TRENDS ON TWO WHEELS: BIKE COMMUTING IN A CAMPUS CORE

BY

MITCHELL T. FRANSEN

THESIS

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Master's Committee:

Associate Professor Mariela Fernandez, Chair
Professor Laura Payne, Director of Research

ABSTRACT

A variety of political, societal, and personal factors continue to impede the equitable use and convenience of bicycling in U.S. urban cores. Various demographics, rider characteristics, and personal factors stand to influence one's propensity to bicycle as a form of urban mobility. This study examined cycling constraints association in a micro-urban campus region. Self-reported constraints were measured among bicyclists in the campus region, who provided responses pertaining to intrapersonal, social/psychological, and built environment constraints. Although no statistically significant results were found, women in the sample associated more closely with constraints across all constraint types than men, and the sample as a whole reported greater association with built environment constraints. These results suggest that built environment improvements influence perceived constraints association across all types of bike commuters, though further exploration of this topic is required to produce ideal outcomes for all demographic profiles.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION 1

CHAPTER 2: LITERATURE REVIEW ON BICYCLE COMMUTING 12

CHAPTER 3: METHODS 42

CHAPTER 4: RESULTS 48

CHAPTER 5: DISCUSSION AND CONCLUSION 54

REFERENCES 62

APPENDIX A: PARTICIPANT SURVEY 82

APPENDIX B: RECRUITMENT FLYER 96

CHAPTER 1: INTRODUCTION

Sustainable urban regions offer their residents fundamental services which support health, financial, and social well-being (Budd, W. et al., 2008). Often, these include thoughtful resource allocation, ample health services, social equity considerations, and elements of community which promote environmental, social, and place-based resiliency (University of Michigan, 2022). In the wake of climate change (Intergovernmental Panel on Climate Change, 2022, U.S. EPA, 2022), cities are faced with a variety of threats that, at the least, can impact the delivery of these essential public services, and at most, the livelihoods of their citizens.

The extent to which cities are a primary force in driving greenhouse gas emissions is increasing, and the net global emissions of all forms of greenhouse gases (GHG) have only continued to increase across all major types of GHGs (IPCC, 2022). The transportation sector alone reflects roughly a third of these emissions in the United States (U.S. EPA, 2021), while over 76% of commuting journeys are taken by passenger vehicle alone, with an average occupancy rate of 1.5 persons per vehicle (U.S. Department of Energy, Oak Ridge National Lab, 2021). A combination of population growth, suburban and exurban expansion, and the development of road systems that are inherently unsafe to traverse by foot or bike (Branion-Calles et al., 2019) have resulted in the United States increasing its vehicle miles traveled (VMT) year-over-year (U.S. EPA, 2023). The transportation sector is responsible for 57% of global oil demand and accounts for 28% of the United States' energy consumption (International Energy Agency, 2020). Passenger vehicle CO2 emissions are also the most rapidly growing type of emitter within the transportation sector, as the United States also stands to realize the slowest progress in vehicle fuel economy across OECD nations. For example, "in 2010, 17% of vehicles sold were SUVs, while in 2021 that value increased to 46%," further delaying the U.S. on its path to fewer tailpipe emissions and reduced particulate matter pollution (IEA, 2018; Boucher & Friot, 2017; Vanderstraeten et al., 2011). While very slow progress is being made in the electrification of the U.S. passenger vehicle fleet, nearly all benefits which would have been realized through cleaner propulsion methods have been offset, if not negated, through greater VMT, longer trip times, and heavier vehicles, supported through loopholes in vehicle classification and fuel emissions standards deregulation in the U.S. automotive sector (Anderson & Auffhammer, 2014; IEA, 2018).

Across the nation, cities are beginning to rethink transportation policies, advocating for greater walkability, and catering to the most efficient mode of human transportation: the bicycle (Dill, 2009; Tucker, 1973; U.S. Census Bureau, 2020). Bike commuting, however, accounts for less than 1% of daily trips in the United States, though there is variance across cities as land use and transportation policies have promoted greater participation in bike commuting in select regions (City of Portland, 2019; Federal Highway Administration, 2020; Pucher et al., 2011).

Bicycling presents itself as an effective transportation option used globally with an inexpensive financial barrier to entry and a significant return on mileage per calorie expended (Tucker, 1973; Kelly et al., 2014). The United States is unique, though, in that it has not widely adopted policies which allow for individuals to make inexpensive and healthy transportation choices at scale (Berrigan et al., 2010; Dill, 2009; Pucher & Buehler, 2016). Much of the United States' policies have been rooted in suburban growth and auto-centrism (Ding & Gebel, 2012), leading to outcomes which are less likely to: reduce CO2 emissions, involve people in much needed physical activity, provide people access to necessities without the requirement of car ownership and maintenance, and allow people to save money on their transportation choices

(Berrigan et al., 2010; Cushing et al., 2016; Environmental Protection Agency, 2022; Nicholas & Cherry, 2015; Smart Growth America 2020).

Policies that result in the widespread adoption of cycling as a viable mode of transportation have been suppressed for many U.S. citizens due to the existence and continued support for policy measures that favor and subsidize automobile ownership and travel (Bigelow et al., 2022; Ewing & Hamidi, 2015). The federally backed funding of highway projects in urban cores has produced increased vehicle traffic, placing vulnerable road users at a higher risk of death and serious injury (Federal Highway Administration, 2022). Due to these safety concerns, those who walk, roll, bike, or navigate outside of a vehicle often face mobility challenges which extend beyond urban regions (Ding et al., 2020; NHTSA, 2022). Due to these safety concerns and the perceived financial and space-based feasibility of personal vehicular use, those in the U.S. experience an inordinately lower bicycle modal share than other developed nations while simultaneously facing increasingly larger traffic delays (OECD, 2013; U.S. Census Bureau, 2020).

Campus towns and university communities, however, are unique in that their urban form must allow several thousands of students to live and move around in a culturally diverse region accessible to all who wish to pursue education there. They must also satisfy students' material, social, and cultural needs, often in a geographically dense region with low automobile use. With this, comes the requirement for mobility options that accommodate accessibility for all. Micro-urban collegiate campus towns are unique, in that they often earn greater walk-scores, bike-scores, and are home to functional transit systems, which are nonexistent in most midsize cities in North America (League of American Bicyclists, 2022).

Further, the League of American Bicyclists (LAB) evaluates U.S. universities' efforts to increase bicycling participation. The League of American Bicyclists awards designations of "bike-friendliness" based on the following criteria: "infrastructure and funding, education and encouragement, traffic laws and practices, policies and programs, and evaluation and planning" (League of American Bicyclists, 2022). Universities that have been awarded the League of American Bicyclists's (LAB) "Bicycle Friendly University" Platinum Award include: Stanford University; University of California (various campuses); Colorado State University; Portland State University; and University of Wisconsin – Madison (League of American Bicyclists, 2022). LAB administers a Gold Award, having been earned by universities such as: Yale University; Indiana University; University of Maryland; Michigan State University; Pennsylvania State University; and the University of Washington. The University of Illinois Urbana Champaign falls into the LAB's Silver rating, and it has increasingly demonstrated that it is "promoting and providing a more bikeable campus for students, staff and visitors" (League of American Bicyclists, 2022). By furthering efforts in these key areas that improve cycling adoption, safety, and future policy, states, cities, and universities can mitigate death and serious injuries to transport cyclists in areas where such policies are enforced.

Although there has been further adoption of cycling policies in cities surrounding university campuses, the bicycle mode share of such places still sit well below international trends (Bagdatli & Ipek, 2022). While the bicycling mode share of U.S. campus communities rivals comparable cities in the nation, they do not see greater mode share than select U.S. cities with high ridership, or stand to compete with modestly-sized cities in other developed nations (Bagdatli & Ipek, 2022). The development of safe cycling networks in campus communities can spur modal shifts in greater metropolitan regions as well; through the installation and upkeep of safe cycling networks, cities can use campus regions and their accompanying policies to spur greater modal shifts in and around their municipal bounds. Cities which have expanded their cycling mode share the greatest from 2000 to 2019 include Chicago (53% growth at 1.7% mode share), Oakland (40% growth at 2.7% mode share), Austin (19% growth at 1.3% mode share), and Missoula (7% growth at 6.2% mode share); all have expanded bike mode share while housing campus communities that have made a concerted effort to improve their LAB score, such as Boston University, Loyola University, University of California Berkeley, University of Texas, Austin, and University of Montana (League of American Bicyclists, 2022; U.S. Census Bureau, 2020). By fostering the development of safe, effective bicycle networks in campus communities, cities can iterate and deploy best practices at a larger scale for connectivity in their greater metropolitan regions.

Present literature on campus bicycle master plans across the U.S. focus on creating environments where bicycle mobility is framed as one of many necessary features of high-quality living. By facilitating the movement of thousands of individuals in dense, resource-rich environments, universities can allow for healthy, cost-effective transportation for all. Given that route and mode preferences are influenced by several factors such as "gender, age, income, and employment," college students are drawn toward bicycling as a means of transport as it emphasizes "the concepts of low cost, flexibility and [social rewards] (Bagdatli & Ipek, 2022, p. 22). In examining the literature on bicycle transportation from various key campus communities which integrate bicycle commuters well into their urban fabric, much emphasis is placed on the benefits to livability and ease of community access that effective bicycle transportation provides (City of Ann Arbor, 2019; University of Arizona, 2023; University of Montana, 2016; University of Colorado, Boulder, 2023; U.C. Davis, 2023; Portland State University, 2021). By engaging with user feedback and implementing effective policy measures through research-backed approaches, major metropolitan regions in the U.S. can stand to improve bicycle use to enhance community livability, as evidenced in dense campus communities.

1.1 Purpose of Study

This study will further the knowledge on the state of bicycle commuting in the University of Illinois Urbana Champaign (UIUC) campus region. Although there have been studies on transportation mode choices in the campus region, there have yet to be any studies conducted that focus on the constraints faced by any given mode choice in the campus core. With a variety of initiatives focused on encouraging active transportation in the UIUC campus region, there has yet to be a study focusing on faculty, staff, and students who utilize bicycles as a means of transportation, noting common concerns, and the personal, societal, and infrastructural constraints that are present.

1.2 Context of Study

The importance of this study is found in its location, as Champaign-Urbana and the central University of Illinois campus region boasts a commendable level of service for non-vehicular transportation per North American standards. Contributing to sustainable mobility options are the efforts from: the Illinois Climate Action Plan (iCAP), steered by the University of Illinois, with their multi-tiered sustainability plan “for [achieving] carbon neutrality as soon as possible” (iCAP Portal, Climate Commitments, 2022, para. 1); and Champaign County Bikes, with dozens of annual events, and whose aim is to “encourage and facilitate bicycling and walking as transportation and recreation, and to promote public awareness of the benefits that active transportation brings to our community” (Champaign County Bikes, Mission Statement, 2022, para. 1). In the State of Illinois, Ride Illinois is a legislative advocacy group that collaborates with cities across the state and advocates for bicycle mobility in varying regions. Additionally, the UIUC department of Facilities and Services is slowly gathering more bicycle and pedestrian-specific data on campus, furthering knowledge on the landscape of urban mobility in the campus region. Advocacy groups cloak the UIUC campus community, with much overlap in their aims. Biking advocacy in the region reaches to commuters, enthusiasts, and infrequent riders through events, activism, group rides, and community-building events (Champaign County Regional Planning Commission, 2022; Champaign County Bikes, 2022, UIUC Facilities and Services, 2022).

The policies and resulting implications now seen in the greater UIUC campus region, and Champaign County stemmed from a range of nationwide movements and from local support. During the early 1970s biking increased across the U.S, spurred in part by the first Earth Day. Widespread support for cycling as a means of transportation also lead to the passage of 252 bicycling bills in 42 states in 1974 (Reid, 2017). During a season of bike-ins and pedal-ins in the early 1970s, and a resulting $120 million in funding from the Federal Highway Administration in 1973 for early-stage bicycle transportation infrastructure across the nation, college campuses and other youth activists saw much of their public efforts gain traction, allowing for safer, better biking for everyone (Reid, 2017). In Champaign County, the university-based environmental group Housewives Involved in Pollution Solutions (HIPS) promoted cycling and the environmental impacts it offered (UIUC iSEE, 2022, Bicycling, Advocacy at Illinois, para. 5). A local “Committee on Bikeways” presented the idea of closing California Avenue to vehicular traffic in 1973, and its chair, Beedy Parker, worked with Champaign and Urbana’s local officials to create a “bike map based on preferred routes between the towns and the existing bike lanes that intersected the central campus, as well as [lobbied] the state government to provide funding for road markings and signs" (UIUC iSEE, Bicycling, Advocacy at Illinois, 2017, para. 8). Referring to the 1970s campus biking trend, past Associate Director of Facilities and Services, Morgan Johnston, noted that "We needed it because of safety; we wanted it because of sustainability. We knew there was a desire from faculty, staff, students, and alumni" (UIUC iSEE, Bicycling, Advocacy at Illinois, 2017). As national trends surrounding cycling advocacy and the greater environmental movement were squashed in the late 1970s (Reid, 2017), so did the support and advocacy on campus, and resulting infrastructural changes. UIUC Facilities and Services now oversees capital projects on campus, and alternative transportation is more heavily regarded, with focused subcommittees and planning initiatives meant to further the campus and greater community's cycling experiences (UIUC Bike at Illinois, 2022).

