MINETA NATIONAL TRANSIT RESEARCH CONSORTIUM

Intermodal Bus and Bicycling Transportation in Southern Nevada

MNTRC Report 12-71

MNTRC
MINETA NATIONAL TRANSIT RESEARCH CONSORTIUM

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

MINETA TRANSPORTATION INSTITUTE
LEAD UNIVERSITY OF MNTRC

The Mineta Transportation Institute (MTI) was established by Congress in 1991 as part of the Intermodal Surface Transportation Equity Act (ISTEA) and was reauthorized under the Transportation Equity Act for the 21st century (TEA-21). MTI then successfully competed to be named a Tier 1 Center in 2002 and 2006 in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Most recently, MTI successfully competed in the Surface Transportation Extension Act of 2011 to be named a Tier 1 Transit-Focused University Transportation Center. The Institute is funded by Congress through the United States Department of Transportation's Office of the Assistant Secretary for Research and Technology (OST-R), University Transportation Centers Program, the California Department of Transportation (Caltrans), and by private grants and donations.

The Institute receives oversight from an internationally respected Board of Trustees whose members represent all major surface transportation modes. MTI's focus on policy and management resulted from a Board assessment of the industry's unmet needs and led directly to the choice of the San José State University College of Business as the Institute's home. The Board provides policy direction, assists with needs assessment, and connects the Institute and its programs with the international transportation community.

MTI's transportation policy work is centered on three primary responsibilities:

Research

MTI works to provide policy-oriented research for all levels of government and the private sector to foster the development of optimum surface transportation systems. Research areas include: transportation security; planning and policy development; interrelationships among transportation, land use, and the environment; transportation finance; and collaborative labor-management relations. Certified Research Associates conduct the research. Certification requires an advanced degree, generally a Ph.D., a record of academic publications, and professional references. Research projects culminate in a peer-reviewed publication, available both in hardcopy and on TransWeb, the MTI website (http://transweb.sjsu.edu).

Education

The educational goal of the Institute is to provide graduate-level education to students seeking a career in the development and operation of surface transportation programs. MTI, through San José State University, offers an AACSB-accredited Master of Science in Transportation Management and a graduate Certificate in Transportation Management that serve to prepare the nation's transportation managers for the 21st century. The master's degree is the highest conferred by the California State University system. With the active assistance of the California Department of Transportation, MTI delivers its classes over a state-of-the-art videoconference network throughout the state of California and via webcasting beyond, allowing working transportation professionals to pursue an advanced degree regardless of their location. To meet the needs of employers seeking a diverse workforce, MTI's education program promotes enrollment to under-represented groups.

Information and Technology Transfer

MTI promotes the availability of completed research to professional organizations and journals and works to integrate the research findings into the graduate education program. In addition to publishing the studies, the Institute also sponsors symposia to disseminate research results to transportation professionals and encourages Research Associates to present their findings at conferences. The World in Motion, MTI's quarterly newsletter, covers innovation in the Institute's research and education programs. MTI's extensive collection of transportation-related publications is integrated into San José State University's world-class Martin Luther King, Jr. Library.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation, University Transportation Centers Program and the California Department of Transportation, in the interest of information exchange. This report does not necessarily reflect the official views or policies of the U.S. government, State of California, or the Mineta Transportation Institute, who assume no liability for the contents or use thereof. This report does not constitute a standard specification, design standard, or regulation.

REPORT 12-71

INTERMODAL BUS AND BICYCLING TRANSPORTATION IN SOUTHERN NEVADA

Alexander Paz, Ph.D., PE
Courtney Coughenour, Ph.D.

March 2017

A publication of
Mineta National Transit Research Consortium

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

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. CA-MNTRC-16-1250	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Intermodal Bus and Bicycling Transportation in Southern Nevada		**5. Report Date** March 2017 **6. Performing Organization Code**
7. Authors Alexander Paz, Ph.D., PE and Courtney Coughenour, Ph.D.		**8. Performing Organization Report** MNTRC Report 12-71
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 University of Nevada, Las Vegas 4505 S Maryland Pkwy Las Vegas, NV 89119		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code**
15. Supplemental Notes		

16. Abstract

Active transportation, such as walking and bicycling, have numerous environmental, health, and economic benefits. Currently, many efforts are underway to increase the rate of active transportation and decrease the rate of travel by private vehicles. The purpose of this study was to understand perceptions and likelihood of using various types of bicycle infrastructure by Las Vegas Metropolitan Area (LMVA) residents. A survey tool was developed to collect data regarding demographics, travel characteristics, safety perceptions of the current bicycling infrastructure, general safety concerns related to bicycling, and the likelihood that residents would use any of eight bicycle infrastructure alternatives. Additionally, stakeholder interviews were conducted with a small number of residents who reported bicycling as their primary mode of transportation.

Study findings suggest that LVMA residents perceive many barriers to bicycling related to safety and infrastructure type. If the goal is to increase the rate of bicycling for transportation, then both the actual and perceived barriers need to be adequately addressed. The authors suggest recommendations to increase the number of LVMA residents who bicycle for transportation.

17. Key Words Active transport; bicycling; walking; infrastructure; travel characteristics	**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** 59	**22. Price** $15.00

Form DOT F 1700.7 (8-72)

Copyright © 2017
by **Mineta National Transit Research Consortium**
All rights reserved

Library of Congress Catalog Card Number:
2017936926

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

032917

ACKNOWLEDGMENTS

The authors would like to acknowledge and thank the Regional Transportation Commission of Southern Nevada for its continued support and feedback throughout this project.

We would also like to thank Dr. Hanns de la Fuente, associate professor at Pontificia Universidad Católica de Valparaíso, who assisted with statistical analysis of the data; Kathleen Larson, research assistant in UNLV's Department of Psychology, who assisted with survey design and data collection efforts; and Julie Longo, technical writer with UNLV's Howard R. Hughes College of Engineering, for her editorial assistance.

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

TABLE OF CONTENTS

I. Introduction	1
II. Study Methodology	7
III. Results	10
IV. Discussion of Findings	25
Appendix A: Survey	29
Appendix B: Qualitative Questions from Key Informant Interviews	44
Appendix C: Frequency of Survey Respondents and Respondents Who Reported Bicycling for Transportation	45
Appendix D: Regression Analysis and Brief Interpretation of Results	47
Abbreviations and Acronyms	49
Endnotes	50
Bibliography	54
About the Authors	58
Peer Review	59

LIST OF FIGURES

1. Conventional Bike Lane: A Standard 5-Foot Bike Lane, with No Buffers, on a Minor Roadway 14

2. Buffered Bike Lane: A Standard 8-Foot Bike Lane with 3-Foot Buffers on a Minor Roadway 15

3. Buffered from Traffic by Parking: A Standard Bike Lane, with 3-Foot Buffers, on a Minor Roadway 16

4. Enhanced Buffered Lane: An 8-Foot Bike Lane, with 3-Foot Buffers, Located on a Minor Roadway 17

5. Physical Separation Involves a Raised Bike Lane with Mountable Curb Separation from Traffic 18

6. A Shared Bus-Bike Lane, Located on a Major Roadway 19

7. Share the Road Concept: A Slightly Wider Right Lane that is Shared by Both Bicycles and Vehicles 20

8. Paved Multiuse Trail: A Paved Bike Trail that is Completely Separated from Traffic 21

9. Frequency of Survey Responses by Zip Code 45

10. Frequency of Survey Responses by Zip Code of Individuals Who Reported that They Used a Bicycle for Any of Their Daily Trips 46

LIST OF TABLES

1. Census Demographic and Mode of Transit to Work Data and Sample Demographic and Primary Mode of Transportation Data 11

2. Survey Results Related to Perceptions of the Current Bicycling Infrastructure 12

3. Safety Concerns Regarding Bicycling for Transportation and Factors that would Result in Starting or Increasing the Amount of Bicycle Travel 13

4. Themes and Sub-Themes from Qualitative Analysis of Key Informant Interviews with Survey Respondents Who Bicycle as their Primary Mode of Transportation 23

5. Results of Multinomial Logistic Regression Model Reflecting the Choice of Infrastructure 48

I. INTRODUCTION

Background

At present, numerous efforts are aimed at increasing the rates of active transportation, which according to a report by the City Club of Portland, Oregon, is "…human-powered transportation such as walking or bicycling."[1] Many health, environmental, and economic benefits would be reaped by increasing the rates of active transportation and decreasing travel by private vehicles. Traffic congestion contributes to poor air quality and has considerable public health implications, including an increase in respiratory symptoms, emergency room visits and hospitalizations, and absenteeism from school and work.[2] More time spent in a vehicle has been correlated with fewer minutes of physical activity, increased risk for obesity, and increased stress levels.[1,3,4]

Rates of inactivity have continued to increase in the U.S.; this is concerning, as physical inactivity is a major risk factor for many chronic diseases and decreased life expectancy. Efforts aimed at increasing levels of physical activity historically have been focused at the individual level, targeting the behavior of one person at a time. Studies have found that individually focused interventions do not have lasting effects, with low rates of maintenance upon cessation of the intervention.[5,6] Therefore, targeting the increase of physical activity levels by increasing the rates of active transportation may prove effective.[7] According to Coughenour et al.,[7] "Active transportation incorporates physical activity into daily routines, such as walking to and from work or errands; enabling the attainment of minutes of physical activity without a conscious decision to do so; and a high level of commitment that is required for recreational physical activity." Additionally, many changes that support active transportation include such environmental modifications as changes to sidewalks or roadway infrastructure. These changes often affect populations rather than individuals.

More recent efforts to increase physical activity levels have focused on variables at the population level instead of more traditional interventions at the level of individuals or small groups. Street-scale, urban-design, land-use policies have been recommended as an effective method to increase physical activity by the Community Preventive Services Task Force[8]–which, are "… a group of independent, unpaid, public health and prevention experts that provide evidence-based findings and recommendations on a number of topics …" Evidence shows that street-scale elements are associated with increased minutes of physical activity; such elements include the availability of sidewalks, bicycling facilities, proximity to transit stops[9] and adequate lighting.[10] Consequently, it is important to understand the role of street-scale factors on physical activity behaviors since modification to such factors may result in increased rates of physical activity and active transportation rates simultaneously.[7]

Investments in transportation infrastructure have economic benefits as well. Using active transportation involves such economic benefits as pedestrians and bicyclists being able to spend more money at local businesses each week than can users of other modes of transportation.[11,12] According to Milne and Melin,[13] a study by Wang et al.[14] determined that customers in Minneapolis and St. Paul, Minnesota, "spent an estimated additional $150,000 in one season at restaurants and other businesses" near the Nice Ride bikeshare stations.

Additionally, studies have shown that the millennial generation–those born between 1977 and 1994–prefer a denser, urban design that allows the use of both active and public transportation. Among college-educated millennials, 64% report that they will make a choice of a preferable place to live first, then look for a job in that area.[15] Attracting this young, educated population has become important for the future vitality of a region.

In addition to direct revenue, the Alliance for Biking & Walking used data from Gotschi[16] in order to estimated that "… every $1 invested in bicycling yields $3.40 in health care cost savings and when the statistical value of lives is considered, every $1 invested yields nearly $100 in benefits …"[13] Various public health and economic benefits should be investigated with regards to infrastructure, which supports transit options.

According to the Alliance for Biking & Walking's 2014 Benchmarking Report,[13] the rates of bicycling and walking in the U.S. have gradually increased since 2003. This reported states that "thirty-six states and 47 of the most populous cities surveyed for this report have a published goal to increase either walking or bicycling levels (most often, both) … a significant increase since 2007" (p. 34). Many communities are investing in biking infrastructure to meet this demand, which has increased significantly over the past few decades.[17] Investment in bicycle infrastructure has been found to result in an increase in rates of bicycling. Pucher, Dill, and Handy[18] reviewed 14 studies and found that rates of cycling increased in nearly all of the cities that had invested in infrastructure changes. Additionally, heavy investment in bicycle infrastructure has been shown to correlate with higher-than-average rates of bicycle commuting.[19]

About 1% of all trips taken in the U.S. are by bicycle, with rates slightly higher in large cities. Recently, both rural and mid-sized cities have started to capture bicycling rates, and have found that the averages are very similar to those for large cities.[13,20] About 50% of all household trips are less than three miles, a distance which is considered bikeable.[21] In order for individuals to choose to travel by bicycle for such trips, an infrastructure that provides a safe and convenient travel route is necessary.

Types of Bicyclists

Understanding the different types of cyclists is useful in determining the effect that specific facility and road types might have on cycling rates. Multiple attempts have been made by planners and researchers to categorize cyclists in order to best understand they determinants of bicycling that are necessary to increase rates.

