

# Analysis and O-D Demand Estimation of a Public Bike-Sharing Program in Las Vegas

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## Abstract

Bike-share systems are an effective way of mitigating congestion on the road. In addition, bike-share systems have been built in universities to serve for trips to work/commuting as well as the trips on campus. In Las Vegas, a bike-share system was proposed at the University of Nevada, Las Vegas. This study analyzed factors that influence the usage of bike-share program and estimated the origin-destination demand. To achieve these objectives, first, a literature review was conducted on university bike-sharing systems in the U.S. and abroad. Then, a survey with a questionnaire was distributed to UNLV to obtain the users' preferences to the locations of the proposed bike-share stations and their likelihood and frequency to use the bike-share program. In total, 241 faculty, staff, and students responded to the survey. About 50% of those participating in the survey expressed willingness to use the bike-share system for commuting and 60% said they are willing to use bike share for on-campus travel. Commuting and on-campus travel are two different types of travel, and the factors to determine whether an individual would use the bike-share system are quite different for each. It was estimated that there would be 3450 members for a bike-share program at UNLV, each making bicycle trips with varying frequencies, producing 1966 trips per day.

## Keywords

Bike-Share System, Commuting, On-Campus Travel, Ordered Probit Modeling, O-D Estimation

## 1. Introduction

Bicycles have been used as a mode of transportation for many years. In the be-

ginning, they were owned individually by travelers and used from the beginning to the end of their trips. Because travelers realize that the first or last mile of their trips may involve significantly long distances to walk after they arrive at the bus stop or park in a garage, bicycles can be made available at strategic locations to complete their trips. Using bicycles for the first or last mile trips might entice them to give up automobiles and use public transportation systems for their trips. In this case, a public or private agency could own a fleet of bicycles and distribute them at these strategic locations. Such a system of sharing bicycles is called bike-share program, and is installed in such communities as businesses agencies and academic institutes within a city.

Bike-sharing 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 based on information technology (IT) coincided with significant system growth. By 2009, seven systems existed in the US 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 program in the U.S. and four IT-based programs in Canada as well as 18 conventional first- and second-generation bike-sharing programs in the U.S. and Canada, which indicates a 229% increase in three years [1]. According to a study by the Toole Design Group and the Pedestrian and Bicycle Information Centre [2], Washington, D.C. was the first major city in the United States to implement a modern bike-share program, followed by Denver in 2010. Many studies on bike-sharing focus on such aspects as demand forecasting, location design of bike parking, bike equipment, marketing, and business models [1] [3].

Various studies have identified universities as the main sources and attractors for bike-share trips. A study by El-Assi *et al.* [4] analyzed a station-level commercial bike-sharing program in Toronto, and evaluated the effects of the built environment and the weather on bike-sharing demand. It was found that the university campuses outpaced the transit zones, employment density zones, and populated zones in the use of the bike-sharing program. In a study located in the cities of Minneapolis and St. Paul in Minnesota, Wang *et al.* [5] revealed that the average trips taken when using city bike-share stations located within the university campus were at least 42.6% higher than the ones located outside this zone. However, in studying Bike Share Toronto, El-Assi *et al.* [4] noted a higher positive correlation between bike share 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. Their finding that university campuses are attractive to bike-share users was consistent with findings by Hampshire and Marla [6] from a study based in the cities of Barcelona and Seville in Spain. Additionally, this study found that the arrival rate of bikes at stations located within the university campuses statistically was significantly higher in the morning.

University of Nevada Las Vegas is the biggest public agency in Las Vegas, and trips to and from the university contribute significantly to the congestion on the

roads in the Las Vegas area. To mitigate the congestion on a regional scale, we propose to develop a bike-share system at UNLV that has stations close to bus stops on one end and close to the buildings on campus on the other end. We realize that bicycles that are available for the work trips to UNLV also could 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 objective of this study was to identify the factors that influence the usage of the proposed bike-share program and to estimate the origin and destination of the demand using the bike-share system. To achieve the objectives, a literature review was conducted on university bike-sharing systems in the U.S. and abroad. A questionnaire survey was distributed to UNLV faculty, staff, and students to obtain their preferences as to the locations of the proposed bike-share stations, the likelihood as well as the frequency they might use the bike-share program. The responses to the survey were used to estimate the origin and destination demand for the bike-sharing system on and around the UNLV campus.