Due to the awareness of, design for, and continuous improvement of safer mobility options, the cities of Champaign and Urbana, and the University of Illinois campus community have been awarded special designations through the League of American Bicyclists. The League of American Bicyclists (LAB) is a national advocacy group which seeks to "create safer roads, stronger communities, and a Bicycle Friendly America" (League of American Bicyclists, 2022. About the League). They award designations to American states, communities, universities, and businesses on their commitment to making cycling safer and more rewarding for all participants. The City of Champaign was awarded a silver rating from the LAB in 2017, as the League awards cities for their steps toward safer cycling through "enforcement, education, engineering, key outcomes, evaluation, and encouragement" (LAB, 2022). The City of Urbana was one of 16 cities in the Unites States to receive a gold rating in 2014 (City of Urbana, 2014).

The University of Illinois campus community received a LAB bronze rating for "promoting and providing a more bicycle-friendly campus for students, staff and visitors" in

2011, and later earned a silver rating in 2019 (UIUC Facilities and Services, 2019; Illinois Climate Action Plan, 2022). The commitments that precede these awards have resulted in greater modal shifts toward bike commuting in the Champaign-Urbana and campus region (UIUC Facilities and Services, 2022), though current trends in injuries and collisions related to vehicle-cyclist interactions are outpacing the development of safe cycling infrastructure nationwide (Arias et al., 2021). Developing safe systems for Champaign-Urbana residents can mitigate traffic incidents, as 30% of pedestrian and cyclist deaths in the C-U region are Type-A crashes – sustaining severe injury to individuals outside of vehicles (Champaign County Regional Planning Commission, 2015).

Despite such work, the Urbana Champaign campus region still does not experience a large bicycle mode share, while simultaneously servicing heavy vehicular traffic between the cities of Champaign and Urbana on main thoroughfares. As of a Spring 2022 mode choice survey administered by UIUC Facilities and Services targeted toward faculty, staff, and students in the campus region, it was found that approximately 5,700 people on campus go by bicycle during months when that is a viable option (UIUC Facilities and Services, 2022). With a robust range of resources available for those who wish to bicycle, the campus must identify and ameliorate concerns related to active transit, specifically bicycle travel, if it is to achieve its sustainability, land use, and environmental goals. Given the nature of campus communities, the campus district must also healthily accommodate a growing student population, city population, and the movement of all who wish to participate in work, education, or leisure in the campus region. Also, to be considered are the environmental and financial costs associated with private vehicle storage, operation, and maintenance (U.S. EPA, 2021) and how this option is financially out of the reach for many university students (Bagdatli & Ipek, 2022).

1.3 Research Objectives

This study examines the experiences of bike commuting trends for riders in the Champaign-Urbana campus region and the constraints they face. We also examine differences in constraint association between genders.

Research questions are as follows:

1. What are the constraints people experience while cycling (for transportation) in the UIUC region?

H1. Respondents will identify more with constraints related to the built environment rather than personal/psychological and societal factors.

H0. Respondents will not identify with constraints related to the built environment more than personal/psychological and societal factors.

2. How does gender affect the perceived risk factors identified by individuals cycling for transportation in the UIUC region?

H2. Across the sample, women will identify more with constraints than men will.

H0. Women will not identify with constraints more than men.

This study will allow for micro-urban transportation officials and those who guide campus capital projects efforts to understand the concerns of bicycle commuters in campus regions. While survey data exist, there is disproportionately less data published on the constraints faced by bike commuters in campus cores, especially at UIUC. By having a richer understanding of this population, regional planning associations, campus master planners, and those who facilitate transportation projects in urban regions can better integrate bicycle networks into communities to serve the urban mobility requirements of their constituencies.

CHAPTER 2: LITERATURE REVIEW ON BICYCLE COMMUTING

This review of literature will address the pertinent literature associated with the challenges affecting the greater urban cycling community. Facilitators to cycling will be noted, as broad realization of the benefits of bicycling for transportation are growing, leading to healthier cities. Further, constraints will be noted, as will the implications of such constraints on varying demographics. Through an understanding of the state of constraints and attitudes regarding urban bicycle commuting in campus regions, policymakers and capital project planners in micro-urban and campus communities can devote attention toward furthering equitable transportation methods in these opportunistic regions.

2.1 Bicycles as Transportation

The United States population in the early to mid-1800s found themselves living in a society where individual mechanized transit would soon be defining their urban landscape (Hadjilambrinos, 2021). Engineers and makers of all industries rapidly produced innovations which allowed society to experience urban mobility with more ease, convenience, and with less required labor; the first iteration of the bicycle had been crafted from necessity in 1817 by German Karl Freiherr (Baron) von Drais (German Patent and Trademark Office, 2022; Cycling UK, 2017). The confluence of economic turmoil and an overarching European climate crisis influenced a Southeast German maker, von Drais, to produce one of the earliest forms of the bicycle (Deutsches Historisches Museum, 2023). Various factors led von Drais to develop a human-powered machine for which a user could propel themselves across pavement and stone. First, the Napoleonic wars brought economic turmoil and agricultural instability to much of Europe (Oppenheimer, 2003). With the introduction of the Corn Laws, tariffs on the export of British grain increased food costs for working people in Western and Southern Europe

(Williamson, 1990). Second, the post-Napoleonic depression was exacerbated by Mount Tambora's eruption, which sent 60 megatons of sulfur into the skies, creating a "global sulfate aerosol veil in the stratosphere," severely impacting climatic conditions in Europe and Asia, with disproportionate impacts on citizens and farmland, near and far (Luterbacher & Pfister, 2015; Oppenheimer, 2003). Particulate matter blanketed the earth and cast prolonged shade across multiple parts of the globe, lowering temperatures by as much as 18 degrees Fahrenheit, led to crop failure, livestock illness and death, and resulting famine for humans relying on such resources (Deutsches Historisches Museum, 2023; Luterbacher & Pfister, 2015). The culmination of factors presented during this "year without a summer" could be likened to a modern-day energy crisis and economic depression, with impacts resulting in a higher death rate than birth rate – uncommon at the time – from Eastern France, spanning across Southwest Germany, to Austria. From such limitations, Baron Karl von Drais imagined a device that could break humanity free from their sole reliance on the horse.

Baron von Drais crafted a "laufmaschine" or pedal velocipede, upon which a user would sit and roll, as livestock were not as active or plentiful than in years prior (Deutsches Historisches Museum, 2023). These machines were a new form of a personal mobility device, and would face deserving critique and resulting upgrades until the 1860s; their early builds were referred to as "pedal velocipedes," or "laufmaschines" (translated as "running machines") as they had gained popularity with their large wooden wheels and open seating, providing a means for their operator to reach the ground and kick themselves along (CyclingUK, 2017; Guroff, M., 2016; Hadjilambrinos, 2021).

By the late 1860s, carriage-makers would create and sell wooden-wheeled, steel velocipedes at the rate of approximately 1,000 per week, with capacity to fulfill only 10% of orders placed

(Guroff, M., 2016). As that demand grew, individuals from a wider variety of demographics pursued ownership of their own bicycles (Guroff, M., 2016). Sales soon plateaued, as roadways in many urban regions were too rough or bumpy, resulting in an unpleasant ride on such machines. Upon the advent of the steel spoke wheel-building system in 1872, the Starley Group released the Starley "Aerial," which was the first mass-produced high-wheel bicycle that could handle the rigors of most types of urban pavement, as the velocipede was critiqued for its poor handling, cumbersome wooden wheels and its resulting discomfort on cobblestone and other pavements of the time (Guroff, 2016). By the late 1800s, cycles such as the Starley had advanced in design to include what we know of today as the modern derailleur and laced spoke system (Guroff, 2016). Adapting little since the dawn of the 20th century, bicycles in their current form have both faced critique and have been celebrated as other cultural and social movements impacted global and American landscapes (Guroff, 2016; Reid, 2017). Society soon found that innovators in the transportation industry from the likes of Henry Ford to the Wright Brothers would soon be using the bicycle as a template for future innovations that impacted society as we know it today (Guroff, 2016).

2.2 Current Urban Infrastructural Investments and Outcomes

Many U.S. cities have crafted policy to align with sustainable development goals, the World Health Organization's Healthy Cities Initiative, and other national, regional, and local benchmarks, though a range of barriers still plague the path toward equitable, sustainable, and cost-effective transportation (Berrigan et al., 2010; Debnath et al., 2021; Dill & Voros, 2007; Pucher & Buehler, 2016; Sanders, 2016). Recently, many organizations, grassroots foundations, and political corners have deemed urban walkability and mobility as important mechanisms to tackle chronic health issues and improve psychological and emotional well-being for those who partake in active transport (Grant et al., 2017; Gunn et al., 2017; Jones & Vaterlaus, 2014). Since the dawn of the Brundtland Commission and the creation of the United Nations' Sustainable Development Goals, national governing bodies across the globe have sought to direct efforts to ameliorate 17 major disparities experienced globally, such as wealth, health, education, access to nutrition, community connectivity, and more (United Nations, 2021).

With the World Health Organization (2023) noting that many who live in the United States fail to meet their basic activity goals, and that national road design standards must be outfitted to support active mobility options for all, key cities in the U.S. have sought to reduce auto-dependency and enact policy which promotes active lifestyles. This includes transportation patterns, as we stand to see growing externalities from current trends in transportation, evidenced in particulate matter runoff to water systems (Vanderstraeten et al., 2011), increases in emissions (Aldred & Woodcock, 2008), personal and societal costs to auto-centric infrastructure (ITDP, 2021), and an inordinately increasing amount of outside-of-vehicle death and serious injuries from roadway collisions (Stewart, T., 2022).

The United Nations (UN) states that Goal 3 is to "ensure healthy lives and promote well-being for all at all ages," while Goal 11 is to "make human settlements inclusive, safe, resilient and sustainable." Many public spaces in the United States are inherently hostile to the pedestrian, and further reduce the likelihood that individuals will seek out active transit for their mobility needs, especially if other mobility options are available, prioritized, and induced through infrastructure (Christian et al., 2017). Coupled with the rise in sedentary lifestyles leading to obesity in children, overweight adults, stroke, heart disease, and variations of cancer, active transportation and the development of environmental features and attributes which incentivize such activities are to be explored for the benefit of urban residents and workers alike (Dill et al., 2012). There is much importance to sustainable, active patterns of mobility, as large bodies of research have showcased that investment in accessible mobility options for all have profound impacts on urban living and can reduce crime (Brookings, 2021), reduce oil dependency (Savitch, 2003), and lead to healthier youth populations (Babey et al., 2009), resulting in long-term economic stability and climate resiliency (Sawhney et al., 2015).

Current emissions and mobility trends are not a result of simple market choice, notes Ewing, stating that the development of places that reinforce driving, greater trip distances, and an overall greater VMT per person is a result of the federal subsidization of the highway system, comparatively inexpensive fuel prices, and tax incentives coupled to homeownership, particularly in suburban regions (Ewing & Hamidi, 2015). The developmental patterns the United States selects are not of pure consumer choice, but of heavily influenced market forces, as Smart Growth America (2020) identifies culprits such as cheap gasoline, the ubiquity of Euclidian zoning across the nation (discernable separation of land uses by type), and a low level of support for public transit, yielding much sprawl and fewer transit-oriented developments – urban design choices which support the accessibility of a variety of amenities, goods, and services within walking distance of residences. Urban policies that promote the resulting population-level consumption and emissions patterns fall under two categories: engineered solutions; and economic solutions (Glaeser, 2012). The outcome of sprawl, and its accompanying burden of high VMT per person, notes Glaeser, (2012) is of the engineered variety; the built environment is shaped in such a way which produces these patterns of human mobility which cannot be individually controlled while remaining within the confines of typical societal structures.

