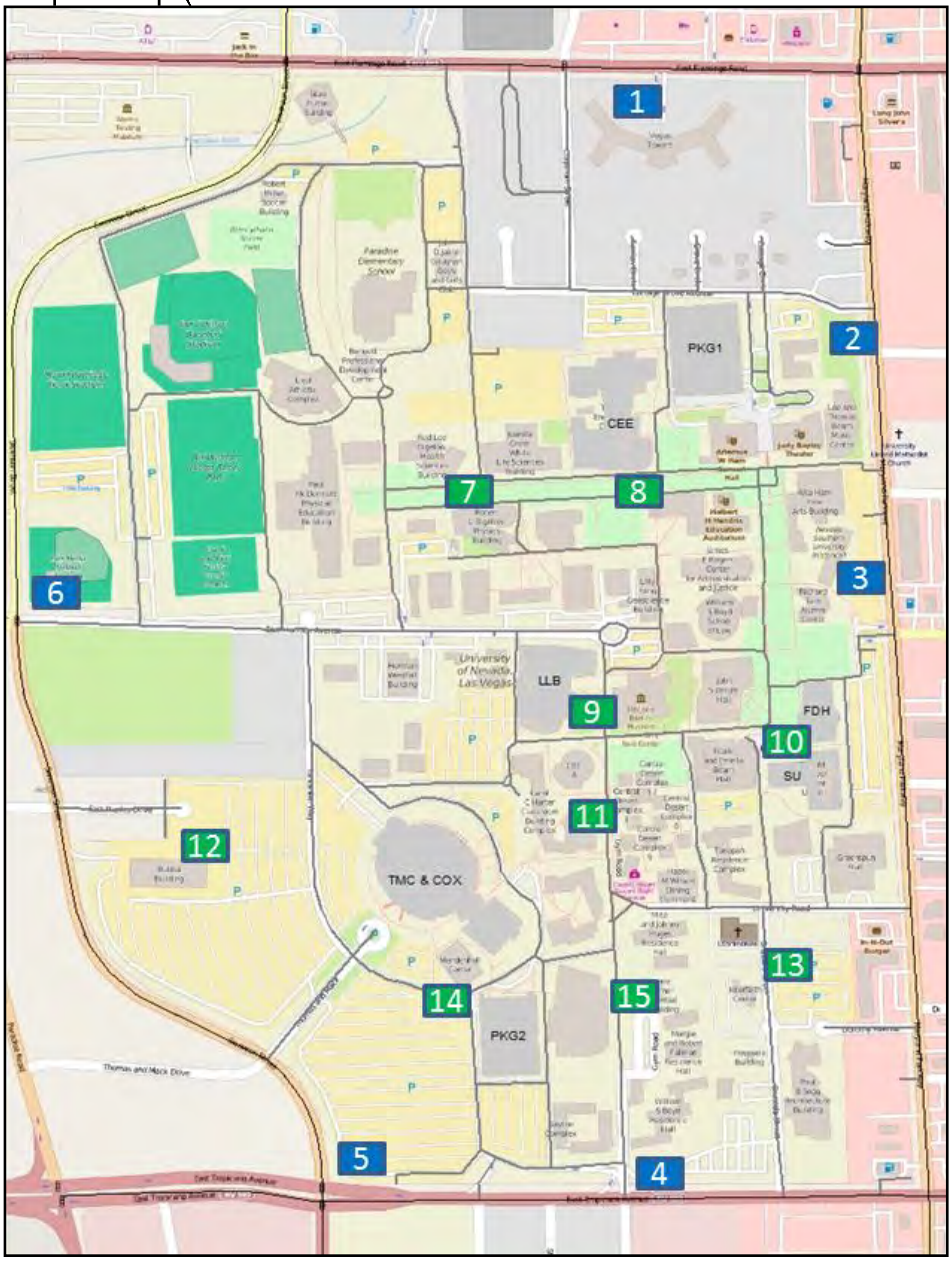
Go to Question 25.

20. **If you live on campus,** how likely are you to use this bikesharing program for your activities in the campus (going to library, attending meetings, etc.)?

 Very likely Somewhat likely Neutral Somewhat unlikely

 Very unlikely

21. If very or somewhat likely, indicate which station you would use for the most frequent trip (see



22.):

To check out a bike:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15

☐ Other location (specify) ________________________________

Where would you likely return a bike:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15

☐ Other location (specify) ________________________________

23. Which building would you go from (TBE, FDH, etc.) for the most frequent trip?

____

24. Which building would you go to (TBE, FDH, etc.) for the most frequent trip?

____

25. How often in a day would you use a bicycle on campus for the most frequent trip?

☐ Once a month ☐ Once a week ☐ Once a day
☐ More than once a day

26. For what activities?

☐ Going to library ☐ Attend meetings ☐ Going to classes
☐ Miscellaneous (specify) __________

27. What is your education level?

☐ Grade 12 or less ☐ High school graduate ☐ Some college credit
☐ Assoc./tech school degree ☐ Bachelor's degree ☐ Graduate degree
☐ Some other degree ☐ Prefer not to answer

28. What is the general category of your annual income?

☐ Less than $10,000	☐ $10,000 to $19,999	☐ $20,000 to $29,999
☐ $30,000 to $39,999	☐ $40,000 to $49,999	☐ $50,000 to $59,999
☐ $60,000 to $74,999	☐ $75,000 to $99,999	☐ $100,000 to $124,999
☐ $125,000 to $149,999	☐ $150,000 to $199,999	☐ $200,000 or more
☐ Prefer not to answer	☐ Do not know	

Thank you for taking this survey.