This paper is organized as follows. The first section provides a literature review that was conducted on university bike-share programs in order to gather information regarding what type of system might be needed at UNLV. Section 2 presents a survey conducted with the university's faculty, staff and students. The factors that influence the usage of the bike-share system are identified in the third section. Section 4 describes how the origin and destination demands are estimated. The last section presents the conclusions and future study needs.

## 2. Literature Review

Bike-share systems have gone through several iterations [7]. In 1965, Amsterdam had a free bike program; users were allowed to use bikes from one location to another, and leave them unlocked at the destination point for the next user. Later, in Copenhagen, Denmark offered users bikes from dedicated locking stations that used coins, which were refunded at the end of the ride. Real-time availability and GPS tracking began in 2005 in Lyon, France.

A comparison of these three bike-share systems indicates an advancement in technological solutions for problems observed from the start. For example, in systems similar to Amsterdam's free program, problems encountered included theft. With the invention of a bike access procedure by using coins, thefts decreased and the rate of return of the bikes were high. With the bikes equipped with GPS technology, identification was easy across the bike fleet in use, and the distance traveled and bike conditions could be tracked as well [8]. Currently, established bike programs have more system components when compared to earlier programs [2]. According to a website known as TheCityFix, published by the World Resources Institute, these include "clean docking stations, touchscreen kiosks, additional bike rebalancing technologies, as well as the integration of one unique card allowing a user to ride both bikes and public transportation" [7].

Various programs that currently are established have different fleet sizes as well as service areas [9]. For instance, bike-share programs established for the purpose of serving community members of universities are small compared to those that focus on serving a large area, such as a city or county. The mode of operation and system characteristics are diverse as well. However, there are common system characteristics between small-scale and large-scale bike programs because both programs focus on facilitating short trips, including last-mile trips.

Various studies have utilized a questionnaire survey to quantify the demand for a bike-share program [10] [11] [12] [13]. Brougham *et al.* [10] in Dalhousie University in Halifax, Nova Scotia analyzed 800 responses, showed "... that 63% of Dalhousie students were interested in a bike share program; 43% of students would use a bike share program for free or for a small fee and 20% would only use the program if it were free". Bhowmick and Varble [11] conducted the feasibility study for having a bike-share 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 samples were used for the data analysis. The analysis revealed that around 65% of the respondents were willing to use a bike-share program if it was made available on campus.

The same trend was observed by [12] at San Jose 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. At Bridgewater State University in Massachusetts, Ashley [13] collected 252 responses (32 electronically and 220 by paper) from students, faculty, administrators, and staff on campus. It was discovered that 84% of the respondent would like to participate in a bike-share program. The proportion of undergraduate students that would like to use the bike-share program were high, but they had opted to have low frequency of use. Among these studies on university bike-share programs, most (40%) wanted to use the bike-share system for travel between classes [14] with a typical use of four times or more every week during the semester [11].

Regardless of what the survey results depict, the real demand might be quite different from what is stated in the questionnaire survey. Kyung [15] summarized the results of a survey across 41 universities located in the United States that had either bike share or bike rental programs around the campuses. This study revealed that 83% of these universities had 1000 members or fewer, and more than 50% had 250 members or fewer. This situation calls for more advanced methodologies to quantify the demand prior to establishing the program.

The presence of bike share station at the periphery of a university would enable faculty and students to use bikes to complete the last mile of their commuting trip from a transit station/stop to their destinations on campus. They could use transit to go to school rather than drive to school. As a result, congestion on roads could be reduced, and air pollution and fuel consumption could be re-

duced correspondingly. With bike-share stations available on campus, faculty and students could use bicycles to travel between buildings for such purposes as attending classes and meetings. Otherwise, they would have to use other means of transportation to make these trips, such as walking. Using bikes, they could reduce time used for travel, which could be used instead to perform more activities on campus. The productivity of their time on campus could improve significantly.