The choices made resulting from built environment patterns lay the cornerstone for the foundation upon which the United States builds its systems of mobility, residences, commercial zones, and public places. The IPCC (2020) finds that these patterns of unsustainable development and the social and economic conditions they produce present a high degree of vulnerability and low adaptive capacity to climate risk. The IEA speaks to patterns of modal shifts, cultural desires of vehicles, and how “if consumers’ appetite for SUVs continues to grow at a similar pace seen in the last decade, SUVs would add nearly 2 million barrels a day in global oil demand by 2040, offsetting the savings from nearly 150 million electric cars,” a projection the U.S. is not estimated to make (IEA, 2019, SUVs, para. 2).

Further studies showcase the requirement for a reduction in passenger vehicles on roadways, as well as a reduction in vehicle miles traveled, if governing bodies are seeking to achieve the desired benchmarks often noted in municipal and regional climate pledges (City of Minneapolis, 2018; Kaul, G., 2019; Next 10, 2019; Small, A., 2019; Smart Growth America, 2018). Whether met, or not, the World Health Organization estimates that climate change will be the driving factor in an additional 250,000 deaths annually between 2030 and 2050 (World Health Organization, 2016). These developmental choices, transportation patterns, and the emissions and pollutants that ensue contribute to population-level health and economic burdens. Human-driven climate impacts are nonlinear, and in their patterns of harm, they render unequal impact to communities and regions which stand to face disproportionate harm from these acute variances in climatic affects and unprecedented weather patterns (Gauderman et al., 2007; NASA, 2022; Taylor, D.E., 2014).

2.3 Trends in Bike Commuting and Municipal Actions

An often-noted policy decision directed toward combatting both inactivity and anthropogenic climate change has been the furtherance of active transportation infrastructure; (Sottile et al., 2019) most notably, cycling as a means of transportation. Cities across the United States have slowly made progress in allowing for the creation of safe cycling routes (United Nations, 2021), creating small modal shifts away from the personal automobile and the negative externalities they present to urban regions, such as particulate matter pollution, increased exhaust emissions, and outside-of-vehicle injury and death (Sawhney et al., 2015). Since first being recorded as part of the American Community Survey in 1960, cycling as a means of transportation in the United States has increased, mostly since the turn of the 21st century – in part due to activism, and resulting policy choices (Cicchino et al., 2020; Cushing et al., 2016; Dill, 2009; Nicholas & Cherry, 2015; Sawhney et al., 2015).

Bicycle mode share in the United States stands at 0.6% (Federal Highway Administration, 2020) and over the past four decades has been slowly increasing, with ridership peaking in 2014, as cities are enacting policy measures to realize a myriad of civic, health, and financial benefits. Marshall and Ferenchak (2019, p. 285) note that cycling is being "reinvented" in the United States as a practical form of urban mobility. The postwar development pattern most closely resembling "suburban sprawl" has crafted for the American people a cyclical pattern of transportation policies which result in increasingly greater commute times (U.S. Census Bureau, 2020), emissions (U.S. EPA, 2022), and roadway deaths (NHTSA, 2020). With greater attention to and adoption of policies targeting roadway user safety (U.S. Department of Transportation, 2022), placemaking (Sawhney et al., 2015), and environmental stewardship (Bigelow et al., 2022), the United States has begun to turn its gaze toward fostering the acceptance and rapid incentivization of bicycle use in its urban environments. However, those in the United States are the least likely of the 33 other OECD nations to transport themselves by bicycle, though most likely to die while on a bicycle (OECD, 2013).

When examining bicycle mode share in U.S. cities, it has been found that those with higher rates of cycling stand to produce safer road conditions for all types of road users (Marshall & Ferenchak, 2019). A 13-year longitudinal spatial analysis by Marshall and Ferenchak (2019) examined the relationship between high-bicycling mode shares and road safety outcomes, across all road user types. They noted that as cities enact policies to expand their bicycle mode share, especially when done rapidly, the death rate per 100,000 people dramatically declines. As these results are not solely due to increased bicycling rates, they nonetheless lay the groundwork for further study into mobility systems which further the human experience. Marshall and Ferenchak (2019) examined multiple major metropolitan areas, and some themes emerged. One, are the simple differences in travel behavior across a population, allowing for more road users to visibly identify cyclists and their regular activities on streets. This is a matter of predictability and broad cycling acceptance. Then, built environment differences exist, which is often the fruit of a community-wide voice of bicyclists and advocates that likewise increase cycling adoption. Further, socio-economic differences impact death and injury rates, as we typically find that newer developments cater toward mostly white, upper-middle class individuals and the neighborhoods they reside in. They are safer, as more political voice is present – and it falls in line with the presence of safe bike/pedestrian infrastructure in white communities and the existence of policy shortcomings in minority neighborhoods, who as a result stand to face disproportionately greater mortality from roadway violence (Raifman & Choma, 2022).

As social factors play into the likelihood that cities will adopt and maintain policy which improves bicycling mode share for productive trips, the term "bikeability" has been used as a term to identify the "suitability of bicycling" in cities across the globe (Gholamialam & Matisziw, 2019. p. 74). Elements of bikeability vary depending on municipal transportation demand management or level of traffic stress methodologies, but Gholamialam & Matisziw (2019, p. 74) note features which stand to promote greater mobility and access for those on bikes, and they are as follows:

1. Length of facilities for bikes, including lanes of all types (Caulfield, Brick, and McCarthy 2012),
2. Number of lanes (Landis, Vattikuti, and Brannick 1997),
3. Speed limits nearby (Harkey, Reinfurt, and Sorton 1998),
4. Presence of *dedicated* bike lanes (Akar and Clifton 2009),
5. Traffic volumes (Broach, Dill, and Gliebe 2012), and
6. Number/type of intersections (Menghini et al. 2010; Caulfield, Brick, and McCarthy 2012).

These features are built into transportation policy alone, or as additional measures within road diets or larger streetscape designs. With a greater degree of bikeability in the United States following the turn of the 21st century, many cities are experiencing dramatic shifts in bicycle mode share due to the expansion of safer and more accessible bicycle networks (Schlossberg, et al. 2019).

Cities realizing dramatically increasing bicycle ridership are those that invest in and provide safety for all road users, starting with those most vulnerable (Ding et al., 2020). While not boasting the largest bicycle mode share of American cities, New York City, through their rapid installation of more cycling lanes, protected infrastructure, and dedicated paths, has found ridership and diversity of the average cycle commuter increase (City of New York, 2019).

New York is the North American city with the quickest growth of bicycle trips (in ridership and daily miles traveled). New York City notes that following the release of PlaNYC in 2007, 1,240 lane miles of demarcated bike routes were installed, with 66 miles of protected lanes installed in 2018 alone. Regarding protected bike lanes, 480 miles were built in New York City, with 20.4 protected miles installed in 2018 alone. This has led to a 175% increase in the quantity of New Yorkers who bike at least once a year, as they have experienced a 26% growth in the number of those who ride a bike several times a month (City of New York, 2019). Gender differences in ridership also stabilized dramatically, as more cycling infrastructure was installed and maintained: "female commuter cycling increased more than 2x faster than male commuter cycling from 2014 to 2017" (City of New York, 2019, p. 13).

The past two decades have experienced many major metropolitan areas significantly increasing bicycling rates, and alongside that, the term "bikeability" emerged at the dawn of the 21st century (NHTSA, 2022). Alongside New York City with its 55% increase in bike commute trips, other major metropolitan regions have deviated from their long-term bicycling rates, realizing an average increase of 27% more cyclists (City of New York). For the years 2005-2017, Chicago noted a 33% increase in bike commute trips, Los Angeles a 20% increase, Portland a 24% increase, Washington, D.C. a 54% increase, Boston a 38% increase, Philadelphia a 38% increase, and Minneapolis a 34% increase (City of New York, 2019). However, as bicycle use increased nationally for commuting and leisure trips, so too has death and serious injury (NHTSA, 2020).

Despite decades of small yet consistent increasing trends in bike commuter participation, there has been a general decreasing trend in the percentage of overall bike commuters in the U.S. during the decade preceding the pandemic; Bike Portland (2017) attributes this to an increase in population and job growth, with disproportionate growth in safe cycling infrastructure to match. This has resulted in the plateauing of bicycle mode share across the U.S. in 2015, with further reductions in sustainable transportation alternatives and land-use decisions during, and in the years following the COVID-19 pandemic (U.S Census Bureau, 2020).

When examining major metropolitan regions in the United States, Portland, Oregon has the greatest percentage of bike commuters; in 2014, they achieved peak ridership with 7.2% of commuters regularly traveling by bike (U.S Census Bureau, 2020), though by the impacts of the COVID-19 pandemic, it has fallen and plateaued around 5% at the time of writing in 2023. Washington, D.C., and Portland currently claim the largest percentage of female ridership, at 34% and 33% of their bike commuters, respectively, which confirm their rank at the top of some of the most bike-friendly large cities in the United States; other notable top-performing large cities are New York City, San Francisco, Minneapolis, and Chicago (Pucher et al., 2011). Female ridership growth indicates a municipal commitment to view overall bike commuting as a viable mode choice for all, as cities with high percentages of female bike commuters are much more likely to be cities with high overall bike commuter rates and greater social and infrastructural considerations toward rapidly increasing bicycling rates (Pucher et al., 2011).

2.4 Facilitators to Cycling

The U.S. National Physical Activity Plan (2018) notes that resources must be spent on involving historically disadvantaged populations in active transit to remedy disparities in use, often driven by perceptions of hazards. In the United States, women and older adults are less likely to engage in bicycling for commute journeys and are “more likely to bike when bike-friendly conditions are present” (U.S. Department of Housing and Urban Development, 2022. p. 186). Given these disparities, “bike-friendly” conditions must be met to allow for safe, pleasurable bicycling for all genders and for individuals across all age groups.

Creating environments where people wish to engage in bicycling requires a commitment from policymakers in the region riders wish to participate in (Márquez & Soto, 2021), social acceptance (Lee et al., 2017), and a willingness rooted in sentiments of safety from the individual (Dill & McNeil, 2016). Expanding on the updated review by Dill and McNeil (2016), research has historically categorized mobility cyclists into four types: the strong and the fearless; enthused and confident; interested but concerned; and no way no how. Often, those in the two most reluctant groups will never find their way onto a bicycle in an urban region, and those who do, may only do so in recreational settings (Dill & McNeil, 2016). While beneficial for individual health, a societal shift to sustainable modes of personal transportation is required to meet energy demand (Cozzi, L. et al., 2019), reduce greenhouse gases (U.S. EPA, 2018), and reclaim urban land (Aldred & Woodcock, 2008).

Further, the Safe Systems approach under Vision Zero has been commonly referenced in pursuits toward pedestrian and cyclist dignity. Established by the Swedish Parliament in 1997 (Berg et al., 2016), this framework for systemic road safety for all users demystifies the causes of many roadway accidents (Cushing et al., 2016; Pucher & Buehler, 2016). The thesis of Vision Zero is that all death and serious injury on roadways are “morally unacceptable and [road planners should] aim to eliminate them entirely (Cushing et al., 2016. p. 2178). This approach counters the flawed statistic that 90% of incidents result from human error; Vision Zero, instead, aims to place responsibility for these incidents on roadway planners and systems which fail to calm and separate traffic modalities (Cushing et al., 2016). By examining roadway conditions which stand to result in more and greater impacts to road users, Vision Zero seeks to advocate for predictable roadway patterns, design for the reduction of points of conflict, and develop equitable systems of mobility for all road users (Cushing et al., 2016).

In the case of roadway death and serious injury, the National Transportation Safety Board (2020) notes that vehicular speeds contribute to impacts more than all other factors, as an individual facing impact outside the vehicle stands to survive the incident 90% of the time when speeds are below 20 miles per hour, 55% of the time when speeds are below 30 miles per hour, and only a 15% chance of survival at speeds of 40 miles per hour or more. Vision Zero and their Safe Systems Approach has worked to hold planners, transportation engineers, and city officials accountable for roadway violence and traffic incidents, as they find that "traffic deaths are preventable," that cities should consider "human failing" in design approaches, and that preventing fatal and severe crashes is not expensive and can be mitigated through systems thinking (Vision Zero Network, 2022).

As Vision Zero addresses various elements of transportation design and planning, so too do major U.S. cities, whether through the implementation of Safe Systems approaches or not. Advocacy organizations have found much success in building and maintaining support for safe streets and resulting conditions for those who bike (Pucher et al., 2011). With a variety of advocacy organizations and nonprofits in recent decades aiming to promote cycling and its safety, from the likes of Transportation Alternatives, Bike Lane Uprising, Active Transportation Alliance, World Bicycle Relief, People for Bikes, League of American Bicyclists, and Cycling USA, the adoption of cycling-focused policy has been rapidly implemented in U.S. cities (Pucher et al., 2011; Schlossberg, 2019).