APPENDIX F: ENROLLED STUDENT COUNTS FOR SPRING 2014 CLASSES AND FALL 2014 CLASSES

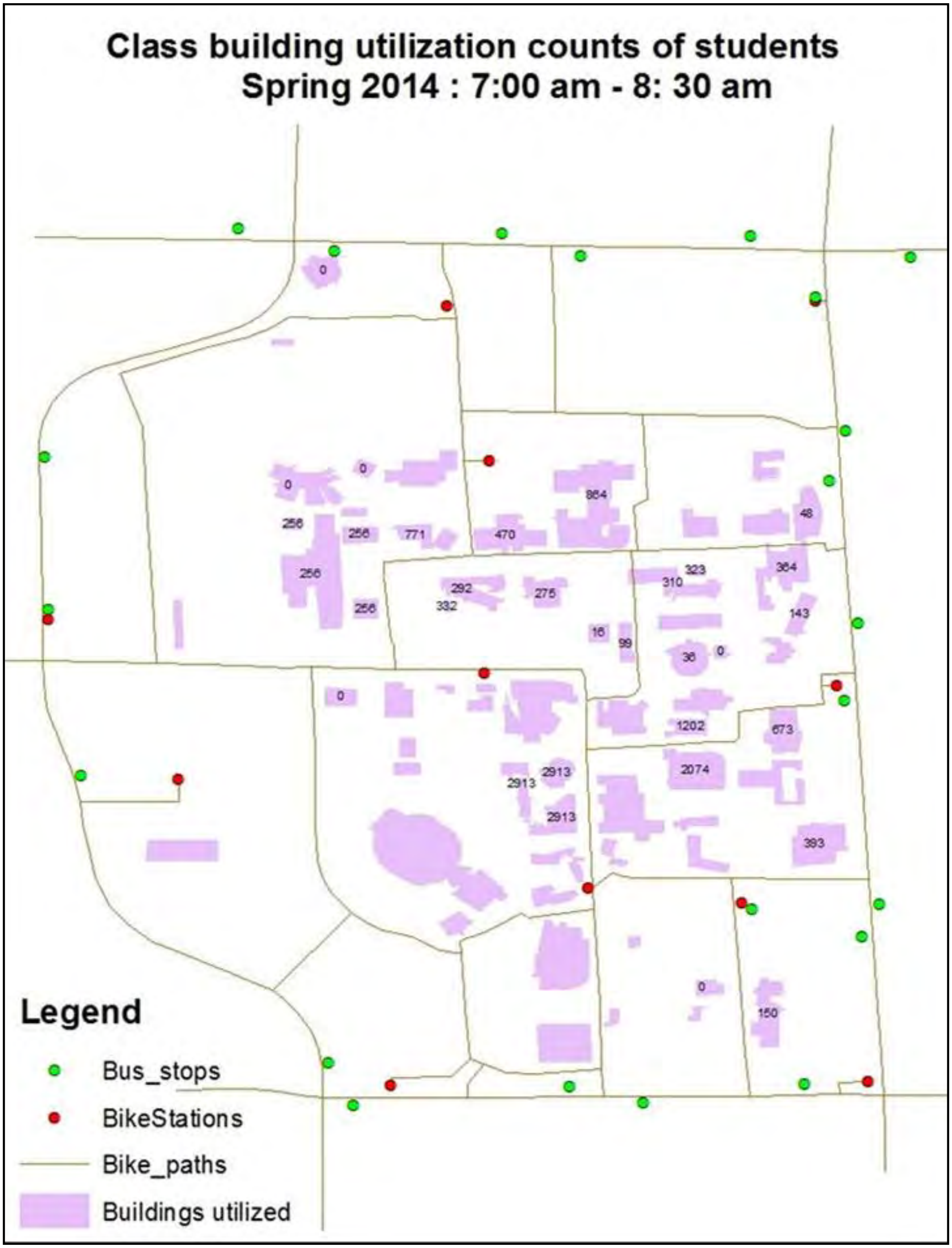


Figure 64. Enrolled Student Counts for Spring 2014 Classes. Scheduled Times from 7:00 a.m. to 8:30 a.m.