An AASHTO report entitled *Guide for the Development of Bicycle Facilities*[22] stated that in 1994, the Federal Highway Administration categorized bicycle users into three different categories:

A: Advanced or experienced riders who use their bicycles for speed and convenience and can "operate under most traffic conditions;" (p. 6)

B: Basic, or less confident, adult riders who may use their bicycle for transportation purposes, but are "less confident of their ability to operate in traffic without special provisions for bicycles;" (p. 6)

C: Children "riding on their own or with their parents" (p. 6). Children still need access to key destinations, but with infrastructure that provides a defined distinction between motor vehicles and bicycles.

This report also stated that:[22]

> "Most adult riders are less confident and prefer to use roadways with a more comfortable amount of operating space, perhaps with designated space for bicyclists, or shared use paths that are away from motor vehicle traffic." (p. 5)

Geller,[23] a city planner for the city of Portland, classified bicyclists into four groups:

1. "No way no how" are individuals who are not at all interested in bicycling.

2. "Interested but concerned" are individuals who like to ride bicycles, but are afraid. They would ride if they felt safe on the roadways and "if cars were slower and less frequent, and if there were more quiet streets with few cars and paths without any cars at all." (p. 3)

3. "Enthused and confident" are bicyclists who are influenced by the infrastructure that is available and are "comfortable sharing the roadway with automotive traffic, but they prefer to do so operating on their own facilities." (p. 2)

4. "Strong and fearless" are bicyclists who will ride regardless of roadway conditions, and view bicycling as a strong part of their identity. Geller notes that there are very few who fall into this category, less than 0.5% of the population.

Dill and McNeil[24] validated these categories, and found that 56% of the respondents surveyed in Portland fell into the "Interested but concerned" category; these researchers identified them as the "largest potential market for increasing cycling for transportation." (p. 137) Infrastructure that increases their physical separation from motor vehicles, such as cycle tracks, results significantly in reported increased comfort. The researchers suggested that such separation is a "necessary condition to increasing their levels of cycling for transportation." (p 137)

Damant-Sirois et al.[25] used survey data from 2,004 bicyclists in Montreal, Canada, to define four types of cyclists:

1. Dedicated cyclists who are not strongly affected by weather conditions and are motivated by the "speed, predictability, and flexibility of bicycle trips …" (p. 1,161) They enjoy using a bicycle, and are less influenced by specific bicycle infrastructures than are other groups. They are "defined by not having received parental encouragement to cycle as children …" (p. 1,161)

2. Path-using cyclists are motivated by the fun and convenience of bicycling and their identity as a cyclist. They prefer dedicated infrastructure that is separated from motor vehicles. According to Damant-Sirois et al., "They were actively encour-

aged by their parents to use bicycles both to reach destinations and for sport or recreational activity.” (p. 1,161)

3. Fair-weather utilitarians are strongly influenced by weather conditions, and will choose another mode of transportation if it is more convenient.

4. Leisure cyclists mostly “cycle as a hobby or as a family activity …” (p. 1,163) Their decision to bicycle is influenced by weather conditions, and they prefer infrastructure that is separated from motor vehicles.

While there have been many classifications of bicyclists, most contain a group that is interested in cycling but influenced by factors that could be modified, such as convenience, safety, or infrastructure type. As Dill and McNeil[24] pointed out, efforts that are targeted at this category of bicyclists are likely to have the greatest effect in terms of increasing bicycling rates.

Preference Regarding Bicycle Facilities

Studies have examined the preferences of various users with regard to the built environment and the type of bicycling facilities. Nuworsoo et al.[26] conducted case studies sponsored by the Mineta Transportation Institute for three cities in California–Davis, Palo Alto, and San Luis Obispo–that were designated as Platinum, Gold, and Silver Cities, respectively, by The League of American Bicyclists. They found that most respondents preferred to use roadways that included bicycle facilities that were “separate from automobile traffic lanes,” indicating that non-motorized travelers preferred to avoid interactions with automobiles. They proposed that facilities located along roadways were an indication that direct routes and decreased travel time were preferred. They concluded that responses from the three California cities indicated that:[26]

> “… the ideal bicycle infrastructure would separate bicycles from autos, provide the most direct routing, and enable network connectivity. It would be physically separated from, but run alongside, the major and minor street network.”

Tilahun et al.[27] conducted a preference survey with 167 individuals in Minnesota. Their findings showed that “users are willing to pay the highest price for designated bike-lanes, followed by the absence of parking on the street and by taking a bike-lane facility off-road.” Respondents were willing to travel about 25 minutes longer to switch from the infrastructure having no bicycle lanes and on-street parking to an off-road bicycle facility. Stinson and Bhat[28] surveyed more than 3,000 Internet respondents about preferences for transportation bicycling facilities, and reported, among other findings, that bicycle commuters “prefer the following: lower travel times; residential roads to major or minor arterials; bicycle lanes, separate paths, and wide right-hand lanes to roads with no bicycle facilities.”

Understanding that bicyclists have “varying levels of tolerance for traffic stress, which is a combination of perceived danger and other stressors,” Mekuria et al.[29] classified roadways into four levels of traffic stress (LTS):

> "LTS 1 is meant to be a level that most children can tolerate; LTS 2, the level that will be tolerated by the mainstream adult population; LTS 3, the level tolerated by American cyclists who are 'enthused and confident' but still prefer having their own dedicated space for riding; and LTS 4, a level tolerated only by those characterized as 'strong and fearless.'"

Of note is that all roadways with a speed limit of 35 miles per hour or greater are classified as LTS 4, regardless of the number of travel lanes. The majority of roadways in the Las Vegas Metropolitan Area (LVMA) that would permit bicycling for transportation–providing direct routes from residences to destinations–have speed limits between 35 and 55 miles per hour. This detail may have potential policy implications related to posted vehicle speed limits.

Study Setting: Las Vegas and Urban Sprawl

The LVMA is a newer, sprawling, western metropolitan area. According to Coughenour et al.:[7]

> "Although this region consists of over 2 million residents, it lacks a central urban core that most traditional – that is, older – cities have. This results in housing and other land uses (retail, office, and commercial) being spread over long distances."

In addition, LVMA traffic congestion increased by 35% between 2000 and 2010. Thus, intermodal transport options are a key factor in both efficiency and attraction of users to public transit. Coughenour et al. further states:

> "Given the amount of urban sprawl in Las Vegas, active transportation that incorporates the use of bicycling would enable residents to travel longer distances in more convenient amounts of time by means of either active transport alone or in combination with public transportation."

Need: Understanding Supports and Barriers at the Local Level

Perceived safety is the most important factor in an individual's decision to travel by bicycle.[27] Study results have been mixed about preferences for transportation infrastructure by bicyclists. In a survey of current and potential cyclists in Vancouver, Canada, 71%-85% of respondents were likely to choose to cycle on off-street paths (bike only or multiuse); 71% on cycle paths on major roads with a physical barrier; and 48-65% on residential routes.[31] A study of Minneapolis cyclists showed that bicycle lanes on existing streets were preferred over off-street trails.[32] No studies could be located that measured motorists' preferences to on-street or off-street facilities.

It is important to understand the perceptions of bicycling infrastructure concerning safety and barriers at the local level, as many metropolitan areas differ in urban design. To date, no data could be found on the perceptions of Las Vegas residents of bicycling infrastructures with regard to safety or preference. This necessitated a need to create and implement a survey that would gauge the current knowledge and perceptions of stakeholders in Las Vegas. Stakeholders include cyclists, bus drivers, bus passengers, and automobile drivers.

Purpose of the Study

The purpose of this study was to understand perceptions and likelihood of using various types of bicycle infrastructures for transportation purposes by Las Vegas residents.

Study Objectives

The primary objectives of this research were to gain a better understanding of:

1. Perceptions with regard to supports and barriers to bicycling for transportation,

2. Perceptions with regard to the current bicycling infrastructure in Las Vegas, and

3. Perceptions regarding safety and the likelihood of using any of eight alternative configurations for bicycle lanes in Las Vegas.

II. STUDY METHODOLOGY

Survey Tools

The survey tools for this questionnaire were created to meet the study's objectives. The survey included questions on:

- Demographics (age, race, sex, and income);
- Travel characteristics (primary mode of transportation, bicycle habits, and public transit use frequency);
- Safety perceptions of the current bicycling infrastructure, based on documented concerns from existing literature;
- General safety concerns about bicycling for transportation;
- Factors that might result in an initiation or increase in bicycling for transportation; and
- Safety perceptions and the likelihood of using any of eight alternative bicycle infrastructures.

See Appendix A for the full survey. Questions that were included were decided based on discussions with local traffic safety engineers and planners from the Regional Transportation Commission of Southern Nevada (RTCSNV). The survey was pilot-tested, and minimal changes were made to accommodate feedback.

Because there are a small number of individuals who report bicycling as their primary mode of transportation in Las Vegas,[33] more in-depth information was collected from a small number of participants who fell into this category. Key informant interviews were conducted with respondents who reported bicycling as their primary mode of transportation and who agreed to be part of the follow-up survey (See Appendix B for interview questions).

Collection of Quantitative Survey Data

Survey collection took place by means of convenience sampling both in person and online, and targeted bus riders, bike riders, and drivers of personal vehicles. Surveyors were instructed on how to approach residents and request participation by self-completion of a paper survey. Trained surveyors approached residents at bus stops, on bus routes, and at local businesses and common areas surrounding major transit corridors.

Those who traveled by private vehicle, whether or not they were bicyclists, were included in data collection efforts. This is because previous studies have noted that individuals who are interested in cycling but are concerned with modifiable factors, such as roadway design or vehicle speed, are likely to have the greatest effect in terms of increasing bicycling rates given that this group constitutes the largest classification of cyclist types. Additional efforts were made to reach those who used public transit and bicycling as their primary mode of transportation. This included riding public transit lines, specifically lines known to carry a larger percentage of bicycle commuters, and conducting survey efforts at the Bonneville Transit Center in downtown Las Vegas, which houses a bicycle center offering free repairs, parking, showers, and lockers.

An identical survey was administered online using Qualtrics software (Provo, Utah), and was distributed to local biking groups and non-biking groups (i.e., adult service and volunteer organizations). In addition, a snowball methodology for sampling was used, by which respondents were asked to share the survey link with local friends and relatives. The survey contained 41 questions, which included questions based on a Likert scale, multiple choice, and open-ended questions; it took approximately 10 minutes to complete, and the respondents were not compensated. Data collection took place from July 2014 through May 2015.

This study design was given “exempt status” from the Internal Review Board (IRB) of the University of Nevada, Las Vegas (UNLV).

Collection of Qualitative Survey Data

The phenomenology method was used for collecting qualitative data, as the intent was to understand the meaning and experiences of those who reported bicycling as their primary mode of transportation. Phenomenological studies do not start with a well-informed hypothesis; rather, they use an emergent strategy. The themes and sub-themes are extracted out, and a structural explanation of findings is developed.[34]

Qualitative data was collected through phone interviews. A structured tool for phone interviews was created to address the primary research questions, which consisted of open-ended questions related to perceived supports and barriers as well as the respondents’ overall experiences of using bicycling for transportation. All surveys were conducted in English, and consisted of one researcher asking the open-ended questions while a second researcher transcribed the answers as close to verbatim as possible for each question.

Analytical Methods

Distribution and frequency data from completed surveys were analyzed to assess perceived safety of the current bicycling infrastructure, factors that would initiate or increase the level of bicycle travel, and the likelihood that respondents would use any of eight infrastructure types presented in the survey. A discrete-choice model was estimated to determine significant attributes and socioeconomic characteristics that are likely to influence preferences about the various infrastructure configurations in the survey.

Probit and multinomial logit models were estimated to determine the best model. A multinomial model is most appropriate, because the respondents had eight different infrastructure configurations to choose from. A multinomial logit model is an extension of multiple regression modeling, where the dependent variable is discrete instead of continuous, enabling the modeling of discrete outcomes. In particular, this study focused on characterizing the probability of individual choices conditioned to the values of the attributes and socioeconomic characteristics. The estimation required defining the reference category with which the results that would be compared. Thus, the infrastructure choice which most resembled the dominant infrastructure type in the Las Vegas metropolitan area was used as the reference category, which was a non-painted, 5-foot bike lane. The model could be used to estimate choice probabilities. In addition, the model provides information about the relative importance of the explanatory variables, both the significant attributes and the socioeconomic characteristics.

Qualitative data analysis was used because it enables researchers to “form new concepts or refine concepts that are grounded in the data” (Neuman, p. 330). Data were analyzed using open coding and axial coding. Coding occurs when the researcher organizes raw data into categories and creates themes within these categories. Open coding consists of the initial categories and themes that emerge as the researcher carefully reads and re-reads the transcripts. Axial coding consists of the organization of the initial categories and themes with the potential to identify additional themes. In the end, key concepts of analysis emerge[35] (Neuman, 2007). Researchers read through the interview responses for familiarization. Next, open coding was conducted in which the material was broken down into broad concepts and categories. Axial coding and clustering were done to reveal thematic categories and meanings beyond the preliminary content analysis. Last, the researcher identified themes and sub-themes that emerged from within the codes.