While not having a direct ability to move the legislative needle, the presence of advocacy organizations and citizen awareness of political and infrastructural shortcomings has played a critical role in holding transportation agencies and cities accountable for systemic issues which fail to protect people on bikes (Sawhney et al., 2015; Short & Caulfield, 2014). The City of Chicago has a municipal site (or 311 call) dedicated to vehicles obstructing bike lanes, though its purpose is not to enforce this offense, but to gain an understanding of the prevalence of these occurrences and where they take place (City of Chicago, 2022). New York City has proposed measures to return to people a small portion of the ticket price upon reporting a bike lane obstruction, though no legal measures have been passed, as city officials feel it may pit certain transportation user groups against one another and stoke violence (Cornell University, 2022).

In the wake of economic downturn, inflation, and rising costs of transportation on individuals of all walks of life, bicycle transportation has been regarded as an inexpensive, yet effective tool for urban mobility (Hayes, 2008). Transportation expenses in the U.S. have inordinate financial impacts on the working poor, and by utilizing a bicycle for urban trips, one can significantly reduce the percentage of their income spent on transportation (Babey et al., 2009; Branion-Calles et al., 2019; Tucker & Manaugh, 2018). The Institute for Transportation and Developmental Policy (2021) notes that many households in developing countries, including in the United States, spend sometimes over a quarter, and often up to one third, of their income on transportation costs alone. There are a variety of factors that result in additional cost for lower-income individuals; distance to required amenities, condition of roadways near their residence, or age/performance of vehicles all contribute to additional expenses for the poor (Babey et al., 2009). When examining incomes across different racial groups above and below the poverty line, Hayes (2008) makes note of the percentage of income spent on transportation in

U.S. cities, as those who are below the poverty line in marginalized communities who require the use of a private automobile to get to work, can find fueling their vehicles cost prohibitive. Apart from developmental forms which may serve as a constraint to viable bicycle commuting (Ewing & Hamidi, 2015; Godbey et al., 2001), the cost of bicycle ownership and maintenance are inexpensive and open to a wide variety of income groups (Ghekiere et al., 2014; Mertens et al., 2016), thus creating a healthy form of efficient transportation that is cost-prohibitive to few, if the urban form facilitates it.

Road design has been cited as one of the primary factors in one's propensity to bicycle for transport (Basch et al., 2019; Cicchino et al., 2020; Firth et al., 2021; Garrard et al., 2008; Nolan et al., 2021). Infrastructural elements often shift perceptions of safety, influencing mode choice patterns (Deliali et al., 2021). By closing the gap on perceived constraints to safe transport options outside of the vehicle, cities stand to experience greater modal shifts toward cycling, as conditions that allow for safe use of bike facilities stand to create cyclical paterns of shared acceptance and thus safety for alternative transportation options (Marshall & Ferenchak, 2019).

To make further use of the bicycle as an effective instrument for personal urban mobility, assistance is often warranted by some, and requested by others. The electric bike is a relatively new concept yet marries the idea of micromobility with easier mileage. The e-bike can serve as an effective mobility device for individuals who would otherwise face physical constraints to ridership, such as the elderly, injured, or weak (Petzoldt et al., 2017). Growing in acceptance across much of European countries and selling at a rate of 10 million per year in China, streets are giving way to the e-bike (Petzoldt et al., 2017), yet in the States, there is much slower adoption (Light Electric Vehicle Association, 2022). The Light Electric Vehicle Association (LEVA) tracks the growth of light electric vehicles, and the rate at which electric vehicles are being sold now outpaces that of electric vehicles; at 880,000 units imported in the United States in 2021 alone, the e-bike is seeing mass appeal at home, and is now being heavily considered by transportation officials, planners, and the automotive industry alike (LEVA, 2022).

Departing from the European trend, where e-bike sales had surpassed that of electric and hybrid automobiles for many years, 2021 marked the first year in the U.S. that e-bikes outsold their electric and hybrid automobile counterparts (LEVA, 2022). Some states are even implementing policies incentivizing e-bike purchase and use for urban mobility (Ride Illinois, 2023). With safer, more efficient motors and batteries becoming available for reliable e-bike models in the U.S., more local bicycle shops are working in tandem with state and local legisatures to offer e-bike rebates or discounts for qualifying consumers in over 13 states (Juiced Bikes, 2023; Streetsblog, 2023). California and Oregon have dozens of cities with their own policy measures aimed toward incentivizing e-bike transportaion, often allowing for lower-income populations to use them as a means of car replacement (Petzoldt et al., 2017). By accounting for e-bikes in our transportation system, the path toward greater bicycle mode share can face fewer burdens, and users can reach more destinations with greater ease (Petzoldt et al., 2017). There are, however, drawbacks and constraints seen in the e-bike space, as they become integreated in urban fabrics, though these will be detailed in a later section.

2.5 Constraints to Cycling & Negotiation

The next element to review is related to the perceived risk factors associated with those who partake in this mode choice in urban environments. Given the higher adoption of cycling as a means of transportation within U.S. campus regions due to elevated user feedback and activism (Pucher, et al., 2011), we seek to understand constraints and attitudes in the very places that urban cycling remains prominent, while nationwide modal share remains low.

Dill and McNeil (2016) revisit the "four types of cyclists" and examine the extent to which individuals wish to partake in cycling for transport; the four categories which individuals identify with are "the strong and fearless, enthused and confident, interested but concerned, and no way, no how." To maintain a strong bicycle mode share for daily trips, a city must seek to involve the most hesitant of riders, as well as reinforce bicycle policies and networks for existing users. Constraints, though, are evidenced across various components of the socio-ecological model of physical activity, as the range of factors related to one's propensity to cycle, and to do so safely, cannot be relegated to single causalities (Gao et al., 2018).

The United States has also been pursuing another goal in its transportation pursuits: a reduction in motor-vehicle related deaths (Lee et al., 2022; U.S. Department of Transportation, 2022). Roadway widths, driver speeds, a lack of viable transportation alternatives, and minimal traffic calming measures are large contributors to roadway deaths and vehicle-human interactions (Berg et al., 2016; Cushing et al., 2016; Goerke et al., 2020; Smart Growth America, 2020). These patterns of harm weigh disproportionately on people of color, low-income people, children, and those with disabilities (Smart Growth America, 2020). The ways the built environment in the U.S. has impacted mode share has led to fewer individuals partaking in an otherwise cost-effective, enjoyable, and clean mode of transportation (Chetty & Hendren, 2018; Gauderman et al., 2007; Institute for Transportation and Development Policy, 2019).

2.5.1 Constraints for women in cycling

Less than 1% of people in the United States commute by bicycle, and when examining gender differences between bike commuters, the present gap is revealing: females in the U.S. do not participate in bike commuting as much as their male counterparts (Debnath et al., 2021;

Mertens et al., 2016). Constraints sensitivity varies by gender, as do nearby driver behaviors (Ampe et al., 2020; Carroll et al., 2020; Garrard et al., 2008).

Trip characteristics are influenced by daily roles in society, as well as surrounding social environments. Home and caring responsibilities disproportionately fall on women in a typical U.S. familial setting (Montoya-Robledo et al., 2020; Ravensbergen et al., 2023). Thus, women tend to take a higher frequency of trips in urban settings, though travel times and distances may vary (Ravensbergen et al., 2023). "Mobility of care" refers to all the travel required to complete the "unpaid work carried out by adults having responsibility for children and other non-physically autonomous individuals, as well as those activities needed for the upkeep of the home" (Sánchez de Madariaga, 2013, p. 1499). These are largely care-focused journeys which are meant to cover necessities such as caregiving for others, homemaking, and other unpaid labor related to the maintenance of a household and its daily personal and material needs (Sánchez de Madariaga, 2013). As women are disproportionately likely.to bear these burdens while carrying more goods and transporting children (Sersli et al., 2020), the ease with which mothers may be able to travel by bike for useful trips is severely reduced, if not eliminated for many women (Montoya-Robledo et al., 2020; Sersli et al., 2020). As gender roles stand in U.S. society, women are more likely to assume the responsibilities of child rearing, caregiving, and homemaking, resulting in more frequent trips, while longer, more predictable work commutes are commonly performed by men in two-parent households (TREC, 2022).

Regarding on-bike experiences, women are more likely to bike for transport when bike friendly conditions are met, as they find greater sensitivity to longer trips (Carroll et al., 2020; Heesch et al., 2012; U.S. Department of Housing and Urban Development. 2022), closer passing distances (Carroll et al., 2020), and when fearing gender-based violence and vulnerability in the public sphere (Debnath et al., 2021; Montoya-Robledo et al., 2020).

Though, in regions where rapid implementation of infrastructural alterations occur, as evidenced in New York City, Minneapolis, and Washington, D.C., cities stand to improve not only population-wide mode share, but promote the rapid increase of bicycle commuting by marginalized groups and those who previously identified strongly with constraints; in many cases this encompasses women and people of color (Branion-Calles et al., 2019; City of New York, 2019, TREC, 2022). The likelihood of women making as many or more necessary trips by bike as men do greatly increases once overall citywide mode shares reach 7% or greater (Goel et al., 2022). Thus, planning for trips which can be taken by women and all desired family members regardless of age, gender, or constraints sensitivity, public infrastructure can be satisfying and dignifying for users regardless of demographics or trip characteristics.

2.5.2 The Challenge of Driver Behavior

In 2021, the United States experienced the highest rate of injury and death to those outside vehicles on its roadways since 1980, and the rate of those who experience fatal collisions outside of vehicles has increased from a low of 20% of all deaths in 1996 to a high of 34% in 2020 (Stewart, 2022). Cycling experiences vary by driver patterns, as the extent to which drivers obey all roadway laws and treat others with courtesy may vary. Cyclists report that drivers at times do not obey traffic signals at intersections or other areas of human/vehicle conflict (Nicholas & Cherry, 2015; Thorslund & Lindström, 2020). When being passed, drivers may make sharp right-hand turns in front of cyclists shortly thereafter or encroach into their lane of traffic while overtaking other vehicles nearby, failing to recognize the bicyclist (Nicholas & Cherry, 2015).

Infrastructural alterations such as the separation of driving routes near bikeways can mitigate the aggression, or even unintended close passage by motor vehicles near bicyclists through raised lane designs that divert into bicycle turn lanes, or into fully protected intersections (Nicholas & Cherry, 2015). Furthermore, close passing distances are found to be intended at times, with cyclists noting the encroachment of their space arises from the expectation that all road users be automobile users (Mayers & Glover, 2021; Nicholas & Cherry, 2015). This can be accompanied by hostility and aggression, as interview participants in a study by Mayers and Glover (2021) noted sentiments of not feeling welcomed by drivers – prompted by infrastructure, and reinforced through driver behavior and the conditions such infrastructure permits. In Ottawa, on shared use paths, or "sharrows," which have been widely regarded as empirically ineffective (Firth et al., 2021; Marshall & Ferenchak, 2019) riders experienced individuals speeding in private automobiles, negating the intended benefit of such lanes, as fear arises from dangerous and more threatening road users nearby (Mayers & Glover, 2021). Thus, improvements must be made in this space to hold accountable road users who fail to use said public infrastructure in a manner that permits all individuals navigate safely in fashions for which it was designed.

Mayers and Glover (2021) noted that there is in a sense a "dehumanization" of those outside the vehicle, as forms of transportation become a key part of our identity. This was reinforced in a new study, as cyclists require visibility clothing or gear to maintain safety on increasingly dangerous roadways (Limb & Collyer, 2023). Cyclists may face the negative effects of this norm, as hostility may be directed toward them while navigating urban environments, especially when negotiating space with other road users in tricky areas such as intersections or lane merges (Carroll et al., 2020; Mayers & Glover, 2021). Unlike the cycle commuter landscape present in the United States, in Northern Europe, there are no considerable differences in cycling rates across income groups, which marks the activity as one of various options people wllingly choose for navigating their cities (Pucher & Buehler, 2008). A private automobile is also a substantial purchase in the U.S. lifestyle, tied heavily into arts, cultural, and musical interests (Lezotte, 2013), and when sunk costs are experienced across a population, there is an expectation of public investment into norms adopted by individuals at large, further prompting subsidization and overall legislative catering to the most deadly (Anderson & Auffhammer, 2014; Arias et al., 2021), air and water polluting (Tucker & Manaugh, 2018; Vanderstraeten et al., 2011), noise polluting (Pucher & Buehler, 2017), and spatially-disruptive (Bigelow et al., 2022; Ewing & Hamidi, 2015; Sturm & Cohen, 2004) form of transportation on our public roadway systems.