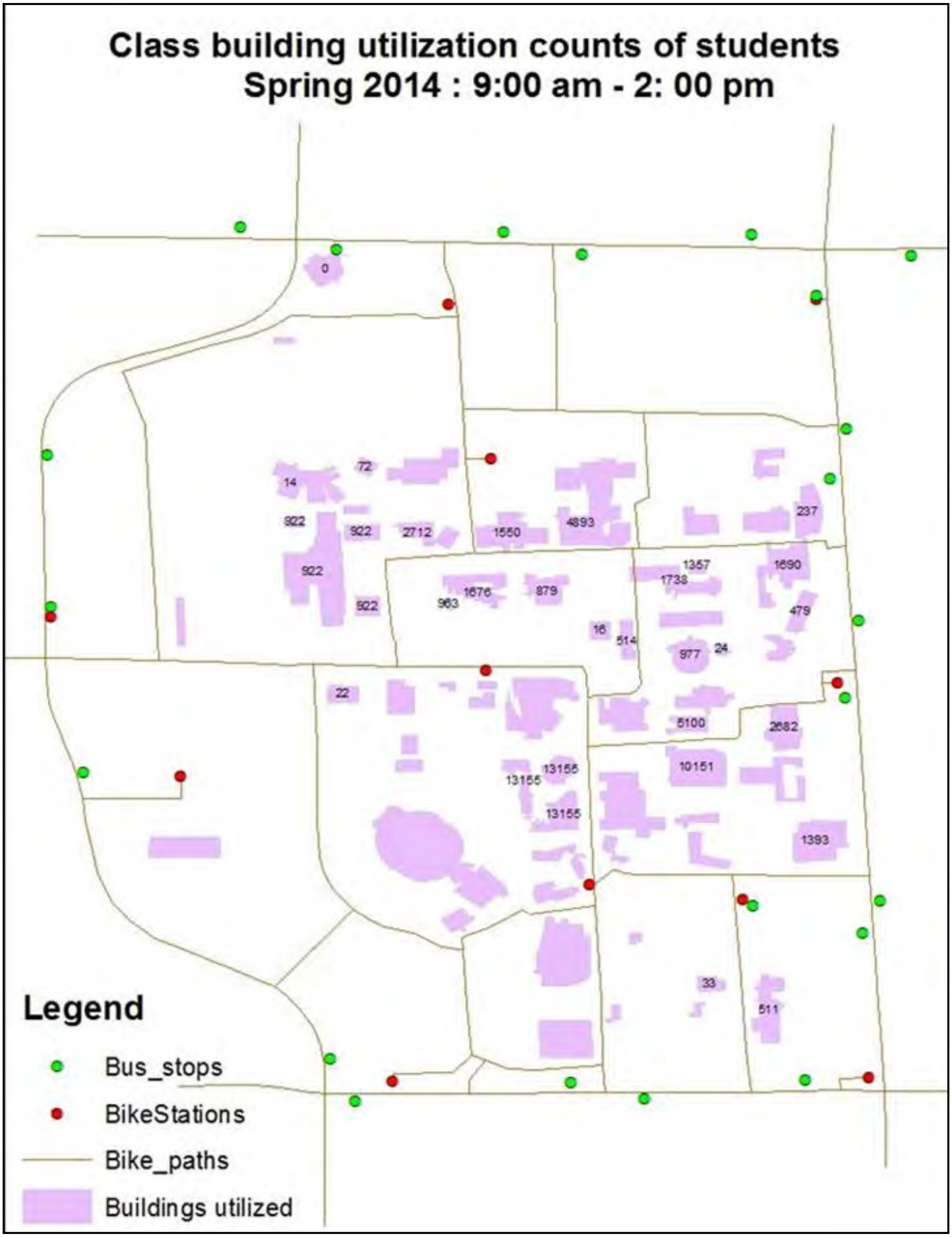


Figure 65. Enrolled Student Counts for Spring 2014 Classes. Scheduled Times from 9:00 a.m. to 2:00 p.m.

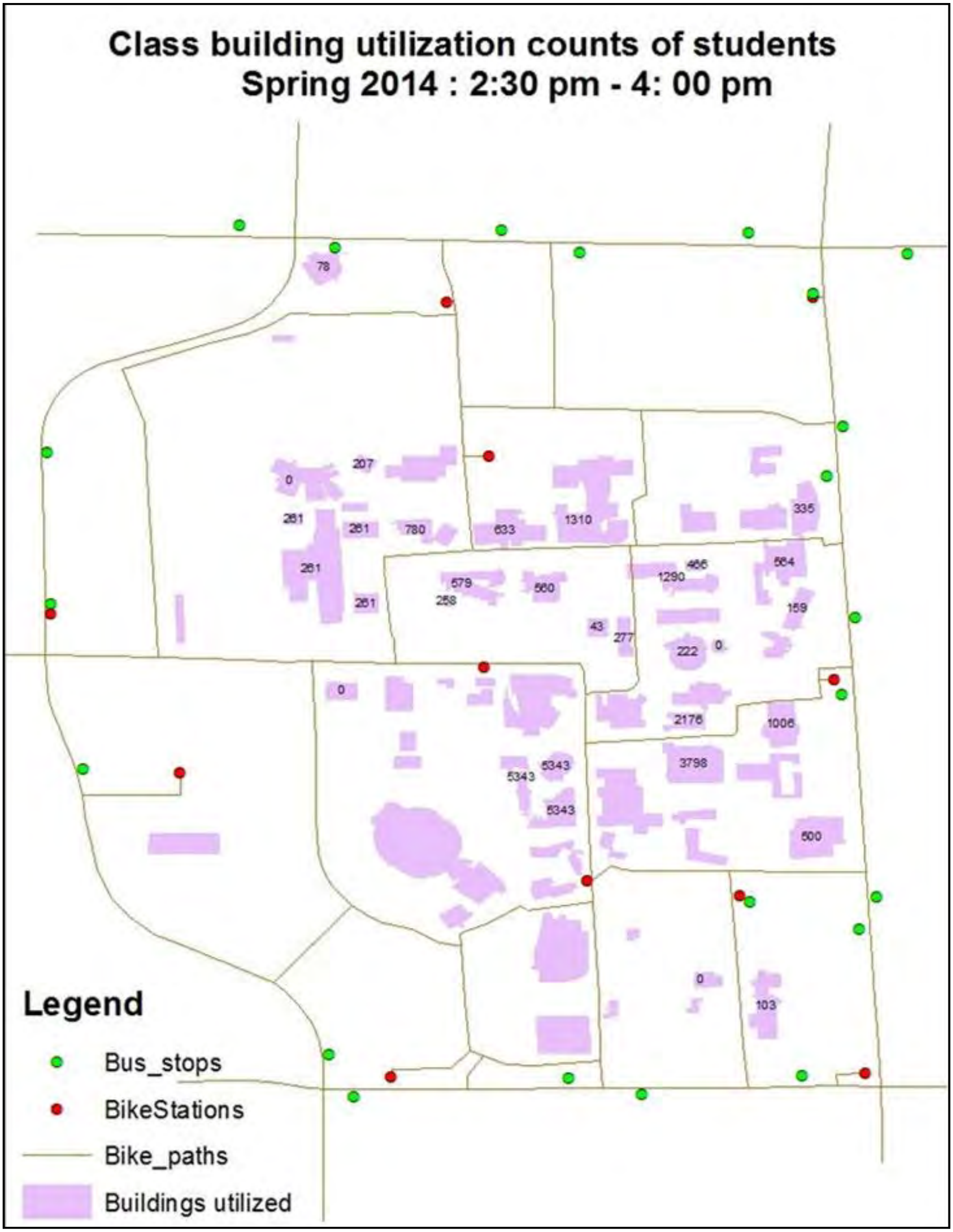


Figure 66. Enrolled Student Counts for Spring 2014 Classes. Scheduled Times from 2:30 p.m. to 4:00 p.m.