III. RESULTS

Descriptive Analysis

There were 461 survey responses, and 41% of the responses were completed by means of the online survey. The mean age of the sample was 34.57 years and the median age was 32 years. Of the respondents, 56.9% were female, the majority reported their race as white (58.4%), and the median income category was $10,000 to $29,999 (34.4%). Table 1 shows the demographic breakdown of respondents. Of the respondents, 56.9% reported using a personal vehicle as their primary mode of transportation, 36.4% reported using public transit (bus), 1.8% reported using a motorcycle or motorized scooter, and 4.1% reported using a bicycle. Appendix C contains a map of respondents by zip code and respondents who reported bicycling for any of their daily trips by zip code.

Considering that less than 1% of the population in Southern Nevada used bikes for transportation (0.4%), it is not surprising that the sample is small. The authors made multiple attempts to increase this number. Additionally, the authors believe that if the goal is to increase the number of people who cycle, it seems counterintuitive to focus environmental modifications around those who already are cycling. If changes were based solely on those who already cycle, and the concerns of those who are interested in cycling but face specific barriers are ignored, the end result only would be making those who are already cycling happier but failing to increase the number people who cycle. As multiple reports discussed earlier have pointed out, most of the population consists of people who are interested in cycling and want more protection/enhanced safety. As Dill and McNeil[24] pointed out, focusing changes around this group likely will have the greatest effect in terms of increasing rates.

Three respondents reported walking as their primary mode of transportation; these were removed from analysis due to the small sample size. When comparing the sample proportion to that of the general population of the LVMA, both transit riders and bicyclists are overrepresented[33] (see Table 1). This is not surprising, however, as specific efforts were made to target these populations because they represent the relevant group of users of the facilities under study.

Table 1. Census Demographic and Mode of Transit to Work Data and Sample Demographic and Primary Mode of Transportation Data

	Sample		
	n	%	Clark County, NV*
Gender			
Male	168	42.4	50.2
Female	227	57.3	49.8
Race			
White	226	55.9	64.9
Hispanic	49	12.1	29.8
African American	60	14.9	10.7
Asian	35	8.7	9.0
Other	34	8.4	5.2
Per capita income for the past 12 months			
Less than $30,000	213	53.8	$26,040
$30,000-49,999	63	15.9	
$50,000-69,999	38	9.6	
$70,000-89,999	21	5.3	
$90,000 or greater	61	15.4	
Primary mode of transportation			
Personal vehicle	243	56.6	89.1%
Motorcycle or motorized scooter	8	1.9	Included in above
Public transportation	157	36.6	4.0%
Bicycle	18	4.2	0.4%
Walking	3	0.7	1.7%
Do you use a bicycle for any of your daily trips?			
Yes	106	23.6	
No	343	76.4	
How often do you use public transportation?			
Often	131	32.6	
Sometimes	69	17.2	
Rarely	81	20.1	
Never	121	30.1	

Note: *Five-year estimates from the 2013 Census, American Community Survey (ACS) of the U.S. Census Bureau.[33]

Respondents were asked about their perception of current bicycle and travel conditions with respect to biking for transportation. While most respondents agreed that vehicle speed was adequate for bicyclists to remain safe, most also disagreed that the likelihood of a collision between a vehicle and a bicycle was low. In addition, most disagreed that there was adequate signage to remind drivers to be aware and courteous to bicycles, and that drivers abide by current laws intended to keep bicyclists safe. See Table 2 for full results.

Table 2. Survey Results Related to Perceptions of the Current Bicycling Infrastructure

	N	%
Speed of vehicles is appropriate for bicyclists safety		
Strongly disagree	27	6.3
Disagree	103	23.9
Agree	269	62.4
Strongly agree	32	7.4
Bike lanes are wide enough for bicyclists safety		
Strongly disagree	49	11.4
Disagree	135	31.4
Agree	221	51.4
Strongly agree	25	5.8
Adequate signage to remind drivers to be aware and courteous to bicyclists		
Strongly disagree	80	18.5
Disagree	172	39.8
Agree	162	37.5
Strongly agree	18	4.2
Drivers abide by the current laws and regulations		
Strongly disagree	118	27.3
Disagree	177	41.0
Agree	122	28.2
Strongly agree	15	3.5
Likelihood of a collision between a vehicle and bicycle is low		
Strongly disagree	43	10.1
Disagree	120	27.8
Agree	228	52.9
Strongly agree	40	9.3
Likelihood of a collision between a bus and bicycle is low		
Strongly disagree	128	29.6
Disagree	186	43.1
Agree	105	24.3
Strongly agree	13	3.0
Likelihood of collision between a pedestrian and bicycle is low		
Strongly disagree	23	5.3
Disagree	92	21.3
Agree	254	58.9
Strongly agree	62	14.4

When asked about safety concerns related to biking for transportation, the most commonly reported concern was motorists/distracted drivers (75.6%), followed by speed of vehicles (58.1%), and conflicts or collisions with vehicles (51.2%). The most commonly chosen factors that would result in starting or increasing the level of bicycle travel were bicycle lanes separated from traffic (61.0%), more bicycle lanes (47.8%), and better lighting around bicycle routes (46.5%). See Table 3 for all the results on safety concerns as well as the factors that would likely increase bicycle travel.

Table 3. Safety Concerns Regarding Bicycling for Transportation and Factors that would Result in Starting or Increasing the Amount of Bicycle Travel

	N	%
Safety concerns about biking for transportation		
Motorists/distracted drivers	328	75.6
Speed of cars/trucks	250	58.1
Too many cars/trucks	159	37.0
Conflicts or collision with cars/trucks	221	51.2
Conflicts or collision with pedestrians	74	17.2
Conflicts or collision with other bicyclists	42	9.8
Potential for crime	88	20.5
Other	31	6.8
I have no safety concerns	57	12.7
Factors that would result in starting or increasing level of bicycle travel		
More bicycle lanes	223	47.8
Bicycle lanes separated from traffic	261	61.0
More paved trails	173	40.7
Secure bicycle parking	130	30.4
Reduced speed of cars	88	20.6
Showers and lockers at destination	119	27.8
Better lighting around routes	199	46.5
More people cycling	73	17.1
Lower cost than personal vehicle commuting	68	15.9
More bicycle racks on the buses	68	15.9
The availability of a rental/shared bicycle	110	25.7
Incentives from work/school (i.e., discounted bus pass/monthly stipends)	143	33.4
More information about where the bicycle lanes and paths are located	77	18.0
More information about where I can access public transit (bus)	51	11.9
More information about cost of bicycle and transit commuting	47	11.0
Other	32	6.9

Respondents were asked the same series of questions related to safety perceptions, adequacy of road markings and signage, and the likelihood they would use any of eight types of bicycling infrastructures. Each of the eight infrastructure options that were provided to survey respondents included perceptions of safety, perceptions of adequacy of signage and markings, the likelihood of whether the respondents would use that option for bike travel, and the frequency of use. Figures 1-8 shows all eight infrastructure types, as described below.

Infrastructure A: Conventional Bike Lane

Figure 1 shows a standard 5-foot bike lane, having no buffers and located on a minor roadway (collector street). According to the survey responses:

- Lane is adequate for bikers to travel safely.
  52.4% agree or strongly agree
- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  38.4% agree or strongly agree
- How likely would you be to bike for transportation in this infrastructure?
  35.2% likely
- Respondents who chose infrastructure as most likely to be used.
  2.2%

Figure 1. Conventional Bike Lane: A Standard 5-Foot Bike Lane, with No Buffers, on a Minor Roadway (Collector Street)

Infrastructure B: Buffered Bike Lane

Figure 2 shows a standard 8-foot bike lane with 3-foot buffers on a minor roadway (collector street). According to the survey responses:

- Lane is adequate for bikers to travel safely.
  65.8% agree or strongly agree

- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  48.5% agree or strongly agree

- How likely would you be to bike for transportation in this infrastructure?
  42.5% likely

- Respondents who chose infrastructure as most likely to be used.
  1.6%

Figure 2. Buffered Bike Lane: A Standard 8-Foot Bike Lane with 3-Foot Buffers on a Minor Roadway (Collector Street)

Infrastructure C: Buffered from Traffic By Parking

As shown in Figure 3, this is a standard bike lane with 3-foot buffers located on a minor roadway (collector street). According to the survey responses:

- Lane is adequate for bikers to travel safely.
  81.2% agree or strongly agree

- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  57.3% agree or strongly agree

- How likely would you be to bike for transportation in this infrastructure?
  63.0% likely

- Respondents who chose infrastructure as most likely to be used.
  7.1%

Figure 3. Buffered from Traffic by Parking: A Standard Bike Lane, with 3-Foot Buffers, on a Minor Roadway (Collector Street)

Infrastructure D: Enhanced Buffered Bike Lane

As shown in Figure 4, this is an 8-foot bike lane, with 3-foot buffers, located on a minor roadway (collector street). According to the survey responses:

- Lane is adequate for bikers to travel safely.
  82.5% agree or strongly agree

- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  74.7% agree or strongly agree

- How likely would you be to bike for transportation in this infrastructure?
  65.5% likely

- Respondents who chose infrastructure as most likely to be used.
  19.6%

Figure 4. Enhanced Buffered Lane: An 8-Foot Bike Lane, with 3-Foot Buffers, Located on a Minor Roadway (Collector Street)

Infrastructure E: Physical Separation

As shown in Figure 5, this is a raised bike lane with mountable curb separation from traffic. According to the survey responses:

- Lane is adequate for bikers to travel safely.
  70.4% agree or strongly agree

- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  59.5% agree or strongly agree

- How likely would you be to bike for transportation in this infrastructure?
  53.6% likely

- Respondents who chose infrastructure as most likely to be used.
  28.6%

Figure 5. Physical Separation Involves a Raised Bike Lane with Mountable Curb Separation from Traffic

Infrastructure F: Shared Bus-Bike Lane

As shown in Figure 6, shared bus and bike lanes are located on major roadways (arterial streets). According to the survey responses:

- Lane is adequate for bikers to travel safely.
  37.5% agree or strongly agree

- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  29.5% agree or strongly agree

- How likely would you be to bike for transportation in this infrastructure?
  24.7% likely

- Respondents who chose infrastructure as most likely to be used.
  0.6%

Figure 6. A Shared Bus-Bike Lane, Located on a Major Roadway (Arterial Street)

Infrastructure G: Share the Road

As shown in Figure 7, this is a slightly wider right lane that is shared by both bicycles and vehicles. According to the survey responses:

- Lane is adequate for bikers to travel safely.
  19.4% agree or strongly agree

- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  13.9% agree or strongly agree

- How likely would you be to bike for transportation in this infrastructure?
  8.7% likely

- Respondents who chose infrastructure as most likely to be used.
  2.5%

Figure 7. Share the Road Concept: A Slightly Wider Right Lane that is Shared by Both Bicycles and Vehicles

Infrastructure H: Paved Multiuse Trail

As shown in Figure 8, this is a paved bike trail that is completely separated from traffic. According to the survey responses:

- Lane is adequate for bikers to travel safely.
  87.0% agree or strongly agree

- There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
  71.9% agree or strongly agree

- How likely would you be to bike for transportation in this infrastructure?
  71.2% likely

- Respondents who chose infrastructure as most likely to be used.
  37.9%

Figure 8. Paved Multiuse Trail: A Paved Bike Trail that is Completely Separated from Traffic

An off-road trail completely separated from the roadway had the highest agreement by respondents, who stated that this type of infrastructure was adequate for bicyclists to travel safely (87.0%); in addition, it had the highest agreement on likelihood of use (71.2%). An on-road, green-painted bicycle lane with a 3-foot painted buffer had the highest agreement with regard to adequate amounts of signage and markings to enable motorists and bicyclists to operate safely in the roadway together (74.7%).

After a written description, the respondents were shown all eight infrastructure options in picture format, and were asked to choose one option that they would be most likely to use bicycling as transportation. The most commonly chosen type of infrastructure was the off-road trail completely separated from the roadway (26.6%), followed by an on-road bicycle lane separated from motor vehicle traffic by a raised curb (20.1%).

Statistical Analysis

A Kruskal-Wallis test revealed a statistically significant difference across primary modes of transportation with regard to an awareness of existing bicycle lanes/paths located throughout the LVMA ($X^2 = 6.33$, $p = 0.042$). Those who used non-motorized transportation (bicycling or walking) as a primary mode of transportation showed increased awareness of existing bicycle lanes ($p = 0.026$) compared to those who used a private vehicle (personal vehicle, motorcycle, or motor scooter). There were no significant differences between public transit users when compared to private vehicle users and non-motorized transportation users.