With bike share stations available off campus, faculty and students could travel to these locations using bicycles for such purposes as shopping. They would not be able to access these types of locations if no bike-share stations were installed there. As a result, economic conditions in areas where the bike share stations are installed could improve. Otherwise, faculty and students might have to drive to these locations, increasing congestion on the roads. The bike-share program to be considered at UNLV only would have stations on the periphery of the campus and on campus.

### 3. Survey Design, Distribution, and Collection

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

**Figure 1** shows the locations of the potential bike-share 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 bike-share system, they were asked which locations they might pick up and drop off the bikes as well as the number of trips they would make. For the on-campus travel, questions are asked about the trip purposes, such as going to class or attending meetings.

Bike-share stations on the periphery of the campus were chosen in terms 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-m radius of the station was used to measure the bus connections. The traffic flow of automobiles in and out of campus represents the potential that people would shift their mode of travel mode from auto to public transportation.

The potential stations on campus were identified based on data about student enrollment and building occupancy of the faculty and staff. These data were used to determine the percentage of building utilization falling within the service

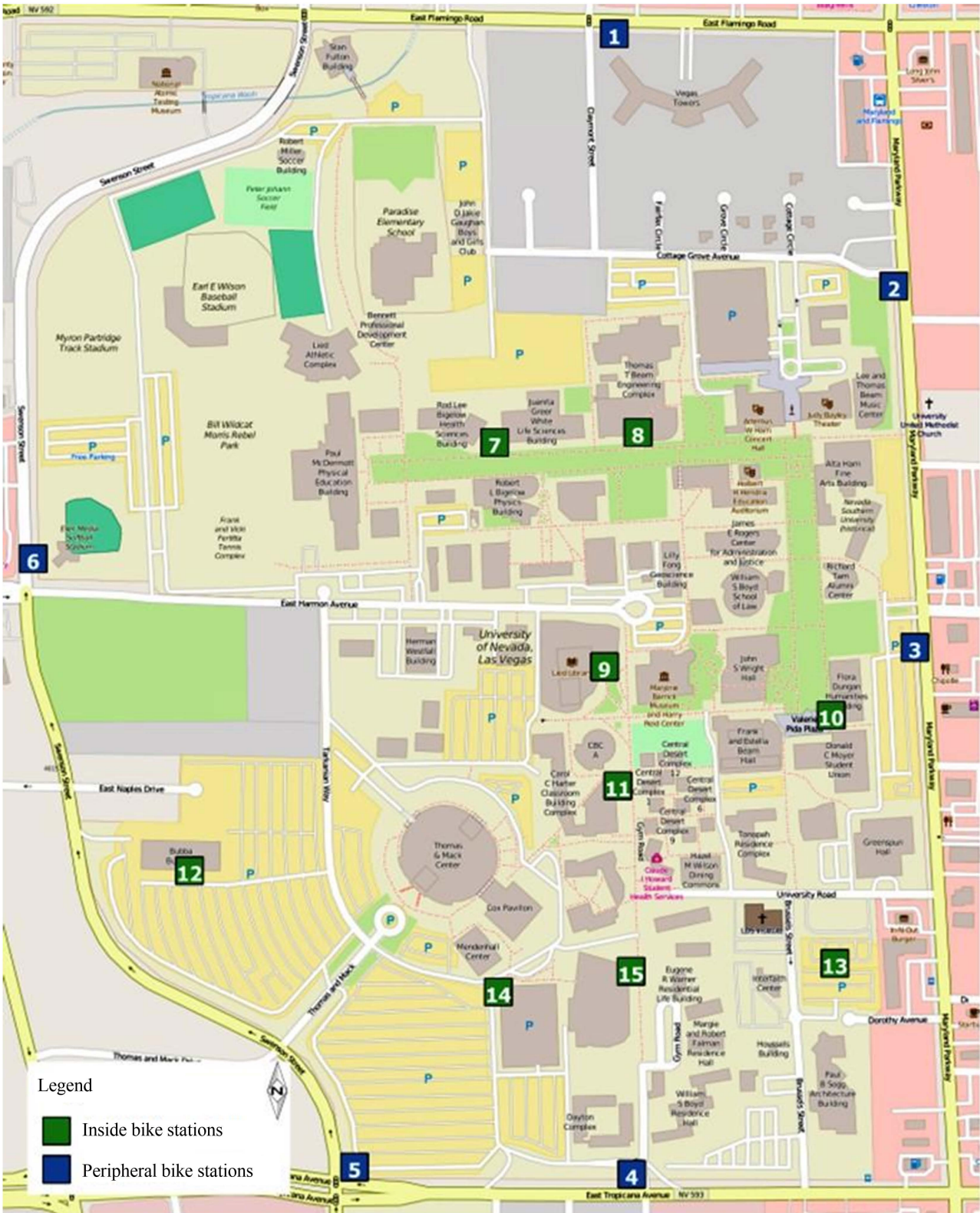


Figure 1. Proposed locations for bike-share stations on the main campus of UNLV.

area of each bike station. Distribution of stations inside the campus was based on the following factors:

- Walking distance: a walking distance of 400 m 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. This would ensure that all bike stations could service the intended users of the university: faculty, staff, and students.

#### 4. Descriptive Statistics of Survey Responses

After four months of sending out the survey (August to December 2015), 241 responses were collected and analyzed in this study. 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 were between 21 and 30 years old (80). This observation is consistent with the age distribution among the university community. Of the 231 respondents to this question about education profile, 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. The responses to the survey revealed the annual incomes of the respondents clustered around two ranges, a lower level of around \$10,000 to \$19,000 and higher level of around \$75,000 to \$99,999. The lower level may represent those of students and the higher level for faculty and staff.

Among the 241 respondents about their ways to come to school, 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. 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. 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 student respondents who live off campus and whose current mode of transportation to UNLV is by car implies that UNLV is a commuting school.