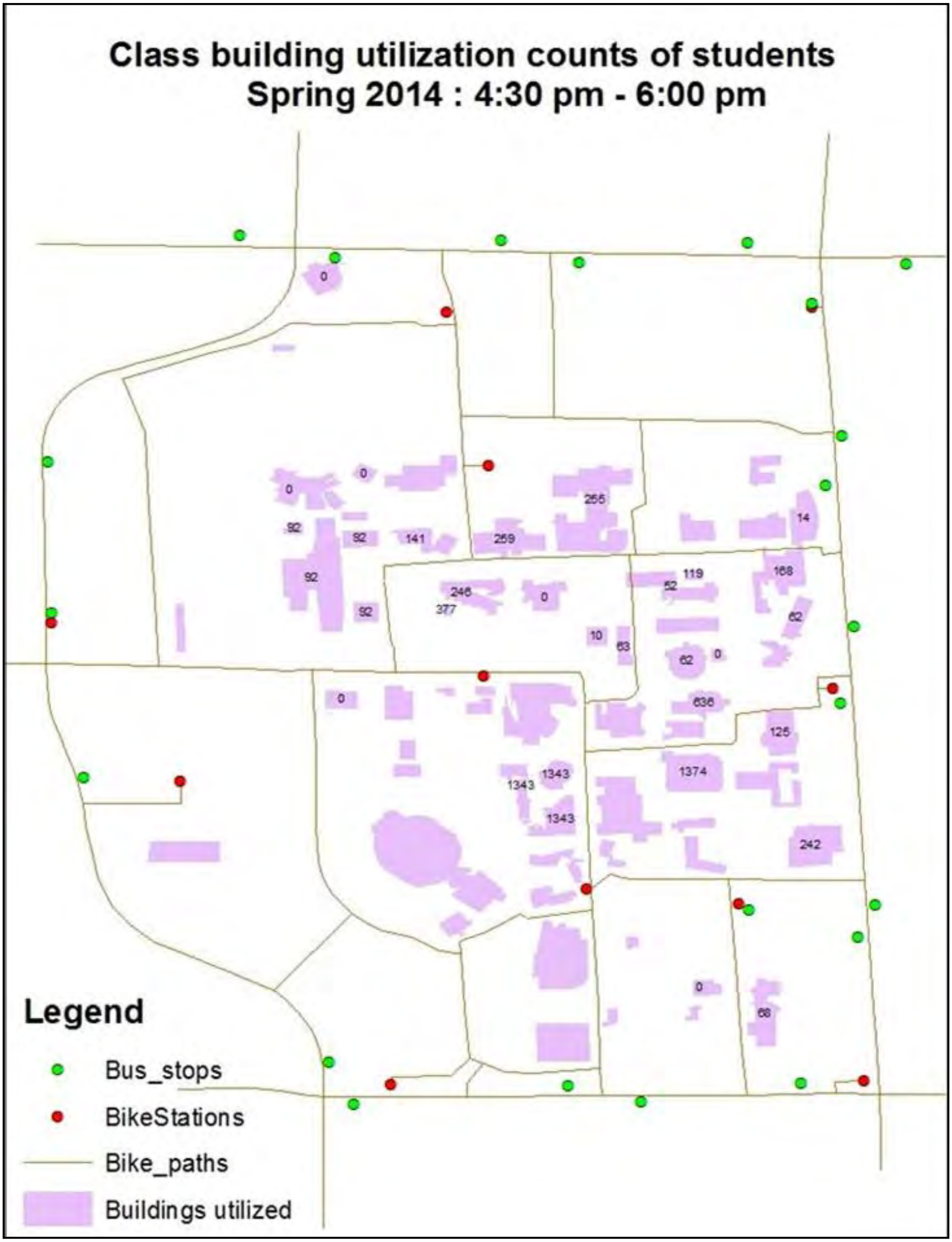


Figure 67. Enrolled Student Counts for Spring 2014 Classes. Scheduled Times from 4:30 p.m. to 6:00 p.m.

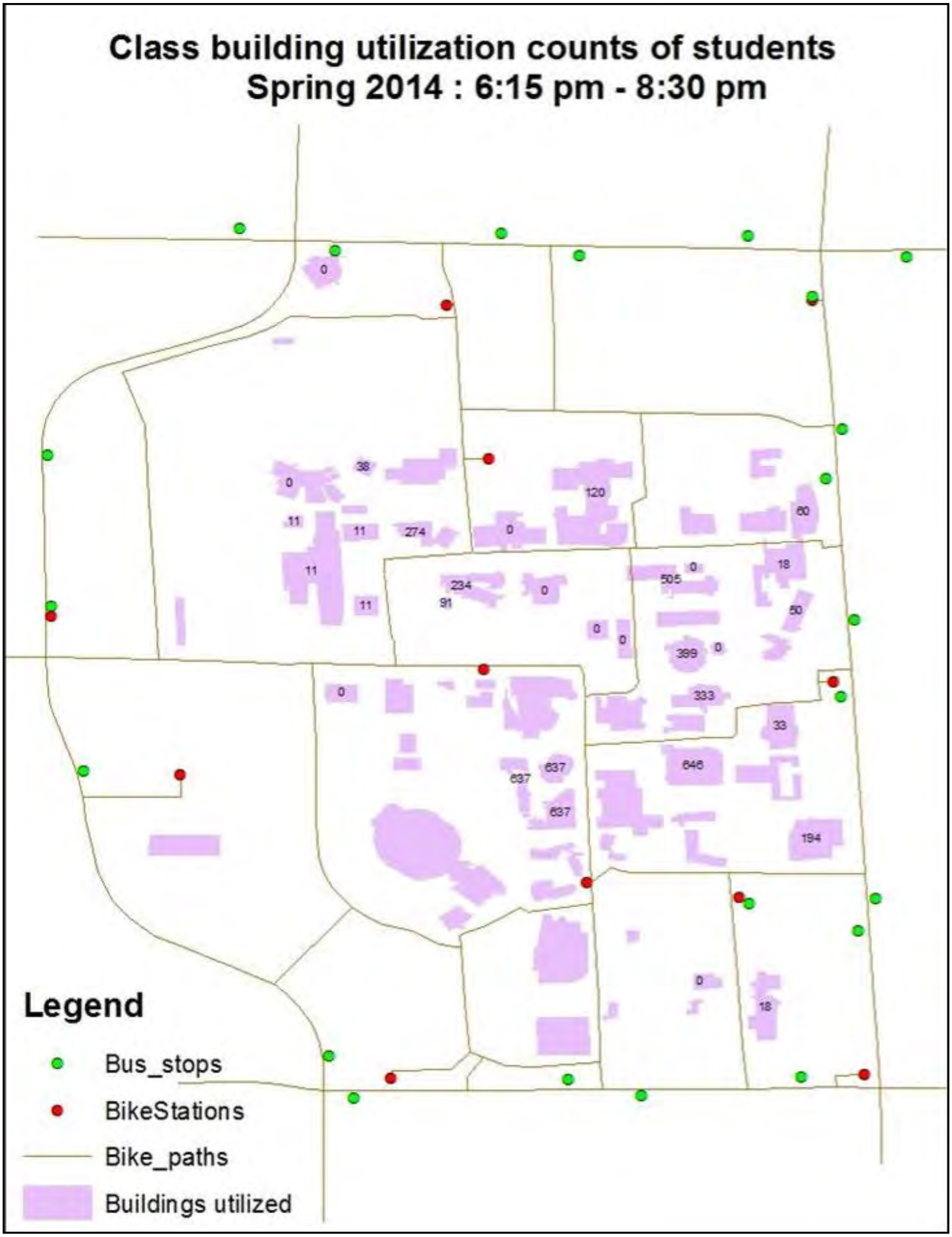


Figure 68. Enrolled Student Counts for Spring 2014 Classes. Scheduled Times from 6:15 p.m. to 8:30 p.m.