Accounting for changes in cycling patterns and the wide variety of cyclists can result in dangerous outcomes. When visibility, awareness of bicycles, and negotiations of space occur in streetscapes, it is often done in a calculated manner where most road users understand the speeds of others (Petzoldt et al., 2017; Stelling et al., 2021). When accounting for relatively new technology, e-bikes, or pedal-assist bicycles, changes in rates of acceleration and speed may reduce awareness or prompt inaccurate decision-making by drivers. A German e-bike study by Petzoldt et al. (2017) examined driver gap acceptance and how drivers may underestimate speeds of oncoming bicycles, leading to crashes. The design was as follows in Figure 1.

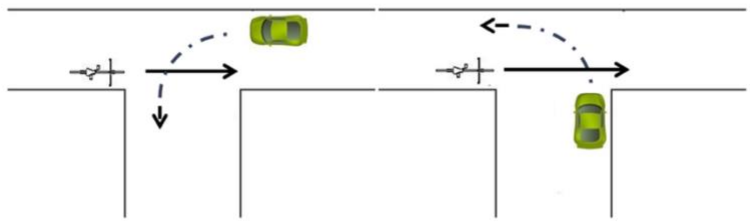

Figure 1: frontal view (left) and side view (right) of the approaching bicycle.

"Selected gaps in front of oncoming e-bikes were significantly smaller compared to the gaps chosen when a conventional bicycle approached" (Petzoldt et al., 2017. p. 287). This can lead to worse negotiation of space and result in more crashes, with greater crash severity, as is typical with e-bikes on U.S. roadways (OECD, 2013). By understanding negotiations of space with bicycle shaped vehicles, policy can be crafted to allow for safest navigaiton of all road users on all types of roadway infrastrucutre (Dozza et al., 2016; Vansteenkiste et al., 2014).

2.6 Infrastructural Constraints

A significant constraint individuals face in their cycling journey is the lack of infrastructure which is suitable for cycling (Ding et al., 2020). The only group which lacks a consideration for infrastructure is the "strong and fearless," which "do not need any accommodation in the form of bicycle specific infrastructure to ride comfortably, even on busy streets" (Dill & McNeil, 2016. p. 90). Though, for the 99% of all other cyclists, users showcase concerns related to infrastructure along their chosen routes (Dill & McNeil, 2016). Cycling infrastructure varies in its purpose, visual elements, and protective properties. A 2019 study by Basch et al. showcased the prevalence of obstructions within designated lanes, limiting their effectiveness in maintaining rider usage patterns and feelings of safety. A study in 2018 in Manhattan, NYC made note of obstructions, and they were categorized into three separate groups: objects, people, vehicles. Data was collected for a week during daylight hours, and obstructions were noted if they required a user to navigate off the bike path and could not permit further travel on the lane. Two hundred thirty-three obstructions were noted, as objects (n=124, 53%) comprised many of the obstructions, people (n=66) at 28%, and vehicles (n=43) at 18.5% (Basch et al., 2019). This study speaks to the conditions which leads toward even well-intentioned cycling infrastructure to perform at levels beneath their potential in urban environments; even if markings or protected lanes exist, cities must integrate bicycle networks into their urban fabric such that their intended purpose makes effective use of public expenditure on them.

Cycling in demarcated or protected lanes is not always a panacea for rider safety, as themes emerge when examining the desires of those in bike "lanes." Width of lanes, the surface material, where buffers exist and how resilient to physical impact they are, and the color of the lane all have impacts on a riders' likelihood of experiencing perceived protection from traffic, and thus comfort when operating a bicycle (von Stülpnagel & Binnig, 2022). A study by Ryerson et al. (2021) measured ocular gaze movements of individuals in bike lanes which had protected and unprotected segments throughout Philadelphia, Pennsylvania. Through millions of microscopic data points, the researchers found that ultimately, more off-mean gaze points are necessary when riders use paths without protected infrastructure from auto traffic and other points of conflict (Ryerson et al., 2021). This leads to an expanded field of not only distractions, but points of gaze in casual riding that deter the cyclist from full attention on the roadway, pedestrians, or path alterations ahead of them, reinforcing their observation of increased cognitive workload on potential distractions while cycling.

When lanes are available and marked for bicyclist use, there are a range of factors which contribute to rider safety, most notably in infrastructural changes surrounding lanes. Schlossberg et al. (2019) noted key interventions in several cities and how they stood to contribute to greater use, safer human throughput, and fewer collisions. A primary contributor to safety for bicyclists is protected bike lanes, which Schlossberg et al. (2019, p. 46) define as “cycling infrastructure,” which is protected by elements such as “curbs, posts, planters, or even parked cars.” Protected bike lanes vary, though, as greater separation from moving traffic, more strategic intersection design, less frequent driveway exposure, and slower speeds stand to reduce points of conflict for cyclists while in lanes (Cicchino et al., 2020). Ultimately, “lack of cycling infrastructure is the largest hurdle that the U.S. currently faces in making cycling viable” (Nicholas & Cherry, 2015, p. 216). Crafting solutions to better protect bicyclists in protected lanes has historically saved lives, though the introduction of facilities alone is typically not enough to result in population-level modal shifts (Stewart & McHale, 2014).

2.7 Negotiating Constraints

An element that has received attention is bicyclist attire and its impact on how they are treated by automobile drivers (Walker et al., 2014). By presenting oneself as a safe, orderly, novice, one might be respected differently than a risk-seeking bike messenger (Aldred & Woodcock, 2015; Walker et al., 2014). For instance, while carrying a child-seat on a bicycle rack, passing distances will be greater than those experienced by a single individual on a bicycle (Ampe et al., 2020). Though a rich body of studies exists on lane markings, separation infrastructure, and related passing distances and the social and built environment factors that yield such results, there are few studies which speak to the effects of driver behavior. A study by Walker et al. (2014) examined the differences in clothing choices of a cyclist, and related passing distances for motorists. A single rider in various outfits on an instrumented bike was outfitted in different clothing types with markings: racer, commute, hi-viz, casual, novice, POLITE (written on reflective vest), and POLICEwitness.com (on reflective vest, with camera attached). Driver behavior, reflected in passing distances, varied across these types of cyclists as the rider's appearance differed, as seen in Figure 2.

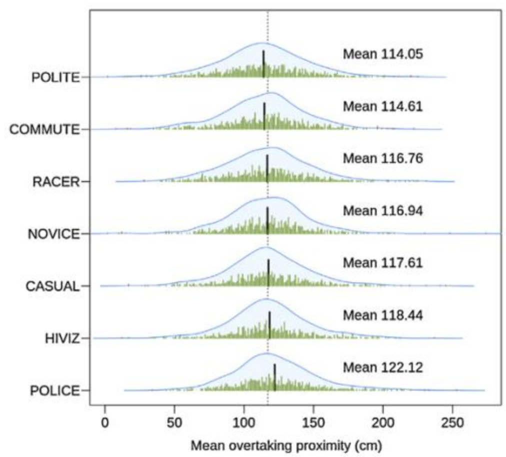

Fig. 2. Mean overtaking proximities (black lines) and kernel density plots for each bicyclist outfit, with individual data points shown in rugs. The dotted vertical line is the overall mean for all data (117.50 cm).

Figure 2: Mean Overtaking Proximities

Results from the instrumented bicycle indicated that a rider in police-like clothing had measured the largest mean overtaking distance, at 122 cm. on average, while those with"POLITE" on their back had measured the least, at 114 cm. Reinforcing an "implied threat of evidence gathering" through the police attire resulted in the most respectful motorist activity nearby (Walker et al., 2014, p. 71).

In noting that bicycling poses a strong "mobility identity," unlike driving, newer or inexperienced cyclists may feel as though the larger group they're in may paint them as risk tolerant, which may serve as a barreir to entry (Aldred & Woodcock, 2015). This reinforces the notion that a cyclist would want to arm themselves with attire that reflects their skill level and risk tolerance, so as to not be stigmatized as a “rule breaker or risk taker.” Ultimately, Aldred and Woodcock (2015) stated that some users feel as though identities shaped by wearing certain types of personal protective equipment (PPE) or apparel can be identified by other road users.

Other elements that result in greater visibility to larger road users at higher speeds with greater blind spots are reflective pieces or lights mounted on the bicycle or bicyclist (Aldred & Woodcock, 2015; Teschke et al., 2012; Walker et al., 2014). As crash prevention is only one aspect of injury mitigation, the use of lights has not been found to play a significant role in harm reduction for bicyclist injuries and vehicular impacts, though there are positive correlations in the wearing of other PPE and helmets with those who employ the use of lights, especially evening running lights (Popa et al., 2017; Teschke et al., 2012). Various studies examine the under-reporting of bicycle crashes and elements of cyclist behavior and lack of PPE use which can contribute to crashes and resulting injuries (Robartes & Donna Chen, 2018; von Stülpnagel & Binnig, 2022). Across various studies, the proper use of PPE and lighting is associated with being risk averse, though comes with a high level of skepticism about its effectiveness (Aldred & Woodcock, 2015).

Various ages and demographics note different constraints when cycling for transport. With much of the United States ‘cycling population fitting a smaller demographic mold, other cities in industrialized nations have embarked on the possibility of more individuals across the lifespan using all forms of personal transportation (Cushing et al., 2016). Actions taken to mitigate risk and injury vary by these participants, as personal protective equipment (PPE) or high-visibility clothing can be worn to reduce harm when navigating streetscapes where drivers may not expect cyclists. Lighted or reflective clothing, vests, or other accessories on or off the bicycle are worn by commuters to be seen, and to ultimately avoid impact by other roadway users, most notably passenger and commercial vehicles and trucks (Aldred & Woodcock, 2015). While much of the cycling space has directed safety efforts toward injury prevention primarily through literature on helmet use, crash and impact prevention through attire and visibility clothing remains an important consideration for cyclists as they navigate urban environments (Teschke et al., 2012). While helmet use will be covered in the following section, their use in all environments and by all cyclists does not serve as a panacea for reducing road impacts to bicycle users (Joseph et al., 2017).

When considering injury prevention measures for those on bicycles, the use of a helmet is widely regarded as one of the most effective ways to prevent death and serious injury (Hwang et al., 2019). When examining further the role helmets play in injury prevention, the benefits vary across demographics and regions. Associations are present with helmet wearing, as it stands to be a predictor for running-light use and high-viz clothing (Teschke et al., 2012); further, different regions and infrastructural policies impact social norms which can alter helmet use across populations. A review by Pucher and Buehler (2008) covers many of the present misconceptions surrounding the use of cycle helmets, primarily as it relates to regional differences and policies that promote safe conditions for urban cyclists. They indicate that at the population level, cycling safety is inversely related to helmet wearing (Aldred & Woodcock, 2015; Pucher & Buehler, 2008). This reality does not serve as the grounds to overlook the helmet as a healthy instrument for injury prevention, but rather to look to global policymakers which produce urban environmetns that are not inherently disabling to those outside of motor vehicles, and build off those urban policies for safer conditions.

Helmets do protect users from traumatic brain injury, when impacts occur which would otherwise result in such harm (Joseph et al., 2017). From a 1-year retrospective study of the National Trauma Data Bank, Joseph et al. (2017) examined 6,267 patients and noted that "helmeted cyclists are at a 51% lower risk of developing severe TBI, 31% lower risk of overall facial fractures, and 27% lower risk of facial contusions and lacerations" (Joseph et al., 2017, p.415). Thus, when examining the role helmets play in injury prevention, the results are as such: they cannot mitigate all injuries, but considerably lessen the severety of the worst injuries (Hwang et al., 2019; Joseph et al., 2017).

Further, driver and cyclists alike indicate that the act of helmet wearing ties into social norms across different groups, as it can be a constraint to cycling. Many participants in a study by Aldred & Woodcock (2015) indicated that there are processes one must take before biking. There is a greater sense of risk aversion for those who do employ the use of helmets and PPE (Aldred & Woodcock, 2015).Wearing a helmet may give the message to drivers that a cyclist is "serious," and will abide by traffic laws, and behave in a logical, controlled manner, resulting in respect from drivers (Walker et al., 2014). However, there have been negative associations found between passing distances provided and helmet use. What is found throughout much of the literature indicates that in places where cycling is a larger social norm, there is less risk aversion, while drivers and cyclists alike may alter their behavior based on bicycling norms in the region and protective wear present (Aldred & Woodcock, 2015; Pucher & Buehler, 2008; Teschke et al., 2012). A sense of public trust, high bicycling mode share, and infrastrucutural elements that separate cyclists from other road users stand to reduce the likelihood of crash severity and resulting injury (Aarts et al., 2013; Aldred & Woodcock, 2015; Walker et al., 2014).