From a map displayed 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. Having an office on campus is important in understanding the possible origin and destinations of the users of a bike-share program. The survey revealed that among the 241 res-

pondents, 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 bike-share program was the most important part of the questionnaire survey. The responses indicated that of the 231 respondents, 50 chose “Very Likely” and 66 chose “Somewhat Likely” to use a bike-share 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 bike-share system for their day-to-day movements within the campus. The on-campus trips could occur in varying frequencies. About 30% of the respondents would make such an on-campus trip once a day, making the bike-share program significant at UNLV.

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 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 be beneficial from the bike-share program.

The motives for using the bike share program were identified as well. Half of the respondents who expressed that they were likely to use the bike-share program due to either the convenience or the health benefits. It was observed that 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 choose using the bike-share 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.

When asked which stations were most likely to be used to check out a bike, the stations mostly chosen were Station 4, followed by Stations 1, 2, 3, 5, 6, 7, and 9. The reason for these stations might be that the respondents could drive their vehicles to school and park at a location close to a bike-share 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. The station most chosen to return their 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 to return bicycles were Stations 10, 9, 11, 15, 12, 13, and 14. No one specified other locations. In addition, the stations most popular for checking out a bike were Stations 8, 9, 10, 7, 15, and 2, which corresponds to the major origins of the trips on the 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.

## 5. Factors Influencing the Usage of the Bike-Share System

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

Based on [6], the 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;  $\beta_i$  represents the coefficient for  $X_i$ ; and  $\varepsilon$  denotes the error term. Let  $y$  represent the variable of the *observed* likeliness and frequency. Based on the ordered probit model,  $y$  can be determined by the unobserved variable  $y^*$  as follows:

$$Y = \begin{cases} 1 & \text{if } y^* \leq 0 \\ 2 & \text{if } 0 < y^* \leq \mu_1 \\ 3 & \text{if } \mu_1 < y^* \leq \mu_2 \\ 4 & \text{if } \mu_2 < y^* \leq \mu_3 \\ 5 & \text{if } y^* \geq \mu_3 \end{cases} \quad (2)$$

The  $\mu$  represents unknown parameters that need to be estimated with  $\beta$ . Under the assumption that the error term  $\varepsilon$  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  $m$  based on maximum likelihood method [16].