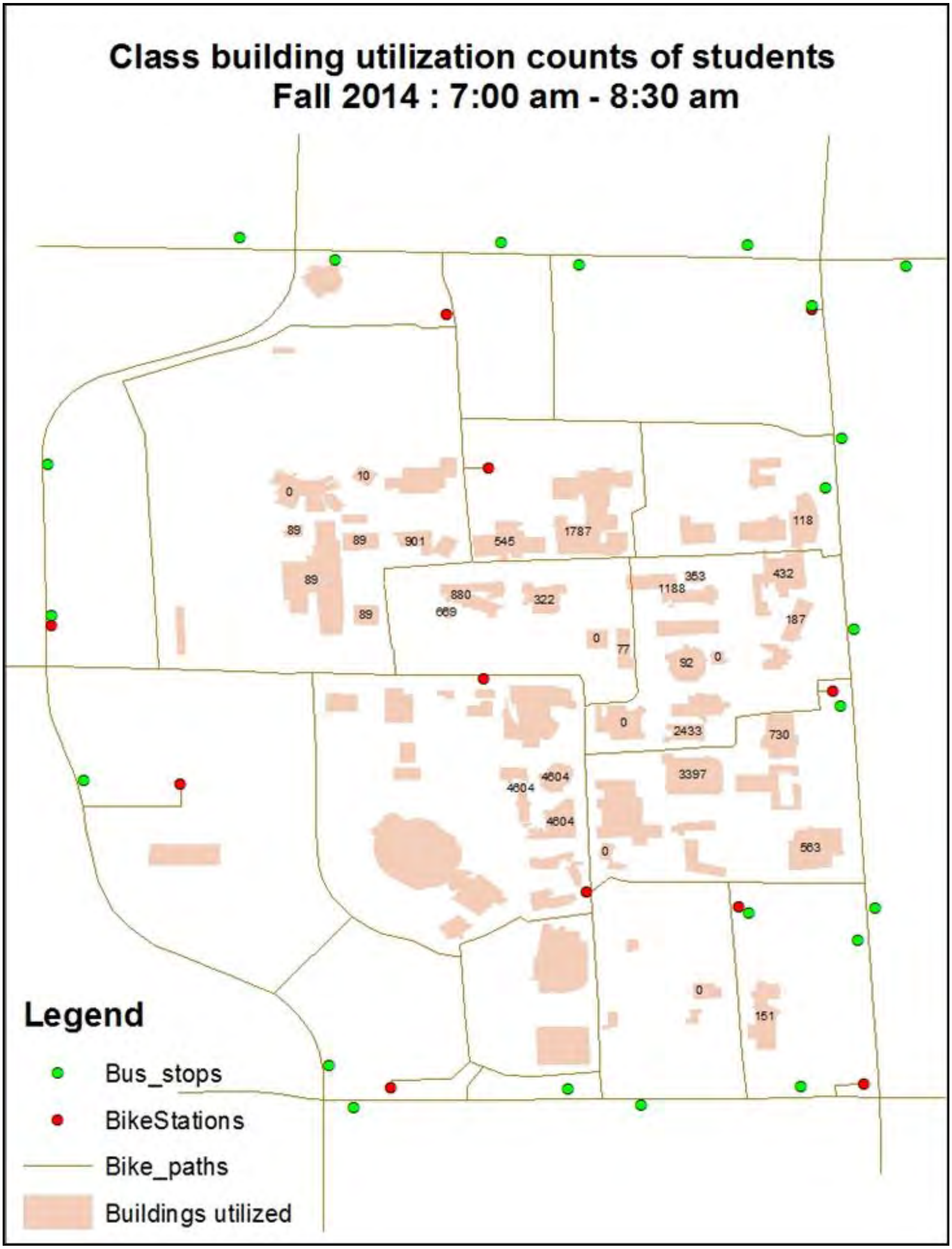


Figure 69. Enrolled Student Counts for Fall 2014 Classes. Scheduled Times from 7:00 a.m. to 8:30 a.m.