Regression Analysis

When logit and probit models were tested to determine which specification best fit the data, logit models provided better goodness of fit compared to the more general probit models. Likely, this can be explained by unobserved factors that are not normally distributed. The dependent variable in the model involved determining which of the eight infrastructure configurations that the respondents chose as the configuration they "would be most likely to use to bike for transportation." The reference category for the model was Infrastructure A (see Figure 1), as it best represented the most common infrastructure in the LVMA, which is a conventional bicycle lane. Modeling efforts were unable to produce a meaningful, good-fitting model. This may be due to the unequal distribution of infrastructure choice, as over 66% of respondents chose two infrastructures (E and H, see Figure 5 and 8). Full model results are located in Appendix D. In the future, additional statistical modeling and data collection are recommended to improve the explanatory power of the model.

Qualitative Data Analysis

Interviews were conducted with all survey respondents who agreed to participate in key informant interviews (*n* = 8). Researchers made multiple attempts at contacting each subject. Two participants agreed to be contacted for a follow-up interview, but then decided not to participate once contacted; one participant could not be reached after three attempts at contact. Qualitative research methodology suggests continuing interviews until saturation is reached or redundancy takes place until no new data emerges; however, the researchers do not think that they reached saturation with this small sample. Even so, the researchers think that those who did participate provided very rich and informative data. Table 4 presents the frequencies of respondents, indicating data that reflect each theme and sub-theme. Using open coding and axial coding, seven major themes emerged from the data. The most frequently reported theme was related to bicycle facilities, with 87.5% of respondents discussing some sub-theme; this was followed by driver behaviors, with 75% of respondents discussing some sub-theme.

Bicycle Facilities

Under the theme of bicycle facilities, many respondents discussed the sub-theme of inadequate connectivity in the existing bicycle infrastructure (62.5%). Respondent comments included statements such as:

> "I commute to the strip from downtown. Currently there aren't any lanes that connect directly. I voiced my concerns at an RTC meeting. We need some safer connecting points from downtown to the Strip. I did get hit by a car one time on my way to the strip, which makes me a bit more cautious."

> "One of the most frustrating things is when, coming up Lake Mead [Blvd.] or Buffalo [Ave.], all of the sudden there is not a bike path. I have to jump streets to find another one."

Table 4. Themes and Sub-Themes from Qualitative Analysis of Key Informant Interviews with Survey Respondents Who Bicycle as their Primary Mode of Transportation

Themes and Sub-themes	*n* (*N* = 8)	%
Construction	3	37.5
Gravel and cones in the road	2	25.0
Bicycle lane paint not replaced after construction	1	12.5
Driver behaviors	6	75.0
Hit by or know someone hit by car	2	25.0
Not following 3-foot law	6	75.0
Cars parked in bicycle lane	1	12.5
Drivers weave in and out of bicycle lanes	2	25.0
Bus drivers not following 3-foot law	1	12.5
Law enforcement	1	12.5
Crime/theft of bicycles	2	25.0
Bicycle facilities	7	87.5
Posted speed limits too high	2	25.0
Lack of connectivity of bicycle lanes	5	62.5
Inadequate signage	2	25.0
Bicycle lane paint faded	1	12.5
Need for more lanes separated from vehicle traffic	2	25.0
More bicycle lanes needed	4	50.0
Available lanes high quality	3	37.5
Incentives/benefits of bicycling	4	50.0
Improved health	2	25.0
Reduced stress	2	25.0
Efficient travel mode	2	25.0
Money/tax incentives to commute to work by bicycle	2	25.0
Reduced environmental pollution	2	25.0
Respondent suggestions/concerns with public transportation	4	50.0
Routes not present in some areas of town	1	12.5
Frequency too low/commute time too long	2	25.0
Too expensive	2	25.0
Option for taking bicycle inside bus	1	12.5
Increase in amount of bicycle storage	2	25.0

In addition, 50% of the respondents also mentioned the need for more bicycle lanes, in general.

> "There are a lot of recreational trails, but the transit commute needs work… Mainly more bike lanes and separating from traffic."

Driver Behaviors

The most commonly discussed sub-theme of driver behaviors was related to drivers not allowing bicyclists a minimum of three feet when passing them (75%), as required by Nevada state law. Respondent comments included statements such as:

> "On occasion I've had run-ins with vehicles who do not respect bike lanes. I've caught up with drivers who almost hit me and had conversations with them. They were within 6 inches or so with their mirrors."

“People that have multiple lanes to move over [but do not]. People don’t know about the three foot law…. People need to know that they have to share the roads. People don’t know that they need to share the roads.”

IV. DISCUSSION OF FINDINGS

It is essential to understand perceptions of the bicycling infrastructure concerning safety as well as barriers at the local level to effectively plan for future development. This study sampled various transit users in the LVMA, using surveys aimed at:

- Determining safety perceptions regarding the current bicycling infrastructure and of bicycling for transportation;
- Factors that might result in an initiation or increase in bicycling for transportation;
- Safety perceptions of eight bicycling infrastructures; and
- Preferences for future development of the infrastructure.

Given the survey results, it is apparent that LVMA residents perceive many barriers to bicycling related to safety and infrastructure type. If the goal is to increase the rate of bicycling for transportation, then the actual and perceived barriers need to be adequately addressed.

One interesting finding was that the infrastructure types chosen most often by the respondents are lanes that offered a physical barrier of separation from motor vehicles, such as a completely separated paved trail and a raised lane with a curb separation. Correspondingly, those infrastructure types that lacked a physical separation were chosen least often. Additionally, during interviews key respondents discussed a desire for more bicycle lanes separated from vehicle traffic. This may suggest that respondents prefer bicyclists to have their own travel lanes that have a physical separation from those lanes used by motor vehicles. This is consistent with previous findings, and also may indicate that many of the respondents belong to the classification of bicyclists who are interested in cycling but are influenced by factors that are modifiable. Efforts that are targeted at this category of bicyclists likely will have the greatest effects in terms of increasing bicycling rates.[24]

Recent efforts to add bicycle lanes in the LVMA involved turning bus lanes into shared bicycle-bus lanes. Results showed that few respondents perceived this infrastructure as safe, and only 0.6% chose this infrastructure as most likely to be used. This, again, supports the notion that respondents prefer bicyclists to have their own lane. One potential explanation for this finding may be that respondents are unfamiliar, and thus unaware, of the utility of this type of lane. As the alternative is stated in the survey, it seems as if the bicyclist and bus would be traveling side by side in the lane; in reality, the procedure is for the bus to leave the shared lane and enter back into the vehicle travel lanes in order to pass a bicyclist.

More education on the procedures related to this type of infrastructure may result in a change of safety perceptions and likelihood of use. If there is a continued increase for this infrastructure type, coupling it with an educational campaign on proper utilization may be useful at increasing perceived safety. A 2012 report prepared for The Florida Department of Transportation Research Center, which conducted case studies on shared bicycle-bus lanes in other municipalities in the U.S., reported varied results.[36] For example, The

Minneapolis Public Works Department conducted an observational survey that indicated increases in bicyclists in the downtown area and decreases in crashes among bicyclists and motorists. Yet, according to Hillsman et al.,[37] 494 survey results, mainly from bicyclists, "expressed dissatisfaction with the changes …, citing lack of adequate space, the desire for a defined or separated facility, and lack of comprehension of the current configuration." (p. 15) Similarly, in Ocean City, Maryland, Hillsman et al. noted that a "number of complaints from transit operators prompted a review of the lanes and consideration to remove them altogether." (p. 44)

Many safety concerns were expressed in the survey and interviews regarding the current infrastructure. Respondents for both reported that many of the perceived barriers were related to concerns about potential collisions due to joint bicycle-vehicle travel, driver behaviors (distracted driving and obedience of safety laws), and speed. These safety concerns likely are valid, given that non-motorized road users are overrepresented in roadway fatalities.[13] Implementing and enforcing policies to ensure the safety of bicyclists is necessary to increase perceived and actual safety.

Nevada does have state laws in place that are intended to improve safety. One state law (NRS 484B.280) mandates that drivers provide at least three feet of space when passing bicyclists, requiring a lane change when possible. Another Nevada law (NRS 484B.165) prohibits the use of handheld devices while driving. The National Highway Traffic Safety Administration (NHTSA) categorizes enforcement of such policies as "Countermeasures that Work," as stated by Goodwin et al.[38] Enforcement of these regulations may lead to increased adherence by drivers and, ultimately, may increase perceptions of safety.

Research shows that persuasive or emotional campaigns are more effective at behavior change than educational campaigns.[39] The Nevada Department of Transportation (NDOT), through its Office of Traffic Safety, does have a roadway safety campaign, currently known as "Zero Fatalities." This campaign includes educational materials, media advertisements, and community engagement efforts aimed at increasing the safety for all road users. As part of its Zero Fatalities program, on March 7, 2016, NDOT unveiled the ePEDemic.org awareness program with the goal of keeping pedestrians safe. Pedestrian crash rates are particularly high in the LVMA.[40] This is very likely a safety concern that relates to the concern of bicyclists as well. Continued investment into these and other similar campaigns in the LVMA is a necessary first step in addressing many of the safety concerns, as perceived safety is one of the most important factors in decisions surrounding travel choice.[41,27]

Key interviews with individuals who are familiar with the current bicycling infrastructure revealed that there are public perceptions of a lack of connectivity between existing infrastructures to destinations of choice as well as a desire for more bicycle lanes in general. Additional findings revealed that road construction is a barrier to bicycle travel; specifically, cones and gravel in the road that result in unsafe bicycling conditions. After construction, bicycle lane markings are not adequately replaced. For example, one respondent reported that:

> "The developers should really keep the bike lanes up after they destroy them. Instead of using the nice path that the city does, they use a cheap coat of paint that disappears quickly."

Thus, it may be necessary to examine existing infrastructure to ensure that lanes are adequately maintained and that such routes to destinations continue to exist. Another finding from the key informants was a fear of bicycle theft from front bus racks, with one respondent stating:

> "If I was going to take my bike on the bus I'd have to take an old bike so that it didn't get scratched or stolen."

The plan most likely to be effective to increase the rate of bicycling for transportation is one that targets a combination of factors. Because behaviors are complex, interventions that are aimed at such behavior changes as increasing bicycling rates are most effective when multiple determinants of the behavior are addressed simultaneously.[42] An example of efforts that would target multiple determinants would include some combination of the following:

- Infrastructure improvements that create a separation between motor vehicles and bicyclists;
- Reduction of speed limits on roadways that are heavily used by bicyclists;
- Expanding upon available infrastructure and increasing connectivity of this infrastructure to various destinations;
- Enforcing safety policies that are in place; and
- Continued investment into safety campaigns and outreach.

Limitations and Concerns

This study is not without limitations. The sampling procedures were not random, as they targeted specific areas in efforts to recruit adequate sample sizes of each transportation user. Surveyors relied on those who agreed to complete the survey, resulting in a convenience sample. About 57% of respondents were female, compared to about 50% of the residents in the LVMA. In addition, in relation to the general population of Southern Nevada, bus riders and bicycle commuters were overrepresented in this survey. This was due to purposeful sampling, as numerous attempts were made to target residents who used a bicycle as their primary mode of transportation. Because only 0.4% of Las Vegas residents use a bicycle when commuting to work,[33] locating and surveying this population was difficult. Even so, a large percentage of respondents reported using a personal vehicle for their primary mode of transportation (56.6%). According to Coughenour et al.:[7]

> "However, it is important to point out that understanding perceptions of those who are not current bicycle commuters likely is most useful in attracting new users and increasing the overall number of active commuters."

These findings could be used for design and retrofitting future infrastructure investments, as well as policy recommendations for the LVMA. In order to increase bicycling for transportation, the infrastructure needs to be one that residents are likely to use.

Our findings complement existing studies in many ways. Perceived safety of existing bicycle infrastructure and of protection from vehicle collisions are important barriers to bicycling for transportation. Lack of driver attention and courtesy are also perceived as a threat. Similar to non-sprawling metropolitan areas, respondents preferred bicycle lanes that have a physical separation from vehicles. Bicycle commuters pointed out that the connectivity of routes could use improvement.

Complementary to Mekuria et al.,[43] who classified all roads with speeds of 35 miles per hour or greater as "LTS 4, a level tolerated only by those characterized as 'strong and fearless,'" most respondents indicated that the speed of vehicles was a safety concern. This was not surprising given that the roadway infrastructure in the LVMA is typical to cities having urban sprawl, which consist of residential communities connected by minor and major arterial roadways that have speeds set at or exceeding 35 miles per hour.