### 5.1. Likelihood of Using the Bike-Share Program for Commuting

The results of the ordered probit model for the likelihood of using the bike-share program for commuting are presented in **Table 1**. 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:

- The distance from residences by zip code to their destinations on campus;
- The distance from the check-in stations to the destinations of the users;
- Whether is any bus line connects from the zip code areas to UNLV;
- Income level (between \$20,000 to \$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 am., between 8 a.m. to 12 pm.;

**Table 1.** Ordered probit model for the likelihood of using the bike-share program for commuting.

Ordered probit regression			Number of observations	=	161	
			LR chi <sup>2</sup> (14)	=	95.79	
			Prob > chi <sup>2</sup>	=	0	
Log likelihood = -190.52611			Pseudo R <sup>2</sup>	=	0.2009	
Likelihood to use shared bikes for commuting	Coef.	Std. Err.	z	P > z	[95% Confid. 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 to \$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 am	0.383	0.216	1.770	0.076	-0.041	0.807
Between 8 am to 12 pm	-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

- Education level (high school, college and associate degree, bachelor degree, and graduate and others).

It can be seen from **Table 1** that the coefficient for the distance between where the users would return the bikes to where their buildings are located was positive, which implies that they are less likely to use shared bikes in their last or first mile for commuting. This observation makes sense, and is consistent to studies in [17] and [18]. This observation suggests locating bike-share stations close to buildings where their offices are located.

The coefficient for having a bus line connecting where they live to UNLV is negative, implying that they would tend to use the bike-share program. It suggests that bus lines should be well connected to the communities to attract more users to use the bike-share program. The coefficient for the high-income users is positive, implying that they tend not to use the bike-share 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 bike-share 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 involve time is limited for them, which may cause them to use other modes having fewer travel transfers.

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

The ordered probit models were developed for how frequently the respondents would use the bike-share program for commuting, and results are presented in **Table 2**. In general, the coefficient for being male was negative for frequency of commuting travel; this implies that male users would use the bike-share program less frequently than females. The coefficient for the prospective users who have offices within the campus was positive, which implies that they would tend to use the bike-share program for commuting less frequently. This observation may indicate that students who usually do not have an office on campus would tend to use the bike-share 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 tend to use the bike-share program less frequently. They might have a fixed travel choice already that they may not want to change. The coefficient for the people whose 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 bike-share program for commuting less frequently. This observation is contradictory to common sense, and need more investigation. The coefficient for users with graduate degrees or higher degree is positive, which implies that they 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 bike-share program.

**Table 2.** Ordered probit model for how frequently the bike-share program would be used for commuting.

<b>Ordered probit regression</b>	Number of observations	=	178		
	LR chi <sup>2</sup> (6)	=	40.15		
	Prob > chi <sup>2</sup>	=	0.000		
Log likelihood = -212.136	Pseudo R <sup>2</sup>	=	0.0865		
<b>Frequency of using bikes for commuting</b>	<b>Coef.</b>	<b>Std. Err.</b>	<b>z</b>	<b>P &gt; z</b>	<b>[95% Conf. Interval]</b>
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
<b>Education level</b>					
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

## 5.2. How Frequently the Bike-Share Program Would Be Used for Commuting

Comparing the results from the ordered probit model for the likelihood of using the bike-share program with the model for how frequently the program would be used for commuting (Table 2), it can be seen that the factors influencing people to use a bike-share program are different from those who would use the program more frequently.

First, the distance between the stations where the bikes are returned and the buildings to which people go as their destination is not an influential factor for people to decide using the bike share program more frequently for commuting. Whether there is a bus line in their neighborhood also is not a factor on whether people would use the bike-share program more frequently. The factors that are important for people to consider using bike share programs more frequently in commuting are gender and whether they have an office on campus. People with lower education do not show a significantly high tendency to use the bike-share program; however, they do show that they are likely to use the program more frequently than people having higher education.

## 5.3. Likelihood of Using the Bike-Share Program for On-Campus Travel

Results of the ordered probit model for on-campus travel are presented in Table 3. The same set of variables used for commuting was used for on-campus travel.

**Table 3.** Ordered probit model for the likelihood of using the shared-bike program for on-campus travel.

Ordered probit regression	Number of observations				=	160
	LR chi <sup>2</sup> (9)				=	23.15
	Prob > chi <sup>2</sup>				=	0.0059
Log likelihood = -183.97765	Pseudo R <sup>2</sup>				=	0.0592
Likelihood to use bike share for on campus	Coef.	Std. Err.	Z	P > z	[95% Confid. 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 to \$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

It can be seen that the distance from the station that the 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 from where they return their bikes to where their destination is, the less likely a person would use the shared bikes; this is consistent intuitively.