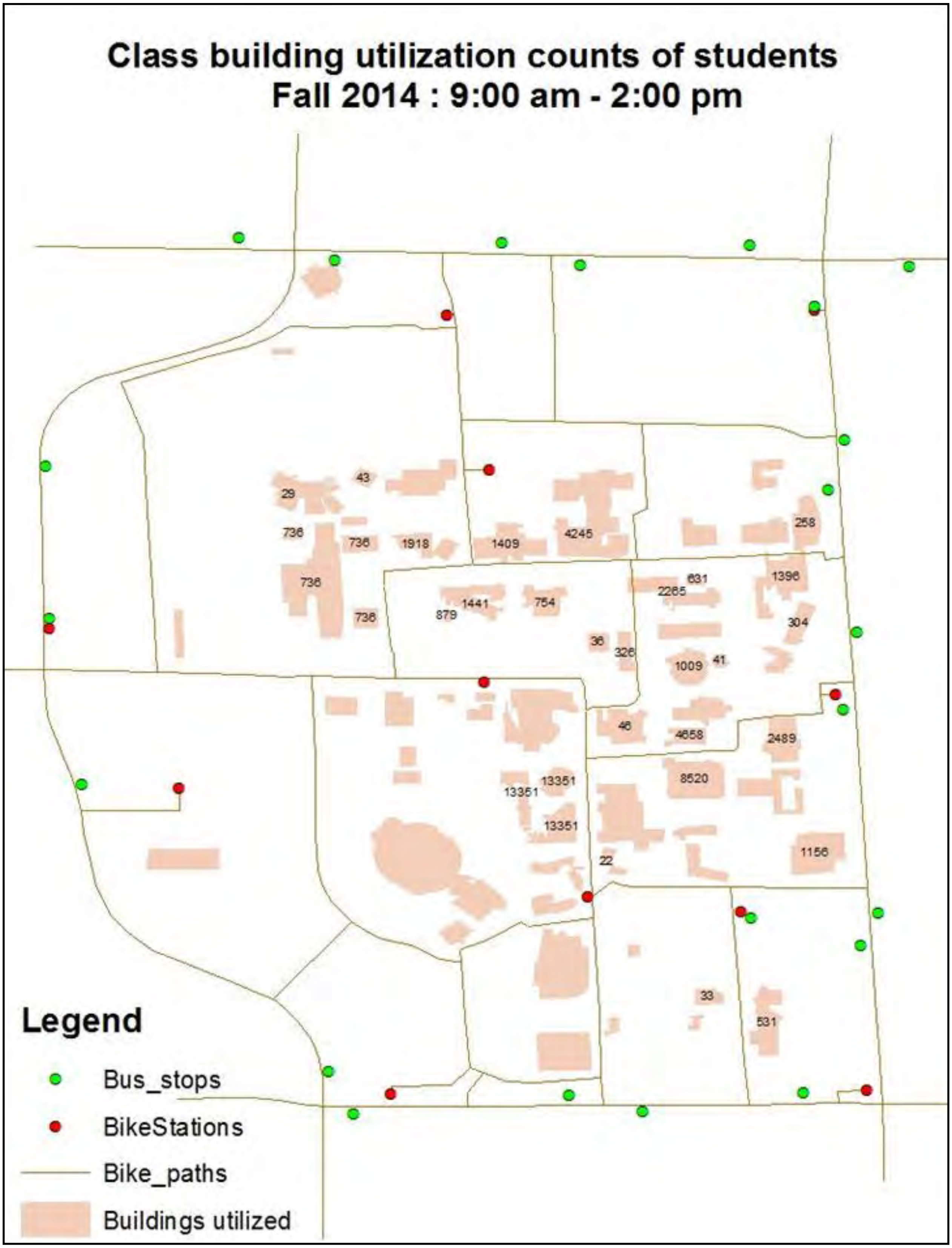


Figure 70. Enrolled Student Counts for Fall 2014 Classes. Scheduled Times from 9:00 a.m. to 2:00 p.m.

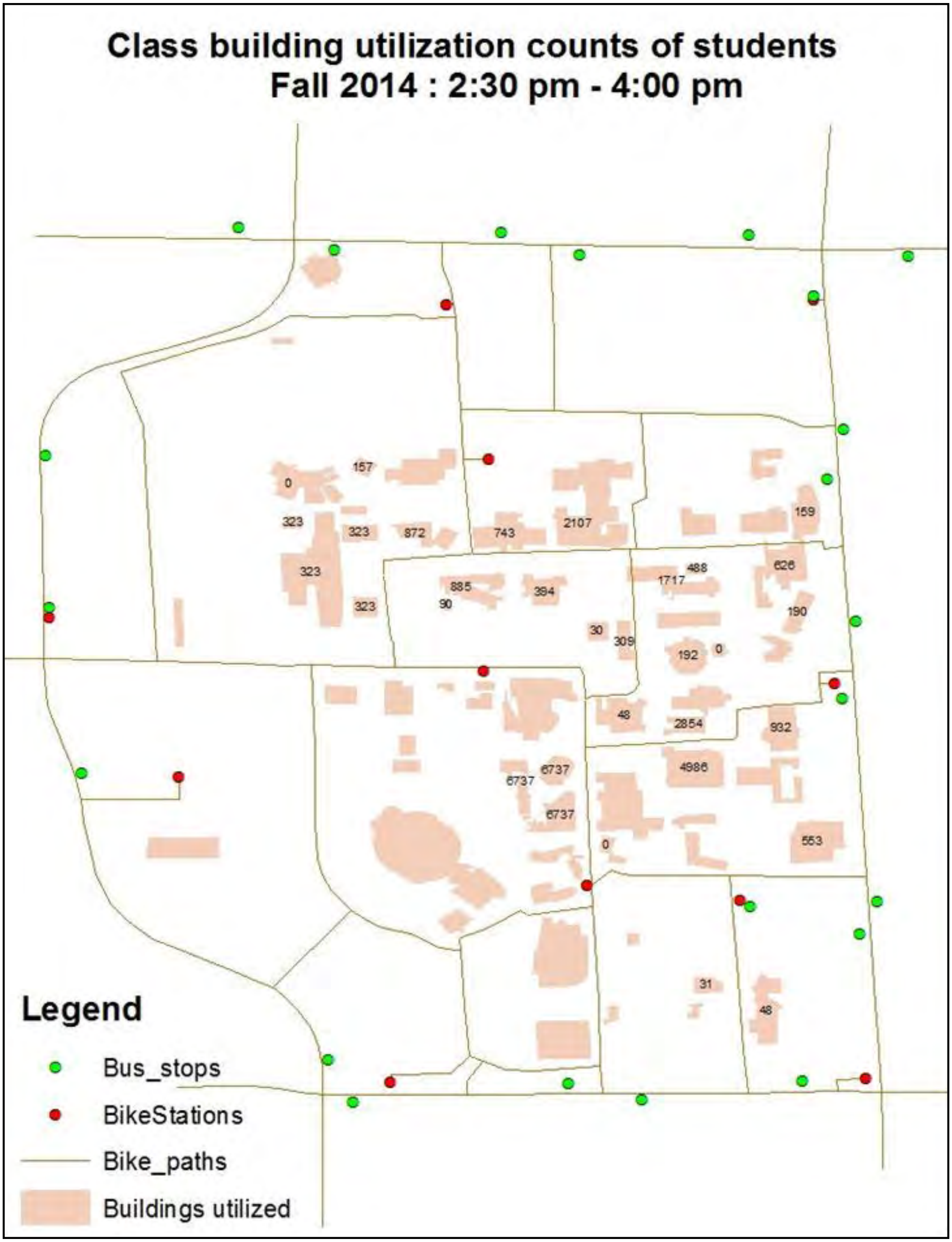


Figure 71. Enrolled Student Counts for Fall 2014 Classes. Scheduled Times from 2:30 p.m. to 4:00 p.m.