While in regions where enforcement of bicycling helmets does occur, minorities and low-income individuals bear the burden of such penalties (Safe Routes to School, 2022). This extends to registration, riding in bicycle-free zones, as well as sidewalk riding. This further reinforces the disparities in built environment characteristics and public space design which place inordinate harm on low-income people in neighborhoods where active transportation is not prioritized, and where the financial obligations associated with auto-dependency may not be attainable by every household (Branion-Calles et al., 2019; Chen et al., 2020; Glassbrenner et al, 2022). Further, there are disparities in the safety of bicycling networks across residential neighborhoods of individuals in differing income groups; as bicycle networks, their protective qualities, and access to resources are inordinately greater for higher-income people (Tucker & Manaugh, 2018), while lower-income individuals and those of lesser educational attainment are found to ride more frequently without the use of a helmet, and live in regions with insufficient bicycle network connectivity (Chen et al., 2020; Robartes & Donna Chen, 2018).

Social norms play a role in the likelihood of cyclists regularly travelling by bike for necessary trips (Mayers & Glover, 2021). When transportation modes have public subsidies from various levels of government, this perpetuates their use; this has, in the United States, favored the infrastructural considerations of the private automobile (Lezotte, 2013). Godbey et al. (2001) noted that value systems and societal norms adopted by certain populations have an effect on these populations' physical activity and mobility patterns. This is clear, in that the U.S. population has found much of its societal norms rooted in individualism, which auto-dependency further perpetuates (Braun et al., 2016; Hess, 2022). Our built environment forms are heavily shaped by social norms, which indirectly influence the types of transportation infrastructure and users of transport systems federal and regional governing bodies invest in.

Those in the U.S. use bicycles as a means of transportation less than those in other OECD nations (Cushing et al., 2016; Pucher & Buehler, 2008, 2017). Though built environment trends heavily dictate mobility patterns (Savitch, 2003), some researchers find that certain bicycle types, local policy, or PPE can play a role in getting more individuals on bicycles for useful trips. Older adults in suburban regions are most likely to suffer the consequences of having fewer mobility options, as well as partaking in less physical activity as part of daily life (Lee, M., et al., 2021). Youth use bicycles to get to school, and the availability of accessible cycle networks around their residential landscapes can either present opportunities or impose challenges on their ability to reach destinations by themselves (Aarts et al., 2013), to get there safely (Babey et al., 2009), and do so on pleasing thoroughfares (Ghekiere et al., 2014). This extends to campus regions, as students in cities experiencing in-person learning experiences must navigate effectively in a geographically dense space and do so in a setting which facilitates thousands of others like them (Braun et al., 2016). By crafting places and shaping policies to suit all ages who wish to cycle, campuses and micro-urban communities can equip themselves to cater to greater demographics and employ smart planning practices to improve cycling mode share in their cities.

CHAPTER 3: METHODS

Cross-sectional data were collected from adult users of UIUC, Champaign, and Urbana bike facilities via an online survey to examine primary experiences and constraints to navigating the campus region by bicycle.

3.1 Study Site

The greater Champaign-Urbana region, and UIUC campus core are ever-improving in their development of infrastructure and policies to mitigate traffic hazards to all road users, though at a national level, trends indicate increasing rates of injury and death for those outside of vehicles, most notably for those who go by bike (NHTSA, 2020). While the Illinois Climate Action Portal (iCAP Portal) exists to reinforce climate commitments from the University of Illinois across all campus services, its transportation initiatives focus on expanding infrastructure with efforts to reduce emissions - primarily through the reduction of single-occupancy automobile usage in the campus region (iCAP Portal, 2022). The University of Illinois Facilities and Services Department manages capital projects across the campus region and exists to assist greater university-wide sustainability initiatives, of which increased active transportation is one (UIUC Facilities and Services, 2022). In measuring impacts across the campus region, the Facilities and Services department has collected data through their Bike Mode Share Survey, which collects data surrounding those who navigate on campus. The survey collects details on the types of transportation modes students and faculty wish to use, how they make their initial trip to campus, how long that takes, how they get around while on campus, and which modes of transportation that requires. It assesses the average daily mileage of individuals upon arriving on campus, the mode of transportation they use while on campus, and the percentages of students across differing academic levels who use bike facilities. Facilities and Services noted the differences in mode share percentages of students who bike from freshman year on through undergrad, differences in ridership across the graduate student populations, measuring bike use across all student levels. There is, however, no clear indication of noted constraints tied to demographic data and their questioning lacks further inquiry into differences in noted constraints across gender groups (UIUC Facilities and Services, Mode Share, 2022).

3.2 Data Collection Procedures

Data collection took place between February and late March of 2023. Those who were eligible for the study included individuals aged 18 and over, who pass through, park, or commute on bike facilities in the UIUC, Champaign, Savoy, and Urbana regions. Those who bike for transportation, non-leisure trips, or to work or school qualify (Bigelow et al., 2022; Ewing & Hamidi, 2015). Participant recruitment occurred by asking key stakeholder groups (i.e., Ride Illinois, Champaign County Bikes, Bikelab by Neutral Cycle, Champaign Cycle, The Bike Project of Urbana-Champaign, and C-U Urbanist Club) to share information about the study. These organizations were selected for their advocacy, membership, and connection to individuals who use bikes in the region. Individuals found biking in the campus region were also asked to participate. Additionally, information about the study was shared with organizations across the UIUC campus region which represent marginalized populations, underserved ethnic groups, and people who may be under-represented in the cycling space.

Eligible participants accessed the survey via a QR code that was distributed through key stakeholders. The QR code took the prospective participant to the landing page with the consent letter, which provided more information about the study. If they had no questions, the prospective participant was asked to continue to the survey. At the end of the survey, participants were asked if they wished to participate in a drawing to win one of two bicycle tune-ups from

Bikelab by Neutral Cycle at the end of the survey. If a participant wished to enroll in the drawing, we gathered their email address, which was only used for purposes of the drawing, and all files regarding participant emails from the drawing were deleted following the study.

3.3 Measurement Instrumentation

Questions asked of respondents (Appendix A, p.82) encompassed commonly cited behaviors, attitudes, and experiences of bicycle commuters, and of the constraints they face personally, societally, and in the built environment (NHTSA, 2020; GHSA, 2020; NRPA, 2022). Participants were asked their age, zip code, gender, race, income, education, their most frequent mode of transport, bicycle journeys, reasons for cycling, ride frequency, type of bicycles they use, the cost of their commuter bike, and they were asked about their past injury or crash experiences (Appendix A). After capturing a wide range of personal and rider characteristics, they were then asked to respond to Likert-scale questions related to their association with three areas of constraints typically observed while bicycle commuting.

3.3.1 Intrapersonal Constraints Measurement

A set of 6 questions were created to assess the frequency of experiencing personal constraints evidenced in bicycling research. These questions were measured on a 5-point Likert scale where 1=never, 2=rarely, 3=sometimes, 4=often, and 5= always. This set of 6 questions focused on intrapersonal factors such as one’s self-reported feelings of safety while navigating environments on their bike (Beck et al., 2021), an individuals’ likelihood to take other modes when they must be presentable at their destination (Aldred & Woodcock, 2015), and their frequency of wearing visibility clothing or helmets (Walker et al., 2014). They were asked about their ability to feel safe navigating around others on foot and on bike, negotiating space in the environment, as well as their sense of endangerment during rush hours (Ryerson et al., 2021;

Stewart & McHale, 2014). Questions related to rider demographics and personal characteristics asked respondents of their crash or injury history which negatively affects their perception toward bike commuting, with an additional open-ended question for those who had responded "yes."

3.3.2 Societal and Driver Behavior Constraints Measurement

A set of 8 questions were created, measured on a 5-point Likert scale, which assessed frequency of noted behaviors or occurrences related to societal and driver-focused constraints evidenced in bicycling research. Respondents were asked about their experiences with close passing distances (Beck et al., 2019), respect in certain types of lanes (Mayers & Glover, 2021), and whether they prefer routes that provide fewer driver interactions (Mertens et al., 2016). Respondents were asked about their perception toward necessary prioritization of cycling conditions in the campus core, as well as experiences facing stigma associated with commuting by bike (Aldred & Woodcock, 2015).

3.3.3 Built Environment Constraints Measurement

A set of nine questions were created, measured on a 5-point Likert scale, which assessed frequency of experiencing noted built environment constraints evidenced in bicycling research. Respondents were asked to recall experiences of intersections (Deliali et al., 2021; Thorslund & Lindström, 2020), sidewalk-to-road designs (Garrett-Peltier, 2011), as well as feelings of safety across various levels of protected lanes (Cicchino et al., 2020; Firth et al., 2021). Riders were asked about their attitudes of campus prioritization of road space to cyclists, integration of cycling lanes to crosswalks and other road features (Pucher & Buehler, 2008), whether lighting is adequate along routes (DiGioia et al., 2017), and the frequency of reported obstructions along bike routes (Basch et al., 2019).

3.4 Data Analysis

In the creation of data suitable for observation and analysis, respondents were removed who did not fit certain criteria. Respondents who had completed less than 85% of the questionnaire were removed, those who completed it in less than 90 seconds were removed, and those who did not complete any Likert-scale items were removed. Missing data were recoded as a "-9" value, indicated as "Missing" in all output tables. As one statistical test used required a grouping variable with only two selections, a separate Male/Female category, listed as "A4_2GEN" was created using "compute variable." Three focus areas of constraints association were assessed with Likert-scale questions. Where needed, categories were recoded so that higher values indicated a greater association with the noted constraints. In the first section related to personal constraints, question 4 was recoded in inverse order, as were questions 1 and 2 in the societal and driver behavior portion, as well as the first 8 questions in the built environment constraints section. After variable recoding was completed, descriptive statistics, t-tests, and one-way analysis of variance were conducted.

3.5 Internal and External Validity

Internal validity may be obscured by the season in which the responses from participants were collected, as fewer bicycle commuters actively navigate streets in later winter months, when data collection began, and thus were less likely to take the survey at such a time. Also, we may have faced more difficulties gathering input from those who are "on the fence" of bicycle commuting, yet have faced constraints before, as they may view the survey as something for avid cyclists only rather than all who ride bikes or have ridden bikes as a form of transportation in the campus region. The survey may have been more attractive to those who wished cycling would be better accommodated in our study region, as they stood to benefit from the results and following action by local stakeholder organizations.

Developing this study in a campus region which sits between two moderately sized micro-urban environments is unique and cannot be replicated at another municipal/campus interface. By understanding the social conditions, environmental and planning goals, and transportation needs of a campus community as it is seated within a greater micro-urban environment, we can best understand what influences individuals toward certain mode choices, as well as examine how campus regions influence greater metropolitan cities in active transportation planning, design, and policy.

3.6 Researcher Positioning

Having been a bicycle commuter in mid-sized cities and the University of Illinois Urbana Champaign campus community, Mitchell Fransen understands firsthand many of the lived experiences of those who go by bike. While working in the public sector at the height of the COVID-19 pandemic, implementing and experiencing iterative policy choices which stood to connect citizens with their communities drove him to study active transportation and its effects on civic life and overall wellbeing. By further understanding the experiences and constraints of bicycle commuters across varying demographics in campus communities, he wishes to impact regional planning organizations and capital project managers in their pursuit toward designing sustainable, safe, and convivial communities for all.

CHAPTER 4. RESULTS

4.1 Sample Description

A total of 137 people responded to the questionnaire. Deletion of surveys with missing data was performed, resulting in a final valid sample size of 102 participants. The median age of the sample was 24.5, with a range between 18 and 79. Respondents were primarily from zip codes 61820 (38.2%), 61801 (35.9%), and 61821 (12.7%), with 10 other nearby zip codes represented. Respondents were 65.7% male (n=67), 33.3% female (n=33), and 1% non-binary/third gender (n=1). The respondents were 68.6% White (n=70), 3.9% Black or African American (n=4), 25.5% Asian (n=26), and 2% Other (n=2). There were no American Indian or Alaska Native, or Native Hawaiian or Other Pacific Islander respondents. Most respondents had an annual income of less than $15,000 USD (41.2%; n=42), while 24.5% (n=25) made $15,000 to less than $50,000. 13.7% (n=14) had an income of $50,000 to less than $75,000, 8.8% (n=9) had an income of $75,000 to less than $100,000, 6.9% (n=7) had an income of $100,000 to less than $150,000, and 4.9% (n=5) had an income of $150,000 or more. The sample was highly educated, as 42.4% (n=43) had obtained a graduate or professional degree, 21.6% (n=22) held a bachelor's degree, 23.5% (n=24) held some college or associate degree, and 12.7% (n=13) were a high school graduate or of equivalent educational status. Most individuals rode frequently each week, during the months they ride, as 17.6% (n=18) reported riding 7 days per week, 19.6% (n=20) reported riding 6 days a week, 28.4% (n=29) reported riding 5 days a week, 16.7% (n=17) reported riding 4 days a week, and 12.7% (n=13) reported riding 3 days a week. Only 5 respondents rode once or twice weekly. Regarding injury and crash experiences, 28.4% (n=29) noted that they had been involved in a crash which negatively affects their perception toward bike commuting, while 71.6% (n=73) had not been involved in collisions or had experienced injuries from bicycle commuting. Descriptive statistics of the sample are presented in Table 1.