Recommendations Based on Current Findings

Based on the current findings from this sub-sample of LVMA residents, and considering findings from previous research, the authors make the following recommendations:

- Invest in modifiable factors that are perceived as barriers. Specifically, when appropriate, include barriers between motor vehicles and bicyclists, such as painted buffers or physically separated curbs. Increase the amount of signage to remind drivers to abide by current laws and regulations put in place to keep all road users safe.

- Create educational information and outreach materials to inform community members of the procedures related to shared bus-bicycle lanes.

- Examine existing bicycle infrastructure for connectivity to major destinations, and enhance connectivity where necessary.

- Ensure that construction done near bicycle lanes takes into consideration bicyclist safety by a careful placement of cones, removal of debris from the roadway, and adequate replacement of damaged bicycle lane markings.

- Continue, and potentially enhance, education efforts that are aimed at informing motorists and bicyclists of the laws and regulations intended to keep all users safe, such as the 3-foot law and distracted driving laws.

- Ensure enforcement of the laws and regulations put in place by the NRS that are intended to keep all road users safe.

APPENDIX A: SURVEY

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

INFORMED CONSENT

TITLE OF STUDY: Intermodal Bus and Bike Transportation in Southern Nevada

INVESTIGATOR(S): Alexander Paz, Courtney Coughenour, and Kathleen Larson

Purpose of the Study
The purpose of this research study is to gain a better understanding on how to make bicycling and bus transit a more practical option in Las Vegas.

Procedures
If you volunteer to participate in this study, you will be asked questions regarding your typical mode of transportation and your opinions on the current and potential future biking infrastructure. This survey will take approximately 10 minutes to complete.

Cost /Compensation
This survey will take approximately 10 minutes to complete. Upon completion of the survey, you will be asked to provide your preferred contact information if you wish to be entered into a drawing to win one of many prizes which include an iPad, iPad mini, $50 gift cards to Target, Amazon, or Zappos.

Contact Information
If you have questions or concerns about the study you can contact Alexander Paz at apaz@unlv.edu or Courtney Coughenour at Courtney.Coughenour@unlv.edu. For questions regarding the rights of research subjects, any complaints or comments regarding 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.

Voluntary Participation
Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without penalty or prejudice to your relations with the university. Your responses will be kept confidential and cannot be linked back to you personally.

Participant Consent:
By beginning the survey, you acknowledge that you have read this information and agree to participate in this research, with the knowledge that you are free to withdraw your participation at any time without penalty.

Introduction: This survey is being carried out to better understand the needs of bicyclists and pedestrians and how they relate to bus travel. The following questions are designed to tell us the most popular routes that people travel and what type of bike facility they would like to see in the future.
The Las Vegas Valley has many bike facilities, including 364 miles of roads with bike lanes, 91 miles of on-street bike routes, and 356 miles of paved multi-use trails. This survey will give a basis for decisions on where and in what form these facilities are expanded, as well as insights into use of bikes on buses.

1. What is the 5-digit zip code where you live? ______________________________________

2. What is your primary method of transportation ***to and from places*** (i. e., home to work, school, the store, errands)? (please choose one)

☐ Automobile ☐ public transit (bus) ☐ motorcycle/ motorized scooter ☐ bicycle ☐ walking/by foot

3. Are you aware that you can travel by bicycle from your home to nearby transit (bus stop), then travel on the bus with your bicycle?

_____ No, I was unaware

_____ Yes, but I don't know where the closest transit (bus stop) is to my home

_____ Yes, and I know where the nearest transit (bus stop) is to my home

4. Are you aware of the bike lanes and bike paths which exist throughout the Las Vegas Metro area?

_____ No, I am unaware of any bike lanes and bike paths

_____ Yes, but I don't know where many are located or where they connect

_____ Yes, I'm aware of the majority of the bike lanes and bike paths and where they connect

5. Do you use a bicycle for any of your daily trips? _____yes _____no If no skip to #8b to complete the map

If yes: How often during a typical week do you travel on bicycle:

To get to and from places, including work? _____hours per week

For recreation/health benefits? _____hours per week

Other? _____________________________ _____hours per week

6. On a typical bicycle trip, what distance do you usually travel? __________ miles

7. In what area of town do you usually bike? (please list frequently traveled roads)

____

____

8a. Do you ride public transit? ☐ Yes ☐ No

8b. On the map on the following page please a) trace the routes that you currently take; -OR-

– if you don't ride transit, b) trace the routes which you WOULD typically take.

9. Please consider the factors listed below and choose the answer that best applies to how you feel about the ***current*** biking/travel conditions in the Las Vegas metro area.

I feel that:	strongly disagree	disagree	agree	strongly agree
the posted speed limit is appropriate for bicyclists to be safe.	1	2	3	4
the bike lanes are wide enough for bicyclists to travel safely.	1	2	3	4
there are an adequate amount of billboards and “share the road” signage urging motorists to be aware of and courteous to bicyclists.	1	2	3	4
drivers abide by the current laws and regulations in place which are intended to keep bicyclists safe.	1	2	3	4
the likelihood of a conflict/collision between a bus and a bike is low.	1	2	3	4
the likelihood of a conflict/collision between a vehicle and a bike is low.	1	2	3	4
the likelihood of a conflict/collision between a pedestrian and a bike is low.	1	2	3	4

10. What are your safety concerns about biking for transportation (check all that apply)?

_____ Motorists, distracted driving

_____ Speed of cars

_____ Too many cars/trucks

_____ Conflicts or collision with cars/trucks

_____ Potential for crime

_____ Conflicts or collisions with pedestrians

_____ Conflicts or collisions with other cyclists

_____ Other ____

_____ I have no safety concerns

11. What factors would result in you starting or increasing your level of biking? (check all that apply)

_____ More bike lanes

_____ Bike lanes separated from vehicle traffic

_____ More paved trails

_____ Secure bicycle parking

_____ Reduced speed of cars

_____ Showers and lockers at destination

_____ Better lighting around routes

_____ More people cycling

_____ Lower cost than personal vehicle commuting

_____ More bike racks on the buses

_____ The availability of a bike share system

_____ Incentives from work or school (i.e.: discounted bus passes or monthly travel stipends)

_____ More information about where the bike lanes and paths are located

_____ More information about where I can access public transit (bus)

_____ More information about cost of bike and transit commuting compared to private vehicle commuting

_____ Other ____

Under a bicycle sharing program, a network of bicycles are made available for shared use in defined service areas for short periods of time. Individuals can rent a bike from an automated docking station, use the bike and return it to any bike docking station in the same network. This service is best suited for short trips, such as getting to/from the transit system, that may be too long to walk, but short enough that other transportation choices are not as convenient or cost effective.

12. If there was a bike share program in the Las Vegas Metro area, how likely are you to utilize it?

Extremely unlikely ☐ unlikely ☐ not sure ☐ likely ☐ extremely likely ☐

12a. If there were a bike share program, where would you like it to be located?

Downtown Las Vegas ☐ UNLV area ☐

Downtown Henderson ☐ Other ____

Please STUDY each of the pictures below.   On the following pages you will be asked individual questions about each picture and at the end you will be asked to choose just one.

Please choose the answer that best represents how you feel about each of the following alternatives when considering biking for **transportation** (traveling by bicycle from place to place; such as going from home to work, the store, or running errands, or biking to transit/bus and continuing your trip on the bus).

A. Bike Lanes: Conventional
Standard 5 foot bike lane with no buffer on minor roadway (collector street)

13. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

14. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

15. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

B. Bike Lanes: Buffered
Standard 8 foot bike lane with 3 foot buffer on minor roadway (collector street)

16. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

17. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

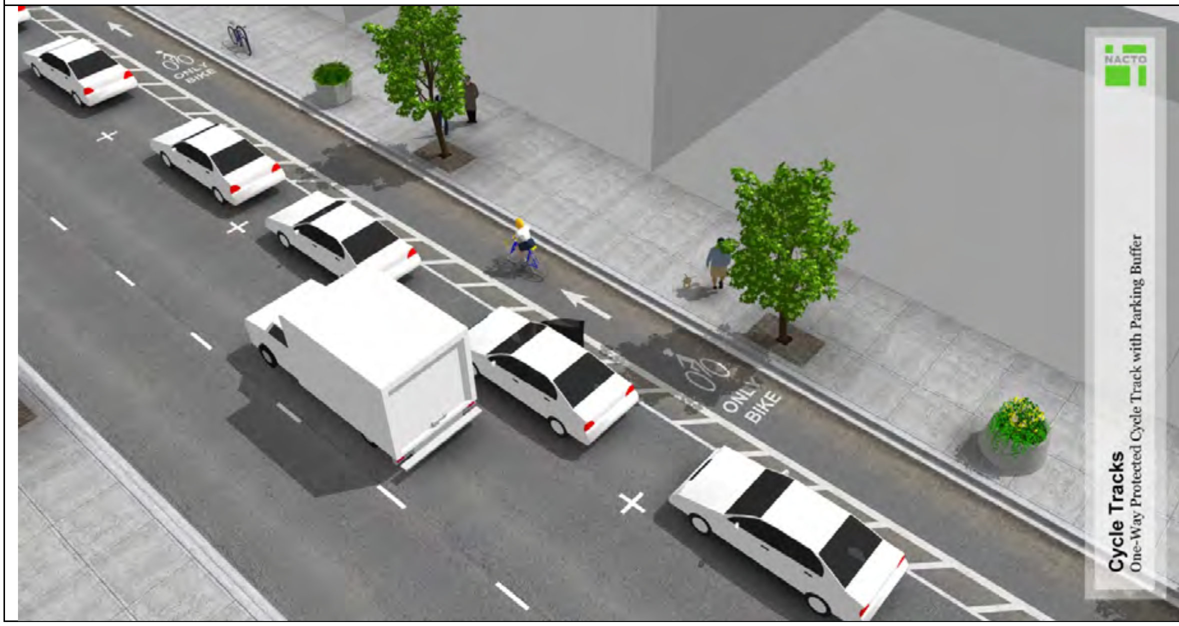
strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

18. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

7

C. Bike Lanes: Buffered from traffic *by parking*
Standard bike lane with 3 foot buffer on minor roadway (collector street)



19. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

20. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

21. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

D. Bike Lanes: Buffered
Enhanced 8 foot bike lane with 3 foot buffer on minor roadway (collector street)

22. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

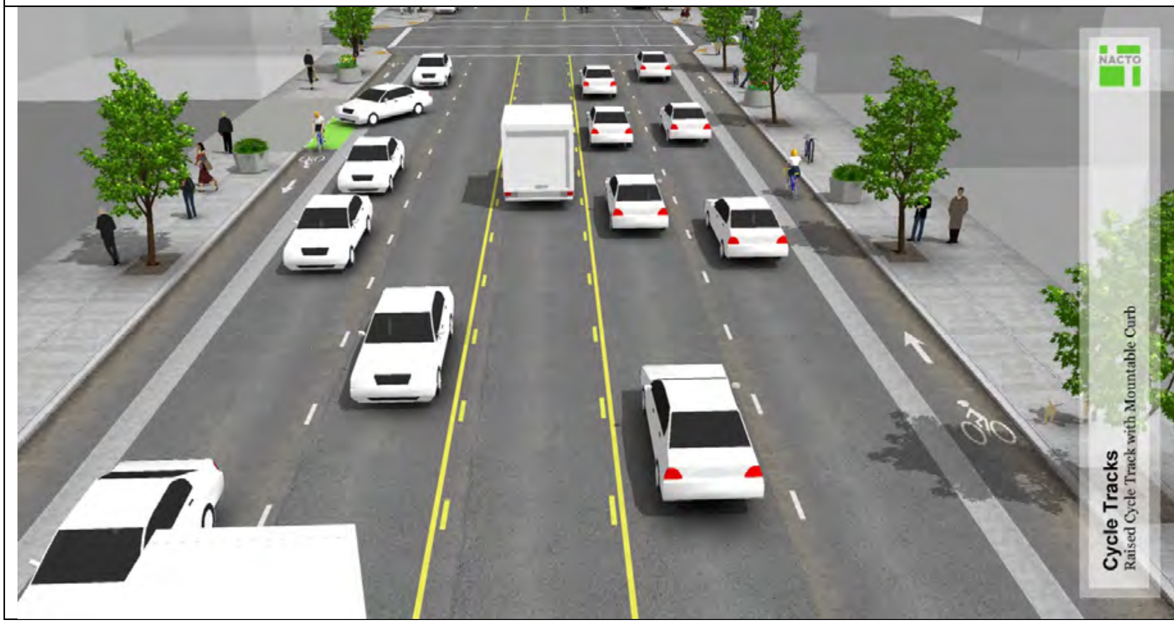
23. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

24. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

E. Bike Lanes: Physical Separation
Raised bike lane with mountable curb separation from traffic



25. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

26. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

27. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

F. Bike Lanes: Shared bus-bike lane
Shared bus and bike lane on major roadway (arterial street)

28. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

29. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

30. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

G. Bike Routes: "Share the Road"
Slightly wider right lane shared by both bicycles and vehicles

31. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

32. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

33. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

H. Paved multi-use trail

Paved bike trail completely separated from traffic

34. I feel that the bike facility shown is adequate for bikers to travel safely.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

35. I feel that there is an adequate amount of signage or pavement markings to enable motorists and bicyclists to operate safely in the roadway together.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

36. I would be likely to bike **for transportation** in the above bike facility shown above.

strongly disagree ☐ disagree ☐ not sure ☐ agree ☐ strongly agree ☐

37. Choose **ONE** of the following bicycle infrastructures that you would be most likely to use to bike **for transportation**. Please circle one.