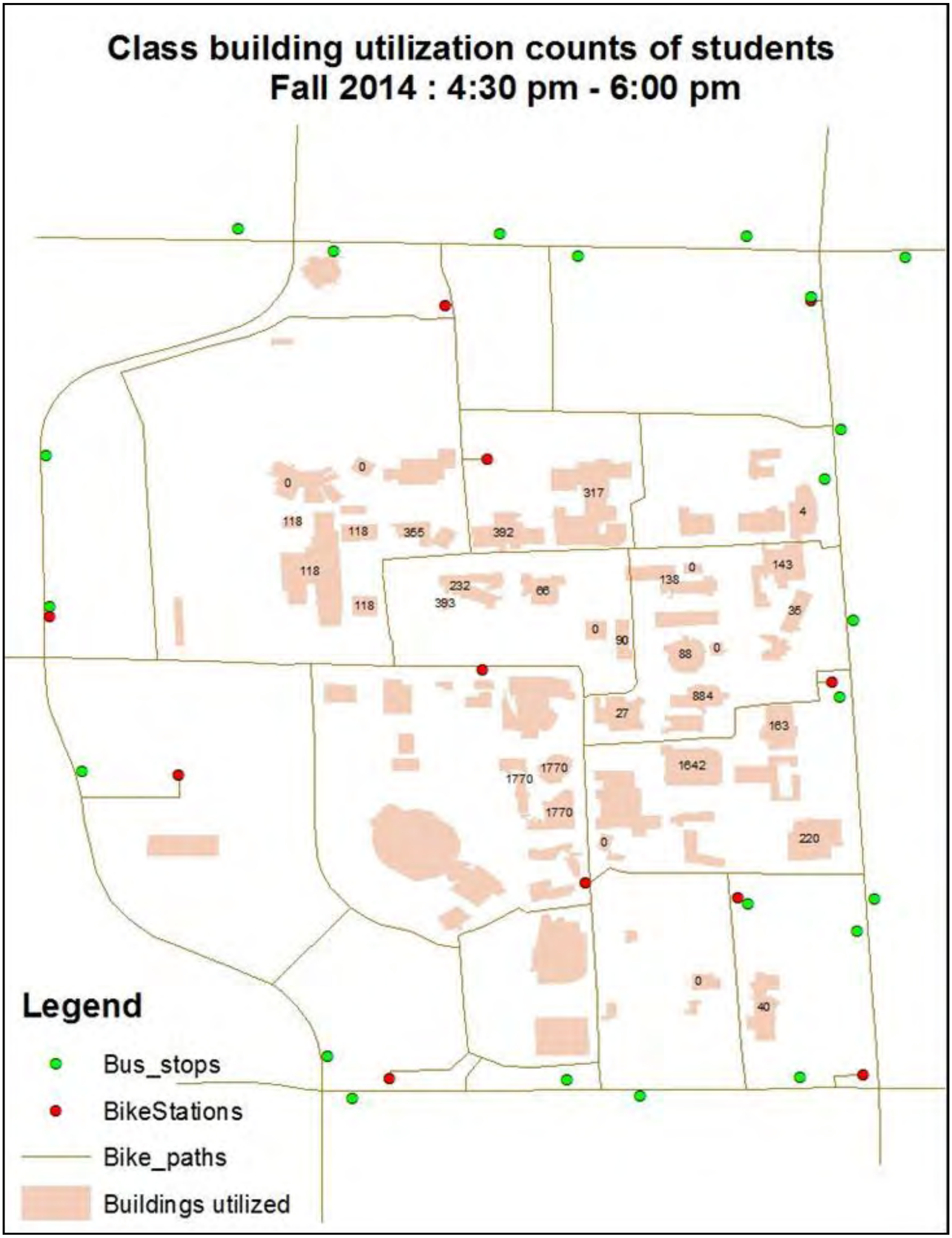


Figure 72. Enrolled Student Counts for Fall 2014 Classes. Scheduled Times from 4:30 p.m. to 6:00 p.m.