Demographic	Frequency (N)	Percent
Age		
18-29	61	59.8
30-49	23	22.6
50-64	16	15.6
65 and over	2	2
Total	102	100
Gender		
Male	67	65.7
Female	34	33.3
Non-binary/third gender	1	1
Total	102	100
Race		
White	70	68.6
Black or African American	4	3.9
Asian	24	25.5
Other	2	2
Total	100	100
Income (in USD)		
less than $15,000	42	41.2
$15,000 to less than $50,000	25	24.5
$50,000 to less than $75,000	14	13.7
$75,000 to less than $100,000	9	8.8
$100,000 to less than $150,000	7	6.9
$150,000 or more	5	4.9
Total	102	100
Education		
High school graduate (or equivalent)	13	12.7
Some college or associate degree	24	23.5
Bachelor's degree	22	21.6
Graduate or professional degree	43	42.2
Total	102	100
Riding days per week		
1	2	2
2	3	2.9
3	13	12.7
4	17	16.7
5	29	28.4
6	20	19.7
7	18	17.6
Total	102	100
Past injuries or crash experiences		
Yes	29	28.4
No	73	71.6
Total	102	100

Table 1: Sample Demographics

4.2 Research Question One: Constraints to Biking

The first research question examined constraints respondents experienced while bicycle commuting in the UIUC campus region. Upon examination of boxplots and removal of outliers, one sample t-tests were conducted across sum scores of constraints focus areas. Results indicate that the sample participants associated more closely with constraints linked to the built environment, with mean scores of 23.84 (SD=4.47) for items related to built environment constraints association, while societal factors had a mean score of 21.75 (SD=3.82) and personal factors had a mean score of 18.37 (SD=3.29). This indicates that across the sample, participants experienced greater constraints association related to the built environment than they did societal factors, or personal factors. Table 2 displays results of the t-tests between groups.

	Test Value = 0						
	t	df	Significance		Mean Difference	95% CI of the Difference	
			One-Sided p	Two-Sided p		Lower	Upper
Intrapersonal	53.89	92	<.001	<.001	18.366	17.69	19.04
Societal	54.91	92	<.001	<.001	21.753	20.97	22.54
Built Environment	49.72	86	<.001	<.001	23.839	22.89	24.79

Table 2: One Sample T-Test Between Groups

4.3 Research Question Two: Effects of Gender on Biking Constraints

The second research question examined gender differences in identification of constraints across the three constraint areas. The hypothesized outcome was that women would identify more with all three areas of constraints than men will. The level of significance used was a .05 p-value. After removal of outliers, results of a one-way analysis of variance test indicated that there were no statistically significant differences between male and female respondents for any of the three noted areas of constraints. While across the sample, women identified more closely with constraints in all three areas than men did (Table 3), greater differences were found in associations with built environment characteristics, and personal factors related to bike commuting. A non-significant affect was found between groups on self-reported measures of built environment constraints (F=3.51, p<.063), personal constraints (F=3.48, p<.065), and societal and driver behavior constraints (F=2.52, p<.116). The ANOVA is found in Table 3.

		Sum of Squares	df	Mean Square	F	Sig.
Intrapersonal	Between Groups	35.333	1	35.333	3.48	0.065
	Within Groups	913.743	90	10.153		
	Total	949.076	91			
Societal	Between Groups	36.385	1	36.385	2.515	0.116
	Within Groups	1301.822	90	14.465		
	Total	1338.207	91			
Built Environment	Between Groups	63.507	1	63.507	3.541	0.063
	Within Groups	1506.632	84	17.936		
	Total	1570.14	85			

Table 3: One-way ANOVA for gender differences on three constraints categories

Figure 3: Means plots between gender groups

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 Discussion of Findings

This study investigated individuals' constraints while cycling. The findings indicated that bicycle commuters experienced the most challenges with the built environment, which aligned with the hypothesis of the study. This also reinforces Nicholas and Cherry's (2016) findings, in that "the lack of cycling infrastructure is the largest hurdle that the U.S. currently faces in making cycling viable" (p. 216). By crafting built environments that cater to human desires of space, designing for slower traffic in urban regions, and prioritizing the safety of humans rather than the throughput (Tucker et al., 2018) and parking (Chen et al., 2019) of automobiles, all road users can benefit from conditions that are socially and physically accommodating for every method of travel (Marshall & Ferenchak, 2019).

Social factors, as well, are one of many outcomes of structural alterations, as they facilitate behaviors on roadways which stand to also alter the level of riding comfort an individual may have in each region (Pucher & Buehler, 2008). Given that many variables effect the factors that shape sentiments toward cycling and perceived safety, societal and driver behaviors cannot be observed in a vacuum. As displayed in this study, there was no significant difference between males and females in the attitudes toward social and driver behavors in the study region (mean difference of 1.4 between groups). Reinforced by Firth et al., (2021) spatial differences exist in and around varying census tracts, demographics of certain eductional outcomes, and those who reside near campus regions. This study reinforces the idea that infrastructural alterations which contribute to more gender-equitable bicycling outcomes are evidenced in this campus region.

This study also investigated how perceived risk factors for biking varied by gender. It was expected that women would identify with more constraints than men. However, the hypothesis was not supported as findings indicated that there are differences in constraints between genders, but these were not significant. Given that differences were noted between gender groups in each constraints category, understanding which forces impose certain stressors on the rider is integral to creating safe journeys, as constraints may be experienced differently across genders (Carroll et al., 2020). Significance may be more present in another region outside of the campus community, as population-level bicycling adoption is not as prevalent, and there would much likely be a wider variance of attitudes toward cycle commuting, with more car-centric places present. When examining the sample, it is highly educated, and generally low-earning, indicating a large response rater from graduate students – those familiar with this or other campus systems. While capturing a wider variation of participants, in differing life stages, from varying ethnicities present, we could potentially uncover statistically significant differences when accounting for demographic variables. Rapid implementation of infrastructural alterations, as seen in New York City, Minneapolis, and Washington, D.C., stands to improve not only population-wide mode share, but promotes the rapid increase of bicycle commuting by marginalized groups and those who previously identified strongly with constraints – in many cases, women, and people of color (Branion-Calles et al., 2019; City of New York, 2019, TREC, 2022). Thus, the gender gap in cycling becomes much less apparent where system-wide infrastructural and social considerations are implemented, providing comfortable riding experiences for all.

5.2 Implications and Insight for Future Studies

Cycling's inherently sustainable movement patterns and required infrastructure provide a safe and effective means for those in campus regions to move freely, resulting in mobility, community, and individual benefits (Aldred & Woodcock, 2008). With growing populations, increased urbanization, and the requirement for cities to adopt place-based strategies for sustainable growth, the need for communities to seek safer, more effective human mobility patterns is more pertinent now than ever (Gao et al., 2018). This study indicates that there is a greater need for improved infrastructure that facilitates feelings of safety for all road users. By expanding on the methods initiated in places such as New York City, Chicago, Davis, Missoula, Minneapolis, and D.C., creating separated routes, as well as involving more voices in active transportation planning could rapidly improve the bicycle mode share of those who previously associated the strongest with constraints (Cicchino et al., 2020; City of New York, 2019; Debnath et al., 2021). Further, land use, types of roadway conflict points and frequency, and the presence of cyle superhighways stand to impact modal share across all demographics (Ding et al., 2020).

By implementing design patterns on roadways which stand to decrease points of conflict, such as the reduction of private driveways (as evidenced on White Street), or the installation of chicanes and pinchpoints (as seen on South 6th Street), city leaders can greatly reduce the likelihood of collission between motorists and cyclists, making all parties safer (NHTSA, 2020). The presence of dedicated cycle superhighways – which do not exist in the campus region – can also serve as a useful piece of transportation infrastructure, promoting expedited cycle access between places where people live and where they work or study – traditionally separated in the context of North American Euclidean zoning (Ding et al., 2020). By channeling commuters through paths that provide safe movement at a steady rate of travel, the presence of high use by riders made confident through consistent infrastrucutre perpetuates a "strength in numbers" sentiment for all road users (Ding et al., 2020; Marshall & Ferenchak, 2019). By forecasting greater city developmental trends and integrating cycle paths into larger corridor improvements, the UIUC campus region can realize an expanded cycling modal share across more demographics for nonleisure trips.

With a greater scientific and moral responsibility to expand social science research beyond binary gender norms, resources, time, and attention should be devoted toward crafting equitable, safe journeys for all genders. As special policy directives are imperative to pleasurable and safe transport experiences for children (Babb et al., 2017; Day & Wager, 2010), older adults (Carlson et al., 2012), and people with disabilities and chronic conditions (Aldred & Woodcock, 2008), women (Lezotte, 2013; Mobilise Your City, 2020), and those with socioeconomic disadvantages (Child et al., 2019), so too should studies account for the lived experiences of nonbinary, transgender, and gender-nonconforming people. Additional societal constraints meet at the intersection of urban environment navigation as a vulnerable road user (NTSB, 2020), and simply existing in public as a member of a marginalized group (Limb & Collyer, 2023). Thus, studies should heaviliy consider these implications for the future of tranport and user constraints. By fostering networks of support, as seen in the greater Seattle cycling scene, in groups and events such as "All Bodies on Bikes," "Black Girls Do Bike," "Moxie Monday," and "North Star Cycling," those who would otherwise be excluded from safe participation in a viable form of urban mobility can do so, with greater community and less regard toward societal constraints (Commute Seattle, 2023). By studying the social spheres that exist, and the related constraints negotiation which occurs in marginalized gender groups, municipal and regional transportation designs may be of best service to the public, as LGBTQIA+ populations still lack broad acceptance in the public sphere.

5.3 Limitations

As this study took place in early to mid-Spring, the quantity of people bicycle commuting were likely fewer than what would be evidenced in late August and September, when peak activity on campus intersects with optimal weather conditions for cycling (Facilities and Services, 2022). Since the bulk of data collection took place during mid-to-late Spring semester, bicyclists may have been too pre-occupied with work, school, or other obligations to participate. A future study conducted during Bike Month, in September, could capture these same sentiments and associated rider characteristics, yet during a more pleasurable season for riding, collecting more responses if coupled with “Bike at Illinois” events.

With the researcher being involved in social circles, groups, and having academic spheres akin to those like himself, the widespread sharing of materials across various groups, RSOs, and university departments still may have lent toward the sample being skewed White, male, and having a median age near most college students. A sample of such nature is also difficult to validate, given that there have been no prior studies accurately recording the demographics of those who ride for transportation in the UIUC campus region, nor the extent of their association with constraints experienced while cycle commuting. The ubiquity of smartphones and reliance on their ownership could have created for researchers a situation where those without one were unable to complete a survey upon first seeing it, whether in print or digital format. If the bicycle is the least expensive tool for urban mobility, we cannot assume all potential participants had access to a smartphone, which was the most accessible and easy method of taking the survey.

While the study advances knowledge in the micro-urban campus region, the results may not extend to other campus cores across the nation. Though not a strong indicator of cycling activity, climate differences may impact seasonality of ridership, and how cyclists negotiate constraints – especially as the peak season intersects with busy months on local roadways. Different campus cores have varying types of policies which impact the successful integration of bicycling facilities within their greater urban streetscape. Student, faculty, and staff norms, and accompanying cycling facilities such as the presence of parking, cyclist showers in buildings, adequate signage, or repair stations may set this study apart from other areas much like it. Response biases are to be considered as well, in that those who participated in this study responded to self-reported scales based on their experiences in a region used by a wide variety of auto users. With a range of behaviors guided by infrastructural considerations unique to this study area, this cannot be duplicated elsewhere.

This study holds value in its ability to identify demographics of riders, their riding characteristics, and the level of constraints association reported across commonly cited concerns by bicycle commuters in a campus core. If iterated upon by agencies with more reach, this type of study can allow for decision-making bodies affiliated with UIUC planning agencies to best serve those who navigate our roadway systems, and to do so in ways which yield efficiency, safety, and desirous streetscapes.