14

38. Are there any changes you would like to see made that would make you feel more comfortable and allow you to ride your bicycle or bike in combination with public transit?

____

____

39. What is your age? ____________ years

40. What is your gender? (*please mark ONE box*) ☐ Male ☐ Female

41. With which race do you primarily identify?

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Hispanic, Latino, or Spanish origin
☐ Native Hawaiian or other Pacific Islander
☐ White
☐ Other race or more than 1 race

42. What was **your** total income for the past 12 months?

☐ Less than $12,000
☐ $12,000 – $29,999
☐ $30,000 – $49,999
☐ $50,000 – $69,999
☐ $70,000 – $89,999
☐ greater than $90,000

43. How often do you use public transportation?

☐ Often ☐ sometimes ☐ rarely ☐ never

44. What is the total number of automobiles in your household? __________

Are you willing to be contacted at a later date to provide more in depth details of your ideas and opinions about biking? ☐ Yes ☐ No

If yes, please provide your name and contact information below.

Name: ____

Phone: ____

Email: ____

Please enter your name and contact information for the drawing on the following page!

Thank you for your time!

15

APPENDIX B: QUALITATIVE QUESTIONS FROM KEY INFORMANT INTERVIEWS

1. Describe your experiences with biking for transit in the Las Vegas area.
2. What are some of the barriers you experience?
3. Describe your experiences with riding the bus in the Las Vegas area.
4. What are some of the barriers you experience?
5. What infrastructure changes would result in you riding your bike more frequently for transit?
6. What infrastructure changes would make your ride more enjoyable?
7. What changes can RTC make to their buses (e.g., schedules, prices, seating on buses) that would result in you utilizing public transportation more frequently?
8. Do you have any other comments or concerns that you would like to share with us?

APPENDIX C: FREQUENCY OF SURVEY RESPONDENTS AND RESPONDENTS WHO REPORTED BICYCLING FOR TRANSPORTATION

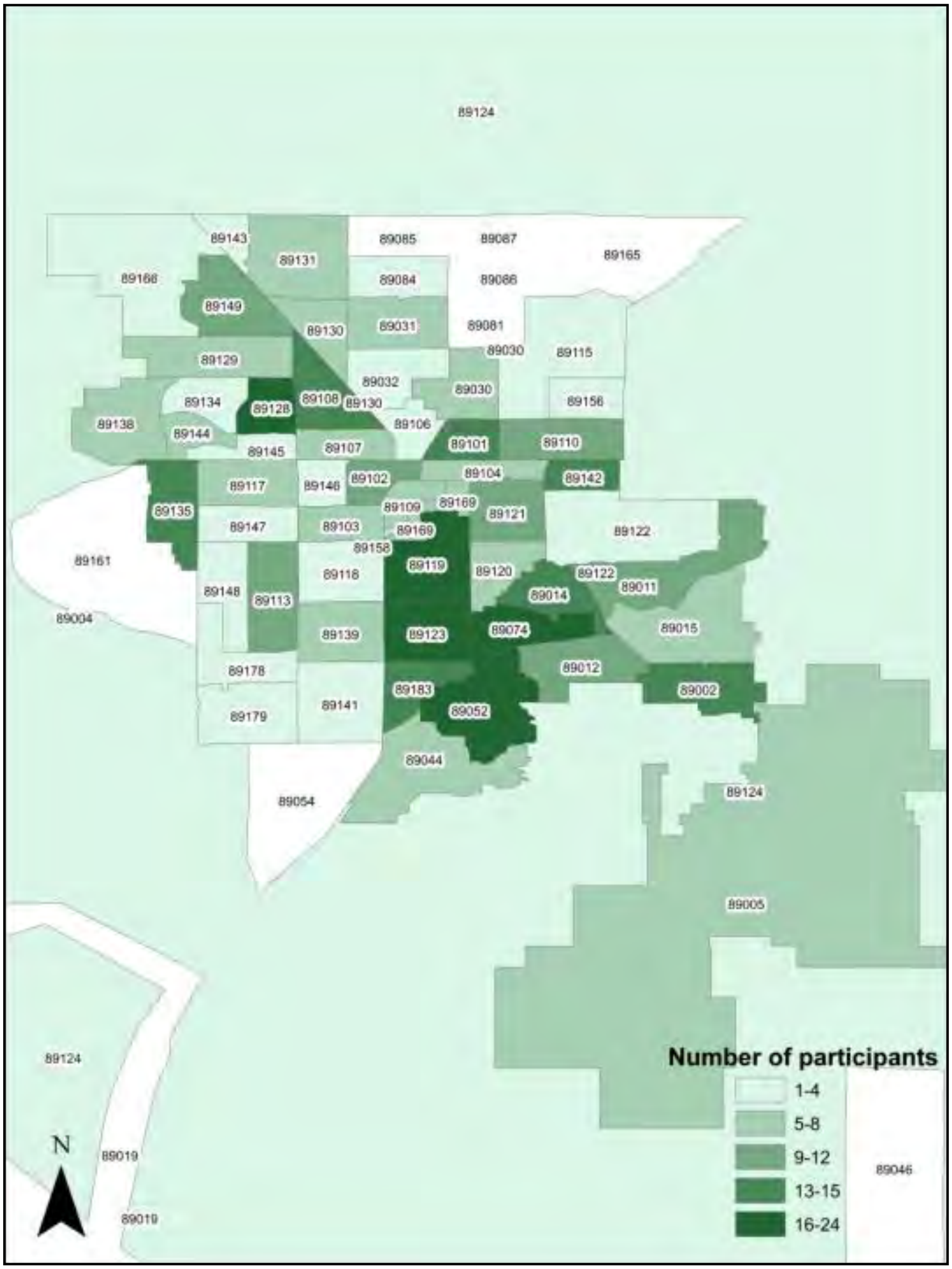


Figure 9. Frequency of Survey Responses by Zip Code

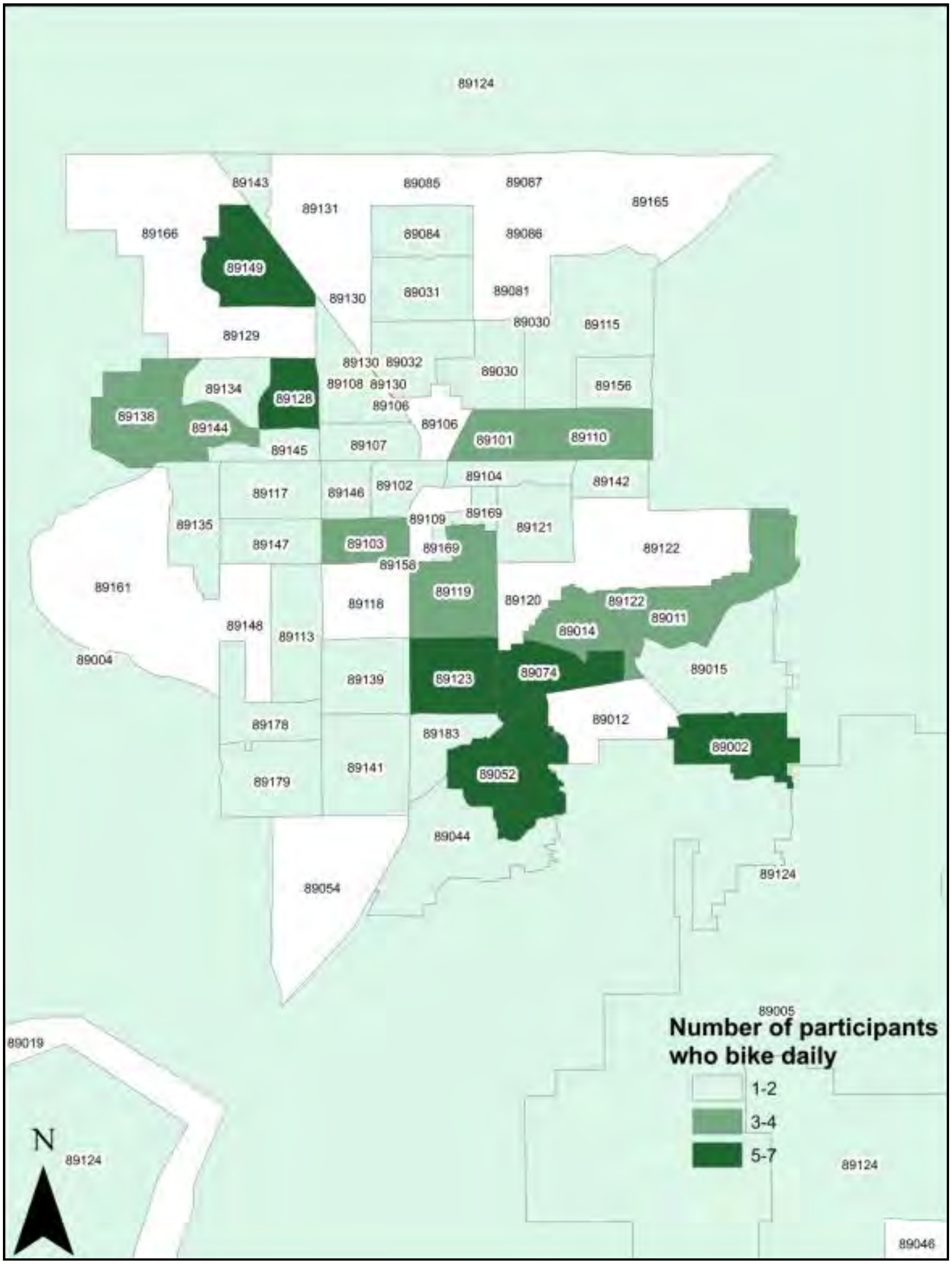


Figure 10. Frequency of Survey Responses by Zip Code of Individuals Who Reported that They Used a Bicycle for Any of Their Daily Trips

APPENDIX D: REGRESSION ANALYSIS AND BRIEF INTERPRETATION OF RESULTS

To ensure that there were no multicollinearity issues the linear model was run on the response as a function of the predictors. A Variance Inflation Factor (VIF) quantified the severity of multicollinearity, and only predictors with a VIF less than ‘2’ were included in this model. When logit and probit models were tested to determine which model best fit the data, logit models provided better goodness of fit compared to the more general probit models. Likely, this can be explained by unobserved factors that are not normally distributed. In addition, the goodness-of-fit indicators and the power of classification of the best probit model were lower than for those obtained by the best logit model. Table 5 shows the results of the regression analysis.

The dependent variable in the model involved determining which of the eight infrastructure configurations that the respondents chose as the configuration they “would be most likely to use to bike for transportation.” The reference category for the model was Infrastructure A (see Figure 1), as it best represented the most common infrastructure in the LVMA, which is a conventional bicycle lane. The logit model correctly classified 52.1% of the known observations, and could be expected to project future estimates. The goodness of fit indicators were a chi-square ratio test of 164,95 (p-value< 0.0004) and a Pseudo R^2 of 0.486.

Age was the most significant variable, with those who were older being less likely to choose Infrastructures B, C, D, E, and H (Figures 2, 3, 4, 5, and 8, respectively) over Infrastructure A. This outcome is difficult to explain; however, Infrastructure A is what respondents are used to seeing on LVMA roadways. Older individuals may have preferred to keep the roadways at *status quo* rather than giving bicyclists more roadway space or physical barriers for protection. Additionally, those who made more money were less likely to choose Infrastructure B, C, G, and H over Infrastructure A. Given that there are no clear consistent differences between these four choices and the other four alternatives, the significance of the variable could be associated with higher safety concerns by those who are exposed more. That is, the more vehicles that a respondent has, the more time spent driving; consequently, there is a greater likelihood that that person had been involved in conflicts or crashes involving bicyclists. As a result, those respondents might be more concerned about particular infrastructure-related alternatives.

In the future, additional statistical modeling and data collection are recommended to improve the explanatory power of the model.