The implication is that the bike-share stations need to be located close to buildings where their offices are located. This observation is consistent with independent survey-based studies by [17] and [18]. Fuller *et al.* [18] found that people living within 250 m of a docking station were over twice as likely to become users of the bike-share system as those living farther away. The coefficient for the income variable is significant and negative. This implies that low-income users tend to more likely use the shared bike, which is consistent to common sense.

## 5.4. How Frequently the Bike-Share Program Would Be Used for On-Campus Travel

**Table 4** 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 bike-share program more frequently than others. This is consistent to the findings in other studies [19] [20].

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 bike-share program less frequently than undergraduate students, who usually do not have an office on campus. The undergraduate students would use the bike-share program frequently and daily for such activities as going to library.

The coefficient for faculty is negative, which implies that they would use the bike-share program more frequently for such purposes as attending meetings, which is understandable. The coefficient for the users who have a graduate degree is positive, implying that they would use the bike-share program less frequently. This is consistent with the previous observation. The coefficient for users who would use the bike-share program to attend class is positive, which implies that they would use the bike-share program to do other things more frequently, such as going to the library and gyms. This might be due to the fact

**Table 4.** Ordered probit model for the frequency of on-campus travel.

Ordered probit regression	Number of observations	=	176		
	LR chi <sup>2</sup> (7)	=	49.50		
	Prob > chi <sup>2</sup>	=	0.000		
Log likelihood = -204.51254	Pseudo R <sup>2</sup>	=	0.1079		
Frequency of using bikes within UNLV campus	Coef.	Std. Err.	z	P > z	[95% C. 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

that attending class is a more time-sensitive activity, and using a bike-share program might have some uncertainty in checking out and returning bikes and then walking to classrooms.

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

- 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 to using bike share.
- Second, people's gender, whether they have an office on campus and whether they are faculty are important in determining the frequency that people use the bike-share program.
- Third, the education level is important to the users when deciding the number of trips made on campus when using the bike share program; however, it is not a factor when deciding whether choose to use bike-share program.
- Fourth, attending class was not a reason given when deciding either if they will use the bike-share program or how frequently.

## 6. Origin and Destination Demand of the Bike Share Program

In order to establish the expected demand from the survey responses, the levels of likelihood in using the bike-share program were tabulated, including the expected frequencies of usage. It was assumed that users those who would choose bike share 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, around 17% of the respondents were very likely to use the bike-share program on a regular basis for commuting, and 12.6% of the respondents were somewhat likely to use the bike-share program on a regular basis for commuting in a regular basis. This indicates these people might be regular users of the bike-share program for commuting. 4.3% of the respondents were very likely to use the bike-share 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 of the bike-share program for commuting.

For on-campus travel, more than 25% of the respondents were very likely to use the program on a regular basis and 12.6% would use it occasionally. In addition, there were higher percentages of the casual users (18.6%) than regular users (10.4%) who were somewhat likely to choose the bike share for on-campus travel.

In this study, the respondents to the survey who were very likely or somewhat likely to use the bike-share program for both commuting and on-campus activities were defined as "members". Not every respondent who expressed likelihood

to participate in the bike-share program was considered 100% trustworthy. It was assumed that 30% of the respondents who stated that they were very likely to use the bike-share program and use the program regularly would be those who actually participate in the program. Additionally, it was assumed that 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 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 5**.

Given these discount factors, the number of members of the bike-share 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:

$$\begin{aligned} & \# \text{ of members} \\ & = [0.3 * 21.25\% + 0.15 * (11.5\% + 8.4\%) + 0.075 * 15.6\%] * 32,882 = 3462 \quad (3) \end{aligned}$$

For convenience, this figure was rounded to 3450 members, in which 73% (2518) 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 1966 (see **Table 6**). The corresponding trip table is provided in **Table 7**.