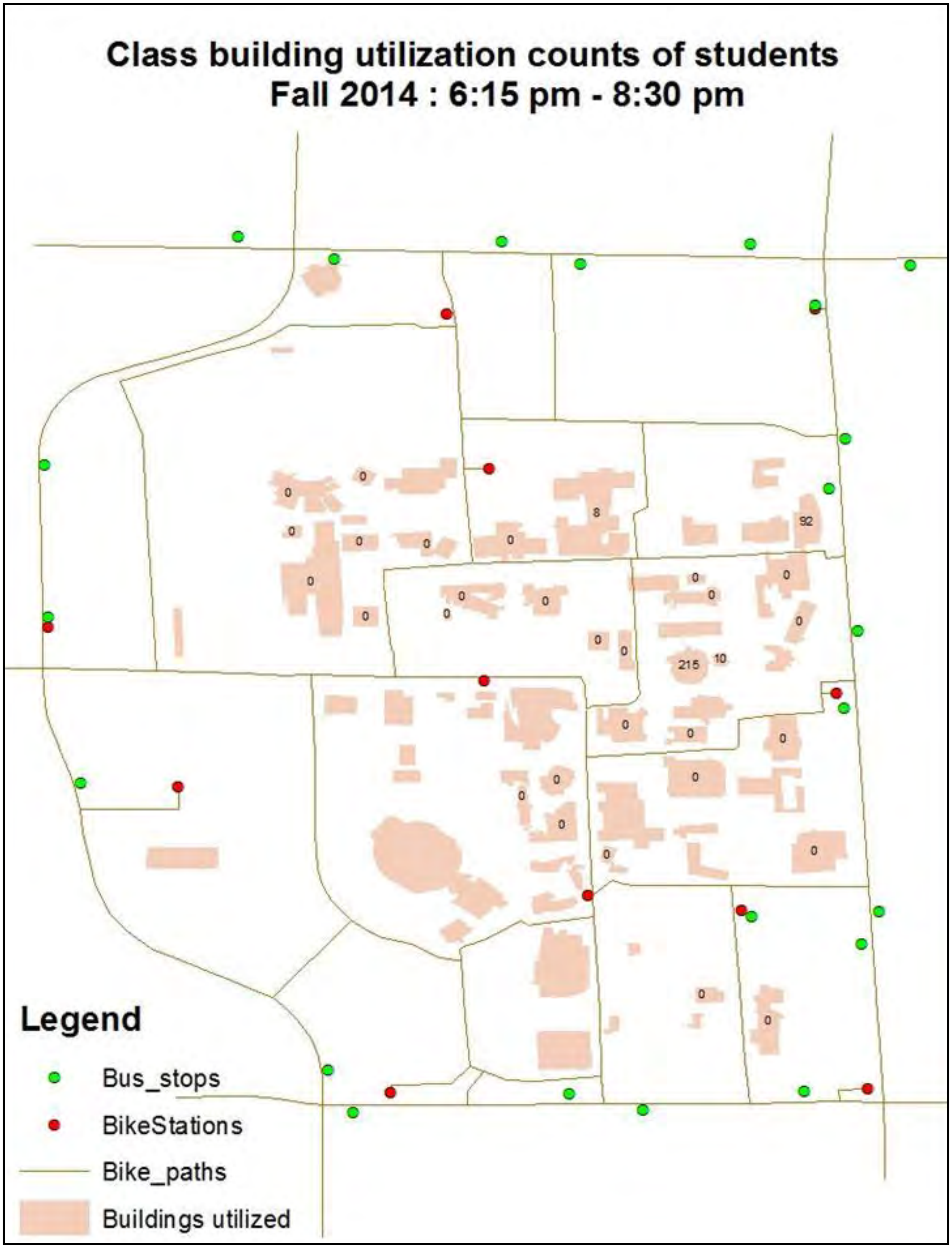


Figure 73. Enrolled Student Counts for Fall 2014 Classes. Scheduled Times from 6:15 p.m. to 8:30 p.m.

ABBREVIATIONS AND ACRONYMS

AREMA	American Railway Engineering and Maintenance-of-Way Association
BS	Bachelor of Science
CBC	Classroom Building Complex
CMAC	Congestion Mitigation and Air Quality
Coef.	Coefficient
Confid. Interval	Confidence Interval
CSC	Campus Services Complex
FDH	Flora Dungan Humanities
GIS	Geographic Information System
GPS	Global Positioning System
IT	Information Technology
LED	Light Emitting Diode
MS	Master of Science
PhD	Doctor of Philosophy
RFID	Radio Frequency Identification
RTC	Regional Transportation Commission
RTCSNV	Regional Transportation Commission of Southern Nevada
RWC	Recreation and Wellness Center
SEB	Science and Engineering Building
Std. Err.	Standard Error
TDM	Transportation Demand Management
TBE	Thomas T. Beam Engineering Complex
UNLV	University of Nevada, Las Vegas
UVA	University of Virginia
VTTS	Value of Travel-Time Saving

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ABOUT THE AUTHORS

HUALIANG (HARRY) TENG, PHD

Dr. Hualiang (Harry) Teng, an associate professor in transportation engineering at UNLV, has about 30 years of research and education experience in transportation engineering and management. He graduated from China's Beijing Jiaotong University with his BS and MS degrees in railroad engineering and management. He has a second MS degree in railroad operations from West Virginia University, and a PhD in civil engineering from Purdue University. In addition to UNLV, he has taught at Beijing Jiaotong University, Polytechnic University of New York and the University of Virginia (UVA), and he served as associate director for the Center for Transportation Studies at UVA.

Dr. Teng initiated and leads UNLV's railroad, high-speed rail and transit program, and he developed its railroad curriculum and certificate program. He oversees UNLV's Transit UTC, for which he has been involved in research with federal and local agencies and organized distinguished seminars. In addition, he is the advisor for the university's American Railway Engineering and Maintenance-of-Way Association (AREMA) student chapter.

Dr. Teng, who is active in railroad professional activities, also is interested in intelligent transportation systems, infrastructure maintenance, air quality analysis, freight transportation, safety, and demand forecasting. So far, he has published about 40 peer-reviewed technical papers.

BONIPHACE KUTELA

Boniphace Kutela is a graduate student in the Department of Civil and Environmental Engineering and Construction at UNLV. He obtained his master's degree from Tennessee State University, and his bachelor's degree in civil and structural engineering from the University of Dar es Salaam in Tanzania. In addition, he has authored technical papers that have been published in professional journals and presented at conferences.

ENELIKO MULOKOZI

Eneliko Mulokozi is a graduate student in UNLV's Department of Civil and Environmental Engineering and Construction. He earned his master's degree in civil engineering from UNLV, and his BS from the University of Dar es salaam in Tanzania. In addition, he has authored technical papers that have been published in professional journals and presented at conferences.

YANG JIAO

Yang Jiao is a graduate student in UNLV's Department of Civil and Environmental Engineering and Construction. He graduated from Beijing University of Posts and Telecommunications with his BS degree.

BINGYI HU, PHD

Bingyi Hu is an associate professor in the School of Computer Science at Beijing Jiaotong University in China. He obtained his PhD degree from Tsinghua University. Dr. Hu has been working in the chief engineer's office of the Xi'an Railway Bureau for more than one year, and has developed a railway information network to improve the exchange of information among departments. His research interests include information sharing and network construction. In addition, Dr. Hu is also interested in device design and development. He has designed more than 10 devices/systems and holds more than 30 patents in China. These designs are related to medical instruments and monitoring devices for railway systems. He was a visiting scholar when he was involved in this study.

HAIQING LI

Haiqing Li is an associate professor in the Transportation Institute of Inner Mongolia University. She obtained her MS from Wu Han University of Technology and her BS from Chang'an University. She was a visiting scholar when she was involved in this study.

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Funded by U.S. Department of Transportation