Future studies should seek to gain an accurate depiction of ridership demographics in the campus region, create heatmaps of use zones, understand unique constraints of riders, and publish results of iterative improvements to create a more equitable landscape for cyclists. Supporting a much greater community reach, Facilities and Services should also seek to administer studies which capture accurate demographics within the greater UIUC campus region, spanning multiple seasons. If primary facilitators of campus capital planners have a rich understanding of the conditions faced by all types of cyclists, more iterative work can be pursued to improve conditions for all riders in all ages and gender groups. Looking beyond obtaining bike counts on major thoroughfares, and understanding parking space utilization, planners should seek to gain an understanding of rider characteristics, and their constraints association regarding factors which can be altered in the dedicated plans set forth by leading campus planning committees – such as the Campus Landscape Master Plan 2022 (CLMP). This way, the UIUC campus core can marry the requirements for water and land sustainability, as well as human desires of space and mobility in their long-term planning initiatives.

While an assessment of rider characteristic and related constraints has not yet been studied in this region, the Champaign County Regional Planning Commission is administering the Champaign Urbana Urbanized Area Regional Transit Study for their C-U Long Range Transportation Plan 2050. It asks respondents of their mode choice and whether they identify with certain constraints listed across a wide range of transportation types, but no components specifically address frequently noted constraints within each mode type and the frequency/impact of them. This study and future studies lay the groundwork for improved transportation in and around the UIUC campus region and should be made available to the full community beyond municipal sites, and in seasons of high bicycle use.

5.4 Conclusion

Bicycle commuting in the United States is rapidly growing, and on campus regions, social and infrastructural alterations are being considered and implemented to guide user behaviors and achieve desirous population-level outcomes. Influential micro-urban campus regions serve as a microcosm of larger cities, while supporting iterative development of mixeduse density and zoning reforms which make greater use of human and infrastructural capital. Thus, bicycling as a means of transportation in areas which support it is not a panacea to effective urban mobility, yet serves as a means of healthy, inexpensive, often enjoyable transportation for all; and most notably for those who cannot afford or wish to not use other modes of transport. By expanding users' options for active transportation, regions are not burdened by the singular option of auto-dependency and its use of land, money, and impactful health externalities, providing cities enhanced opportunity to utilize increasingly valuable land for housing, recreational amenities, or civic spaces.

Through the completion of this study, I feel a greater sense of ownership toward the places I call home. Communities maintain strength by the quantity and quality of our interactions, and when we design cities for people, spurious interaction and negotiation of public space can be performed through methods which result in friendships and civic growth rather than pollutants and burdensome costs. By facilitating the sustainable use of public space, healthy transportation networks, and access for all regardless of age or ability, the places we live and work can be alive and grow, much like the communities which steward them.

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APPENDIX A: PARTICIPANT SURVEY

INFD_CONST

You are being asked to participate in a voluntary research study. The purpose of this study is to understand experiences of urban bike commuters in the UIUC campus region.

Participating in this study will involve responding to a survey which should take about 12 minutes. Risks related to this research are no more than the risks of everyday life; benefits related to this research include improving conditions for bicycling in the UIUC campus region.

Principal Investigator Name and Title: Dr. Mariela Fernandez, Ph.D., Associate Professor

Department and Institution: University of Illinois Urbana Champaign Department of Recreation, Sport & Tourism

Contact Information: mfrnndz2@illinois.edu

Why am I being asked?

You are being asked to be a participant in a research study about urban bike commuting in the UIUC campus region. The purpose of this research is to understand attitudes and behaviors of those who bike commute. You have been asked to participate in this research because we as the investigators are in correspondence with several entities which stand to improve service based your responses.

Your participation in this research is voluntary. Your decision whether or not to participate will not affect your current or future dealings with the University of Illinois at Urbana-Champaign. If you decide to participate, you are free to withdraw at any time without affecting that relationship.

What procedures are involved?

The study procedures are completing an online questionnaire which will help us better understand your experiences while bike commuting on or near the UIUC campus.

This research will be performed online, and a link and QR code are provided for participants, based on how they discover the study.

What are the potential risks and discomforts?

Risks are no more than that of daily life.

Are there benefits to participating in the research?

Benefits to society are as follows:

University of Illinois Facilities and Services can utilize this research as a more in-depth investigation complimentary to their "mode share survey." They manage capital development projects in the campus core and play a large role in shaping our built environment for walkers, bicyclists, and all other modes. Local and regional planning organizations can best understand the constraints people face while bicycle commuting. This can allow for stakeholders involved in increasing bicycle mode share to know the unique constraints of varying demographics in the campus region and help tailor policy to match intended results.

Benefits to the individual are as follows:

Those who bicycle as a means of transportation will have their attitudes and sentiments reflected in such a manner that will best inform local stakeholders and policymakers. At the least, there will be more focused information surrounding bike commuting and related constraints with no action taken, while at the most, there may be additional investments in bicycle-focused transportation policy.

What other options are there?

You may quit the study at any time.

Will my study-related information be kept confidential?

Faculty, students, and staff who may see your information will maintain confidentiality to the extent of laws and university policies. Personal identifiers will not be published or presented.

Will I be reimbursed for any expenses or paid for my participation in this research?

You will not be reimbursed for taking the survey, but participants will have a chance to win one of two bicycle tune-ups courtesy of Bikelab by Neutral Cycle, if they elect to enroll at the end of the survey.

Can I withdraw or be removed from the study?

If you decide to participate, you are free to withdraw your consent and discontinue participation at any time.

Will data collected from me be used for any other research?

Your de-identified information could be used for future research without additional informed consent.

Who should I contact if I have questions?

Contact researcher Mariela Fernandez at mfrnndz2@illinois.edu if you have any questions about this study or your part in it, or if you have concerns or complaints about the research.

What are my rights as a research subject?

If you have any questions about your rights as a research subject, including concerns, complaints, or to offer input, you may call the Office for the Protection of Research Subjects (OPRS) at 217-333-2670 or e-mail OPRS at irb@illinois.edu. If you would like to complete a brief survey to provide OPRS feedback about your experiences as a research participant, please follow the link here or through a link on the OPRS website: oprs.research.illinois.edu/. You will have the option to provide feedback or concerns anonymously or you may provide your name and contact information for follow-up purposes.

I have read the above information. I have been given an opportunity to ask questions and my questions have been answered to my satisfaction. I agree to participate in this research.

1-CONSENT Are you a student, faculty, or staff of UIUC and give consent to continue the survey?

o Yes (1)

o No (2)

Skip To: End of Survey If 1-CONSENT = No

Page Break

2-ZIP What is your 5-digit zip code?

____

Page Break

3-AGE What is your age? (Numerical Format. ex: 21)

____

Page Break

4-GENDER Select your gender.

o Male (1)

o Female (2)

o Non-binary/third gender (3)

o Other (5) ____

o Prefer not to say (4)

Page Break

5-INCOME Select is your annual income. (in USD)

o Less than 15,000 (1)

o 15,000 to less than 50,000 (4)

o 50,000 to less than 75,000 (5)

o 75,000 to less than 100,000 (6)

o 100,000 to less than 150,000 (7)

o 150,000 and more (8)

Page Break

6-RACE Select your race. (Please select all that apply.)

▢ White (4)

▢ Black or African American (5)

▢ American Indian or Alaska Native (6)

▢ Asian (7)

▢ Native Hawaiian or Other Pacific Islander (8)

▢ Other (9) ____

Page Break

7-ETHNICITY Are you of Hispanic, Latino, or Spanish origin?

o Not of Hispanic, Latino, or Spanish origin (5)

o Yes, Mexican, Mexican American, Chicano (6)

o Yes, Puerto Rican (7)

o Yes, Cuban (8)

o Yes, another Hispanic, Latino, or Spanish origin (9)

Page Break

8-EDU What is your highest completed level of education?

o Did not complete high school (4)

o High school graduate (or equivalent) (5)

o Some college or associate's degree (6)

o Bachelor's degree (7)

o Graduate or professional degree (8)

End of Block: Informed Consent-Demo

Start of Block: Travel Behavior

9-MODE How do you frequently get to work or school? (Select all that apply.)

▢ Private vehicle, like a car or motorcycle (1)

▢ Public Transit, CU-MTD (2)

▢ Bicycle (3)

▢ Walk (4)

▢ Other (5) ____

10-BIKE30DAYS Have you biked in the last 30 days for transportation?

o Did not bike (1)

o Biked, some for transportation (2)

o Biked, only for recreation/leisure (3)

11-BIKE TRIPS What was your primary type of bike trip made in the past 30 days?

o On the way to/from work (1)

o On the way to/from public transportation (2)

o Running errands, shopping, eating out (3)

o Only for exercise (4)

12-REASONS What are your reasons for cycling? (Select all that apply.)

▢ Health or exercise benefits (1)

▢ To enjoy the outdoors (2)

▢ Reduce impact on environment / air quality (3)

▢ Save money on gas & travel costs (4)

▢ To avoid parking fees (7)

▢ Faster or more convenient than driving (8)

13-RIDEFREQ During the months when you ride, how many days out of the week do you ride?

1 2 3 4 5 6 7

Slide to select ()

14-BIKETYPE What type of bicycle do you use in the campus region?

o Regular Pedal (1)

o Compact/Folding (2)

o E-bike (3)

o Cargo (4)

o Not sure (5)

15-COST What was the purchase price of your primary commuter bicycle? (in USD)

o 0 to less than $100 (1)

- o $100 to less than $250 (2)
- o $250 to less than $500 (3)
- o $500 to less than $1000 (4)
- o $1000 or more (5)

16-INJ_HIST Do you have any past injuries/crash experiences which negatively affect your perceptions toward bike commuting?

- o Yes (1)
- o No (2)

Display This Question:

If 16-INJ_HIST = Yes

17-CRASHEXP If yes, please explain.

____

End of Block: Travel Behavior

Start of Block: Likert Qs

18-PERSONAL Please indicate the extent to which you agree with each statement.

	Never (1)	Rarely (2)	Sometimes (3)	Usually (4)	Always (5)
I feel less safe while riding a bicycle. (1)	o	o	o	o	o
I take other modes of transportation when I require a presentable appearance at my destination. (3)	o	o	o	o	o
I feel safer bicycle commuting if I wear visibility clothing. (6)	o	o	o	o	o
I feel safe navigating around pedestrians and other cyclists. (7)	o	o	o	o	o
I wear a helmet when riding for transportation in the campus region. (8)	o	o	o	o	o
More danger exists during morning and evening rush hours. (9)	o	o	o	o	o

a Please indicate the extent to which you agree with each statement.

	Never (1)	Rarely (2)	Sometimes (3)	Usually (4)	Always (5)
Drivers provide adequate passing distances while in sharrow lanes. (1)	o	o	o	o	o
Drivers respect my space in painted bike gutters. (2)	o	o	o	o	o

I experience driver hostility or aggression. (3) o o o

o o

I commonly navigate to roads where I am less likely to experience dangerous drivers. (4) o

o o o o

Drivers express something to the effect of "get off the road" while I ride. (5) o

o o o o

I feel the campus region prioritizes other forms of transportation much more than cycling. (6)

o o o o o

I get pushed to the gutter while riding from larger road users. (7) o o

o o o

My friends or colleagues frequently ask questions to the effect of "why don't you just drive?" (8)

o o o o o

20-BLTENVI Please indicate the extent to which you agree with each statement.

Never (1) Rarely (2) Sometimes (3) Usually (4) Always (5)

Intersections facilitate my safe movement and right-of-way. (1) o o

o o o

Switching from bike lanes to sidewalks/crosswalks to roads is accessible and easy. (2) o

o o o o

Bikeways are designed to keep me protected from heavier vehicles. (3) o o

o o o

I feel safe in protected bicycle lanes. (4) o o o o

o

I feel safe in painted bicycle lanes. (5) o o o o

o

Campus streets facilitate the sharing of space between bikes and other road users. (6) o

o o o o

Lighting during evening hours is sufficient when I ride. (7) o o o

o o

Crosswalks or bike lanes intersect with car traffic in safe manners. (8) o o

o o o

Bike lanes have obstructions in them. (9) o o o o

o

End of Block: Likert Qs

Start of Block: Drawing

16-DRAWING Thank you for the time spent taking this survey. If you wish to enroll in a drawing for one of two free bicycle tune-ups courtesy of Bikelab by Neutral Cycle, please enter your email.

Your email will only be used for the purposes of the drawing.

APPENDIX B: RECRUITMENT FLYER