**Table 5.** Stated preference for data discount factors.

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

**Table 6.** 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%	1154	427	0.39	450	167
More than once a day	19%	4%	595	220	1.56	927	343
Total	57%	43%	2518	932		1435	531
	100%		Total trips			1966	



**Table 7.** Origin-destination matrix.

		Destination															
Origin	Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
		1	0	0	0	0	0	0	20	150	14	7	0	0	0	7	7
	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	1966

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;
- 4) From internal to internal stations.

These four groups of trips occur during different periods during the day. The first group of trips occurs during the day 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 the maximum utilization of the system would not occur during the first years of operation. Experiences of 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.

The trips per day, shown in **Table 7**, were used to obtain the number of trips during peak hours. The peak-hours factor was computed based on the utilization of the bike-share system in the Bay area of San Francisco, and the peak-hour flow is shown in **Table 8**. Note that the bike-share system in the Bay area is a city

**Table 8.** 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	

bike-share program; this is different from a university bike-share 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 bike-share program.

## 7. Conclusions and Future Study Needs

### 7.1. Conclusions

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

In total, 241 faculty, staff, and students responded to the survey. About 50% of those participating in the survey expressed a willingness to use the bike-share 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 to determine whether an individual to use the bike-share system for each is quite different. For commuting to the university's campus, factors critical for cus-

tomers to decide whether they would use the bike share program are: 1) the distance from where the users would return the bikes to where their buildings are located, 2) having a bus line connecting to where they live, 3) their income, 4) whether they drive to school, 5) whether they come to school before 8 a.m., and 6) the level of education. The factors that influence the frequency of using the bike-share system are quite different, and they are: 1) gender, 2) whether they have an office on campus, 3) whether they are faculty members, and 4) the level of education.

For on-campus travel, it was found that factors critical for customers to choose to use the bike-share program are: 1) the distance from the station where the users return the bikes on campus to where their buildings, and 2) income. The factors that determine whether the customers use the bike-share program frequently are: 1) gender, 2) whether they have an office on campus, 3) whether a customer is a faculty, 4) education level, and 5) whether they use the bikes to attend classes.

It was estimated that there would be 3450 members for the bike-share program at UNLV; each user would make bicycle trips with various frequencies, which would produce an estimated 1966 trips per day.

## 7.2. Future Study Needs

First, the demand could be estimated more accurately by collecting a greater sample size of the surveys. In this study, about 250 samples were collected from the various colleges and schools on UNLV's campus. This sample size was on the lower end in terms of numbers.

Second, the 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 bike-share 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 of the bike trips were out of the College of Engineering to other buildings on campus. Whether this actually is the case should be further verified by conducting a second survey.

Third, interviews face-to-face or by phone should be conducted when collecting the survey samples. The bike-share 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. This would cause some questions to be misunderstood, which causes the survey quality to be degraded. By having an interview, the people surveyed could be given clear explanations about the bike-share program, thus improving the quality of the survey data.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