Table 5. Results of Multinomial Logistic Regression Model Reflecting the Choice of Infrastructure

	Infrastructure Choice[a]													
	B		C		D		E		F		G		H	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Intercept	52.84	608.08	1.08	469.66	14.45	422.69	21.69	402.57	-221.54	972.73	-7.28	517.21	14.82	412.70
Age	-0.38*	0.18	-0.12*	0.06	-0.13*	0.06	-0.12*	0.06	3.92	2.15	0.09	0.06	-0.13*	0.06
Number vehicles in household	1.84*	0.99	1.25	0.87	0.78	0.85	0.731	0.85	37.44	19.64	1.25	0.89	1.35	0.85
Income	-3.32*	1.23	-2.32*	1.02	-1.70	1.01	-1.81	1.01	4.91	243.77	-2.26*	1.03	-2.32*	1.01
Gender[b]	1.28	1.31	-0.44	0.93	0.08	0.89	-0.14	0.88	23.38	13.76	0.53	0.99	0.14	0.88
Primary transit – private vehicle	1.40	602.81	-26.59	467.31	25.59	421.71	16.75	401.43	-186.60	908.32	25.90	511.18	25.64	411.69
Primary transit – public transit	-17.74	601.70	0.84	466.36	-3.60	420.66	-12.55	400.32	-71.98	941.74	-2.17	510.31	-1.81	410.62
Primary transit – motorcycle	13.63	613.48	22.41	483.55	31.67	431.09	21.33	411.27	-110.93	812.53	21.24	531.33	30.52	421.29
Primary transit – bicycle	7.71	606.37	23.89	472.56	31.85	423.98	22.71	403.82	158.00	942.00	32.44	513.06	31.67	414.02
Hispanic[c]	-7.58	391.45	2.01	1.25	1.54	1.14	2.08	1.12	-65.08	69.28	10.07	55.21	1.08	1.08
Black[c]	-8.74	1,470.09	0.29	40.59	-10.24	16.42	-9.11	16.42	75.34	299.23	-0.52	50.97	-9.09	16.42
Other[c]	-25.58	3,440.48	-17.06	33.12	-17.40	33.11	-16.21	33.12	12.90	0.0	16.43	33.12	-16.72	33.12
Public transit use frequency – often[d]	22.81	44.66	33.51	39.41	32.86	39.42	32.61	39.41	20.64	555.99	32.23	39.42	32.51	39.41
Public transit use frequency – sometimes[d]	4.19	49.21	20.24	29.43	21.38	29.44	20.85	29.43	40.46	124.44	20.37	29.44	19.96	29.43
Public transit use frequency – rarely[d]	-10.38	39.53	6.82	24.38	6.93	24.38	6.94	24.377	-7.19	39.23	6.23	24.38	6.06	24.38

[a] *reference category:* Infrastructure A * $p < 0.5$

[b] *reference category:* females

[c] *reference category:* white

[d] *reference category:* never

ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation (Office)
FHWA	Federal Highway Administration (of the U.S. Department of Transportation)
IRB	Internal Review Board
LTS	Levels of Traffic Stress
LVMA	Las Vegas Metropolitan Area
NDOT	Nevada Department of Transportation
NHTS	National Household Travel Survey
NRS	Nevada Revised Statutes
PBIC	Pedestrian & Bicycle Information Center (of the FHWA)
RTC	Regional Transportation Commission (of Southern Nevada)
RTCSNV	Regional Transportation Commission of Southern Nevada
UNLV	University of Nevada, Las Vegas
VIF	Variance Inflation Factor

ENDNOTES

1. City Club of Portland. *No Turning Back: A City Club Report on Bicycle Transportation in Portland* 95, no. 37 (2013).

2. Frumkin, Howard, Lawrence Frank, and Richard J. Jackson. *Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities* (Island Press, 2004).

3. Frank, Lawrence D., Martin A. Andresen, and Thomas L. Schmid. "Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars," *American Journal of Preventive Medicine* 27, no. 2 (2004): 87-96.

4. Lopez-Zetina, Javier, Howard Lee, and Robert Friis. "The Link between Obesity and the Built Environment. Evidence from an Ecological Analysis of Obesity and Vehicle Miles of Travel in California." *Health & Place* 12, no. 4 (2006): 656-664.

5. Castro, Cynthia M., Abby C. King, and Glenn S. Brassington. "Telephone versus Mail Interventions for Maintenance of Physical Activity in Older Adults." *Health Psychology 20*, no. 6 (2001): 438.

6. Bess H. Marcus, et al. "Physical Activity Behavior Change: Issues in Adoption and Maintenance." *Health Psychology* 19, no. 1S (2000): 32.

7. Courtney Coughenour, et al. "Multinomial Logistic Regression to Estimate and Predict Perceptions of Bicycle and Transportation Infrastructure in a Sprawling Metropolitan Area." *Journal of Public Health* (2015): fdv179.

8. Community Preventive Services Task Force. "What Works to Promote Health." *The Guide to Community Preventive Services*. https://www.thecommunityguide.org/ (accessed October 27, 2016).

9. James F. Sallis, et al. "Neighborhood Environments and Physical Activity among Adults in 11 Countries." *American Journal of Preventive Medicine 36*, no. 6 (2009): 484-490.

10. Cheryl L. Addy, et al. "Associations of Perceived Social and Physical Environmental Supports with Physical Activity and Walking Behavior."*American Journal of Public Health 94*, no. 3 (2004): 440-443.

11. San Francisco Municipal Transportation Authority. Polk Street Intercept Survey Results (2013). https://www.sfmta.com/sites/default/files/projects/PolkIntereptSurveyFindings.pdf

12. Alternatives, Transportation. "East Village Shoppers Study: A Snapshot of Travel and Spending Patterns of Residents and Visitors in the East Village." Transportation Alternatives (2012).

13. Milne, Andrea and Maggie Melin. *Bicycling and Walking in the United States: 2014 Benchmarking Report.* Alliance for Biking & Walking (2014).

14. Wang, Xize, Greg Lindsey, Jessica E. Schoner, and Andrew Harrison. “Modeling Bike Share Station Activity: Effects of Nearby Businesses and Jobs on Trips to and from Stations.” *Journal of Urban Planning and Development 142*, no. 1 (2015): 04015001.

15. The Segmentation Company (TSC). *Attracting College Educated Young Adults to Cities*. Chapel Hill, NC: 2006. http://www.centerforhoustonsfuture.org/cmsFiles/Files/Attracting%20College-Educated%20Adults%20to%20Cities.pdf (accessed October 27, 2016).

16. Gotschi, Thomas. “Costs and Benefits of Bicycling Investments in Portland, Oregon.” Journal of Physical Activity and Health 8, no. 1 (2011): S49-S58.

17. Pedestrian and Bicycle Information Center & Federal Highway Administration. *The National Walking and Bicycling Study: 15-year Status Report*,” (May 2010). http://atfiles.org/files/pdf/NatBikeWalkStudy2010.pdf (accessed October 27, 2016).

18. Pucher, John, Jennifer Dill, and Susan Handy. “Infrastructure, Programs, and Policies to Increase Bicycling: An International Review,” *Preventive Medicine 50*: S106-S125.

19. Dill, Jennifer and Theresa Carr. “Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them,” *Transportation Research Record: Journal of the Transportation Research Board* 1828 (2003): 116-123.

20. Rails to Trails Conservancy. (2011). Active Transportation Beyond Urban Centers: Walking and Bicycling in Small Towns and Rural America. Retrieved from http://www.railstotrails.org/resources/documents/ourWork/reports/BeyondUrbanCentersReport.pdf.

21. Federal Highway Administration (FHWA). 2009 National Household Travel Survey (NHTS). Tabulation created on the NHTS website at http://nhts.ornl.gov.

22. American Association of State Highway and Transportation Officials (AASHTO). Guide for the Development of Bicycle Facilities (1999).

23. Geller, Roger. “Four Types of Cyclists.” *Portland Bureau of Transportation*. http://www.portlandoregon.gov/transportation/article/264746. (accessed April 17, 2015).

24. Dill, Jennifer and Nathan McNeil. “Four Types of Cyclists? Examination of Typology for Better Understanding of Bicycling Behavior and Potential.” *Transportation Research Record: Journal of the Transportation Research Board* 2387 (2013): 129-138.

25. Damant-Sirois, Gabriel, Michael Grimsrud, and Ahmed M. El-Geneidy. “What’s Your Type: A Multidimensional Cyclist Typology.” *Transportation 41*, no. 6 (2014): 1,153-1,169.

26. Nuworsoo, Cornelius, Erin Cooper, Katherine Cushing, and Eugene Jud. *Integration of Bicycling and Walking Facilities into the Infrastructure of Urban Communities,* (2012).

27. Tilahun, Nebiyou Y., David M. Levinson, and Kevin J. Krizek. "Trails, Lanes, or Traffic: Valuing Bicycle Facilities with an Adaptive Stated Preference Survey." *Transportation Research Part A: Policy and Practice 41*, no. 4 (2007): 287-301.

28. Monique Stinson and Chandra Bhat. "Commuter Bicyclist Route Choice: Analysis using a Stated Preference Survey." *Transportation Research Record: Journal of the Transportation Research Board 1828* (2003): 107-115.

29. Mekuria, Mazza C., Peter G. Furth, and Hilary Nixon. *Low-stress Bicycling and Network Connectivity* (2012).

30. Schrank, David, Bill Eisele, and Tim Lomax. "TTI's 2012 Urban Mobility Report." *Texas A&M Transportation Institute. The Texas A&M University System* (2012).

31. Winters, Meghan and Kay Teschke. "Route Preferences among Adults in the Near Market for Bicycling: Findings of the Cycling in Cities Study." *American Journal of Health Promotion 25*, no. 1 (2010): 40-47.

32. Krizek, Kevin J. "Two Approaches to Valuing Some of Bicycle Facilities' Presumed Benefits: Propose a Session for the 2007 National Planning Conference in the City of Brotherly Love." *Journal of the American Planning Association 72*, no. 3 (2006): 309-320.

33. U.S. Census Bureau; American Community Survey, 2013 *American Community Survey 5-Year Estimates, Commuting Characteristics*. Generated using American FactFinder: http://factfinder2.census.gov (April 17, 2015).

34. Lindquist, Sandy. *Qualitative Research Designs*. http://www.umsl.edu/~lindquists/qualdsgn.html

35. Neuman, W. Lawrence. *Basics of Social Research: Qualitative and Quantitative Approaches*. (2nd Ed). Pearson: Boston, MA.

36. Hillsman, Edward L., Sara J. Hendricks, and JoAnne Fiebe. *A Summary of Design, Policies and Operational Characteristics for Shared Bicycle/Bus Lanes*. Prepared for the Florida Department of Transportation Research Center. Project No. BDK85 977-32.

37. Hillsman, Edward L., Sara J. Hendricks, and JoAnne Fiebe. *A Summary of Design, Policies and Operational Characteristics for Shared Bicycle/Bus Lanes*. Prepared for the Florida Department of Transportation Research Center. Project No. BDK85 977-32 (2012).

38. Goodwin, A., B. Kirley, L. Sandt, W. Hall, L. Thomas, N. O'Brien, and D. Summerlin. "Countermeasures that Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices (DOT HS 811 727)." *Washington, DC: Author* (2013).

39. Delaney, Amanda, Bella Lough, Michelle Whelan, and Max Cameron. "A Review of Mass Media Campaigns in Road Safety." *Monash University Accident Research Centre Reports 220* (2004):85.

40. Smart Growth America. *Dangerous by Design*. (2014). http://www. smartgrowthamerica.org/research/dangerous-by-design/dbd2014/home/ (accessed September 19, 2016).

41. Gatersleben, Birgitta and Katherine M. Appleton. "Contemplating Cycling to Work: Attitudes and Perceptions in Different Stages of Change." *Transportation Research Part A: Policy and Practice 41*, no. 4 (2007): 302-312.

42. U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion. *Healthy People 2020* (2010).

43. Mekuria, Mazza C., Peter G. Furth, and Hilary Nixon. *Low-stress Bicycling and Network Connectivity* (2012).

BIBLIOGRAPHY

Alternatives, Transportation, "East Village Shoppers Study: A Snapshot of Travel and Spending Patterns of Residents and Visitors in the East Village," Transportation Alternatives (2012).

American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities (1999).

Bess H. Marcus, et al., "Physical Activity Behavior Change: Issues in Adoption and Maintenance," *Health Psychology* 19, no. 1S (2000): 32. City Club of Portland, *No Turning Back: A City Club Report on Bicycle Transportation in Portland* 95, no. 37 (2013).

Castro, Cynthia M., Abby C. King, and Glenn S. Brassington, "Telephone versus Mail Interventions for Maintenance of Physical Activity in Older Adults," *Health Psychology 20*, no. 6 (2001): 438.

Cheryl L. Addy, et al., "Associations of Perceived Social and Physical Environmental Supports with Physical Activity and Walking Behavior," *American Journal of Public Health 94*, no. 3 (2004): 440-443.

Community Preventive Services Task Force, "What Works to Promote Health," *The Guide to Community Preventive Services*, https://www.thecommunityguide.org/ (accessed October 27, 2016).

Courtney Coughenour, et al., "Multinomial Logistic Regression to Estimate and Predict Perceptions of Bicycle and Transportation Infrastructure in a Sprawling Metropolitan Area," *Journal of Public Health* (2015): fdv179.

Damant-Sirois, Gabriel, Michael Grimsrud, and Ahmed M. El-Geneidy, "What's Your Type: A Multidimensional Cyclist Typology," *Transportation 41*, no. 6 (2014): 1,153-1,169.

Delaney, Amanda, Bella Lough, Michelle Whelan, and Max Cameron, "A Review of Mass Media Campaigns in Road Safety," *Monash University Accident Research Centre Reports 220* (2004):85.

Dill, Jennifer and Nathan McNeil, "Four Types of Cyclists? Examination of Typology for Better Understanding of Bicycling Behavior and Potential," *Transportation Research Record: Journal of the Transportation Research Board* 2387 (2013): 129-138.

Dill, Jennifer and Theresa Carr, "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them," *Transportation Research Record: Journal of the Transportation Research Board* 1828 (2003): 116-123.

Federal Highway Administration (FHWA), 2009 National Household Travel Survey (NHTS), Tabulation created on the NHTS website at http://nhts.ornl.gov

Frank, Lawrence D., Martin A. Andresen, and Thomas L. Schmid, "Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars," *American Journal of Preventive Medicine* 27, no. 2 (2004): 87-96.

Frumkin, Howard, Lawrence Frank, and Richard J. Jackson, *Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities* (Island Press, 2004).

Gatersleben, Birgitta and Katherine M. Appleton, "Contemplating Cycling to Work: Attitudes and Perceptions in Different Stages of Change," *Transportation Research Part A: Policy and Practice 41*, no. 4 (2007): 302-312.

Geller, Roger, "Four Types of Cyclists," *Portland Bureau of Transportation*, http://www.portlandoregon.gov/transportation/article/264746 (accessed April 17, 2015).

Goodwin, A., B. Kirley, L. Sandt, W. Hall, L. Thomas, N. O'Brien, and D. Summerlin, "Countermeasures that Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices (DOT HS 811 727)," *Washington, DC: Author* (2013).

Gotschi, Thomas, "Costs and Benefits of Bicycling Investments in Portland, Oregon," Journal of Physical Activity and Health 8, no. 1 (2011): S49-S58.

Hillsman, Edward L., Sara J. Hendricks, and JoAnne Fiebe, *A Summary of Design, Policies and Operational Characteristics for Shared Bicycle/Bus Lanes*, Prepared for the Florida Department of Transportation Research Center, Project No. BDK85 977-32.

James F. Sallis, et al., "Neighborhood Environments and Physical Activity among Adults in 11 Countries," *American Journal of Preventive Medicine 36*, no. 6 (2009): 484-490.

Krizek, Kevin J, "Two Approaches to Valuing Some of Bicycle Facilities' Presumed Benefits: Propose a Session for the 2007 National Planning Conference in the City of Brotherly Love," *Journal of the American Planning Association 72*, no. 3 (2006): 309-320.

Lindquist, Sandy, *Qualitative Research Designs*, http://www.umsl.edu/~lindquists/qualdsgn.html

Lopez-Zetina, Javier, Howard Lee, and Robert Friis, "The Link between Obesity and the Built Environment. Evidence from an Ecological Analysis of Obesity and Vehicle Miles of Travel in California," *Health & Place* 12, no. 4 (2006): 656-664.

Mekuria, Mazza C., Peter G. Furth, and Hilary Nixon, *Low-stress Bicycling and Network Connectivity* (2012).

Milne, Andrea and Maggie Melin, *Bicycling and Walking in the United States: 2014 Benchmarking Report,* Alliance for Biking & Walking (2014).

Monique Stinson and Chandra Bhat, "Commuter Bicyclist Route Choice: Analysis using a Stated Preference Survey," *Transportation Research Record: Journal of the Transportation Research Board 1828* (2003): 107-115.

Neuman, W. Lawrence, *Basics of Social Research: Qualitative and Quantitative Approaches*, (2nd Ed). Pearson: Boston, MA.

Nuworsoo, Cornelius, Erin Cooper, Katherine Cushing, and Eugene Jud, *Integration of Bicycling and Walking Facilities into the Infrastructure of Urban Communities,* (2012).

Pedestrian and Bicycle Information Center & Federal Highway Administration, *The National Walking and Bicycling Study: 15-year Status Report*," (May 2010), http://atfiles.org/files/pdf/NatBikeWalkStudy2010.pdf (accessed October 27, 2016).

Pucher, John, Jennifer Dill, and Susan Handy, "Infrastructure, Programs, and Policies to Increase Bicycling: An International Review," *Preventive Medicine 50*: S106-S125.

Rails to Trails Conservancy, (2011), Active Transportation Beyond Urban Centers: Walking and Bicycling in Small Towns and Rural America, Retrieved from http://www.railstotrails.org/resources/documents/ourWork/reports/BeyondUrbanCentersReport.pdf

San Francisco Municipal Transportation Authority, Polk Street Intercept Survey Results (2013), https://www.sfmta.com/sites/default/files/projects/PolkInterceptSurveyFindings.pdf

Schrank, David, Bill Eisele, and Tim Lomax, "TTI's 2012 Urban Mobility Report," *Texas A&M Transportation Institute, The Texas A&M University System* (2012).

Smart Growth America, *Dangerous by Design*, (2014), http://www. smartgrowthamerica.org/research/dangerous-by-design/dbd2014/home/ (accessed September 19, 2016).

The Segmentation Company (TSC), *Attracting College Educated Young Adults to Cities*, Chapel Hill, NC: 2006, http://www.centerforhoustonsfuture.org/cmsFiles/Files/Attracting%20College-Educated%20Adults%20to%20Cities.pdf (accessed October 27, 2016).

Tilahun, Nebiyou Y., David M. Levinson, and Kevin J. Krizek, "Trails, Lanes, or Traffic: Valuing Bicycle Facilities with an Adaptive Stated Preference Survey," *Transportation Research Part A: Policy and Practice 41*, no. 4 (2007): 287-301.

U.S. Census Bureau; American Community Survey, 2013 *American Community Survey 5-Year Estimates, Commuting Characteristics*, Generated using American FactFinder: http://factfinder2.census.gov (April 17, 2015).

U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion, *Healthy People 2020* (2010).

Wang, Xize, Greg Lindsey, Jessica E. Schoner, and Andrew Harrison, "Modeling Bike Share Station Activity: Effects of Nearby Businesses and Jobs on Trips to and from Stations," *Journal of Urban Planning and Development 142*, no. 1 (2015): 04015001.

Winters, Meghan and Kay Teschke, "Route Preferences among Adults in the Near Market for Bicycling: Findings of the Cycling in Cities Study," *American Journal of Health Promotion 25*, no. 1 (2010): 40-47.

ABOUT THE AUTHORS

ALEXANDER PAZ, PH.D., PE

Alexander Paz, PhD, is an associate professor of civil engineering at the University of Nevada, Las Vegas (UNLV). Dr. Paz is also the director of the Transportation Research Center at UNLV, and is licensed as a professional engineer (PE) in Nevada. Dr. Paz has been working on developing methods and software tools to bridge the gap between the state-of-the-art and the state-of-the-practice, and well as the integration, expansion, and use of advanced applications for the management of highway infrastructure. Some of Dr. Paz's work has been adopted by the industry, including data warehouses and software applications. Dr. Paz has authored more than 60 publications including books, journals, and conference papers. A multidisciplinary and systems perspective characterizes Dr. Paz's research and teaching. His broad interests include the application of operations research, control theory, econometric methods, and computer science to the modeling, analysis, operations, and control of large-scale dynamic transportation and infrastructure systems.

COURTNEY COUGHENOUR, PH.D.

Courtney Coughenour, PhD, is an assistant professor in the UNLV School of Community Health Sciences. Her research area of interest relates to Health & Place, the notion that health is greatly influenced by our environment. Much of her work focuses on disparities in access to a health-promoting environment, such as equitable and safe access to transportation options, opportunities for physical activity, and risks for pedestrian injury. She has presented her work at local, national, and international conferences. Some current projects include an evaluation of rural Nevada communities on resident perceptions and available resources which prevent or promote obesity, assessment of the built environment on active transport to school rates, and driver yielding bias to pedestrians within marked crosswalks.

PEER REVIEW

San José State University, of the California State University system, and the MTI Board of Trustees have agreed upon a peer review process required for all research published by MNTRC. The purpose of the review process is to ensure that the results presented are based upon a professionally acceptable research protocol.

Research projects begin with the approval of a scope of work by the sponsoring entities, with in-process reviews by the MTI Research Director and the Research Associated Policy Oversight Committee (RAPOC). Review of the draft research product is conducted by the Research Committee of the Board of Trustees and may include invited critiques from other professionals in the subject field. The review is based on the professional propriety of the research methodology.

MTI FOUNDER

Hon. Norman Y. Mineta

MTI/MNTRC BOARD OF TRUSTEES

Founder, Honorable Norman Mineta (Ex-Officio)
Secretary (ret.), US Department of Transportation
Vice Chair
Hill & Knowlton, Inc.

Honorary Chair, Honorable Bill Shuster (Ex-Officio)
Chair
House Transportation and Infrastructure Committee
United States House of Representatives

Honorary Co-Chair, Honorable Peter DeFazio (Ex-Officio)
Vice Chair
House Transportation and Infrastructure Committee
United States House of Representatives

Chair, Nuria Fernandez (TE 2017)
General Manager and CEO
Valley Transportation Authority

Vice Chair, Grace Crunican (TE 2019)
General Manager
Bay Area Rapid Transit District

Executive Director, Karen Philbrick, Ph.D.
Mineta Transportation Institute
San José State University

Anne Canby (TE 2017)
Director
OneRail Coalition

Donna DeMartino (TE 2018)
General Manager and CEO
San Joaquin Regional Transit District

William Dorey (TE 2017)
Board of Directors
Granite Construction, Inc.

Malcolm Dougherty (Ex-Officio)
Director
California Department of Transportation

Mortimer Downey* (TE 2018)
President
Mort Downey Consulting, LLC

Rose Guilbault (TE 2017)
Board Member
Peninsula Corridor Joint Powers Board (Caltrain)

Ed Hamberger (Ex-Officio)
President/CEO
Association of American Railroads

Steve Heminger* (TE 2018)
Executive Director
Metropolitan Transportation Commission

Diane Woodend Jones (TE 2019)
Principal and Chair of Board
Lea+Elliot, Inc.

Will Kempton (TE 2019)
Executive Director
Transportation California

Art Leahy (TE 2018)
CEO
Metrolink

Jean-Pierre Loubinoux (Ex-Officio)
Director General
International Union of Railways (UIC)

Abbas Mohaddes (TE 2018)
CEO
The Mohaddes Group

Charles W. Moorman IV (Ex-Officio)
CEO
Amtrak

Jeff Morales (TE 2019)
CEO
California High-Speed Rail Authority

Malu Roldan, Ph.D. (Ex-Officio)
Interim Dean
Lucas College and Graduate School of Business
San José State University

Beverley Swaim-Staley (TE 2019)
President
Union Station Redevelopment Corporation

Michael Townes* (TE 2017)
President
Michael S. Townes, LLC

Richard A. White (Ex-Officio)
Interim President and CEO
American Public Transportation Association (APTA)

Bud Wright (Ex-Officio)
Executive Director
American Association of State Highway and Transportation Officials (AASHTO)

Edward Wytkind (Ex-Officio)
President
Transportation Trades Dept., AFL-CIO

(TE) = Term Expiration or Ex-Officio
* = Past Chair, Board of Trustee

Directors

Karen Philbrick, Ph.D.
Executive Director

Peter Haas, Ph.D.
Education Director

Hilary Nixon, Ph.D.
Research and Technology Transfer Director

Brian Michael Jenkins
National Transportation Safety and Security Center

Ben Tripousis
National High-Speed Rail Connectivity Center

Asha Weinstein Agrawal, Ph.D.
National Transportation Finance Center

MNTRC
MINETA NATIONAL TRANSIT RESEARCH CONSORTIUM

SAN JOSÉ STATE UNIVERSITY

Funded by U.S. Department of Transportation