- [1] Shaheen, S.A., Martin, E.W., Cohen, A.P. and Finson, R.S. (2012) Public Bikesharing in North America: Early Operator and User Understanding. 2012 MTI Report 11-26. A Publication of Mineta Transportation Institute.
- [2] Toole Design Group and the Pedestrian and Bicycle Information Center (2012) Bike Sharing in the United States: State of the Practice and Guide to Implementation. Report for USDOT Federal Highway Administration.
- [3] Gauthier, A., Colin, H., Kost, C., Li, S., Linke, C., Lotshaw, S., Mason, J., Pardo, C., Rasore, C., Schroeder, B. and Treviño, X. (2013) The Bike-Share Planning Guide. [http://www.uemi.net/uploads/4/8/9/5/48950199/itdp\\_bike\\_share\\_planning\\_guide\\_publication\\_small.pdf](http://www.uemi.net/uploads/4/8/9/5/48950199/itdp_bike_share_planning_guide_publication_small.pdf)
- [4] El-Assi, W., Mahmoud, M.S. and Habib, K.N. (2015) Effects of Built Environment and Weather on Bike Sharing Demand: A Station Level Analysis of Commercial Bike Sharing in Toronto. *Transportation*, **44**, 589-613. <https://doi.org/10.1007/s11116-015-9669-z>
- [5] Wang, X., Lindsey, G., Schoner, J.E. and Harrison, A. (2015) Modeling Bike Share Station Activity: Effects of Nearby Businesses and Jobs on Trips to and from Stations. *Journal of Urban Planning and Development*, **142**, 04015001. [https://doi.org/10.1061/\(ASCE\)UP.1943-5444.0000273](https://doi.org/10.1061/(ASCE)UP.1943-5444.0000273)
- [6] Hampshire, R.C. and Marla, L. (2012) An Analysis of Bike Sharing Usage: Explaining Trip Generation and Attraction from Observed Demand. *91st Annual Meeting of the Transportation Research Board*, Washington, 22-26 January 2012, 12-2099.
- [7] Colin, B. (2013) Four Generations of Bike-Sharing. TheCityFix, World Resources Institute. <https://thecityfix.com/blog/generations-bike-sharing-generations/>
- [8] Shaheen, S.A., Guzman, S. and Zhang, H. (2010) Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future. *Transportation Research Record: Journal of the Transportation Research Board*, **2143**, 159-167. <https://doi.org/10.3141/2143-20>
- [9] Kutela, B. and Teng, H. (2019) The Influence of Campus Characteristics, Temporal Factors, and Weather Events on Campuses-Related Daily Bike-Share Trips. *Journal of Transport Geography*, **78**, 160-169. <https://doi.org/10.1016/j.jtrangeo.2019.06.002>
- [10] Brougham, T., Isabelle, L., MacDougall, A., MacFarlane, S., Maxwell, D. and Sanderson, M.-C. (2009) Dalhousie Bike Share Program: Exploring the Potential for a Bike Share Program at Dalhousie University. <https://cdn.dal.ca/content/dam/dalhousie/pdf/science/environmental-science-program/ENVS%203502%20projects/2009/BIKESHARE.pdf>
- [11] Bhowmick, S. and Varble, D.L. (2015) Bike-Share: A Bicycle Program for Campus. *Journal of Case Studies*, **33**, 25-37.
- [12] Zonobi, E. and Otto, M. (2012) Bike Share Survey Report. Associated Students, San Jose State University Transportation Solutions. <https://www.sjsu.edu/as/docs/ts/SJSU%20Fall%202012%20Commute%20Survey%20Report.pdf>
- [13] Ashley, J. (2012) Bike Sharing as Alternative Transportation at Bridgewater State University. *Undergraduate Review*, **8**, 16-25.
- [14] Work, L., Gardner, P. and DeGoey, K. (2013) Boise State University Bike Share Program. <https://www.boisestate.edu/sps-environmental/experiential-learning/capstone-projects/boise-state-university-bike-share-program/>

- [15] Kyung, G. (2015) University Bike Share Survey Analysis. Prepared for University of Illinois Institute of Sustainability, Energy, and Environment.
- [16] Greene, W.H. (2000) Econometric Analysis. 4th Edition, Upper Saddle River, Prentice Hall.
- [17] Bachand-Marleau, J., Lee, B.H.Y. and El-Geneidy, A.M. (2012) Better Understanding of Factors Influencing Likelihood of Using Shared Bicycle Systems and Frequency of Use. *Transportation Research Record: Journal of the Transportation Research Board*, **2314**, 66-71. <https://doi.org/10.3141/2314-09>
- [18] Fuller, D., Gauvin, L., Kestens, Y., Daniel, M., Fournier, M., Morency, P. and Drouin, L. (2011) Use of a New Public Bicycle Share Program in Montreal, Canada. *American Journal of Preventive Medicine*, **41**, 80-83. <https://doi.org/10.1016/j.amepre.2011.03.002>
- [19] Beecham, R. and Wood, J. (2014) Exploring Gendered Cycling Behaviors within a Large-Scale Behavioral Data-Set. *Transportation Planning and Technology*, **37**, 83-97. <https://doi.org/10.1080/03081060.2013.844903>
- [20] Akar, G., Fischer, N. and Namgung, M. (2013) Bicycling Choice and Gender Case Study: The Ohio State University. *International Journal of Sustainable Transportation*, **7**, 347-365. <https://doi.org/10.1080/15568318.2012.673694>